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Book of Abstracts

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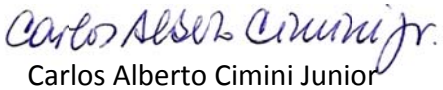
Preface

The 1st Brazilian Conference on Composite Materials (BCCM1) is the first of a series of conferences that will take place biennially in Brazil, intended to provide a forum for the presentation and discussion of the latest research and technology in the field of composite materials.

The Organizing Committee has had the support of many colleagues and distinguished scientists from all over the world. Plenary lectures are delivered by scientists of international prestige in the field and representatives of the Brazilian industry.

The members of the BCCM1 Organizing Committee would like to thank all speakers and delegates for their contribution and participation and wish all an enriching and joyful event.

José Daniel Diniz Melo
Chair of BCCM1



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Contents

BCCM1-paper-001	LIGHTWEIGHT FLAME RETARDANT THERMOSET COMPOSITES WITH LOW SMOKE GENERATION	1
BCCM1-paper-002	DYNAMICAL MECHANICAL ANALYSIS OF HYBRID COMPOSITES REINFORCED WITH RAMIE AND GLASS FIBERS	2
BCCM1-paper-003	MODELING FAILURE OF COMPOSITE MATERIALS DUE TO EVOLVING MICROCRACKS USING A TWO-WAY COUPLED MULTISCALE MODEL WITH TRANSITION OF MICROCRACKS INTO MACROCRACKS	3
BCCM1-paper-004	DYNAMIC FRAGILITY OF VEGETAL-FIBER COMPOSITE MATERIALS	4
BCCM1-paper-005	AEROELASTIC STABILITY ANALYSIS OF ORTHOTROPIC PLATES WITH EMBEDDED PIEZOELECTRIC MATERIALS: FINITE ELEMENT FORMULATION	5
BCCM1-paper-007	CARBON-CARBON COMPOSITES MADE BY VEGETABLE OIL	6
BCCM1-paper-008	EFFECT OF PP GRAFTED WITH ITACONIC ACID AS COUPLING AGENT ON THE MECHANICAL AND THERMAL PROPERTIES OF PPr/WOOD FLOUR COMPOSITES	7
BCCM1-paper-009	EXPERIMENTAL CHARACTERIZATION AND SIMULATION OF VARTM PROCESS TO OBTAIN CARBON/EPOXI COMPOSITES	8
BCCM1-paper-010	THERMOGRAVIMETRY USE FOR DETERMINING THE FIBER VOLUME FRACTION OF COMPOSITE POLYMERIC	9
BCCM1-paper-011	WASTE RECYCLING FOR LIGNOCELLULOSIC COMPOSITE PRODUCTION: ADDITION OF IMPREGNATED PAPER RESIDUE TO PRODUCE MDP WOOD PANEL	10
BCCM1-paper-012	POLY(ETHYLENE-CO-VINYL ACETATE) AND WOOD FLOUR EXPANDED COMPOSITES	11
BCCM1-paper-013	INFLUENCE OF PLATE CURVATURE ON COMRESSION AFTER IMPACT RESPONSE OF WOVEN-FIBER REINFORCED COMPOSITES – A NUMERICAL STUDY	12
BCCM1-paper-014	EUCALYPTUS PARTICLEBOARDS: ADDITION OF OAT HULLS	13

BCCM1-paper-015	PROGRESSIVE FAILURE ANALYSIS OF COMPOSITE LAMINATES USING LARC03 CRITERION	14
BCCM1-paper-016	ELASTIC BEHAVIOR OF Ni-TI/GLASS/EPOXY BEAMS	15
BCCM1-paper-017	CRACK PATH INFLUENCE ON DETERMINATION OF CF/EPOXY LAMINATES MODE I FRACTURE TOUGHNESS	16
BCCM1-paper-018	FATIGUE UNDER SHEAR STRESS BY USING THE IOSIPESCU METHOD	17
BCCM1-paper-020	STUDY OF THE NATURAL AGING OF HIGH MELT STRENGTH POLYPROPYLENE (HMSPP) WITH ADDITION OF CLOISITE 20 A	18
BCCM1-paper-021	EVALUATION OF PROGRESSIVE FAILURE OF FILAMENT WINDING COMPOSITE STRUCTURES UNDER MULTIPLE STRESS STATE	19
BCCM1-paper-022	EXPERIMENTAL ANALYSIS OF LOW ENERGY IMPACT IN FILAMENT WINDING CYLINDERS	20
BCCM1-paper-023	BAMBOO FIBER-REINFORCED POLYMER COMPOSITE	21
BCCM1-paper-024	COMPARISON OF MECHANICAL TESTS IN COMPOSITE LAMINATES JUNCTIONS	22
BCCM1-paper-026	DYNAMIC RESPONSE OF REINFORCED CONCRETE SHELTERS SUBJETED TO BALLISTIC IMPACT: A NUMERICAL APPROACH	23
BCCM1-paper-027	RECYCLED MULTILAYER CARTONS AS CELLULOSE SOURCE IN HDPE BASED COMPOSITES	24
BCCM1-paper-028	RESIN TRANSFER MOLDING (RTM) MODELING AND SIMULATION WITH CONSIDERATION OF FILLER PARTICLE RETENTION AT PREFORM	25
BCCM1-paper-029	COMPOSITES FROM COCONUT FIBERS WITH POLYPROPYLENE AND THEIR THERMAL PROPERTIES	26
BCCM1-paper-032	EFFECT OF METAL OXIDES ADDITION ON THE CURING OF EPOXY MATRIX NANOCOMPOSITES SYSTEMS	27
BCCM1-paper-034	POLYMERIC NANOCOMPOSITE OF LAPONITE RD PREPARED BY GAMMA IRRADIATION	28
BCCM1-paper-037	INFLUENCE OF THE CLAY CONTENT ON THE MECHANICAL PROPERTIES OF POLY(LACTIC ACID)/EMA-GMA NANOCOMPOSITES	29
BCCM1-paper-038	DIFFERENCES AND APPLICABILITY OF THREE BONDED LAP SHEAR TESTS	30
BCCM1-paper-042	HOOP TENSILE STRENGTH IN SPLIT-DISK TEST OF FILAMENT WOUND COMPOSITE TUBES BY FINITE ELEMENT ANALYSIS	31

BCCM1-paper-047	FLEXURAL CHARACTERIZATION OF BAMBOO/POLYESTER MATRIX COMPOSITES	32
BCCM1-paper-048	FAILURE PREDICTION IN SINGLE LAP BONDED COMPOSITE JOINTS SUBJECTED TO LOW ENERGY IMPACT LOADING	33
BCCM1-paper-051	CHARACTERIZATION OF CARBON FIBER/EPOXY RESIN PREPREG BY THERMOGRAVIMETRY AND FT-IR	34
BCCM1-paper-052	FUNCTIONALIZATION OF MULTI-WALLED CARBON NANOTUBES THROUGH BALL-MILLING PROCESS AND THEIR USE AS FILLERS IN PP-BASED NANOCOMPOSITES	35
BCCM1-paper-054	COMPRESSIVE BEHAVIOUR OF POLYMERIC COMPOSITES REINFORCED WITH SAWDUST	36
BCCM1-paper-055	BENZOXAZINE RESIN DEGRADATION KINETIC	37
BCCM1-paper-056	ANALYSIS OF THE DRILLING DELAMINATION OF COMPOSITE MATERIALS	38
BCCM1-paper-058	MECHANICAL TENSILE PROPERTIES OF COMPOSITES REINFORCED WITH SHORT FIBERS OF BAMBOO AND GLASS	39
BCCM1-paper-059	EVALUATION OF POLYMERIC MATRICES FOR APPLICATION IN COMPOSITE CORE OF CONDUCTOR CABLES	40
BCCM1-paper-062	TENSILE STRENGTH OF POLYESTER MATRIX REINFORCED WITH NATURAL FIBERS (SISAL) ALIGNED	41
BCCM1-paper-063	MOISTURE ABSORPTION OF CASTOR OIL POLYURETHANE COMPOSITES REINFORCED SUGARCANE STRAW CELLULOSE	42
BCCM1-paper-065	PREPARATION OF BLENDS OF POLYAMIDE 6/COMPOUND RECYCLED RUBBER BLENDS	43
BCCM1-paper-066	SKIN-STIFFENER INTERFACE ANALYSIS OF COMPOSITE PANELS	44
BCCM1-paper-067	CERAMIC MATRIX COMPOSITES DERIVED FROM TiSi2-FILLED POLYSILOXANE	45
BCCM1-paper-068	MECHANICAL AND PHYSICAL CHARACTERIZATION OF GLASS/POLYESTER AND SISAL/POLYESTER COMPOSITES	46
BCCM1-paper-070	CHARACTERIZATION OF THERMAL PROPERTIES OF HDPE AND CASHEW NUTSHELL POWDER MIXTURES	47
BCCM1-paper-073	ASSESSMENT OF AUTOMATED FIBER PLACEMENT COVERAGE GENERATION ALGORITHMS	48

BCCM1-paper-074	EXPERIMENTAL EVALUATION OF AUTOMATED FIBER PLACEMENT MANUFACTURING PARAMETERS	49
BCCM1-paper-076	THE INFLUENCE OF FABRIC STRUCTURE ON THE MECHANICAL PROPERTIES OF GLASS FIBER AND ARAMID FIBER REINFORCED POLYESTER COMPOSITES	50
BCCM1-paper-077	EVALUATION OF THE MECHANICAL PROPERTIES OF HYBRID PLAIN WEAVE REINFORCED EPOXI COMPOSITES	51
BCCM1-paper-078	COMPOSITES OF TAQUARA-LIXA FIBERS WITH POLYESTER RESIN	52
BCCM1-paper-079	PREDICTION OF TENSILE PROPERTIES OF CARBON FIBER REINFORCED CARBON-SIC HYBRID MATRIX COMPOSITE BY A MODIFIED MICROMECHANICS APPROACH	53
BCCM1-paper-083	INFLUENCE OF INTERFACIAL ADHESION ON FLEXURAL STRENGHT OF STRUCTURAL COMPOSITES	54
BCCM1-paper-085	PROCESS EVOLUTION DURING DENSIFICATION OF 3D CARBON FIBER REINFORCED CARBON COMPOSITES BY THERMOSET RESIN AND PITCH	55
BCCM1-paper-086	THERMAL AND MECHANICAL BEHAVIOR OF GLASS/POLYESTER COMPOSITES MOLDED AT DISTINCT TEMPERATURES	56
BCCM1-paper-088	RESEARCH AND DEVELOPMENT ON COMPOSITES – A STRATEGY TO OVERCOME TECHNOLOGICAL CHALLENGES	57
BCCM1-paper-090	EVALUATION OF THE PROCESS OF CALCINATION OF NICKEL FERRITE IN OBTAINING COMPOSITE POLYMERIC	58
BCCM1-paper-091	MULTI-SCALE ANALYSIS OF FAILURE IN COMPOSITE MATERIALS	59
BCCM1-paper-092	SYNTHESIS OF NEW HYBRID MATERIALS BASED ON CHITOSAN AND $ZnAl_2O_4$	60
BCCM1-paper-093	MORPHOLOGICAL ANALYSIS OF HYBRID CHITOSAN-ZnAl2O4	61
BCCM1-paper-094	NUMERICAL AND EXPERIMENTAL DYNAMIC ANALYSES IN SMART COMPOSITES	62
BCCM1-paper-095	FAILURE ANALYSIS OF COMPOSITE LAMINATE USING A FAILURE CRITERION BASED ON PHYSICAL PHENOMENA	63
BCCM1-paper-097	BENDING OF ADAPTATIVE Ni-Ti/PP CIRCULAR BEAMS	64
BCCM1-paper-098	EVALUATION OF VISCOSITY OF THE ASPHALT CEMENT AFTER INCORPORATION OF EVA WASTE	65

BCCM1-paper-101	APPLYING MIXED-MODE NETWORK ARCHITECTURE TO MODEL THE FATIGUE LIFE OF A COMPOSITE MATERIAL	66
BCCM1-paper-104	ROLE OF OPEN INNOVATION MODELS AND IPR IN TECHNOLOGY TRANSFER	67
BCCM1-paper-107	PREPARATION AND PROPERTIES OF NANOSTRUCTURED WC-Co COMPOSITE POWDERS AND COATINGS	68
BCCM1-paper-108	MECHANICAL AND STRUCTURAL PROPERTIES OF THERMAL SPRAYED CR3C2-25(NI20CR) NANOCOMPOSITE COATINGS	69
BCCM1-paper-109	ANALYSIS OF MULTISTABLE VARIABLE STIFFNESS COMPOSITE PLATES	70
BCCM1-paper-111	THE BEHAVIOR OF FIBER-CONCRETE INTERFACE IN CEMENT MATRIX COMPOSITES	71
BCCM1-paper-112	ANT COLONY ALGORITHM APPLIED TO FUNDAMENTAL FREQUENCY MAXIMIZATION OF LAMINATED COMPOSITE CYLINDRICAL SHELLS	72
BCCM1-paper-113	IMPERMEABLE COMPOSITE PIPES WITH METALLIC LINER FOR SOLVENT APPLICATIONS	73
BCCM1-paper-114	SYNTHESIS OF POLYANILINE/CLAY CONDUCTING NANOCOMPOSITES	74
BCCM1-paper-116	A FULL FACTORIAL DESIGN OF PARTICULATE COMPOSITES REINFORCED WITH SILICA MICROPARTICLES	75
BCCM1-paper-117	DAMPING RATIOS DURING A FATIGUE TEST OF A 3MW WIND TURBINE BLADE	76
BCCM1-paper-118	THERMAL SHOCK INFLUENCE ON VISCOELASTIC BEHAVIOR OF WELDED CONTINUOUS FIBER/PPS LAMINATES	77
BCCM1-paper-119	EVALUATION OF CHEMICAL INTERACTION BETWEEN THE MWCNT FUNCTIONALIZED WITH FURFURYL ALCOHOL RESIN SYNTHESIZED	78
BCCM1-paper-120	INFLUENCE OF UV RADIATION ON GLASS TRANSITION TEMPERATURE OF PEI/ GLASS FIBER COMPOSITES	79
BCCM1-paper-123	THERMAL SHOCK EFFECT ON INTERLAMINAR SHEAR STRENGTH OF CARBON FIBER/PEKK COMPOSITE	80
BCCM1-paper-124	ADDITION MAGNETIC NANOPARTICLES FOR NON-DESTRUCTIVE EVALUATION OF POLYMER COMPOSITES	81
BCCM1-paper-125	INFLUENCE OF THICKNESS IN THE ANALYSIS OF CURAUA/GLASS HYBRID LAMINATES - PART I: MECHANICAL PROPERTIES	82

BCCM1-paper-126	INFLUENCE OF THICKNESS IN THE ANALYSIS OF CURAUA/GLASS HYBRID LAMINATES - PART II: EXPERIMENTAL X THEORETICAL ANALYSIS	83
BCCM1-paper-127	STUDY OF FILMS OF POLYAMIDE 6/BENTONITE CLAY NANOCOMPOSITES	84
BCCM1-paper-128	MECHANICAL AND THERMAL PROPERTIES OF POLYPROPYLENE REINFORCED WITH CARBON NANOTUBES	85
BCCM1-paper-129	SALT WATER CORROSION BEHAVIOR ON MECHANICAL AND THERMAL PROPERTIES OF WELDED CONTINUOUS FIBER/PPS LAMINATES	86
BCCM1-paper-130	EVALUATION OF MOISTURE EFFECT ON VISCOELASTIC PROPERTIES OF CARBON FIBER/PEI LAMINATES	87
BCCM1-paper-131	MECHANICAL AND BARRIER PROPERTIES OF POLYPROPYLENE/ORGANOCLAY NANOCOMPOSITES	88
BCCM1-paper-132	FATIGUE PERFORMANCE EVALUATION OF TWO TYPES OF NON CRIMP FABRIC COMPOSITES MANUFACTURED VIA RTM PROCESS	89
BCCM1-paper-133	WRINKLING OF CARBON FIBRE COMPOSITES DURING CONSOLIDATION	90
BCCM1-paper-134	PRESSURE ASSISTED MANUFACTURING OF A NOVEL POLYMER INFILTRATED CERAMIC WITH INTERPENETRATING MATRICES	91
BCCM1-paper-135	MECHANICAL PROPERTIES OF SANDWICH STRUCTURES USING PET AND PVC CORE	92
BCCM1-paper-136	TOWARDS THE APPLICATION OF ARTIFICIAL NEURAL NETWORK TO NONDESTRUCTIVE INSPECTION OF COMPOSITE SANDWICH PANEL HONEYCOMB CORES	93
BCCM1-paper-137	LINEAR LOW DENSITY POLYETHYLENE AND ZIRCONIUM PHOSPHATE NANOCOMPOSITE: EVIDENCES FROM THERMAL, THERMO MECHANICAL AND MORPHOLOGICAL TECHNIQUES	94
BCCM1-paper-139	RECYCLING OF AIRCRAFT WASTE: NEW COMPOSITES BASED ON POST CONSUMER EXPANDED POLYSTYRENE	95
BCCM1-paper-140	ANALYSIS OF PVC AND PRO-BALSA WOOD CORE SANDWICH STRUCTURES MOLDED BY RESIN INFUSION	96
BCCM1-paper-141	GAS PERMEABILITY OF LLDPE/BENTONITE FILMS	97
BCCM1-paper-142	EFFECT OF COMPATIBILIZER ON THE PROPERTIES OF BABAÇU FIBER/POLYPROPYLENE COMPOSITES	98
BCCM1-paper-143	UNSATURATED POLYESTER/CAROA FIBER COMPOSITES	99

BCCM1-paper-144	EVA RESIDUE/STARCH COMPOSITES: INFLUENCE OF STARCH CONTENT AND CASTOR OIL ADDITION	100
BCCM1-paper-148	STUDY OF COMPOSITES OF HIGH DENSITY POLYETHYLENE AND COFFEE DREGS	101
BCCM1-paper-149	THE ULTRA PULSE VELOCITY AND PHYSIC-MECHANICAL PROPERTIES OF POLYMERIC COMPOSITES CONTAINING RUBBER PARTICLES	102
BCCM1-paper-151	COMPARISON OF FLEXURAL PROPERTIES OF JUTE AND FIBERGLASS FABRICS REINFORCED EPOXY MATRIX COMPOSITES MOLDING BY RESIN TRANSFERING	103
BCCM1-paper-153	EVALUATION OF THE ADDITION OF AN EPOXY-REACTIVE DILUENT ON THE PROPERTIES OF EPOXY-CARBON NANOTUBES NANOCOMPOSITES	104
BCCM1-paper-154	FUNCTIONALIZATION OF CARBON NANOTUBES AND THEIR USE TO OBTAIN NANOCOMPOSITES	105
BCCM1-paper-155	INTERNAL STRESS DEVELOPEMENT DURING THE CURING OF AN EPOXY-VALIDATION BY FIBRE MICROBUCKLING PREDICTION	106
BCCM1-paper-157	MECHANICAL CHARACTERIZATION OF ANGLE PLY FIBERGLASS/EPOXY MATRIX COMPOSITES AT DIFFERENT ANGLES	107
BCCM1-paper-161	STUDY OF THE THERMAL EXPANSION BEHAVIOR OF THE COMPOSITE MG-B (20%)	108
BCCM1-paper-163	USE OF OOF2 TO STUDY THE RELATIONSHIP BETWEEN MECHANICAL PROPERTIES AND THE SPATIAL DISTRIBUTION OF REINFORCEMENT IN COMPOSITE MATERIALS	109
BCCM1-paper-164	ACCELERATED TESTING METHODOLOGY FOR LONG-TERM LIFE PREDICTION OF CFRP LAMINATES	110
BCCM1-paper-165	POLYESTER COMPOSITES OF THE HOLLOW GLASS MICROSPHERES	111
BCCM1-paper-166	DESIGN AND CONSTRUTION OF A ELLIPSOIDAL COMPOSITE SHELL COVERING A METALLIC GEODESICAL STRUCTURE	112
BCCM1-paper-169	MECHANICAL BEHAVIOUR OF LIGNOCELLULOSIC COMPOSITES: SUGARCANE BAGASSE FIBERS/HIPS	113
BCCM1-paper-170	FLEXURAL PROPERTIES OF SISAL AND COCONUT NON-WOVEN FABRICS REINFORCED EPOXY MATRIX COMPOSITES AFTER CONDITIONING	114
BCCM1-paper-174	EVALUATION OF COMPOSITE SLEEVES FOR REINFORCEMENT OF DENTED PIPELINES ON LONGITUDINAL WELD	115

BCCM1-paper-175	INFLUENCE OF NATURAL GRAPHITE IN THE PROPERTIES OF RECYCLED POLI (ETHYLENE THEREPHTHALATE)	116
BCCM1-paper-176	STUDY OF DIFFERENT PREPARATION METHODS OF COLLAGEN/HYDROXYAPATITE COMPOSITES	117
BCCM1-paper-177	CHARACTERIZATION OF CUPUAÇU SHELL PARTICLES (*Theobroma grandiflorum*) AND THEIR POTENTIAL USE AS FILLER IN COMPOSITES: A PRELIMINAR STUDY	118
BCCM1-paper-178	THE EFFECT OF SILICON CARBIDE ADDITION INTO FIBREGLASS REINFORCED COMPOSITES	119
BCCM1-paper-179	THE USE OF CaCO3 FILLED RESIN ON THE RTM PROCESS	120
BCCM1-paper-180	DEVELOPMENT OF NANOCOMPOSITES BASED ON EVA AND STRUCTURAL EVALUATION BY LOW-FIELD NMR	121
BCCM1-paper-181	THE EFFECTS OF CHEMICAL TREATMENT AND FIBRE ORIENTATION IN SISAL COMPOSITES	122
BCCM1-paper-182	EVALUATION OF CRYSTALLINITY FROM POLYAMIDE 6/ORGANOCLAY NANOCOMPOSITES	123
BCCM1-paper-184	TRANSVERSAL SHEAR CARACTERISATION OF THICK LAMINATED COMPOSITE USING A REPRESENTATIVE VOLUME ELEMENT (RVE)	124
BCCM1-paper-185	DYNAMIC MECHANICAL PROPERTIES OF HYBRID CURAUA/GLASS COMPOSITES	125
BCCM1-paper-187	NON CRIMP FABRICS FOR ADVANCED COMPOSITES APPLICATIONS: A SURVEY	126
BCCM1-paper-189	POLYAMIDE 11/TITANIUM NANOXIDE NANOCOMPOSITE	127
BCCM1-paper-190	CHARACTERIZATION OF SYAGRUS CORONATA (MARTIUS) BECCARI (LICURI) FIBER	128
BCCM1-paper-198	EPOXY THERMOSET TOUGHENED WITH AMPHIPHILIC BLOCK COPOLYMERS	129
BCCM1-paper-199	IMPACT LOCALIZATION IN COMPOSITE PLATES WITH DISTRIBUTED PIEZOELECTRIC SENSORS SETUP	130
BCCM1-paper-200	INFLUENCE OF THE ADDITION OF NATURAL MICAS IN THE POPERTIES OF EVA	131
BCCM1-paper-201	STUDY OF ADDITION OMMT IN UV CURING POLYURETHANE COATING	132

BCCM1-paper-202	MASS EFFECT AND HEATING RATE ANAYLYSIS IN CARBON FIBER/EPOXY COMPOSITES	133
BCCM1-paper-203	INFLUENCE OF THE CLAY CONTENT IN THE POROSITY OF MEMBRANES OBTAINED FROM POLYAMIDE 6 NANOCOMPOSITES	134
BCCM1-paper-204	FLEXURAL BEHAVIOR OF SISAL/CASTOR OIL-BASED POLYURETHANE AFTER UV RADIATION	135
BCCM1-paper-205	MECHANICAL CHARACTERIZATION BY NANOINDENTATION OF POLYURETHANE DERIVED FROM CASTOR OIL REINFORCED WITH SISAL	136
BCCM1-paper-207	THERMAL ANALYSIS OF SISAL COMPOSITES	137
BCCM1-paper-208	STUDY OF MECHANICAL PROPERTIES OF HIGH DENSITY POLYETHYLENE/MONTMORILLONITE NANOCOMPOSITE RECYCLED BY EXTRUSION	138
BCCM1-paper-210	STUDY OF CHEMICAL TREATMENTS OF CARBON FIBERS	139
BCCM1-paper-211	MICROMECHANICS-BASED FATIGUE LIFE PREDICTION OF COMPOSITE MATERIALS	140
BCCM1-paper-214	FLEXIBLE POLYMER COMPOSITES WITH NATURAL FIBERS	141
BCCM1-paper-219	COUPLING AGENTS AND THEIR INFLUENCE ON MORPHOLOGICAL AND MECHANICAL PROPERTIES OF COMPOSITE PLA / BURITI	142
BCCM1-paper-222	A NEW TRANSVERSELY-ISOTROPIC ELASTIC-VISCOPLASTIC CONSTITUTIVE MODEL FOR FIBER REINFORCED POLYMERS	143
BCCM1-paper-224	INFLUENCE OF THE ADITTION OF FUNCTIONALIZED MWCNT ON MECHANICAL PROPERTIES ON EPOXY/CARBON FIBER AND EPOXY/CARBON-ARAMID FIBER COMPOSITES	144
BCCM1-paper-225	DAMAGE IDENTIFICATION IN COMPOSITES STRUCTURES USING ARTIFICIAL NEURAL NETWORK	145
BCCM1-paper-226	DYNAMIC FRACTURE OF FIBRE METAL LAMINATES UNDER BLAST: ANALYSIS AND EXPERIMENT	146
BCCM1-paper-227	INFLUENCE OF THE ORGANOCLAY ON THE RHEOLOGICAL BEHAVIOR OF POLYPROPYLENE	147
BCCM1-paper-228	HYBRID NANOCOMPOSITES BASED ON PLA/CELLULOSE/SILICA SYSTEMS	148
BCCM1-paper-230	TOWARDS AN INTEGRATED XFEM-CE APPROACH FOR THE MODELING OF MATRIX CRACKS AND DELAMINATION INTERACTIONS	149

BCCM1-paper-232	PARAMETRIC SENSIBILITY STUDY OF A PUCK-MATZENMILLER'S THEORY BASED MODEL	150
BCCM1-paper-233	MECHANICAL EVALUATION OF A THERMOSET POLYMERIC MATRIX	151
BCCM1-paper-234	MULTI-SCALE MODELING OF VARIABLE ANGLE BRAIDED TEXTILE COMPOSITES AND ITS VALIDATION	152
	AUTHOR INDEX	153

LIGHTWEIGHT FLAME RETARDANT THERMOSET COMPOSITES WITH LOW SMOKE GENERATION

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Abstract: Nowadays the terrestrial public mass transportation walk hand in hand with its regular airlines counter-part, meaning that engineers, vehicles and building architects and other experts should reach a tough challenge to develop, produce and deliver strong, lightweight, durable, sustainable, ready for reverse logistic and recycling even re-use and most of all, technical parts that meet even surpass stringent European, American and Asiatic standards related to confined mass-transportation places rules. The aim of this paper is to show an updated thermoset compounds technology based on unsaturated polyester resins and additives that meet even surpass the ASTM E-162 "Standard test Method for surface flammability of materials using a radiant heat energy source" and the ASTM E-662 "Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials" and Boeing Specification Support Standard BSS 7239-1988 "Test Method for Toxic Gas Generation by Materials on Combustion" which is still in place in Brazil and boundaries. The Brazilian railway (trains and underground metro and others rolling stock) market is growing by two digits on a regular basis due to a large demand mainly to huge closer sports events such as World Cup and Olympic Games on which the currently local commercial airlines do not comply the demand based on lack of the necessary airports infra-structure.

Keywords*: Flame retardant unsaturated polyester compounds, Polymeric composites compounds*.

DYNAMIC MECHANICAL ANALYSIS OF HYBRID POLYMER COMPOSITES REINFORCED WITH RAMIE AND GLASS FIBERS

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Abstract: The use of vegetable fibers as reinforcement in polymeric composites has increased due to their low cost, biodegradability and low specific weight that may yield reasonably high specific strength and stiffness. The properties of natural fiber composites can be enhanced via hybridization with synthetic fibers (e.g. glass fiber), aiming to improve, among other properties, stiffness, strength and moisture resistant of the composites. This study focused on evaluating the dynamic mechanical properties of ramie/glass hybrid polymer composites including storage modulus (E'), loss modulus (E") and damping behavior (tan δ) as a function of the fiber composition. The natural fibers were first washed in distillated water for 50 min, dried at 105 ºC in an oven with air circulation for 60 min. After that, the fibers were mixed and manually arranged in a premold in order to produce a hybrid mat. The overall fiber loading was constant (21 vol.%) and the following relative volume fraction between glass (GF) and ramie fibers (RF) were used: 75:25, 50:50, 25:75, 0:100 (GF:RF). The composites were obtained by resin transfer molding (RTM). Dynamical mechanical analysis showed an increase in storage modulus with fiber incorporation. The highest value was found for the composites containing 75% glass fiber, as expected. Also, higher loss modulus peaks were noted when the glass fiber was incorporated in the neat resin. Finally, lower tan delta peaks were found for the composites (in comparison with the neat resin), due to segmental motion hindrance of the polymer molecules caused by fiber incorporation.

Keywords: *Natural fiber, Ramie, Hybrid composites, DMA*

MODELING FAILURE OF COMPOSITE MATERIALS DUE TO EVOLVING MICROCRACKS USING A TWO-WAY COUPLED MULTISCALE MODEL WITH TRANSITION OF MICROCRACKS INTO MACROCRACKS

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Abstract: New applications for polymer composite materials are occurring at a rapid pace today. These include structural components in the aerospace, energy, transportation, and biomedical fields. Many if not all of these new applications will require that part performance is insured with some degree of sustainable damage. Multiscale computational techniques play a major role in solving such problems related to viscoelastic composite materials due to the complexities inherent to these materials. In the present work, a numerical approach for multiscale modeling of dynamic/impact and quasi-static loading on heterogeneous viscoelastic solids containing evolving microcracks is presented. A two-way coupled multiscale approach is employed and damage is considered in the form of multiple cracks evolving in the local (micro) scale. The loading observed at the global scale is applied on the external boundary of the local scale Representative Volume Element [RVE] (global-to-local coupling), and the (incremental) homogenized constitutive properties are then calculated from the solution of the local Initial Boundary Value Problem and passed back to the global scale (local-to-global coupling), thus producing a two-way coupled global-local scheme. The developed technique allows the computation of the full anisotropic incremental constitutive tensor of solids containing evolving microstructure by solving the micromechanical boundary value problem only once at each time step. The objective of such a model is to develop the ability to consider energy dissipation due to both bulk viscoelastic dissipation and the development of multiple cracks occurring on multiple length scales. While predictions of these events may seem extraordinarily costly and complex, there are multiple structural applications where effective models would save considerable expenses. In some applications, such as aerospace, energy and military, experimentally based design methodologies are extremely costly, therefore suggesting the need for improved models. In this paper, the authors focus on the application of the developed two-way coupled multiscale model, including the recently developed scheme to account for the transition of microcracks into macrocracks, to the solution of some example problems involving quasi-static and impact loading of viscoelastic heterogeneous materials with growing cracks.

Keywords*: failure, composites, multiscale model, microcracks, viscoelasticity*

DYNAMIC FRAGILITY OF VEGETAL-FIBER COMPOSITE MATERIALS

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Abstract: In this study, the dynamic fragility of vegetable-fiber composite materials was evaluated, correlating it with its dynamic mechanical properties. Composites containing two different types of fibers, kenaf and jute, were produced by resin transfer molding. The behavior of the composites was evaluated with dynamic mechanical analysis in the isochronal mode. With the scaled storage modulus, it could be observed that the slope of the curve did not change with fiber incorporation. On the other hand, the point of maximum loss was lower for the more reinforced composites. By derivating the scaled storage modulus, a clearer notion of the dynamic fragility could be noted by the new parameter obtained. The more reinforced material showed a less pronounced peak dissipation, indicating the reinforcement effect with fiber incorporation. Finally, the scaled tan delta curves showed similar peak maximum width curves (point of maximum dissipation) indicating that the relaxation times do not appear to change with fiber incorporation, whereas the overall tan delta spectra showed broader distribution for the more reinforced material, indicating that the structure gradually changes as the fiber is added to the composite material.

Keywords: *Dieletric measurements, Dynamic fragility, Viscoelasticity*

AEROELASTIC STABILITY ANALYSIS OF ORTHOTROPIC PLATES WITH EMBEDDED PIEZOELECTRIC MATERIALS: FINITE ELEMENT FORMULATION

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Abstract: This work aims to study the aeroelastic stability boundary of flutter in aircraft panels, curved or flat, subject to the stress stiffening effects induced by the piezoelectric actuator (PZT). The Hamilton's principle was used for the formulation of the energy functional and the Principle of Virtual Displacements to obtain the equilibrium equations and boundary conditions of the problem. The finite element method was employed to solve the equations. Composite panels with two layers of piezoelectric material, symmetrically bonded on the upper and lower surfaces of the laminates were investigated. Voltage was applied to the piezoelectric actuator, to determine the dynamic pressure corresponding to the point of occurrence of flutter of the structure. The study showed that mechanical strain-induced piezoelectric effect increases the rate of occurrence of flutter, stabilizing the plate. The stress stiffening is related to the voltage applied on the actuators and the geometrical parameters of the plate. Thus, one can control the occurrence of flutter speed by controlling the voltage applied and the proper design of the geometric properties of the panel.

Keywords: *Flutter, composite materials, finite elements*

CARBON-CARBON COMPOSITES MADE BY VEGETABLE OIL

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Abstract: Samples of carbon reinforced with carbon fiber were prepared using film boiling chemical vapor infiltration with hexane and vegetable oil at 1123K, 1273K and 1373K. Kinetics and densities of the samples were studied and microstructure of carbon depositions was examined by SEM. The results show that the infiltration rate increased as temperature increased. The densification kinetics relied on temperature deposition of the surface, as carbon is a thermal and an electrical conductor, the surface temperature remains constant and assures the continuous deposition. Differences of microstructure were observed and can be attributed to precursor viscosity. Composition of microstructure was also investigated using EDS and DRX. The experiments result in rigid porous samples for vegetable oil and dense samples to hexane ones. A small reactor similar to that described by Rouvillain et al [1] was used. The perform was a carbon felt (SGL Carbon) trespassed by a carbon fiber (Toray T300 3K) as a susceptor. Inert gas was nitrogen, and precursor were hexane (LabSynth) and Soy beam oil (Cargill). The samples were attached, one at a time, in the electrodes, put inside the reactor and the electrical power turned on till the end of densification. Samples were characterized by weight gain, densities were measured by Archimedes method, microstructures were observed by SEM, EDS and DRX. SEM images shows that hexane and vegetable samples were porous. DRX result showed that both precursors produce amorphous materials (Figure is in the full article). EDS analysis indicate contamination by Na in the vegetable oil samples. This was not observed in hexane samples. Weight gain rate is higher with vegetable oil, but density was lower. As vegetable oil has a higher viscosity than hexane, it is concluded that that porosity of the samples is due to this viscosity.

Keywords: *carbon-carbon, fast densification, vegetable oil, porous, microstructure*

EFFECT OF PP GRAFTED WITH ITACONIC ACID AS COUPLING AGENT ON THE MECHANICAL AND THERMAL PROPERTIES OF PPr/WOOD FLOUR COMPOSITES

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Abstract: In this work, post-consumer polypropylene (PP) and waste wood flour from *Pinus elliottii* were used to development thermoplastic composites. The effect of using polypropylene grafted with itaconic acid (PPgIA) as a coupling agent on mechanical properties, thermal stability and morphology of the composites was investigated and compared with the composites developed with polypropylene grafted with maleic anhydride (PPgMA), commonly used as coupling agent in thermoplastic composites reinforced by natural fibers. The composites with 30 wt% of wood flour and 2 wt% of coupling agent were development in a co-rotating twin-screw extruder at 200 rpm with temperature profile from 170 to 190°C and molded by injection process. The mechanical properties showed that flexural strength improved on 29% and 35% with addition of PPgIA and PPgMA as a coupling agent respectively, when compared with the composite without coupling agent. On the other hand, the incorporation of PPgIA does not alter the impact strength values significantly. Additionally, the temperature corresponding to 3 wt% of weight loss determined by thermogravimetry for composites with PPgAI increased in 14°C when compared with composite without coupling agent, while addition of PPgMA increased approximately 6°C the composite thermal stability. A morphological study revealed the positive effect of the PPgIA on the interfacial bonding of PPr wood flour composites.

Keywords*: Composites, Wood flour, Itaconic acid, Coupling agent*

EXPERIMENTAL CHARACTERIZATION AND SIMULATION OF VARTM PROCESS TO OBTAIN CARBON/EPOXI COMPOSITES

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Abstract: The present work comprises the process VARTM (Vacuum Assisted Resin Transfer Molding) for manufacturing carbon/ epoxy composites. It was employed the software RTM-Worx to simulate the resin flow through a porous preform, which consists on a rectangular plate and a C spar. In order to run the simulation, the resin viscosity and the preform permeability and fiber volume fraction were previously determined by experimental trials. Using the simulation of resin flow to help obtain a C spar, three strategies for positioning resin inlet and vacuum outlet on the mold were evaluated. Once the simulation had led to the best proposal of infusion, the C spar was manufactured. The experimental results showed that unidirectional permeability was suitable for the application in this work, with a good linear adjustment of points. However, the filling time obtained from simulation was underpredicted when compared with experimental values (6% lower for rectangular plate and 11% for C spar). In addition, even though some inputs of software RTM-Worx were estimated, it was observed a slight deviation of simulation results and within an acceptable range according to the literature. The performing stage revealed to be a key parameter to obtain parts without defects.

Keywords: *VARTM, Unidirectional permeability, Resin flow simulation*

THERMOGRAVIMETRY USE FOR DETERMINING THE FIBER VOLUME FRACTION OF COMPOSITE POLYMERIC

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Abstract: The increase demand of new materials with improved performance that meets the design requirements has attracted increasing interest of researchers around the world. In recent years were carried out all sorts of combinations with different materials in order to obtain a composite material that would act in a specific way, which the performance of the resulting material is superior to their constituents, when analyzed individually. However, most composites consist of two phases. The first is called matrix and can be a metal, polymer or ceramic material, and another phase is called the dispersed phase or reinforcement. The interaction and the distribution of the dispersed phase in the matrix determine the final properties of the composite material. As well, the relationship matrix / fiber is of extreme importance in determining the final properties of the product. One of the most used way to evaluate the content of the matrix / fiber is the evaluation of fiber volume fraction of polymer composite by acid digestion. However, it is possible to determine the fiber volume fraction using the thermogravimetry (TGA) technique. Thus, this study aims to compare the results of fiber volume fraction of polymer composite carbon fiber / epoxy resin obtained by acid digestion of the polymeric matrix (ASTM 3171-09, Procedure B) with those obtained from TGA curves. The results show a good variance of the population, with Snedecor F equal to 0.75, indicating that the samples can be considered homogeneous at the level of 95% when comparing the data obtained via thermogravimetric with the data obtained in the traditional analysis acid digestion.

Keywords*: termogravimetry, fiber volume fraction, acid digestion, polymeric composite*

WASTE RECYCLING FOR LIGNOCELLULOSIC COMPOSITE PRODUCTION: ADDITION OF IMPREGNATED PAPER RESIDUE TO PRODUCE MDP WOOD PANEL

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Abstract: Brazilian market for wood panels is expanding. Among the types of produced panels, particleboards deserve, being MDP panel the main product. MDP means Medium Density Particleboard that is a lignocellulosic composite made with matrix of synthetic adhesive (urea formaldehyde resin) and reinforcement phase of particles of wood, and composed of three layers. This product can be marketed coated, being the Low Pressure (LP) coating the most widely used. The LP coating is defined as a special impregnated paper with melamine resin, fused to the wood panel by the action of heat and pressure. During production activities of the MDP with LP coating, impregnated paper waste are generated, which are commonly disposed in landfills, generating costs of transport and disposal of waste. However, this residue can be better applied. In order to promote better use of that waste, this study aims to evaluate the technical feasibility of incorporating the impregnated paper waste as an aggregate in the inner layer of the MDP. Other expected benefit from this proposal is the decrease of costs production because of optimization for wood consumption. For the new composite suggested a technical feasibility has been conducted by tests performed according to Brazilian standard NBR 14810/2006. To this end, physical tests were performed to determine the density of the panel, swelling in thickness, and water absorption. Also, mechanical tests were conducted of perpendicular tensile (internal adhesion) and static bending of specimens. To prepare the studied panel, were collected impregnated paper waste, and mixed them with the wood particles with resin, in proportions of 0% (condition 1), 4% (condition 2), 8% (condition 3) and 12% (condition 4), based on wood particles weight. It was checked that insertion of impregnated paper waste in the inner layer of MDP panel hasn't affected the physical and mechanical properties in comparison with the conventional product. All the results were in line with the NBR 14810 for conditions 1, 2 and 3. Some problems were noted to condition 4, where part of the results were not in consonance with the Brazilian standard for particleboards. These conclusions were also engaged in the results of statistical variance analysis performed. However, the recycling proposal of utilization the impregnated paper waste is technically feasible, contributing favorably to the rational use of raw materials, reducing operational costs with waste treatment and a greater level of environmental sustainability within the industry.

Keywords: *wood panel, MDP, particleboard, impregnated paper, recycling*

POLY(ETHYLENE-CO-VINYL ACETATE) AND WOOD FLOUR EXPANDED COMPOSITES

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Abstract: This research study the incorporation of an exothermic chemical blowing agent (2 phr) in EVA and the EVA/wood flour composite and to evaluate the effects of this agent on cell structure, (size, form and cells number/surface), density and mechanical properties. The composites were produced by a two roll mixer and molded by thermal compression. The content of wood flour of the *Eucalypthus dunnis* specie used was of 0, 10, 20 and 30 phr and the particle size used was between 80 and 150 mesh. The azodicarbonamide activated with ZnO was the chemical blowing agent used and the peroxide of dicumyl the crosslinker . The results shown that the presence and content of wood flour affects strongly on the cellular structure (morphology) and the mechanical properties (tear strength and hardness) of the expanded composite when compared with expanded EVA. The increase of wood flour content difficult the expansion capacity of the expanded composite, increase the density and the mechanical properties. Based on the experimental results, it can be deduced that the expanded composites exhibit a possible combination of relatively good engineering properties and lower density for different technical applications.

***Keywords**: EVA, Foams, wood flour, composite, chemical blowing agent*

INFLUENCE OF PLATE CURVATURE ON COMPRESSION AFTER IMPACT RESPONSE OF WOVEN-FIBER REINFORCED COMPOSITES – A NUMERICAL STUDY

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Abstract: The current industry standards used to assess the compressive residual strength of impacted composite indicates the usage of flat plates. Several studies have been published focusing on the analytical and numerical prediction of Compression After Impact (CAI) behavior, based on current standards. Commonly, the composite parts are designed with a single curvature pattern. Based on that, this paper presents a numerical study on the influence of the composite plate curvature in the CAI behavior and residual strength, using a proposed energy based constitutive damage model, implemented as an user defined material into ABAQUS/Explicit commercial finite elements package. The damage model formulation combines continuum damage mechanics and fracture mechanics approaches within a unified way by using a smeared cracking formulation. The damage model formulation allows the prediction of fiber failure and matrix cracking either in tension or compression, and an additional damage variable is also included into the formulation to account for in-plane shear failure at ply level. The curvature effects were predicted for the composite configuration proposed, showing that larger curvatures, more tolerating to compression after impact are the composite.

Keywords: *Composites, CAI, Curvature, Damage Model, Finite Elements*

EUCALYPTUS PARTICLEBOARDS: ADDITION OF OAT HULLS

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Abstract: Wood-based panels have been widely used around the world, replacing solid wood in various segments of the timber industry, such as furniture, panels, structures and other components in construction. The generation of agroindustrial residues created possibility of using other materials for the sustainability end up, motivating development of alternative solutions to their employment, highlighting chipboards. These panels are composites, so factors and levels associated with these products may provide different mechanical properties, leading research and development of new materials. Thereafter, this paper presents a study of the production and evaluation of *Eucalyptus grandis* particleboards and oat hulls, pressure bonded with two types of adhesive (castor oil based polyurethane resin and urea formaldehyde). Physical-mechanical performance of the panels produced was evaluated based on ABNT NBR 14810:2006 requirements. We carried out an analysis of variance (ANOVA) to evaluate the influence of: *Eucalyptus grandis*, with mass ratios 70%, 85% and 100%; oat hulls, in 15%, 30% and 100% proportions: and adhesives (10% over dry particles mass) as well as the combination of both, in response variables: modulus of elasticity (MOE) and modulus of rupture (MOR) in static bending; internal adhesion and density. Particleboards produced with urea formaldehyde resin did not show good physical-mechanical performance, while panels made with a polyurethane resin based on castor oil showed satisfactory performance. Statistical analysis results revealed that interactions of the fractions of oat hulls, *Eucalyptus grandis* and adhesive did not affect significantly MOE, being influential in MOR. The addition of oat hulls and the reduction of wood provided a significant increase in composites density.

Keywords: Cluster panels, waste recovery, reforestation wood.

PROGRESSIVE FAILURE ANALYSIS OF COMPOSITE LAMINATES USING LARC03 CRITERION

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Abstract: This paper presents a numerical analysis of progressive failure in composite laminates under the action of quasi static loads applied in the plane of the laminate. Stresses in each lamina are calculated using Boundary Element Method for plane elasticity. Increasing loads are imposed until the first ply failure is identified using LaRC03 failure criterion, then, using information from the failure mode, the properties of this ply (or group of plies) are reduced according to the dominance of failure (fiber or matrix). Stresses in the laminate for these new properties are recalculated until the next ply or ultimate failure occurs. Implementation of the progressive failure coupled with stress analysis using Boundary Element Method allows the identification of ultimate load that multidirectional laminates can be submitted in structural applications.

Keywords: *progressive failure, composite materials, failure criterion*

ELASTIC BEHAVIOR OF Ni-TI/GLASS/EPOXY BEAMS

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Abstract: This work in mainly concerned with the fabrication as well as the elastic flexural behavior of hybrid, Ni-Ti/Glass/Epoxy, beams tested at the temperatures: 25 ^{O}C and 69 ^{O}C. The material of such beams, which is adaptative, is known as SMAHC (Shape Memory Alloy Hybrid Composite) and, among other applications, can be adopted in vibration control. The functional phase in the SMAHC tested in this investigation is comprised by Ni-Ti wires, embedded in an epoxy matrix. The Ni-Ti alloy present two important transformation temperatures: $\mathbf{T_M}$, slightly above 25 ^{o}C; and $\mathbf{T_A}$, slightly below 69 ^{o}C. For $T<T_M$ Ni-Ti presents 100% Martensitic phase, whereas for $T>T_A$ it is fully converted in the Austenitic phase; and its elasticity modulus increases by a factor greater than two. This significant change in stiffness of Ni-Ti, without changing its mass, has motivated the application of such alloy in machine vibration control. The beams tested in this study are endowed with two symmetric plies of Ni-Ti/epoxy, relatively to their middle surfaces and located as far as possible from each other, combined with adjacent chopped E-glass mat/epoxy layers plies. The composite adaptative beams tested in this work showed a change up to 11.5% in bending stiffness, when the temperature of the wires varied from 25°C to 69°C, by means of applying a controlled electric current in the Ni-Ti wires. The results indicate that such SMAHC components can be explored in vibration control, particularly to avoid dangerous forced vibrations to take place.

Keywords*: adaptative hybrid beams, bending behavior*

CRACK PATH INFLUENCE ON DETERMINATION OF CF/EPOXY LAMINATES MODE I FRACTURE TOUGHNESS

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Abstract: In this paper the crack path influence on determination of mode I fracture toughness carbon fiber / epoxy resin laminates is discussed. Two preimpregnated systems of carbon fiber and epoxy resin and two layers architecture (plain weave fabric and unidirectional tape) are compared against their behaviour on mode I crack propagation. The mode I interlaminar fracture toughness (G_{Ic}) was determined using methodology for testing in double cantilever beam (DCB) specimen. Observed differences in crack propagation between fabric and unidirectional tape laminates are in their load-displacement curves shapes. This study will show how a resin dominated property, propagation G_I, is affected by the layer architecture.

Keywords: *Mode I fracture toughness, CF/Epoxy composites, crack propagation.*

FATIGUE UNDER SHEAR STRESS BY USING THE IOSIPESCU METHOD

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Abstract: Composite materials have increasingly being used on aerospace industry due to its low density and high mechanical strength as well as high fatigue endurance. Consequently, increase attention is being devoted to study the fatigue behavior of these materials under cyclic loads. This work presents results on fatigue under shear stress by using the Iosipescu method. For fatigue testing a cured neat epoxy resin and a glass fiber/epoxy composite having orientations of 0/90º and ± 45º in relation to the loading axis were tested by using the Iosipescu coupon. Firstly, the specimens were submitted to static tests in order to obtain the ultimate shear strength (τ) and the in-plane shear modulus (G_{12}). Further batches of specimens were tested under definite levels of stress ratio as a function of number of cycles. So, the S-N curves were obtained. The maximum number of cycles was set at 120,000 cycles, which corresponds approximately to two times the life of a structural element from a civilian airplane. The stress ratio used was R=0.1 and R=0.5. At the limit of 120,000 cycles the epoxy resin exhibited a shear strength of 10 MPa, for a stress ratio of R=0.5, and 20 MPa for a stress ratio of R=0.1. The glass fiber/epoxy 0/90º composite, at the limit of 120,000 cycles, showed a shear strength of 55 MPa for a stress ratio of R=0.1, and 85 MPa for a stress ratio of R=0.1. For the glass fiber/epoxy ±45º composite, at the limit of 120,000 cycles, a shear strength of 80 MPa and 90 MPa, where found for a stress ratio of R=0.1 and R=0.5, respectively.

Keywords: *Composite, fatigue, in plane shear, epoxy resin, glass fiber*

STUDY OF THE NATURAL AGING OF HIGH MELT STRENGTH POLYPROPYLENE (HMSPP) WITH ADDITION OF CLOISITE 20 A

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Abstract: Nanocomposites, particularly polymer/clay, has been the subject of research and developments with regard to intercalation in polymer matrix. Polypropylene is a commodity and when modified by gamma irradiation polypropylene with high melt strength (HMSPP) is obtained. In this work nanocomposite of HMSPP was obtained with nanoclay (Cloisite 20A), the nanocomposite was processed in twin screw extruder where the clay was homogenized in the melt. The material was pelletized and thermopressed to dumbbell samples submitted to natural aging for a period of four months. The aged dumbbell samples were characterized by Tensile Test, Differential Scanning Calorimetry (DSC), Scanning Electronic Microscopy (SEM) and Infrared Spectroscopy (FTIR) in comparison with a pristine HMSPP. After four months appears some superficial cracks and a decrease in the values of elongation and tensile stress was found in the nanocomposite with Cloisite 20A.

Keywords*: Polypropylene, HMSPP, Nanocomposite, Nanoclay and Cloisite*

EVALUATION OF PROGRESSIVE FAILURE OF FILAMENT WINDING COMPOSITE STRUCTURES UNDER MULTIPLE STRESS STATE

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Abstract: During last decades the improvement in manufacture process and materials properties associated with good mechanical characteristics and low weight makes composite materials very attractive for industrial applications as well as for aeronautical industry, sports equipment's, etc. Even primary structures in modern aircrafts design (Boeing 787) uses composite materials without loss of airworthiness. Despite manufacture process and material improvement, even new designs still very conservative because the composite failure is very complex. Several failure criteria and theories were developed to describe the damage process and how it evolves. This study applies a model based in continuum damage mechanics to describe the damage process of carbon fiber filament winding composite structures. These material model were implemented as a FORTRAN subroutine linked to commercial finite element software ABAQUS. Figure 1 shows the finite element model for four point bending. The material model were evaluate not only under in-plane loads but also under more complex load case obtained by simulating four point bending test of $[30^o]_{10}$ off-axis coupon as well as for conventional tensile test of $[0^o]_{10}$ and $[90^o]_{10}$ and checking the numerical results vs. the experimental test result. The results presented in Fig. 2 shows a good correlation between the numerical and experimental results. The model presented in performs well to simulate composite structures under uniaxial stress state as well as multiple stress state.

Keywords: *Damage analysis, composite, progressive failure, filament winding*

EXPERIMENTAL ANALYSIS OF LOW ENERGY IMPACT IN FILAMENT WINDING CYLINDERS

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Abstract: Composite material is very attractive for structural applications due to its inherent mechanical properties and low weight. Also, because of many manufacture process, it is possible to apply composite materials even in parts with complex geometry. Among the manufacture process, filament winding is very suitable for automation and this process is used for several applications as pressure vessels, aircrafts fuselage, tubes, etc.During service life composite structures can be damaged by collisions with objects during operations, dropping tools during assembly or maintenance, etc. Despite the effects of impact are well known, the analysis can be very difficult. Several studies present failure analysis of impacted plates, but few for cylinders. This study presents the experimental test of low energy impact filament winding cylinders. Three different lay-up for the cylinders and two levels of energy were tested. Figure 1 shows the carbon fiber filament winding cylinder test set-up for impact test.For the first energy level (11 J), the cylinders were tested using a flat plate as a support. For the other energy level (30 J) a V support were used for the tests. Two bi-directional strain gages and one accelerometer plus the force and displacement sensors were used for data acquisition.Figure 2 shows the experimental results for force and displacement for three different layups. In this figure it is possible to observe that the force peak is not the first one. This tendency is observed for all cylinders layups and test energy level regardless the support used during the tests.Also, for the energy level of 11 J C-Scan does not indicate any sign of damaged. On the other hand, for 30 J impact test, the cylinders were damaged.

Keywords*: Impact, filament winding, composite, damage.*

BAMBOO FIBER-REINFORCED POLYMER COMPOSITE

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Abstract: It is necessary to reduce environmental impacts related to global warming which are accelerated by high consumption of petroleum, a nonrenewable resource, as raw material or energy source in obtaining various materials such as glass fibers. We identified the need to develop and market composite materials based on constituents derived from renewable sources, minimizing the environmental and economic impact and dependence on non-renewable materials. The growing interest in natural vegetable fibers is mainly because it is a low-cost production that does not require sophisticated equipment for their processing. A very interesting aspect about the natural fibers are their positive environmental impact. In this study were made composites with bamboo fibers, it were manually extracted from the bamboo plantations of Federal University of Pará. The fibers were manually cut (scissors) in length of 5, 10 and 15 mm, and characterized physically by optical microscopy, mechanically through tensile testing and microstructurally by scanning electron microscopy. In the making of the composites was adopted a method using simple pre-accelerated and unsaturated terephthalic polyester resin, with the ratio of curing agent/resin, 0.33% v/v, combined with bamboo fiber length of 5, 10 and 15 mm and mass fractions of 5.41%, 4.87% and 3.90% respectively. The mechanical characterization of composites was through tensile testing and characterization of fractured surfaces using scanning electron microscopy (SEM). The results of the characterizations of the fibers were effective; bamboo fibers obtained 501.04 MPa tensile strength, 1.35 g/cm³ of specific mass. For the bamboo composites, the mechanical resistance obtained was from 15.97 MPa to the composite fiber of 5mm, 18.47 MPa to the composites with fibers of 10 mm and 22.77 MPa to the composite fibers of 15 mm. The evaluation of the fibers and composites were effective to reveal the characteristics of the fibers and the fractured surfaces of the composite produced.

Keywords*: Composites, Natural fibers, Materials.*

COMPARISON OF MECHANICAL TESTS IN COMPOSITE LAMINATES JUNCTIONS

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Abstract: More and more in aviation bonding procedure are being used and the need to explore this knowledge is increasing. With this focus, this paper explores three different composite junction, co-cure, co-bonding and secondary bonding processes are compared in an element approach according to building block definition. These processes are used in a T-shape subcomponent with carbon fiber/ epoxy laminates in shear, pullout and tensile load tests. In order to complement this study, Finite Element Method was used to preview the initial behaviour of the testing elements. This study will compare all the results based on mean values, coefficient of variance, standard deviation data and failure mode.

Keywords*: co-cure, bonding, co-bonding, carbon fiber, epoxy.*

DYNAMIC RESPONSE OF REINFORCED CONCRETE SHELTERS SUBJETED TO BALLISTIC IMPACT: A NUMERICAL APPROACH

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Abstract: This work focuses on the development of a numerical model to predict the ballistic response of reinforced concrete shelters subjected to high velocity impact induced by penetration bombs. The dynamic response of reinforced concrete shelters was modeled using the Johnson-Holmquist JH2 model. The Johnson-Cook model combined with an equation of state (EOS) for explosives were used to model the transient dynamic response of the bomb. Three different bomb geometries were investigated in this work. A comparison in terms of ballistic impact resistance on the reinforced concrete shelter is presented and conclusions are drawn.

Keywords*: High velocity impact, finite elements, composite materials, reinforced concrete.*

RECYCLED MULTILAYER CARTONS AS CELLULOSE SOURCE IN HDPE BASED COMPOSITES

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Abstract: In this paper a mechanical recycling of multilayer carton scraps (MC), consisting in the utilization of MC without the physical separation of its different fractions is proposed. In particular, pre-consumer MC industrial residues constituted by cellulose (80 wt%) and LDPE (20 wt%), have been used as a source of cellulose fibers in the obtainment of HDPE based composites. Materials containing up to 60 wt% of milled MC were prepared by reactive processing, i.e. different amount of a maleated linear low-density polyethylene (MAPE) were added during the mixing as coupling agent. Then, structure/properties relationships were investigated as a function of the compatibilizing agent and composition. Morphological analysis performed by SEM underlined strong polymer/MC interfacial adhesion in presence of MAPE. On the contrary, in uncompatibilized samples severe pull out phenomena were evidenced. The compatibilization also induced an improvement of mechanical properties of composites in terms of Young's Modulus, stress at break and toughness. Moreover, the water permeability of composites was also reduced by one order of magnitude in compatibilized samples. The effect of MAPE and MC on thermal properties was further investigated by DSC and TGA. In particular, the crystallization kinetics of composites was analyzed as function of composition both in isothermal and non-isothermal conditions. The multilayer carton scraps appear to promote the onset of crystallization of HDPE, acting as efficient nucleating agent. The presence of MAPE as compatibilizer slightly reduces the nucleating efficiency of MC. The thermal degradation of composites was also studied by means of dynamic thermogravimetric analysis. The degradation kinetic of the cellulosic fraction was evaluated and an increased thermal stability of this fraction was evidenced in compatibilized samples.

Keywords*: composites, multilayer cartons, polyethylene, recycling, properties*

RESIN TRANSFER MOLDING (RTM) MODELING AND SIMULATION WITH CONSIDERATION OF FILLER PARTICLE RETENTION AT PREFORM

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Abstract: Composite materials molded with resin, fillers and fibers are of great practical interest in materials technology applications. Resin Transfer Molding (RTM) is one of the most widely known processes for manufacturing composite parts. In order to improve the properties of composites obtained from RTM processes, resin can be filled with solid particles in nano or microscale dimensions, producing a polymeric suspension that flows through the fiber perform. Particles retention during the filled resin flow is an observed phenomenon and can promote the undesired formation of a *cake.* This terminology used in filter theory is useful to be applied here, for coupling of Darcy´s law and a filtration model able of representing the particles retention behaviour. This retention phenomenon promotes the production of poorly manufactured parts and flow front stops in space and time. The main goal of the present work is to simulate the flow of a microscale filled (calcium carbonate) epoxy resin along a rectangular mold with a fiber glass perform, considering particles retention phenomenon in order to predict the conditions in which the flow front stops. The mathematical model shown here was based upon Lefèvre et al. (2007) work. Experimental data in different operating conditions were used to estimate an expression of the flow front velocity. A set of experimental data was available and from it subsets of data were used for model parameters estimation and for model validation. Results showed that the proposed model was able to predict the position where the flow front stops. In addition, dynamic behaviour of particles retention during injection was also evaluated.

Keywords: *RTM, filtration, simulation, parameter estimation, retention.*

COMPOSITES FROM COCONUT FIBERS WITH POLYPROPYLENE AND THEIR THERMAL PROPERTIES

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Abstract: Thermal analysis was considered a valuable tool for characterize the composite materials based on lignocellulosic fibers. This composites generally presented different thermal behavior when is compared to neat fiber and polymeric matrices. In this way, this work aims to study the thermal behavior of polypropylene composites reinforced with coconut fibers. In addition, the influence of different chemical treatments and fiber content were also considered. Previously, different treatments was applied to chemically characterized fibers, and then mixed with PP using a thermokinetic mixer. The efficiency of each treatment has been evaluated by SEM and the obtained composite materials were characterized by differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA). The SEM characterization showed that the chemical modification of the fibers changed the morphology of the fibers. The thermal characterization of composites based on untreated and treated presented intermediary stability in respect to matrix and fiber. Finally, DSC curves exhibited that the crystallization process was favored by the insertion of the fibers.

Keywords: *Coconut fibers, surface modification, polypropylene, composites, thermal analysis*

EFFECT OF METAL OXIDES ADDITION ON THE CURING OF EPOXY MATRIX NANOCOMPOSITES SYSTEMS

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Abstract: The thermoset polymers obtained from diglycidyl ether of bisphenol A (DGEBA) and o-tolylbiguanidine (OTBG) are usually employed as coatings for electrical applications. The properties of the nanocomposites depends on several factors, and are in some part related to the curing reaction, thus related the crosslinks density distribution. We studied the results of adding zinc oxide (ZnO), titanium oxide (TiO_2) and aluminum oxide (Al_2O_3) in the thermal properties of the matrix DGEBA/OTBG. An increased cure heat of the reaction DGEBA/OTBG was noticed with the addition of nanoparticles. The cure enthalpy increased from about 70J/g of the pure polymer towards 90J/g after addition fillers. The catalytic mechanism to crosslinks formation must occur more intensely in the interface between particles and matrix, which will lead to a change in the crosslinks density distribution, thereby modifying molecular relaxation, give decreased of active activation energy of 65kJ to pure polymer until 54kJ to zinc oxide composite. This behavior can be observed through the increased glass transition temperature (T_g) of the nanocomposites. Non-isothermal data of curing kinetics of these materials were performed by differential scanning calorimetry.

Keywords: *nanocomposites, epoxy resin, metal oxides nanoparticles, curing kinetics, glass transition.*

POLYMER NANOCOMPOSITE OF LAPONITE RD PREPARED BY GAMMA IRRADIATION

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Abstract: A series of nanocomposite hydrogels based on polyvinyl alcohol (PVAl) and polyvinylpirrolidone (PVP) containing 0–5 wt % of the synthetic laponite RD clay were prepared by gamma irradiation process. The morphology of the nanocomposite hydrogel was observed by characterizations techniques using: scanning electron microscopy (SEM) and atomic force microscopy (AFM). The structural properties crosslinking was determined by measuring the crosslink gel content extraction on mesh 500 sizes and swelling kinetics at 22 °C. The results showed that crosslinks have inverse dependence on the clay level in the nanocomposite hydrogels, while swelling shows direct dependence.

Keywords*: Hydrogels, clay, nanocomposite*

INFLUENCE OF THE CLAY CONTENT ON THE MECHANICAL PROPERTIES OF POLY(LACTIC ACID)/EMA-GMA NANOCOMPOSITES

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Abstract: The biopolymer poly(lactic acid) (PLA) has attracted great attention of researchers due to it come from renewable resources and be biodegradable, besides posses excellent transparency and high strength. However, the PLA presents some drawbacks, like high brittleness, that should be overcome to make possible its wide application. In this work, the influence of the Cloisite organoclay content on the mechanical and morphological properties of PLA/EMA-GMA blends was evaluated. The samples were tested by impact and tensile tests. Scanning Electronic Microscopy was realized in the fracture surface of the impact samples. DRX analyses were conduced to determinate the arrangement of the clay into the blends. Morphological interpretations through SEM revealed a change on the dispersed phase since with the presence of the organoclay in PLA/EMA-GMA blends. Mechanical tests revealed that with lower clay content better impact resistance was reached.

Keywords*: polylactic acid, biopolymers, nanocomposites*

DIFFERENCES AND APPLICABILITY OF THREE BONDED LAP SHEAR TESTS

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Abstract: As the use of adhesive increases in aerospace industry, the need to know how to acquire the correct data to calculate allowable and methods to improve process confidence rises as well. All these factors motivated this study, which compares three different ways to acquire shear properties: Single Lap Shear, Double Lap Shear and Thick Adherend Lap Shear, via ASTM methods, to test adhesive properties in shear by tension loading and check if their results are comparable. This article also discusses why or why not use each method, depending on the type of information required, supported by FEM failure simulation.

Keywords*: single lap shear, double lap shear, thick adherends lap shear, adhesive film*

HOOP TENSILE STRENGTH IN SPLIT-DISK TEST OF FILAMENT WOUND COMPOSITE TUBES BY FINITE ELEMENT ANALYSIS

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Abstract: Filament wound composites are widely used in industry as pipelines and pressure vessels. In such situations materials are often subjected to complex loads involving tension, compression, hydrostatic pressures and bending. Hence, helical fiber layers are used to improve structures load bearing resistance. The aim of this study was to investigate the hoop tensile strength at split-disk tests of composite tubes for different fiber winding angles in configurations with helical layers and both helical and hoop layers. For this purpose, finite element models were built in order to evaluate the mechanical behavior of different lay-up configurations under hoop stress at split-disk test, according to ASTM D2290. Experimental results were used to validate the finite element models and the maximum discrepancy between numeric and experimental values was 8.4%. An increase of hoop tensile strength with the winding angle was found for both configurations and for angles larger than 75^{o} the difference between configurations was quite small, tending to zero up to 88^{o}. It was also found that for smaller winding angles hoop layers increase hoop tensile strength substantially.

Keywords*: filament winding, finite elements analysis, split-disk test.*

FLEXURAL CHARACTERIZATION OF BAMBOO/POLYESTER MATRIX COMPOSITES

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Abstract: The aim of this study was to develop composites and characterize them by means of flexural tests. Composites were made with polyester matrix and taquara (*Merostachys sp*.) filler. For its production, taquara sticks with 280 mm length were cut, and they were dried. Some blocks were made with dried taquara, others with chemically treated taquara, and others with taquara fibers. Some blocks suffered compression, with a 3000 kgf load. Mold dimensions are approximately 280x60x50 mm, and dimensions of the extracted specimens (SPs), 280x20x14 mm, according to ASTM D790. Chemical treatment consisted in a immersion of taquara sticks in a 10% wt. sodium hydroxide (NaOH) solution for 3 hours and a posterior immersion in water (H_2O) for 5 hours, changed every hour. It was determined that the increase of the content of sticks in the composites raises the flexural modulus for all the analyzed composites. Flexural stress ranged from 115 ± 17 to 179 ± 82 MPa, being the measurement dispersion calculated by t Student test. It was possible to create graphics with flexural stress and flexural modulus in function of volumetric fraction of taquara (VF_T), and the behavior of flexural modulus of the composites and 1st rupture flexural stress of the composites with taquara sticks can be described by rule of mixtures. 1st rupture flexural stress of the composites with taquara fibers was described by rule of mixtures and Halpin-Tsai model.

Keywords: *taquara, flexural modulus, flexural stress*

FAILURE PREDICTION IN SINGLE LAP BONDED COMPOSITE JOINTS SUBJECTED TO LOW ENERGY IMPACT LOADING

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Abstract: *The purpose of this work is to predict the failure modes of single lap composites joints subjected to low energy impact loading (10 J), through finite element analysis. The composites joints were manufactured by bonding process. Experimental data were collect during tests at the laboratory of structure at ITA (Instituto Tecnológico de Aeronáutica) by impacting the specimen using a Drop Test Tower (DTT). Maximum impact induced force and the dissipated energy for each specimen were measured. Finite element simulations were carried out using continuum damage mechanics based failure models, which enables prediction of intra and interlaminar failure modes. Good correlation in terms of impact force, displacement and damage pattern was obtained.*

Keywords: *Composite materials, finite elements, impact, damage mechanics*

CHARACTERIZATION OF CARBON FIBER/EPOXY RESIN PREPREG BY THERMOGRAVIMETRY AND FT-IR

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Abstract: Thermogravimetry (TGA) and Fourier transform-infrared spectroscopy (FT-IR) conjugated with different techniques as transmission and attenuated total reflectance (ATR) have been used for the characterization of differents materials and especially for high performance materials such as prepreg. This present work aims to contribute to the domain of physical and chemical characterization of prepreg. For this, the carbon fiber/modified epoxy prepreg was evaluated by termogravimetry and Fourier transform infrared spectroscopy (FT-IR). The TGA results show two steps of weigth loss, one between 155 °C- 244 °C (only 1.2%) and another at 274 °C (27%) in nitrogen atmosphere. Probably, the first step was corresponding the loss of volatile products and water from curing reaction. And the second step could be the weight loss of the resin system. In addition, it was also possible to identify by FT-IR technique some of the prepregs constituents, such as epoxy resin (DGEBA- Diglycidyl ether of bisphenol-A); curing agent (DDS- 4,4-diamino diphenyl sulfone) and also the type of toughening agent used (thermoplastics as polyamide 6 and poly-ether-sulfone).

Keywords*: termogravimetry, infrared spectroscopy, prepreg, polymeric composite*

FUNCTIONALIZATION OF MULTI-WALLED CARBON NANOTUBES THROUGH BALL-MILLING PROCESS AND THEIR USE AS FILLERS IN PP-BASED NANOCOMPOSITES

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Abstract: In this work, the ball milling process was used to functionalize the surface of multiwalled carbon nanotubes (MWCNTs) with maleated polypropylene (MAPP), with the aim of preparing MWCNT/polypropylene composites with improved matrix/nanotube compatibility. The occurrence of the grafting reaction was evaluated by FT-IR spectroscopy and the yield was quantified by thermogravimetric analysis, as a function of the milling time. Dispersion experiments confirmed the nanotube surface modification of the nanotubes since functionalized MWCNTs remained stably dispersed in an ethanol solution for prolonged times after sonication. Transmission electron microscopy demonstrated the absence of significant structural damage after the mechano-chemical treatment. Moreover, an evident layer attributable to the presence of grafted MAPP chains on MWCNT walls was clearly detected. The average thickness of this amorphous layer was evaluated and compared with quantitative TGA data. PP-based nanocomposites containing functionalized NWCNTs were also prepared and characterized in their rheological, mechanical and morphological properties. From rheological tests it was inferred that more effective polymer/nanotube interaction took place with grafted nanotubes, particularly in the case of samples containing the 3.0 % wt. of functionalized nanofillers. Moreover, the milling process improved the dispersion of nanotubes into the PP matrix, resulting in enhanced mechanical properties.

Keywords*: carbon nanotubes, nanocomposites, mechano-chemical functionalization*

COMPRESSIVE BEHAVIOUR OF POLYMERIC COMPOSITES REINFORCED WITH SAWDUST

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Abstract: The sawdust or waste arising from wood processing is aggravating when indiscriminately discarded in nature, providing environmental impacts. The reuse of sawdust wastes as reinforcement phase in polymeric composites has been the focus of much research for sustainable construction applications. This work evaluates the mechanical behaviour of composite materials in compression testing. The epoxy matrix was reinforced with sawdust from *Eucalyptus* and *Ipê* species. The sawdust particle sizes of 4-10 and 50-80 US Tyler, and the volume fractions of 30 and 50% were investigated in the experiment. Compression tests were performed to determine the mechanical strength. The results revealed that *Eucalyptus* wood provided better results compared to *Ipê* specie. The sawdust particle size and volume fraction significantly affected the responses. This testes performed in this study were the basis for the analysis of the mechanical behavior using a composite wood in nature, ie without any treatment.

Keywords: *composite particles, sawdust, epoxy resin.*

BENZOXAZINE RESIN DEGRADATION KINETIC

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Abstract: In the last decades a new class of thermoset fenolic resins is emerging as a substitute of the traditional epoxy and phenolic resins in the aerospacial industry. This new class is called polybenzoxazines and it associates the epoxy resin's mechanical properties and fenolic resin's thermic and flame retardant properties, resulting in a resin with superior properties when analyzed with the others singly. This way, benzoxazines are considered polymers of elevated performance with high temperature resistance, dimensional stability, good electrical properties, high glass temperature, low humidity absorption, and no need of catalyzes and no sub products generation during the cure, so it's possible to store them in ambient conditions. In this context the polybenzoxazines are excellent candidates to substitute the current thermoset matrix used in the processing of high performance composites either reinforced with continuous fibers or nanometric structures. Thus, in order to analyze the thermostabillity of the benzoxazine resin, the thermal degradation kinetic was studied using its thermogravimetric curves. For that, different heating rates were used 2, 4, 6, 8 and 10ºC.min^{-1} to the achievement of the kinetic parameters (activation energy, E, and pre-exponential factor, A) based on the Flynn-Wall-Ozawa model (F-W-O). The results shows good agreement between the thermogravimetric curves and fit in the F-O-W model. The pure resin shows the onset point (beginning of the degradation) of thermal decomposition when in presence of nitrogen in 210ºC and the activation energy increases with the heating rate.

Keywords*: termogravimetry, benzoxazine resin, degradation kinetic, polymeric composite*

ANALYSIS OF THE DRILLING DELAMINATION OF COMPOSITE MATERIALS

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Abstract: In this paper experimental studies are performed, analyzing two cutting parameters, namely the feed rate and the cutting speed, and its influence in the delamination of composite materials. As these parameters can be controlled a better drilling performance can be achieved by an appropriate choice of these parameters. The drilling delamination is analyzed at the hole exit, after the drilling process is performed. A standard carbon fiber with epoxy matrix and a new material are tested. The new material is manufactured with carbon fiber and matrix of epoxy resin and anhydride, its matrix is modified with hydroxylated liquid polybutadiene in a portion of 20%. Delamination factor is calculated for different feed rates and cutting speeds. The specimens are scanned and then using *Image J* software the delamination caused by the drilling process is measured. An analysis of the damage is related to the different cutting speeds and feed rates used, as well as the influence of the composition of the material in the delamination factor. A new mathematical model is proposed to characterize the delamination, which is performed in a simple way and considers the damaged area in the delamination factor.

Keywords*: Delamination, Composite Materials, Drilling.*

MECHANICAL TENSILE PROPERTIES OF COMPOSITES REINFORCED WITH SHORT FIBERS OF BAMBOO AND GLASS

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Abstract: Natural resources play an important role in the economies of all countries of the world, including assisting in the social sector in developing countries. Therefore, it's not surprise the rising tide in search of new process applications and products originating from renewable sources. Another important factor is the reduction of environmental pollution, with the use of materials obtained from renewable sources. Between the natural resources are the natural plant fibers, with properties that deserve mentioning as biodegradability that are found in abundance in nature, have good mechanical properties, low cost, etc. Combined with these vegetable fibers appears the polymeric composites materials, which are an alternative of sustainable material for replacement of synthetic materials that degrade the environment. In this article was crafted polymer composites with short fibers of glass and bamboo, the bamboo fibers were manually extracted and glass fibers were acquired in trade from Belém - PA. The fibers do not suffered any treatment. Being the fibers manually cut (scissors) in length of 5 mm, they were physically characterized by optical microscopy, mechanically through tensile testing and microstructurally by Scanning Electron Microscopy (SEM). In confection of the composite was adopted a simple method using polyester resin and pre-accelerated and unsaturated terephthalic polyester resin, with the ratio of curing agent/resin 0.33% v/v, bamboo fiber combined with glass and length of 5 mm and mass fraction of 10.41% and 5.41% respectively. The mechanical characterization of composites was through tensile testing and characterization of fractured surfaces using scanning electron microscopy (SEM). The results of the characterizations of the fibers were effective; bamboo fiber obtained 501.04 MPa of tensile strength, 1.35 g/cm³ of specific mass, and the fiber glass got 1685.76 MPa of tensile strength, 2.40 g/cm³ of specific mass. The results of mechanical characterization of bamboo composites obtained 24.12 MPa tensile strength, and glass composites obtained 33.80 MPa tensile strength. The microstructural analysis of both the fibers and the composites were very efficient to identify the peculiarities of the fibers and the fractured surfaces of composites manufactured.

Keywords*: Mechanical characterization, Composites, Fibers.*

EVALUATION OF POLYMERIC MATRICES FOR APPLICATION IN COMPOSITE CORE OF CONDUCTOR

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Abstract: The increase in demand and the difficulty in constructing new transmission towers have brought a great challenge to supply electricity in various cities around the world. The cables used in towers are conducting more current, which brings a problem of excessive cable sag and limits the span length. Consequently, it is necessary to develop new cables with low thermal expansion, low specific weight and high mechanical resistance. The use of composite cores for this kind of cables helps to improve all these properties. However the use of new materials in the cores may create a series of problems in relation to applicability that need to be assessed. The use of polymers in composite cores of transmission cables may cause problems of degradation due to exposure to high temperature, humidity and ultraviolet (UV) radiation. The aim of this work is to evaluate carbon fiber pultruded composites with Isophthalic Polyester, Epoxy and Phenolic resin matrix in relation to the thermal stability and mechanical properties. First, the material was identified by Fourier Transform Infrared Spectroscopy (FTIR) and thermal stability was evaluated by Thermogravimetric Analysis (TGA). Then the mechanical properties of the composite materials - tensile strength, Young modulus and Poisson ratio were determined.

Keywords*: Fiber Reinforced Polymer, Thermal Analysis, Mechanical performance, Electricity transmission lines*

TENSILE STRENGTH OF POLYESTER MATRIX REINFORCED WITH NATURAL FIBERS (SISAL) ALIGNED

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Abstract: The production of composites using natural fibers has been growing in the recent years. In this context the search for new options of materials that can provide composites with high resistance is increase. Among fibers that shows good mechanical strength are the natural fibers as the Curauá, which have great mechanical strength, thus being used in many studies in the field of natural polymer composites. This study try to use a uncommon way to make composites with natural fibers, in that it is difficult to manufacture the alignment of long fibers at 0° unidirectional and evaluate the mechanical behavior of a polyester matrix composite reinforced with sisal fibers. The manufacturing process consists in manual laminating of sisal fibers after they were aligned and transformed into pre-pregs (slides). Three slides were used for the manufacture of the composite. After curing, the specimens were normalized for mechanical assessment of the composite through the tensile tests. The maximum values were 1179.59 N for force in the test and tension of 129.49 MPa. It also calculated the volume fraction of fibers Vf of the sisal fibers present in the composite, whose value was Vf = 41.26%.

Keywords: *Sisal fibers, Composites, Fiber laminating, Tensile test ,Aligned fibers.*

MOISTURE ABSORPTION OF CASTOR OIL POLYURETHANE COMPOSITES REINFORCED SUGARCANE STRAW CELLULOSE

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Abstract: Composites materials formed by natural fibers and polymeric matrices constitute a current area of interest in composites research. The incorporation of lignocellulosic material as a reinforcing component in polymer composites has received increased attention in recent years, particularly due to the price driven and high volume applications. Polyurethane resins are attractive due to their structural versatility, as well as the fact that they can be derived from either petroleum or vegetable oils. Using castor oil polyurethane (PU) as matrix for composites reinforced with lignin and cellulose from sugarcane straw is in tune with economical and environmental interests. This work is concerned with the development of polyurethane composites reinforced with cellulose fibers attained from sugarcane straw. For the obtainment of cellulose, sugarcane straw was pretreated by steam explosion, followed by a delignification with NaOH. For the production of the PU, the polyol (castor oil) to diisocyanate mass ratio was 1.5:1.0. Reinforcement of the matrix was done changing the concentration of cellulose fibres (5,10,15,20% w/w). The efficiency on the obtainment of cellulose fibers was verified by chemical characterization and the morphological aspects by SEM. The moisture absorption of the composites were evaluated.

Keywords: *Sugarcane straw; Cellulose; Castor oil polyurethane; Composites; Natural fibers*

PREPARATION OF BLENDS OF POLYAMIDE 6/COMPOUND RECYCLED RUBBER BLENDS

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Abstract. The polymer blends are polymeric materials originating from the mixture of at least two polymers and/or copolymers, without a high degree of chemical reaction between them. The blends of polymers with different physical properties can help improve the material properties through a combination of each system component. However, mixing two immiscible polymers is a big problem because the mixing materials are hardly processed, extruded or injected, and are very brittle. One of the agents most often used to improve the interaction between two immiscible polymers is the addition of a third component to the mixture, called a compatibilizing agent, which increases the adhesion between the polymers and improves the mechanical properties of the resulting material. The application of polyamides is limited by low impact performance when notched in room temperature conditions. This situation is worsening, especially for use in temperatures below zero degrees Celsius. One way to outline this limitation is to prepare polymer blends where the dispersed phase is an elastomer, and then classified as an immiscible blend. Therefore, this study aims to develop blends of polyamide 6/compound by recycled rubber styrene-butadiene (SBR), with addition of compatibilizer PP-g-MA and PE-g-MA in order to achieve a balance between stiffness and tenacity. The results obtained with the rheological study showed that mixtures of PA6/PE-g-MA presented the best results in comparison with mixtures of PA6/PP-g-MA, indicating that there was probably a reaction between the components, which may allow a better dispersion and thus can achieve better properties.

Keywords: *polyamide 6, SBR, compatibilizers*

SKIN-STIFFENER INTERFACE ANALYSIS OF COMPOSITE PANELS

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Abstract: Integrated panels has been extensively studied. One of this study is the integration between skin and stiffener. Skin and stiffener integration without mechanical joint has advantages and disadvantages. Advantages can be in assembly and weight saving, but guarantee of manufacture, inspection and reliability are some of the challenges to be overcome. This is a part of the problem that will not be discussed in this paper but it deserves attention. In terms of analysis there are also issues to be investigated. For example, failure criteria. Therefore, the objective of this paper is to present a summary of the directions in the field of structural analysis. Firstly, based in some papers and thesis published, some paragraphs and figures of these references are reproduced for the article proposal. In the theoretical part, cohesive element is presented. To support the analysis, standard test used to obtain the allowable for interface analysis criteria are presented and commercial software results for different applications are showed. Finally, in conclusion, are cited the challenges that were not included in this present work.

Keywords*: composite panel, bonding, cohesive element, standard test, applications.*

CERAMIC MATRIX COMPOSITES DERIVED FROM $TiSi_2$-FILLED POLYSILOXANE

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Polymer-derived ceramics is a material science field that has attracted great interest since it has a greater potential to produce ceramics with controlled composition, shape and porosity. During the last two decades much research efforts have been reported on preparation and properties of silicon oxycarbide glasses (SiOC) in order to obtain new advanced ceramic materials. This work focuses on the preparation of ceramic matrix composites based on silicon and titanium oxycarbide glasses (SiTiOC) by pyrolysis of a siloxane network using $TiSi_2$ as reactive filler. The polysiloxane was prepared by hydrosilylation reaction between the homopolymer poly(methylsiloxane), $(CH_3HSiO)_n$ (PMHS) and the cyclic oligomer 1,3,5,7-tetramethyl-1,3,5,7-tetravinylciclotetrasiloxane (D_4Vi) in a mass ratio of 1:1 and 3:7, respectively, using a Pt catalyst. After cure the polysiloxane was grinded (200 meshs) and $TiSi_2$ was added to the powder in proportions of 5, 10, 20 and 30wt%. The mixture was uniaxially pressed (~10 MPa) in a steel mould, and the stabilization of the green bodies were achieved by adding an amount of the liquid precursor. The polymer-to-ceramic conversion occurred through the pyrolysis under inert atmosphere (Ar) at temperatures of 1000, 1250 and 1500ºC. Samples were analyzed by FTIR, XRD, SEM and the electrical properties were measured as well. The results for the concentration of 1:1 showed that the morphology of the obtained materials is porous and the sintering occurs at higher temperatures. The porosity decreases with increasing amounts of $TiSi_2$ and pyrolysis temperature. At temperatures of 1000 and 1250ºC no reaction between the filler and the derived-ceramic was observed by XRD. However, at 1500ºC it was observed the formation of new crystalline phases such as titanium carbide and cristobalite. The electrical characterization showed that the SiOC obtained at 1000ºC can be used as an electrical insulator.

Keywords*: polysiloxanes, polymer-derived ceramics, ceramic matrix composites, SiTiOC.*

MECHANICAL AND PHYSICAL CHARACTERIZATION OF GLASS/POLYESTER AND SISAL/POLYESTER COMPOSITES

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Abstract: Recently, researches on ecomaterials have gained considerable prominence, especially in the area of composite materials. Ecomaterials have properties environmentally friendly as compared to traditional materials. Within this context, this paper aims to study the tensile mechanical properties and fracture characterization referring to three composite materials: a biosensor (fabric on the based sisal fiber), a hybrid composite (based on fabric and the fiber mat of glass fiber) and a reference material made with glass fiber mat. These composites were made by hand lay up process, each one with five layers of reinforcement. After the fabrication of the composites, tensile tests were performed (ASTM D 3039). A comparison was later carried out to verify the feasibility of using the biosensor based on the fiber fabric.

Keywords*: Sisal / polyester, Mechanical Properties, Final Fracture.*

CHARACTERIZATION OF THERMAL PROPERTIES OF HDPE AND CASHEW NUTSHELL POWDER MIXTURES

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Abstract: The development of polymeric composites using renewable reinforcement has growth astonishingly in the last years. The use of this kind of reinforcement in composites has increased due to its low cost, recyclability, biodegradability and low density. In this work, mixtures of recycled high density polyethylene (HDPE), 5 wt% of polypropylene modified with maleic anhydride (PP-g-MA) and 5 wt% of Strutkol TPW 113 without and with 20 and 30 wt% of cashew nutshell powder were melt-processed, using an internal mixer. Thermal properties of composites were characterized by Differential Scanning Calorimetry (DSC) and Thermogravimetry (TGA). The thermal analysis by DSC was used to determine the melting temperature (Tm), crystallization temperature (Tc) and degree of crystallinity (Xc) of composites. All these thermal properties remained almost constant for all formulations. The temperature at maximum decomposition rate was determined by TGA, and differences were restricted to thermal behavior of main components. Thus, in terms of thermal properties, the use of cashew nutshell powder in mixtures of wood plastic composites can be a way to achieve environmentally friendly materials.

Keywords*: polyethylene, composite, cashew nutshell, TGA, DSC.*

ASSESSMENT OF AUTOMATED FIBER PLACEMENT COVERAGE GENERATION ALGORITHMS

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Abstract: The automated fiber placement process has been developed to allow manufacturing of complex shape structural composite parts. In order to achieve high process repeatability, numerical control (NC) machines or robotic platforms are used, and Computer Aided Manufacturing (CAM) software is employed for generating the coverage (i.e., the machine's head paths over a mandrel surface), optimizing the manufacturing sequence and generating the NC or robotic machine code. In this work, several algorithms are employed in the coverage generation of a complex part, representative of a rear fuselage section. The results show that there is a compromise between minimizing gaps/overlaps and minimizing fiber angle deviation, and that the coverage generation is strongly dependent on the manufacturing strategy.

Keywords: *coverage, fiber placement, gaps, overlaps, fiber angle deviation*

EXPERIMENTAL EVALUATION OF AUTOMATED FIBER PLACEMENT MANUFACTURING PARAMETERS

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Abstract: Composites are being continually used to fulfill nowadays demands for lighter and high performance parts. Automated Fiber Placement is being used as a technique to achieve best results to manufacture complex composite parts. However, the process induces some defects in laminate, such as Gaps, Overlaps and tow drops. This work studied the correlation between manufacturing main parameters: feedrate, tow temperature, tow tension and compaction pressure; and laminate defects. Tests have revealed that it is possible to control the parameters to avoid such defects.

Keywords: *fiber placement, gaps, overlaps, feedrate, composite manufacturing*

THE INFLUENCE OF FABRIC STRUCTURE ON THE MECHANICAL PROPERTIES OF GLASS FIBER AND ARAMID FIBER REINFORCED POLYESTER COMPOSITES

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Abstract: In this work, was evaluated the influence of the reinforcing structure and composition on the mechanical properties of polyester composites. The material under study was developed in laboratory scale using handloom machine for producing aramide fabrics and aramide/glass hybrid (65/35) fabrics using plain woven structures. Composites of polyester/aramid fabrics (CTA) and polyester/aramid and Glass fiber (CTH) are produced using compression molding under 5 ton for 4h at room temperature. The composites with similar fiber contents in warp direction were obtained, although the fiber content in weft direction was varied as function fiber content into structure of fabrics. Tensile testing was carried along the warp and weft direction out according to ASTM D 3039 standards at room temperature and 1 mm/min test speed. The results obtained showed a strong influence on the composition of the woven in the tensile properties of the composites. It was also observed that for CTH composites best properties were obtained when the test was carried out in warp direction, aramid fiber. Comparing the values of tensile strength of the composite CTH tested in warp direction with CTA composite, is observed an increase of about 100% in the resistance using a hybrid fabric with the same structure as Kevlar fabric.

Keywords*: Plain Wave; Aramid Fiber; Glass Fiber; Polyester Resin; Composite*

EVALUATION OF THE MECHANICAL PROPERTIES OF HYBRID WEAVE FABRICS REINFORCED EPOXI COMPOSITES

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Abstract: The influence of structure and composition of the technical textiles in the mechanical properties of epoxy composite as evaluated. Thus, two different fabric structures are used: plain woven and twill woven for reinforced epoxy composite. Raman Spectroscopy was applied to characterize the epoxy resin and components are evaluated before and after premixed epoxy mixture was analyzing in gel time and pre determined time of 70, 100, 130, 160, 190, 220 e 1.440 minutes Composite materials were obtained through of compression molding process under 5 ton for 12 h at room temperature. Laminate made of 3 layers of biaxial fabrics produced using Kevlar 49 fibers plain weave structure and hybrid Kevlar 49/S-glass fibers, twill weave structure and the volume fraction was 35% in matrix of epoxy resin. Tensile testing was carried out according to ASTM D 3039 standards at room temperature and 1 mm/min test speed. Preliminary results showed that the composites reinforced with fabric, the design of the structure in this case has no influence on the mechanical properties in tension. However, the process of hybridization structures becomes of interest due to lower content of aramid maintains the properties of the composite, thus reducing the cost of material

Keywords: plain weave; aramid fiber; glass fiber; epoxy resin; composite

COMPOSITES OF TAQUARA-LIXA FIBERS WITH POLYESTER RESIN

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Abstract

The aim of this study was to develop composites using "Taquara-Lixa" (*Merostachys sp.*) and orthophthalic unsaturated polyester resin at different volumetric concentrations and determine the mechanical properties by means of flexural tests and the tensile strength of the fiber by means of tensile tests. The preparations of the fibers had the following methodology: 48 hours after extracting taquara from nature, the percentage of moisture was determined by drying it in an oven at 100º C under vacuum. Drying was conducted for a period of 42 hours in 5 samples, where the average moisture obtained was 46%m/m. For these samples, a chemical treatment was carried out with sodium hydroxide solution (NaOH) at 10%m/m for 1.5 hours in order to soften and remove partially the extractives which cover the cellulose fibers. The extraction was performed using a mechanical device that crushed the structure among the taquara fibers and at the same time allowed the fibers to be partially loose. This procedure was repeated twice. The next step was to treat these fibers with hydrogen peroxide solution (H_2O_2) at 10%v/v for 20 minutes, in order to bleach the fibers. After this, the fibers were rinsed and dried. Then the masses of fibers were determined and the percentage of extractives was calculated. The average percentage found was 14%m/m. After being partially loose and approximately 280 mm in length, the fibers were placed in a steel mold used in the compression molding process. After the dispersion of resin among the fibers, both were compressed until the final cure of the resin. Due to the increase of volumetric fraction, different loads were applied. This procedure allowed the manufacture of composite blocks from which specimens were extracted according to standard method for flexural tests ASTM D-790. The flexural strength values of the composites have been described by the rule of mixtures until the volumetric fraction of 75%v/v, the tensile strength of the fiber was higher than the extrapolated, suggesting delamination in the fiber/resin interface. The Young's Modulus variation of the composite can be described by the rule of mixtures, allowing to obtain by means of extrapolation, the Young's Modulus of the fiber, which was 29.5 ± 5.3 GPa.

Keywords: *Taquara fibers, composites, flexural tests, Young's Modulus, tensile strength.*

PREDICTION OF TENSILE PROPERTIES OF CARBON FIBER REINFORCED CARBON-SIC HYBRID MATRIX COMPOSITE BY A MODIFIED MICROMECHANICS APPROACH

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Abstract: Advanced fiber-reinforced composite materials are been widely used in various load bearing structures. Nowadays their usage span from sporting goods to aerospace structures. The ever-increasing popularity of fiber-reinforced composites is due largely to their lightweight, high strength, and superior structural durability. Composites can be classified by their temperature use. At high temperatures (T> 500 ^{o}C) only composites made with carbon or ceramic-like matrices and carbon fiber or other ceramic fibers can be capable for use in structural applications. The microstructure of composites plays a dominant role in forming all the composite properties, which includes also the failure mechanisms. In principle, property characterization of fibrous composites should be based on their precise microstructures. In practice, however, the true microstructures of the composites are often simplified in the characterization models, both geometrically and materially. The degree of simplification depends on the desired engineering accuracy. Compression strength, shear strength and tensile strength are design base material properties. Characterization of the mechanical properties for these composites at low and high temperatures is a demanding task since they are brittle in nature. This is particularly true for tensile tests since grip fixtures and testing coupon shapes can be difficult to machine. This work proposes a new approach based on micromechanics to predict tensile strength of a type of thermostructural composite based on carbon fiber reinforced carbon modified by Silicon Carbide (CFRC-SiC). Calculations were done for CFRC-SiC in the range of 35%/volume fibers to 55%/volume fibers and assuming porosity varying from 5%/volume to 20%/volume. SiC content in the CFRC-SiC was assumed to be 20%/volume, which is in agreement with all commercial materials. Results for predicted tensile strength of CFRC-SiC calculated by the model proposed in this work are in the range of 140 MPa to 240 MPa, depending on fiber volume fraction, pore volume fraction and the apparent tensile strength of the C-SiC hybrid matrix (97 MPa to 107 MPa).

Keywords*: thermostructural composites, carbon fiber, C-SiC matrix, tensile strength, modeling properties*

INFLUENCE OF INTERFACIAL ADHESION ON FLEXURAL STRENGHT OF STRUCTURAL COMPOSITES

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Abstract: In this paper the effect of T800HB (Toray) and IM7 GP (Hexcel) on polymeric composites interfacial adhesion was evaluated by flexural analysis. The interface were analyzed by Fourier Transform Infrared Spectroscopy (FTIR) and Dynamical Mechanical Analyses (DMA). The Scanning Electronic Microscopy (SEM) was used as a complementary evaluation technique. Both composites were manufactured with Cycom 890 RTM resin via resin transfer molding (RTM) process. The analysis revealed that structural composites manufactured with IM7 GP fibers (TW-IM7GP) have higher interfacial adhesion.

Keywords*: interfacial adhesion, structural composites, DMA, FTIR, RTM.*

PROCESS EVOLUTION DURING DENSIFICATION OF 3D CARBON FIBER REINFORCED CARBON COMPOSITES BY THERMOSET RESIN AND PITCH

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Abstract: Carbon is an ubiquitius material that is essential for the everyday life. Properties of carbon materials depends on material´s history, and this is particularly important when processing Carbon Fiber Reinforced Carbon (CFRC). Exotic fiber performs and unusual processing routes are kin to these materials. Many areas of chemical processing and materials science permeate the processing routes to achieve a role solid carbon structure. The unique behavior of carbon composites allows it to be obtained by solid, liquid and gas routes. For instance, by using liquid impregnation, thermoset resins and pitch binders are used. In this case, pores of the preformed carbon fibers are filled by the liquid precursor, followed by pyrolysis up to 2800 ^{o}C, where a graphite like structure is formed. Release of unwanted low molecular gas compounds and matrix shrinkage leads to a porous CFRC material. As a consequence, a number of other new steps of impregnation/pyrolysis processes are done to achieve a maximum possible density of the body. The development of a pore network during processing cycles is a key issue to improve process efficiency. The intent of this work is to make theoretical calculations for the densification process, related to density, and based on liquid phase processing using a termoset resin and pitch. The efficient processing of CFRC composite can be influenced mainly by the preform architecture, the carbon yield of the precursor impregnation matrix, temperature and pressure, and dimensional changes of the material during processing. Theoretical calculation shows that the limit for liquid impregnation efficiency using standart pitches is ~55% and gets down to 15-20% when processing is made at atmospheric pressure. For liquid impregnation/pressure carbonization the densification efficiency increases as a function of the number of processing steps. The efficiency of processing is an important issue in the manufacture of CFRC composites to assure quality warranty of the material for thermostructural applications. For rocket nozzle throats, efficient processing of CFRC is a key issue, because it keeps porosity at a lower level, improving erosion resistance.

Keywords*: Carbon Fiber Reinforced Carbon, Carbon Fiber, Pitch, Resin Matrix, 3D Composite*

THERMAL AND MECHANICAL BEHAVIOR OF GLASS/POLYESTER COMPOSITES MOLDED AT DISTINCT TEMPERATURES

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Abstract: Among the manufacturing process for thermosets composites, hand lay-up is one of the most used techniques due to its simplicity and low cost. One of the processing parameters that most influence the behavior of the material is the curing temperature. Thus, the aim of this study is to investigate the effect of the curing temperature on the characteristics of glass fiber reinforced polyester composites. The composites were laminated using a glass mold (two plates) by alternating layers of glass fiber cloth and resin. According to the differential scanning calorimetry (DSC) results, the cross-linking reaction of the resin was considered complete for temperatures of at least 80 °C. Besides, the composites with cured at higher temperatures showed higher storage and loss moduli and higher glass transition temperature. The hardness did not show a clear trend, whereas impact strength achieved a maximum at 100 °C. The interlaminate shear strength (ILSS) was found to increase up to 120 °C. In all, the composites cured between 100-120 °C showed superior mechanical behavior.

Keywords*: polymer composites, curing temperature, thermal analysis, mechanical analysis.*

RESEARCH AND DEVELOPMENT ON COMPOSITES – A STRATEGY TO OVERCOME TECHNOLOGICAL CHALLENGES

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Abstract: Affordable structures, with less weight and less cost will enable the achievement of a sustainable society. For complete sustainable life cycles the materials to be used on the affordable structures will have its origins on renewable sources and will be safely recycled or disposed. Recent years faced the up growing demand for the application of composite materials. Several advances in manufacturing techniques and material science are leading composites as one of the best options for lightweight structures. Aerospace represents the most important market for such advances, basically for the continuous demand for lighter and reliable materials. However, the demand for new techniques and materials represents a technological challenge for the high competitive markets, such as aerospace, automotive, energy, petrol and gas, and telecommunication. A strategy that most leading companies are pursuing to overcome such challenge is to create an environment where research and development (R&D) can be conducted. Highly trained teams, advanced manufacturing equipment and financial support for innovation are the main requirements R&D institutions for lightweight structures have to look for. Designing and installing the Lightweight Structures Laboratory-LEL of the Institute for Technological Research (IPT), represents one of the Brazilian efforts on the development of lightweight structures.

Keywords*: lightweight structures, composites, research, technological solution*

EVALUATION OF THE PROCESS OF CALCINATION OF NICKEL FERRITE IN OBTAINING COMPOSITE POLYMERIC

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Abstract: The lines of research in composites attempt to predict the physico-chemical and mechanical properties a given mixture of materials. In this work, a composite was produced using as polyamide 6 matrix and how load the nickel ferrite after calcination at 700, 900 and 1200°C in the concentration of 50 wt.%. This mixture was compacted in a hydraulic press with heating and characterized by XRD and SEM. The XRD results showed the characteristic peaks of polyamide 6 and ferrite. SEM results showed that the sample that presented better dispersion was the composite of polyamide 6/ nickel ferrite calcined at 1200° C, presented a good dispersion of nickel ferrite in the matrix that is identified by presence of larger clusters and evenly distributed.

Keywords: *composite, polyamide 6, nickel ferrite, calcined;*

MULTI-SCALE ANALYSIS OF FAILURE IN COMPOSITE MATERIALS

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Abstract. This paper presents a numerical analysis of failure in composite materials using multi-scale modeling. The stresses are calculated by the boundary element method for plane elasticity in the macroscale. The microscale problem is analyzed considering the macroscale solution as boundary condition. A representative volume element (RVE) is applied to evaluate the damage occurrence in some geometric points.

Keywords: *Composite Materials, Multi-scale Modeling, Boundary Element Method*

SYNTHESIS OF NEW HYBRID MATERIALS BASED ON CHITOSAN AND ZNAL2O4

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Abstract: The aluminate is zinc oxide with a spinel-type structure consisting of AB_2O_4 normal a closed packing arrangement of CFCs. Hybrid organic-inorganic materials are of great interest in commercial applications due to their mechanical, optical and thermal properties, which combine thermal and chemical stability of ceramic materials, with the flexibility and processability of the compounds and organic polymers. This study aims to develop hybrid organic-inorganic nanoparticles from $ZnAl_2O_4$ obtained by combustion reaction and chitosan biopolymer in a ratio of 1:1. The powders of $ZnAl_2O_4$ were obtained according to the theory of explosives and propellants. The powders were synthesized unbundle and passed 325 mesh sieve and then added to the chitosan diluted in 1% acetic acid. These were filtered, placed in Petri dishes and subjected to an oven at 60°C. After drying the films, a solution of 1M sodium hydroxide was added with the intention of obtaining neutral pH. The powders synthesized by combustion reaction and the organic-inorganic hybrids were characterized by XRD and FTIR. $ZnAl_2O_4$ nanoparticles showed characteristic peaks of crystalline phase of spinel. The hybrids showed peaks of $ZnAl_2O_4$ and chitosan. The vibrational bands observed in the spectra in the infrared spectroscopy, below 1000 cm^{-1} are assigned to the spinel $ZnAl_2O_4$. The hybrid showed chitosan/$ZnAl_2O_4$, C = O band, present in the characteristic spectra of complex formation and Si-O bands absorption that proves the silanization of the spinel.

Keywords*: chitosan, hybrid material, $ZnAl_2O_4$*

MORPHOLOGICAL ANALYSIS OF HYBRID CHITOSAN-$ZnAl_2O_4$

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Abstract: Recent technologies require materials with a combination of properties not found in conventional materials. Organic-inorganic hybrid materials are prepared by combination of organic and inorganic compounds and are an alternative for the production of new multifunctional materials with a wide range of applications. Typically, the desired characteristics are not found in a single material. The development of this has accelerated since the decade 80, especially the preparation of inorganic gels, impregnated by organic polymers. In this context, the objective of this study was to develop and characterize the hybrid quitosana/$ZnAl_2O_4$ at a ratio of 5:1; 5:3 e 5:5 by scanning electron microscopy. First, $ZnAl_2O_4$ nanoparticles (NPs) were deagglomerated and sieved through 325 mesh and added to chitosan diluted in 1% acetic acid, and dried at 60°C. After drying, a solution of 1M sodium hydroxide was added to obtain a film with neutral pH. The films were characterized by SEM and showed no blistering, while the nanoparticles of the zinc aluminate is present both on the surface, and encapsulated in the chitosan matrix. Through the micrographs it was realized that there was a greater encapsulation of the NPs concentration $ZnAl_2O_4$ 5:1 with lower content of NPs and agglomerated of $ZnAl_2O_4$ the film surface.

Keywords: *chitosan, hybrid materials, $ZnAl_2O_4$*

NUMERICAL AND EXPERIMENTAL DYNAMIC ANALYSES IN SMART COMPOSITES

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Abstract: Smart composites present great potential for applications in aerospace industry. Thus, it became important to the study of problems of electromechanical coupling. In the aerospace industry, the use of smart materials as sensors and/or actuators have occurred in different areas, e.g., control of noise and vibration, and motion control systems for Structural Health Monitoring (SHM). Piezoceramic patch are commercially available in a variety of designs, based on a range of piezoceramic wafers, fibers or macro-fibers which are embedded into a polymer matrix material. Although, much research work has been done to analyze and predict of the effective properties of piezoelectric composite materials, there is no standard methodology for calculating the coefficients. This paper consists on evaluation of the methodology using modal analysis, this methodology is based on a development of unit cell numerical models for smart composite materials. In order to evaluate the methodology, dynamic analyses were performed to compare the FRF (Frequency Response Function) obtained experimentally and computationally. Computational models via Finite Elements Method (FEM) was developed using the methodology for determination of the effective properties the patches piezoelectric (Midé QP10n). After that, it was used an aluminum cantilever beam which were glued two piezoelectric patches, one to carry the excitement of the structure and the second to make the data acquisition. In this test, a random signal is applied to the actuator and then measure the excitation through the sensor. Comparing the input and output signals, one can obtain the FRF. Computational model using Abaqus™ and employing the element Solid C3D20 was used to model and the patches were modeled with solid piezoelectric element C3D20E. The DOFs allow fully coupled electromechanical analyses. Therefore, these FRFs are compared in order to evaluate the potential and limitation of the methodology investigated. Thus, based on the results, this methodology is a suitable alternative to determine effective coefficients for smart composite materials, especially in case AFCs (Active Fiber Composites).

Keywords: *Effective coefficients, piezoelectric materials, finite element modeling, experimental analysis*

FAILURE ANALYSIS OF COMPOSITE LAMINATE USING A FAILURE CRITERION BASED ON PHYSICAL PHENOMENA

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Abstract: This paper presents a numerical analysis of failure in unidirectional laminate composites using the LaRC03, a failure criterion based on physical phenomena, as proposed by Dávila et al. [1]. A comparison between the LaRC03 and the traditional failure criterion by Tsai-Wu is also presented. The laminate strains are obtained using ABAQUS and a Python script is applied to evaluate the laminate failure. Data are post processed in MATLAB to find where the failure is located and which phenomenon is responsible for the failure.

Keywords: *Composite Materials, Failure Criteria, LaRC03 Criterion, Tsai-Wu Criterion*

BENDING OF ADAPTATIVE Ni-Ti/PP CIRCULAR BEAMS

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Abstract: This investigation is concerned with the mechanical behavior of Shape Memory Alloy Hybrid Composite Beams (SMAHC), that consist of a circular bar of Ni-Ti alloy incorporated in a 500 mm long cylindrical tube of polypropylene (PP), with external diameter 50 mm and nominal wall thickness 7 mm, wound with a nylon/epoxy layer. The Ni-Ti alloy was characterized using: (i) scanning electron microscopy (SEM) images; X-ray diffraction patterns (XRD); and DSC thermal analysis. The nominal chemical composition of the alloy is 50.05 % of Ni / 49.95% of Ti, and the softer martensite is the predominant phase at room temperature and the approximate phase transformation temperatures were M_s = 32°C, M_f = 46°C, A_s = 38 °C and A_f = 60°C. For T<M_f Ni-Ti presents 100% Martensitic phase, whereas for T>A_f it is fully converted in the Austenitic phase; and its elasticity modulus increases by a factor up to three times. This significant change in stiffness of Ni-Ti, without changing its mass, has motivated the application of such alloy in machine vibration control. The SMAHC beams were subjected to static three point bending tests, in the elastic regime. Experimental results showed that, in average, at 21°C, the PP tubes effective flexural elastic modulus (E_f = 757 MPa for PP) increased 112% (from 757 MPa to 1609 MPa) when the Ni-Ti bar and the external layer of nylon/epoxy were incorporated to the PP tube, creating a SMAHC beam. In addition, when the austenitic transformation induced by temperature was explored, for the SMAHC beams, when temperature of the Ni-Ti bars increased from T=21 °C (Ni-Ti in the martensite phase) to 56 °C (Ni-Ti in the austenite phase) E_f increased from about 15% to 23%. These last results indicate that the SMAHC beams can work as an adaptative structure. In these experiments, the Ni-Ti bars were in the longitudinal direction of the PP tubes. Both, the applied loads and the Ni-Ti bars belong to the symmetry vertical plane of the beam.

Keywords*: adaptative composite beams, elastic behavior*

EVALUATION OF VISCOSITY OF THE ASPHALT CEMENT AFTER INCORPORATION OF EVA WASTE

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Abstract: The Ethylene-Vinyl Acetate (EVA) copolymer is formed from random sequences of polyethylene and poly (vinyl acetate) (PVAc), its properties are generally intermediate to that of the pure components, which is due to its complex morphology. EVA has been frequently used by the shoe manufacturing industry, being one of their applications in insoles, where about 20% of its chips are discarded. Aiming the reuse of this residue this work studied its use in asphalt mixtures to obtain improvements in the mechanical properties of the pavement. The EVA residue was incorporated into the Petroleum Asphalt Cement (CAP) by wet process, where the grounded residue was added to CAP occurring reaction between the components and changes of properties. Brookfield kinematic viscosity tests were conducted with different residue contents (2, 3, 4 and 5%) and particle passing through the 2.0 mm sieve. The use of the residue proved to be satisfactory, and an increase in viscosity of the binder with the addition of EVA residues was observed, which represents an increase in resistance of permanent deformation.

Keywords*: EVA, petroleum asphalt cement, viscosity.*

APPLYING MIXED-MODE NETWORK ARCHITECTURE TO MODEL THE FATIGUE LIFE OF A COMPOSITE MATERIAL

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Abstract: The present study proposes novel network architecture to train an ANN (Artificial Neural Network) designed to model fatigue life diagrams for composite materials subjected to cyclic loads. The concept of this new architecture is based on using an analytical equation (Adam Equation) for a given material and applying an ANN to merely correct the difference between this result and the desired material. The purpose of this strategy is to incorporate knowledge into the neural network model, improving the robustness and generalizability of the ANN.

Keywords: *Neural networks, Composite, Fatigue, Adam Equation.*

ROLE OF OPEN INNOVATION MODELS AND IPR IN TECHNOLOGY TRANSFER

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Abstract: In a globalized market the Governments are increasingly aware that technology and innovation are the winning weapons to compete and increase the employment. This conviction pushed the industrialized countries to be equipped with proper tools to increase the technology transfer between companies-companies and enterprises-Public Institutions of Research/Universities to convey this flow of knowledge in the better way [1]. Innovation is a process starting from the ideation of a new product/process till its introduction on the market successfully. So the innovation can be defined as a set of measures which induce changes in the product/process and that may cover the technological, organizational and/or managerial area.

Keywords*: innovation, technology transfer, intellectual property*

PREPARATION AND PROPERTIES OF NANOSTRUCTURED WC-Co COMPOSITE POWDERS AND COATINGS

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Abstract: In WC-Co composites, the hard carbide particles provide strength and the Co, toughness. WC-Co composites are used in the manufacture of cutting tools because of its high hardness, wear resistance and high temperature strength. Preparation of nanostructured (NS) composite powders is the first step in the synthesis of nanostructured composite coatings by thermal spraying. Nanostructured WC-17Co composite powders were prepared by high energy ball milling and the coatings using NS and as-received (AR) composite powders were prepared by HVOF thermal spraying on 3 mm thick AISI 310 sheet samples. This paper presents: (a) the effect of milling time on WC-17Co powder particle size and crystallite size; (b) the effect of heat treatment on phase changes; (c) mechanical properties of NS and AR WC-17Co coatings. Milling altered the powder morphology from rounded particles to facetted particles. The average particle size of the powder decreased with milling time to 8 hours and further increase in milling time resulted in particle agglomeration. The average crystallite size decreased to 32 nm after 24 hours of milling. In terms of thermal stability, no degradation was observed up to 350 °C. The hardness of the nanostructured coating was higher than that of the coating prepared with AR powders.

Keywords*: Tungsten carbide; powder properties; coatings; thermal stability*

MECHANICAL AND STRUCTURAL PROPERTIES OF THERMAL SPRAYED CR_3C_2-25(NI20CR) NANOCOMPOSITE COATINGS

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Abstract: Coatings prepared with Cr_3C_2-25(Ni20Cr) composite powders are widely used to protect components exposed to severe conditions in a variety of industries. In this investigation as-received (AR) and nanostructured (NS) Cr_3C_2-25(Ni20Cr) composite powders were used to deposit ~200 µm thick coatings by HVOF thermal spraying on AISI 310 samples. The Vickers microhardness, the elastic modulus and the fracture toughness of the coatings were determined. The erosion-oxidation (E-O) resistance of the coatings was determined at room temperature, 450, 700 and 800 °C. The hardness and Young modulus of the coatings prepared with NS powders were approximately 26% higher than that of the coatings prepared with AR powders. The fracture toughness of the NS coating was 36% higher. The E-O resistance of the NS coating was around 52% higher than that of the coating prepared with AR powders at 800 ºC. The E-O wastage of both types of coatings increased consistently with temperature beyond 450 ºC.

Keywords*:* Cr_3C_2-25(Ni20Cr) composite, erosion-oxidation, high energy milling, Young Modulus and fracture toughness.

ANALYSIS OF MULTISTABLE VARIABLE STIFFNESS COMPOSITE PLATES

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Abstract: This paper presents a new concept for morphing composite structures based on variable stiffness composite plates. The variable stiffness morphing laminate proposed in this paper consists in a modified version of a straight fiber laminate composed of two regions, one with symmetric and the other with unsymmetric stacking sequence. Since there is a lay-up mismatch where the two regions meet, stress concentrations are expected to occur when straight fibers are used. A solution to mitigate this effect in which the fibers are allowed to vary smoothly along the plane from one region to the other is analyzed. The particular trajectories followed by the curved fibers were designed such that the plate can be manufactured using Advanced Fiber Placement technology (AFP). A finite element analysis of the laminate is performed to predict its out-of-plane displacements for the two possible stable configurations that may be obtained after the curing process. Then, the plate may be snapped from one shape to the other with the application of a force. This snap-through behavior is analyzed and compared with the original straight-fiber laminate. The concept of a bistable Variable Stiffness Panel (VSP) composed of regions of symmetric and unsymmetric lay-ups that preserve the tangential continuity of the fibers could be of great importance in morphing or shape-adaptable structures for aerospace applications, such as winglets or flaps.

Keywords: *bistable composites, unsymmetric composites, variable stiffness panels, morphing structures*

THE BEHAVIOR OF FIBER-CONCRETE INTERFACE IN CEMENT MATRIX COMPOSITES

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Abstract: The application of composites in civil construction has been quickly widespread regarding the recovery of structures that show some kind of pathology due to the continuous action of aggressive agents or when they are submitted to a load that is beyond the strength limit they have been designed for. However, studies on structures of cement matrix composites with continuous synthetic fiber have been barely related in the literature. In the present work, the properties of fiber-cement interface were evaluated by using concrete specimens with strength compression of 29 N/mm², with carbon fiber inserted 50 mm in the cement matrix. The specimens containing carbon fiber were submitted to pullout tests and the bond strength values were determined and compared to bond strength obtained by similar tests with steel bars which are normally used in civil construction. On such tests the reinforcement diameters were 6.4 mm for steel and 6.5 mm for carbon fiber.

Keywords*: composites; fiber-cement; carbon fiber*

ANT COLONY ALGORITHM APPLIED TO FUNDAMENTAL FREQUENCY MAXIMIZATION OF LAMINATED COMPOSITE CYLINDRICAL SHELLS

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Abstract: Cylindrical composite shell structures are used in many applications, especially in aeronautical, aerospace and petroleum/gas industries. The knowledge of the dynamic response of these structures is an important issue in their design in which the ply thicknesses are often predetermined and the ply orientations are usually restricted to a small set of angles due to manufacturing constraints. To find the best stacking-sequence of the laminated shell leads to a problem of combinatorial optimization. As this problem is hard to be solved, several techniques have been developed. Ant colony optimization (ACO) is a class of heuristic optimization algorithms inspired by the behavior of real ants, related to their ability to find the shortest path between the nest and the food source. ACO has been applied successfully to different kinds of problems. In this way, this paper deals with optimal stacking sequence of laminated cylindrical composite shells aiming to maximize their fundamental frequency using the ACO technique. The ACO algorithm was implemented in Matlab platform and was linked to a commercial finite element code to compute the structural response. Cylindrical shells without and with a cutout geometry are studied. Fundamental frequencies were maximized for both cases and the results were presented and discussed.

Keywords: *Ant colony optimization, Laminated cylindrical shells, Frequency maximization*

IMPERMEABLE COMPOSITE PIPES WITH METALLIC LINER FOR SOLVENT APPLICATIONS

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Abstract. Organic solvents have no effect (long-term or short-term) on the glass fibers used in the manufacture of composite pipes. The resin matrix, however, shows strong interaction with some organic solvents. The resin-solvent interaction governs the performance of composite pipes in contact with organic solvents. The large amount of solvent that is picked up by the resin matrix reduces the ability of the composite to perform in structural applications. The market clearly needs a low cost solution that would allow the use of composites in high pressure pipelines for the transmission of solvents, especially the transmission of ethanol. Such a solution would open huge opportunities for composite pipes in a variety of load-bearing applications. Tests made to determine the solvent absorption of resins mainly used in composite pipes showed a high absorption rate. The solution proposed in this paper is low cost, simple and straightforward. Our solution consists essentially in making composite pipes, fittings and joints that are impermeable to the solvent. The impermeable composite prevents the ingress of solvents into the structural wall of the pipe component. The solvents kept out of the laminate cannot swell the resin and cannot do any structural harm to the composite. The proposed solution is market-ready and does not require extensive and expensive testing and product development. The pipe components made with this new technology easily meet and exceed the requirements in product standards like AWWA C950, ISO 14692 and API 15HR.

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Keywords: *composite pipes; metallic liner*

SYNTHESIS OF POLYANILINE/CLAY CONDUCTING NANOCOMPOSITES

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Abstract: Nanomaterials have been considered as highly promising materials for various technological applications. In engineering, polymer nanocomposites are a new class of composite materials, where a clay or filler with nanometric dimensions is dispersed in a polymer matrix at low concentration or volume. When added in quantities below 5% in the nanocomposites, clay cause a significant increase in these properties, such as mechanical, optical, magnetic barrier, and especially permeability and flammability. In this context, this work aimed to obtain the polymeric nanocomposites of polyaniline (PAni) with different commercial clays (Cloisite Na^+, 10A, 15A, 20A and 30B). The preparation of PAni and montmorillonite (PAni-MMT) nanocomposites was performed by in situ polymerization of aniline in acidic media (HCl). Electrical conductivity measurements, FT-IR, TGA and X- ray diffraction were some of the techniques used to characterize the nanocomposites.

Keywords*: Nanocomposite; Conductive polymers; Polyaniline; Clay, Montmorillonite*

A FULL FACTORIAL DESIGN OF PARTICULATE COMPOSITES REINFORCED WITH SILICA MICRO PARTICLES

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Abstract: The investigation of the mechanical performance of fibrous composites made of polymeric matrices reinforced with micro and nano ceramic particles has been the focus of several researches, especially for those composites manufactured with thermoset resin and glass fibres. In general, the ceramic particles are added at low percent levels (less than 10%wt); however, large percent additions from 15wt% to 30%wt of silica nano particles are also investigated on compressive loadings. A previous work has investigated the addition of silica micro particles as a second reinforcement phase of composites manufactured with unidirectional natural fibres such as sisal and banana fibres, in order to improve the modulus of the composites and to enhance the physical adhesion between the phases. This work investigates the addition of silica micro particles and maleic anhydride (as a coupling agent between the phases) into the epoxy resin, which will be used as matrix phase of hybrid biocomposites. A full factorial design was conducted to evaluate the effect of silica micro particles and chemical additive into the epoxy matrix under compressive loadings. The apparent density was also evaluated. The experimental factors such as weight fraction of silica micro particles (0%wt, 20%wt and 33.3%wt) and weight fraction of maleic anhydride, (0%wt and 2%wt) were investigated using a full factorial design of $2^1 3^1$, resulting on 6 experimental conditions. The software Minitab 14 was used to manipulate the data using the Design of Experiment (DOE) and Analysis of Variance (ANOVA) tools. Two replicates were set for this experiment. The results showed that the maleic anhydride did not affect the apparent density of the composites, however the silica micro particles increases the apparent density of the composites. The statistical analysis revealed that the interaction between "silica and maleic anhydride" was significant; however this interaction affects less than 1% on the apparent density of the composites. The interaction of the factors "chemical additive and silica addition" affected the compressive strength of the composites. The chemical additive was able to increase the compressive strength. One the other hand, the silica micro particles addition reduced the compressive strength of the composites. The main factors "*chemical additive*" and "*silica addition*" exhibited significant effects on the compressive modulus of the composites. Both factors significantly increased the modulus of elasticity of the composites.

Keywords: *composites, epoxy resin, silica micro particles, full factorial design*

DAMPING RATIOS DURING A FATIGUE TEST OF A 3MW WIND TURBINE BLADE

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Abstract: Wind energy is the most promising one among the renewable energies. Applying composite technology to wind turbine blades, wind industry increases the length of the blades up to 73.5m in order to capture more wind energy. Since the service lives of wind turbines are over 20 years, wind turbine blades have to endure high cycle fatigue that comes from the gravitational force, the wind shear, and the wind turbulence during that period. A fatigue test of a wind turbine blade is one of the methods that can evaluate its fatigue life. Moreover, the test is mandatory to earn the blade's certification based on the standard of DNV (Det Norske Veritas) or IEC (International Electrotechnical Commission). However, a fatigue test of a wind turbine blade having its length of several tens meters is one of the most difficult challenges to be overcome. Especially a bottleneck of the test is prediction and control of a blade's cyclic motion, which is severely affected by its damping property because during the test the blade is oscillating at its resonance frequency. In this study, we performed a fatigue test of a 3MW blade with the length of 44m. From the measured accelerations and a FE beam model of the test blade, a damping ratio at each test condition is calculated. Finally we analyzed the tendency of damping ratios with respect to test conditions.

Keywords*: wind turbine, composite blade, fatigue, damping ratio, air damping*

THERMAL SHOCK INFLUENCE ON VISCOELASTIC BEHAVIOR OF WELDED CONTINUOUS FIBER/PPS LAMINATES

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Abstract: An ideal structure would be designed without joints, since joints are potentially sources of weakness and additional weight. In practice however, upper limit to component size is generally determined by the manufacturing processes. Further requirements for inspection, accessibility, repair and transportation or assembly mean that load bearing joints will be part of an engineering structure. This is particularly so in the manufacturing of thermoplastic composites (TPC) for which high melt resin viscosity and constraints imposed by the continuous reinforcement limit the production to relatively simple geometry components which must be joined together to produce large, complex structures. One of the junction processes, the resistance welding, consists in the actuation of an electric current between the parts to be jointed, and creating heat until the matrix starts to soften/merge. The objective of this work is to evaluate the effect of temperature and moisture on the dynamic mechanical properties of the carbon fiber/PPS composite, welded with the electric resistance method. Therefore, hybrid carbon PPS plates were welded to glass fiber /PPS laminae with the electric resistance method. The welded and non-welded materials were characterized by microscopy and DMA (dynamic mechanical analyses). Then, the welded materials were conditioned in hygrothermal environment and in thermal shock chamber. According to the results, when compared with the no welded specimens the welded PPS/carbon fiber presented a similar glass transition temperature value and both conditionings were not affected significantly the T_g, since increases only up to 5% has been observed in the specimens studied.

Keywords: *thermoplastic composites, environmental conditioning, PPS/ carbon fiber, glass transition temperature, resistance welding.*

EVALUATION OF CHEMICAL INTERACTION BETWEEN THE MWCNT FUNCTIONALIZED WITH FURFURYL ALCOHOL RESIN SYNTHESIZED

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Abstract: The furfuryl alcohol resin is a thermosetting resin of furan class which gained great importance due to be obtained from renewable resources. Nowadays, this resin has a wide range of applications such as adhesives, glassy carbons, carbon nanoporous, polymer nanocomposites, etc. Many studies have been undertaken to develop thermoplastic and thermosetting polymer composites with multiwall carbon nanotubes (MWCNT) as the reinforcing element. The mechanical and electrical properties of a composite of polymer with MWCNT depend on the dispersion between the two materials and of good chemical interaction between MWCNT and the matrix polymer. The literature presents several possible mechanisms of polymerization of furfuryl alcohol with various types of catalysts, but there is not an understanding about the interaction chemical between carbon nanotubes and furfuryl resin. In this work we intend to evaluate the chemical interaction between the functionalized MWCNT, with percentages varied and the furfuryl resin composite cured with hardener and para-toluene sulfonic acid (APTS). The composite resin will be manufactured with percentages of 0%, 0.5%, 1.0% and 2.0% of functionalized MWCNT. The MWCNT are characterized by XPS, Raman, TEM and FT-IR/ATR. The chemical interaction of the composite formed will be evaluated by FT-IR/ATR and from the results will be proposed mechanisms of chemical interaction between MWCNT and furfuryl resin synthesized.

Keywords: *composites FT-IR/ATR, interaction of MWCNT, chemical analysis in nanocomposite, functionalization of MWCNT.*

INFLUENCE OF UV RADIATION ON GLASS TRANSITION TEMPERATURE OF PEI/ GLASS FIBER COMPOSITES

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Abstract: Advanced polymer composites are used in aeronautical and space applications. They have contributed, in the last years, to the development of science and technology of materials. Currently, the vast majority of advanced polymer composites is obtained from the impregnation of reinforcement with thermosetting matrices, knowing that generally these materials have problems of residual stresses due to processing and to the brittle nature of the resin. By comparison, thermoplastic polymers presents excellent service properties such as high stiffness, high values of mechanical strength and low density, replacing the materials commonly used in engineering. However, these materials are subject to many environmental conditions, such as: UV radiation, moisture and temperature variations which reduce their time of service, since they can bring physical and chemical changes in the structure of the laminate. This work aims to study the influence of UV radiation in the viscoelastic behavior, in particular, the glass transition temperature of PEI /glass fiber thermoplastic laminate used in aeronautical application. For this purpose, the specimens were submitted to a UV chamber in three maximum times: 200, 600 and 1200 hours. After this, the specimens were evaluated by DMA (dynamic mechanical analyses), FT-IR (infrared spectrometry) and optical microscopy. According to the found results the UV radiation used was not enough to induce significant changes in PPS/glass fiber structure since the glass transition temperature was not significantly affected for the exposure durations employed in this investigation. However, it can be expected that over long periods of environmental exposure, the synergism between UV and condensation will cause so much damage that load transfer between fibers will longer possible owing to matrix erosion.

Keywords*: thermoplastic composites, environmental conditioning, PEI/ glass fiber, glass transition temperature.*

THERMAL SHOCK EFFECT ON INTERLAMINAR SHEAR STRENGTH OF CARBON FIBER/PEKK COMPOSITE

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Abstract: In the last years, advanced thermoplastic composites have contributed to the rapid development in science and technology applications. In the aeronautical field, the composite structures are exposed in several environmental conditions involving moisture, sunlight and mainly variations in the temperature (thermal shock) that can generate the degradation of the mechanical properties of the material. These factors normally have a great influence on the overall performance of these materials and can affect the interlaminar shear strength. The aim of the present work is to evaluate the influence of the thermal cycling effects on interlaminar shear strength of carbon fiber/PEKK thermoplastic composite. The laminate was produced with 12 plies of plain weave fabric carbon fiber and 13 foils of PEKK by using hot compression molding processing. The carbon fiber/PEKK specimens were exposed using 1000 cycles of thermal shock during thirty minutes at 80°C and thirty minutes at –50°C. After this, interlaminar shear strength (ILSS) tests were carried out in an appropriate device at Shimadzu test machine. The interlaminar shear strength tests values obtained from non-conditioned and thermal shock conditioned specimens were similar (98,9 ± 4,8 and 98,1 ± 4,6 MPa), showing that carbon fiber/PEKK composites, after to be submitted to thermal shock environment, had a suitable interlaminar shear strength variation and can be considered for application that require high performance for aerospace application.

Keywords*: Thermal shock, ILSS, PEKK, thermoplastic*

ADDITION MAGNETIC NANOPARTICLES FOR NON-DESTRUCTIVE EVALUATION OF POLYMER COMPOSITES

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Abstract: The objective of the present work was to develop polymer composites with the addition magnetic nanoparticles to allow the application non-destructive evaluation techniques (NDE) which use magnetic sensors to detect small-sized damage. Nanosized nickel and cobalt ferrites were synthesized and subjected to thermal treatment. Glass-epoxy composite flat, circular plates were fabricated with the addition of the ferrite nanoparticles and notches were introduced on the plates´ surfaces. The influence of these notches on the measured magnetic properties of each material was measured. According to the results, the technique proved capable of detecting damage in polymer composites.

Keywords*: Composite materials, Magnetic markers, Nanoparticles, Non-destructive evaluation.*

INFLUENCE OF THICKNESS IN THE ANALYSIS OF CURAUA/GLASS HYBRID LAMINATES - PART I: MECHANICAL PROPERTIES

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Abstract: The interest in using vegetable fibers for nobler applications, such as reinforcement in polymer composites, has been increasing over the years due to aspects like environmental legislation and community awareness about life cycle of products. The aim of this work is to develop curaua/glass/polyester laminate composites and analyze the variation in their properties with thickness. The composites were molded by hot compression molding using a total of 4 layers ($[g,c]_s$), 8 layers ($[g_2,c_2]_s$) and 12 layers ($[g_3,c_3]_s$) of glass (g) and/or curaua (c) fiber mats. Mechanical tests were carried according to ASTM standards. Void content and uniform distribution of reinforcement are important factors for these properties. The void content, impact strength and flexural strength and modulus increase with thickness whereas hardness and short beam shear strength not showed the same tendency. Finally, our results indicate composite properties to de thickness dependent.

Keywords*: curaua fiber, hybrid composites, thickness, laminate.*

INFLUENCE OF THICKNESS IN THE ANALYSIS OF CURAUA/GLASS HYBRID LAMINATES - PART II: EXPERIMENTAL X THEORETICAL ANALYSIS

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Abstract: Over the past few years, there has been a renewed interest in using vegetal fibers as reinforcement materials to some extent in the plastics industry. This resurgence of interest is due to the increasing cost of plastics and also because of the environmental aspects of using renewable and biodegradable materials. The aim of this work is to investigate curaua / glass hybrid interlaminate polyester composites. In part II, tensile and shear (Iosipescu) tests were carried out, and the experimental results were compared with those obtained using a commercial software used for the mechanical analysis of composites. The composites were molded by hot compression molding and using a total of 4 layers ($[g,c]_s$), 8 layers ($[g_2,c_2]_s$) and 12 layers ($[g_3,c_3]_s$) of glass (g) and/or curaua (c) fiber mats. Mechanical tests were carried according to ASTM standards. The experimental results compared to the theoretical results show good compatibility.

Keyword: *curaua, laminate, hybrid, mechanical analysis*

STUDY OF FILMS OF POLYAMIDE 6/BENTONITE CLAY NANOCOMPOSITES

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Abstract: The polymeric nanocomposites have been widely used in recent years, mainly due to its scientific and technological importance. These materials have unique properties resulting from the combination of its components, such as flexibility and moldability of the polymer, associated with high hardness and thermal stability of inorganic materials. In this work, nanocomposites of polyamide 6/bentonite clay were obtained through a high speed mixer, Homogenizer, in the proportions 1, 3 and 5 wt% clay. Then, polymer films were prepared by compression. The used clay was Brasgel and for organophilizated it was used the Praepagen HY quaternary ammonium salt. By differential scanning calorimetry (DSC), it was observed that the nanocomposites showed some variations in temperature and melting enthalpy as compared with polyamide 6. By XRD, it was observed the disappearance of the characteristic peak of clay, and this can be the possible exfoliation of clay in the produced films from the nanocomposite.

Keywords*: polymer films, nanocomposites, polyamide 6, bentonite clay.*

MECHANICAL AND THERMAL PROPERTIES OF POLYPROPYLENE REINFORCED WITH CARBON NANOTUBES

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Keywords*: thermoplastic composites, carbon nanotubes, mechanical properties, thermal properties.*

Abstract: Extensive studies have been devoted to the use of carbon nanotubes (CNTs) as nanofibers, because of their unusual mechanical, thermal and electronic properties, to improve the performance of a matrix or to achieve new properties. One of the advantages of CNTs as a reinforcement is their large surface area that can induce a better adhesion with the polymeric matrix, which is an important factor for an effective enhancement of the composite properties. Among the most versatile polymer matrices, polyolefins such as polypropylene (PP) are thermoplastics having a higher consumption because of their well balanced thermal and mechanical properties and their easy processability at a relatively low cost. In PP matrix composites, the crystalline morphology of the polymer can be influenced by the fibers that can act as nucleate agents, influencing the crystallization process. In this work, we have investigated the effects of different concentrations of multiwalled carbon nanotubes (MWCNT) on the thermal (glass transition temperature and crystallization kinetics) and mechanical properties (tensile, flexure, impact and tribological properties) of polypropylene matrix composites. According to the mechanical results obtained in this work, it was observed that the addition of CNT up to 2wt% was not enough to change significantly tensile, flexure and impact results, but the tribological results were significantly modified. According to the thermal results was observed that the glass transition temperature values were similar between specimens loaded up to 1wt% CNT, indicating that it is necessary amounts higher than 1 wt% CNT to modify this property.

Keywords*: Polypropylene, carbon nanotubes, mechanical properties*

SALT WATER CORROSION BEHAVIOR ON MECHANICAL AND THERMAL PROPERTIES OF WELDED CONTINUOUS FIBER/PPS LAMINATES

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Abstract: Joining plays an important role in manufacturing of composite structures in marine, automotive and aerospace industry. Mechanical fastening and adhesive bonding are widely being used to assemble metals or composite components. However, there are disadvantages associated with these methods such as stress concentration induced by drilling holes in mechanical fastening or extensive surface preparation during adhesive bonding. In the case of joining thermoplastic composite components, fusion bonding, or welding, is an alternative method that can eliminate the abovementioned disadvantages. In order to evaluate the success of these processes, mechanical tests can be used for evaluating the joining technology and also the environmental influence in composite materials. Environmental influence is commonly considered to be responsible for failures of these materials, resulting from a combination of the effects of heat, light, salt, water and mechanical stresses on the material. Several studies have addressed the important effects of absorbed water and ageing temperature and salt on the physical and mechanical properties of composite materials. It has been observed that mechanisms other than simple diffusion can take place within the material above a threshold related to a given temperature and a given ageing time. The objective of this work is to evaluate the effect of salinity on mechanical and glass transition temperature of the carbon fiber/PPS composite, welded with the electric resistance method. Therefore, hybrid carbon PPS plates were welded to fiber glass/PPS laminate with the electric resistance method. The welded and non-welded materials were firstly submitted in a salt spray chamber for 20 days, and, after this characterized by using microscopy, shear tests (ILSS and Iosipescu tests) and DMA (dynamic mechanical analyses). According to the results, when compared with the non-welded specimens the welded PPS/carbon fiber laminate presented a similar behavior. Therefore, the specimens after being submitted to salt spray chamber, presented a decrease of 7% and 3% of ILSS and Iosipescu shear strengths values, respectively, when compared to the values obtained from no conditioned specimens.

Keywords: *thermoplastic composites, environmental conditioning, PPS/ carbon fiber, glass transition temperature, mechanical properties, resistance welding.*

EVALUATION OF MOISTURE EFFECT ON VISCOELASTIC PROPERTIES OF CARBON FIBER/PEI LAMINATES

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Abstract: During use composites may be exposed to atmospheric moisture, ranging from mild humidity to precipitation. Water absorption often causes swelling and degradation to polymer composites. Different mechanisms may occur simultaneously according to the severity of the exposure conditions which eventually reduces the overall composite performance. In order to investigate the humidity effect on the properties of poly(ether-imide) (PEI) reinforced with continuous carbon fabric, a climatic chamber was used. In the chamber, specimens were exposed to 80°C temperature and at 90% relative humidity atmosphere during a period of eight weeks. Water uptake and the interactions between water and the PEI matrix were considered. Dynamic mechanical analysis (DMA) was carried out to investigate the effect of moisture in viscoelastic properties of carbon fiber/PEI laminates. The interlaminar shear strength (ILSS) was also evaluated in order to analyze the water influence on fiber/matrix interface. The results showed a decrease in the glass temperature (Tg), followed by a decrease in the storage modulus, which indicate a plasticization process for hygrothermally aged carbon fiber/PEI laminates. Moreover, ILSS tests showed that the fiber/matrix interface was not weakened by the moisture absorbed.

Keywords: *PEI, carbon fiber, hygrothermal aged, dynamic mechanical thermal analysis (DMA), interlaminar shear strength (ILSS)*

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MECHANICAL AND BARRIER PROPERTIES OF POLYPROPYLENE/ORGANOCLAY NANOCOMPOSITES

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Abstract: In this work nanocomposites were prepared from polypropylene, maleic anhydride grafted polypropylene (PP-g-MA) as compatibilizer and two organoclays kinds, a pristine and a purified one, coded of ANO and APO, respectively synthesized at the Laboratory of Polymer Nanocomposites (NanoPol) of UFCG. The filmes containing 1 wt% organoclays (ANO and APO) and 15 wt% compatibilizer (PP-g-MA) prepared by melt intercalation technique were characterized by X ray diffraction, mechanical (breaking factor and maximum strength) and barrier properties (fat and oxygen permeation). The results indicate the formation of nanocomposites with structures probably intercalated and that the presence of the clay provided increase of mechanical properties and decrease in the permeability, corroborating with the X ray data.

Keywords: *Nanocomposites, polypropylene, organoclay*

FATIGUE PERFORMANCE EVALUATION OF TWO TYPES OF NON CRIMP FABRIC COMPOSITES MANUFACTURED VIA RTM PROCESS

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Abstract: The fatigue damage in composites is highly complex when compared to isotropic materials, which has a sharp crack that propagates as the number of cyclic loadings increases, while the composite material has its stiffness continuously reduced by multiple cracks. These nucleate by defects introduced during the manufacturing process such as microcracks, voids or entrapped air. The studied case goes beyond these problems as the non-crimp fabrics present through-to-thickness yarns, which have the hole of stitching the carbon layers in multiple directions, that may create stress concentration effects as resin-rich regions. Two types of stitches were tested: tricot and chain patterns. The first one used to stitch the IM7 carbon fiber as the second one used to stitch IMS 5131 carbon fiber, and they were produced by RTM6 and CYCOM 890 resin systems, respectively. The shape of S-N curves for both laminates were compared and the ratio of delamination/rupture cycles were analyzed as this factor can indicate through-to-thickness properties. Besides, fractographic analyses were performed to better understand the fail process. The chain laminate type overcame the tricot laminate type regarding the strength to delamination cycles, which was most attributed to the irregularity of the stitch pattern.

Keywords*: Non-crimp fabric (NCF); Fatigue; Carbon/epoxy laminates.*

WRINKLING OF CARBON FIBRE COMPOSITES DURING CONSOLIDATION

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Abstract: An analytical model for the formation of wrinkles following consolidation of carbon fibre composites over an external radius is presented. Three experiments which parameterize the consolidation behavior, bending stiffness and inter-ply shear properties of carbon fibre pre-preg in the model are then described. These initial results indicate that the inter-ply shear resistance of a material is the important factor influencing the appearance of wrinkles. Extensions of the modeling to consider the nonlinear post-buckling behavior, and additional experimental work investigating the influence of temperature, are briefly discussed.

Keywords*: wrinkling, buckling, consolidation, manufacturing*

PRESSURE ASSISTED MANUFACTURING OF A NOVEL POLYMER INFILTRATED CERAMIC WITH INTERPENETRATING MATRICES

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Abstract: Particularly in the fields of medical and light weight constructions applications, composite materials increased construction possibilities, manageability and efficiencies. An example of these successfully used materials is polymer/ceramic composites. They are intensively used in the medical and engineering sectors, when the mechanical properties of polymers are insufficient. Different from the classical approach, where ceramic particles are imbedded in a polymer matrix, this novel composite material consists of two self-interpenetrating matrices. The interpenetrating structure is generated by infiltrating a liquid monomer in a porous ceramic precursor succeeded by a polymerization process. While the infiltration of a precursor with huge pore radius can be reached easily by capillary forces, the infiltration of precursors with nano-scale capillaries is difficult to achieve. Unfilled domains as well as other failures in the microstructure, like surface boundary loss between the polymer and the ceramic, (generated by the volume reduction during the polymerization) can affect the general applicability and the mechanical properties of the composite. Therefore, the first aim of this study was to design an infiltration method for nano-scale precursors which guarantees complete monomer filling. The second aim was to investigate a polymerization method that compensates polymerization shrinkage and therefore avoids surface boundary loss. To infiltrate the nano-scale precursors with a highly viscous monomer, pressure was used. Before the pressure was applied to the cubic specimens, cast silicon seals were used to prevent monomer flow around the edges of the specimen. After evacuating the specimen chamber, the monomer was pressed inside the ceramic with a pressure of 10 MPa. The pressure was kept constant for 12 h. To avoid surface boundary loss, the polymerization was also realized with pressure assistance. The monomer soaked specimens were vacuum packed in a commercial polymer wrap and placed in a water filled pressure chamber. After the defined pressure levels were reached, the temperature inside the chamber was raised to 100 °C to activate the crosslinking of the polymer. Four different pressure values up to 300 MPa were tested. Besides pressure, different heating rates were tested to study the influence of polymerization time on the mechanical strength. With the developed infiltration device and the used process parameters, the specimens with a mean capillary size of 100 nm could be filled completely. For the pressure assisted polymerization, an influence of the polymerization pressure and the heating rate was found. The mechanical strength of the manufactured Polymer Infiltrated Ceramics (PICs) was tested using a biaxial flexure test. The results show significant differences for the varied manufacturing parameters. The results of the strength tests were correlated with the results of the microstructural analysis. Cracks generated in the precursors during the polymerization process. By the use of an adapted process control, cracks could be avoided. The described infiltration method shows a possibility to infiltrate a highly viscous monomer into a precursor with nano-scale capillary diameters. With this method, PICs with high ceramic/polymer ratios can be produced.

Keywords*: Polymer Infiltrated Ceramic (PIC), Pressure Infiltration, Pressure Polymerization, Precursors*

MECHANICAL PROPERTIES OF SANDWICH STRUCTURES USING PET AND PVC CORE

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Abstract: Different materials are used by the marine industry for high-performance structures, such as sandwich composite assemblies, which are built of two external faces/skins (usually made of synthetic fiber/resin) and a foam core, being lightweight and with high stiffness. Usually these composites are processed by RTM Light or infusion. In this study, the RTM Light process is used to inject the polymeric resin (vinyl ester) into the porous cavity between the impermeable core and the mold walls. The main goal of the present work is to study the mechanical characteristics of different sandwich structures. Two types of core materials were evaluated, PVC and PET, with different combinations of faces with either glass fiber cloths or mats. Specimens were subjected to flexural, flatwise and edgewise compression and Shore-D hardness testing. The main findings show that PVC core had a greater shear strength than the core of PET and Flatwise Compressive Strength that is similar for both. It was observed that facing stress and flexural modulus depends on the layer numbers of glass fibers that are used in the faces, as shown by the results PET-4M, PET-4T and PVC-4M.

Keywords: *sandwich structure, PVC foam, PET foam, RTM Light, mechanical properties*

TOWARDS THE APPLICATION OF ARTIFICIAL NEURAL NETWORK TO NONDESTRUCTIVE INSPECTION OF COMPOSITE SANDWICH PANEL HONEYCOMB CORES

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Abstract: The first step towards the implementation of artificial neural network (ANN) -based tools for X-ray radiography and NMRI inspection methods to detect, identify and discriminate liquid contaminants entrapped in honeycomb core cells of structural composite sandwich panels, as well as to differentiate liquid substances from repair resin compounds is described. Scilab® Image Processing (SIP) of NMR images by means of pixel intensity histograms was worthwhile in distinguishing liquids with different densities, albeit NMRI inspection did not allow for imaging solid polymers, even when containing intensifier filler. On the other hand, SIP methodology applied to digital X-ray radiographic images succeeded in differentiating water and other liquid substances from repair resin loaded with contrasting material.

Keywords: *artificial neural network, nondestructive inspection, structural sandwich panels.*

LINEAR LOW DENSITY POLYETHYLENE AND ZIRCONIUM PHOSPHATE NANOCOMPOSITE: EVIDENCES FROM THERMAL, THERMO MECHANICAL AND MORPHOLOGICAL TECHNIQUES

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Abstract: Lamellar alpha-zirconium phosphate (α-ZrP) was synthesized by direct precipitation method and (α-ZrP) and was also directly expanded with octadecylamine, through alcoholic solution. In order to produce nanocomposite, the filler was incorporated to linear low density polyethylene (LLDPE) in the molten state, using a counterrotating twin-screw extruder set at 170-190°C and 100 rpm. The differential scanning calorimetry (DSC) analysis revealed a decreasing on polyolefin melting temperature and crystallinity degree. The polymer thermal stability sharply increased concerning thermogravimetry (TG) results. Dynamic-mechanical analysis (DMA) evidenced an increase in both moduli – storage and loss – indicating the stiffening in the composites. Wide angle x-ray diffraction (WAXD) showed additional peaks - diffraction angles appeared in the region beneath 12° - which were attributed to partial intercalation. The results strongly suggested the formation of the intercalated/exfoliated structures in the composite in which octadecylamine was used as intercalant agent of the zirconium phosphate.

Keywords*: LLDPE, Nanocomposites, Zirconium Phosphate, Octadecylamine*

RECYCLING OF AIRCRAFT WASTE: NEW COMPOSITES BASED ON POST CONSUMER EXPANDED POLYSTYRENE

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Keywords: *recycling, aircraft waste, composites*, *cold mixing*

Abstract: The world-wide demand for carbon fibres (CFs) reached approximately 35,000 t in 2008; this number is expected to double by 2014, representing a growth rate of over 12% per year. Carbon Fiber Reinforced Polymers (CFRP) are now used in a widening range of applications, being the aircraft industry an impressive example, with the new Boeing 787 and Airbus A350 having up to 50% of their weight in CFRP, and military aircraft showing a similar trend. The increase of the composite market seriously contributes to overburden the management of their waste disposal, therefore the requirement to recycle materials at the end of their useful life is now of high priority. In this paper a sustainable, cost effective technological approach aiming at the recycling of post-consumer carbon fibres reinforced thermosets (CFRT) is proposed. This research activity is part of the EU-funded project "Clean Sky" on the sustainable management of dismissed aircraft.
CFRT sheets (provided by Alenia Aeronautica S.p.A., Italy), derived from the dismantling of end-of-life aircrafts, were ground and sorted by means of different mesh sieving, and employed as filler to obtain high loaded composites. New composites containing 50 and 70 wt% of CFRT particles were prepared by incorporating the filler fraction into a fluidified post consumer expanded polystyrene (EPS) matrix, by a cold mixing approach using a low boiling solvent as a binder to guarantee the dispersion homogeneity on micro and macroscopic level.
For comparison, analogue composites were also prepared through melt mixing process. Morphological and mechanical analyses were performed to evaluate the effectiveness of the cold mixing approach and the influence of particle size on the performance of new recycled composites.

Keywords: *recycling, aircraft waste, composites, cold mixing*

ANALYSIS OF PVC AND PRO-BALSA WOOD CORE SANDWICH STRUCTURES MOLDED BY RESIN INFUSION

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Abstract Sandwich composite structures are continuously increasing their use in many applications. Some of the reasons for that include their excellent characteristics related to low weight, transverse loads bearings, bending stiffness and acoustic damping, which are all needed for the maritime industry. One of the most used process to fabricate hulls is resin infusion, and this process enable the manufacture of large structures with high mechanical properties. This study aims to experimentally evaluate the mechanical properties of different cores and composite faces of sandwich structures using bending and compression tests. The results show that the wood core performed better than PVC core, in cost and density.

Keywords: *Sandwich structures, PVC foam, Balsa wood, mechanical properties, resin infusion.*

GAS PERMEABILITY OF LLDPE/BENTONITE FILMS

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Abstract: Polyethylene films are mainly used in plastic packing applications, such as plastic bags and packing for the storage or protection of materials. The films also used in agriculture to protect the harvests and seeds of plagues and illnesses. The property requirements for these films vary according to their application. One of the properties that can define the application of a polymeric film, besides its mechanical characteristics, is its gas permeability, particularly to oxygen, nitrogen and water vapor. The transport and the solubilization of gases in plastic packaging are a topic of great interest for the application of these materials in the preservation of products that are sensitive to these environmental agents. In the present work, hybrid LLDPE/bentonite systems were prepared by flat film extrusion and their permeability to the gases nitrogen and oxygen were evaluated. Nanoparticulate bentonite clays in their pristine, purified and purified organophilized forms were added to the LLDPE matrix. A masterbatch (3:7 clay/matrix) was prepared in an internal mixer, pelletized and diluted into enough matrix before extrusion to yield films with 1% w/w clay contents. The permeability of the films to the N_2 and O_2 gases was determined on a Brugger gas permeameter equipment according to ASTM D-1434 and ISO 15105/1 standards, operating with purified dry gases. The results showed that: (a) gas permeability (O_2 and N_2) of the hybrids was greater than that of the matrix; (b) higher permeation rates were obtained for the O_2 gas, and (c) the gas permeability displayed by the hybrids prepared with purified organoclay was smaller than those containing either pristine or purified clay. The higher gas permeability displayed by the hybrids when compared to the neat matrix was attributed to filler/matrix interfacial defects generating very small pores on the hybrids. The relative lower gas permeability displayed by the organoclay containing hybrids, on the other hand, was attributed to improved filler/matrix interface. Our results indicate that there is a promising market for LLDPE/bentonite films.

Keywords: *hybrids, permeability, films*

EFFECT OF COMPATIBILIZER ON THE PROPERTIES OF BABAÇU FIBER/POLYPROPYLENE COMPOSITES

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Abstract - Babaçu is a palm tree of widespread occurrence within Northwestern Brazil; lignocellulosic fibers can be extracted from the fruit, and are used in a great variety of applications. In the present work, composites containing 10% and 20% by weight of vegetal fibers from the epicarp of the babaçu fruit dispersed in polypropylene, were prepared and its thermal and mechanical properties determined. A homopolymer of propylene PPH 301, with MFR = 10 dg/min (at 230°C/2.26 kg condition, according to ASTM D1238) supplied by Braskem (Brazil) was used as the polymer matrix; 7% maleated polypropylene (PP-*g*-MA) Polybond 3200, with MFR = 115 dg/min (same conditions) was used as compatibilizing agent. Composites were prepared in an intermeshing corotating twin-screw extruder and test specimens were molded by injection. Composites were characterized by differential scanning calorimetry (DSC), dynamical mechanical analysis (DMA), and scanning electron microscopy (SEM). Tensile and impact mechanical properties were determined according to ASTM D638 and D256, respectively. Results show an increase in tensile modulus with the addition of fiber. The presence of fiber increased the crystallization temperature, as well as the crystallinity of the composites in the compatibilized samples. SEM images show that the compatibilizer promoted a better matrix/load interaction and the formation of a more uniform structure.

Keywords: *polypropylene, natural fiber compounds, babaçu*

UNSATURATED POLYESTER/CAROA FIBER COMPOSITES

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Abstract

This work deals with the manufacture and mechanical testing of unsaturated Polyester composites reinforced with caroa fibers. The matrix employed is a new product from Elekeiroz, coded Biopoli BP290, a tixotropic unsaturated polyester resin partially obtained from renewable sources and a recycled resin. Composites, with random fiber distribution, were manufactured by compression molding on a hot hydraulic press. The caroa fibers were cut up in average length of 2cm and composites with fiber contents of 14 and 23% w/w were manufactured and mechanically tested. For comparison, a composite with 23% w/w was also manufactured. The mechanical behavior of matrix and composites were determined. Our data indicate that although the mechanical properties ascertained - flexural, tensile and impact strengths - increased with fiber content, their initial value was smaller than that of the neat matrix. The most significant increase was observed for the impact properties. The impact strength of the vegetable fiber reinforced composites was significantly higher than that of the polyester matrix.

Keywords:. *Composite, unsaturated polyester, vegetable fiber, caroa, coir*

EVA RESIDUE/STARCH COMPOSITES: INFLUENCE OF STARCH CONTENT AND CASTOR OIL ADDITION

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Abstract: In recent years, environmental issues and the preservation of natural resources have prompted the significant growth on scientific search for the use of alternative materials. The present work deals with the development of composites using 100% alternative material. The composites manufactured here were obtained from a mixture of EVA residue from the shoe industry; thermoplastic starch, which is obtained from renewable sources, and castor oil. Preliminary results showed exceptional values assigned to specific properties, which were attributed to chemical reactions among the elements of the compositions.

Keywords: *Biodegradable composites, EVA residue, strarch, crosslinking.*

STUDY OF COMPOSITES OF HIGH DENSITY POLYETHYLENE AND COFFEE DREGS

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Abstract: Composites of high density polyethylene (HDPE) and coffee dregs (COFD) were elaborated using four different types (integral, extracted, major size and minor size) of COFD. The goal was to study the effects of particle size and soluble extraction over the properties of the HDPE. Four blends were made at the proportion of 90-10% polymer-filler. The materials were evaluated through optical and scanning electron microscopy, thermogravimetry/derivative thermogravimetry, differential scanning calorimetry and tensile test. The results showed that the integral COFD has a performance similar to the minor size one, and superior to the extracted. The composites degraded in two steps. The first one was in a temperature lower than the neat HDPE, but higher than the processing temperature of the polymer. The melting temperature and the degree of crystallinity of the composites resulted similar to the neat HDPE ones. The tensile properties showed some decrease in the modulus, stress at yield and strain at break, and did not varied significantly for the stress at break and the strain at yield. In general, extraction and particle size of the COFD have little influence on the thermal behavior of the HDPE, but has reduced its tensile resistance. The results show that COFD can be used as filler without previous treatment or size separation and, depending on the application, may be used as inert filler in polymeric composites.

Keywords*: Composites; HDPE; fibers; thermal properties.*

THE ULTRA PULSE VELOCITY AND PHYSIC-MECHANICAL PROPERTIES OF POLYMERIC COMPOSITES CONTAINING RUBBER PARTICLES

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Abstract: The pulse velocity method has been shown, for some time, to provide a reliable means of estimating properties and offers a unique opportunity for direct, reliable, quick, safe, inexpensive and non-invasive quality control of materials. This paper investigates the use of this technique in order to identify the correlation between the ultrasonic pulse velocity (UPV) and the compressive strength, bulk density, apparent porosity, modulus of elasticity of a polymeric composite made of epoxy resin and rubber particles from scrap tires. A full factorial design of type $2^1 3^1$ was conducted in order to identify the effect of the experimental factors such as, particle size (20/30 and 50/80 US-Tyler), addition of particles (10wt%, 25wt% and 50wt %) on the responses. The ultrasonic pulse velocity and its correlation with the physic-mechanical properties were able not only to identify the factor effects on the responses but also to estimate the properties of the composites, being a potential non-destructive method for this proposal.

Keywords*: ultrasonic pulse velocity, polymeric composite, epoxy resin, rubber waste*

COMPARISON OF FLEXURAL PROPERTIES OF JUTE AND FIBERGLASS FABRICS REINFORCED EPOXY MATRIX COMPOSITES MOLDING BY RESIN TRANSFERING

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Abstract: Fiberglass reinforced epoxy matrix composites are advanced materials very used to substitute some metallic materials in components of the aeronautical industry. Additionally, these composites can be used in other areas like home construction, navy and automotive industries. The use of vegetable fibers in composites presents some advantages over some synthetic fibers such as: low cost, low density, reduction in the use of instruments for fiber processing. Hybridization can alter both mechanical performance and cost of polymer composites, and novel composite materials can be obtained by the combination of both vegetal fibrous and inorganic mineral reinforcements. Within this context, this work describes the molding of epoxy matrix composites reinforced with jute fiber fabric, and hybrid composites reinforced with glass-fiber fabric and jute. Flexural tests were employed to determine the mechanical properties of materials and for comparative purposes. The main results of flexural strength of the composites with four plies of jute fabric have showed highest flexural modulus values when compared with epoxy matrix without reinforcement. Hybrid composites prepared with fabrics of jute and glass fibers with two plies' to each, showed higher bending tension values compared to others composites in this work. Finally, all composites obtained in this work showed better mechanical properties when compared to matrix without reinforcement.

Keywords*: jute fabric, glass, epoxy, R.T.M., flexural test*

EVALUATION OF THE ADDITION OF AN EPOXY-REACTIVE DILUENT ON THE PROPERTIES OF EPOXY-CARBON NANOTUBES NANOCOMPOSITES

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Abstract: Difficulties related to carbon nanotubes (CNTs) dispersion and high resin viscosity are major drawbacks in nanocomposites molding. To allow better molding conditions, several studies propose the use of additives and solvents. The aim of the present work is to use an epoxy-reactive diluent to decrease resin viscosity and to study its effect on the final nanocomposites produced. For the preparation of nanocomposites, CNTs were dispersed in the resin/diluent (5% and 10% v/v) mixture. The nanocomposites (0.25% CNT) were produced by casting into a silicone mold and curing at room temperature. The samples were evaluated by TGA, DSC and Shore D hardness. The diluent addition was found to decrease resin viscosity and enhance CNTs dispersion, without having a negative effect on the nanocomposites, being the best results obtained with 5% diluent content.

Keywords*: carbon nanotubes, nanocomposites, epoxy resin, diluent.*

FUNCTIONALIZATION OF CARBON NANOTUBES AND THEIR USE TO OBTAIN NANOCOMPOSITES

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Abstract: Chemical functionalization is a procedure used to oxidize the surface of carbon nanotubes and insert functional groups. Several studies employ this technique to improve carbon nanotube interaction and their dispersion in a polymeric resin. The present work evaluates the functionalization of carbon nanotubes with sulfuric, nitric and chloridric acids and their use in nanocomposites. The methodology used to functionalize the nanotubes was considered efficient following Fourier-transform infrared spectroscopic (FT-IR) analysis. Functionalized nanotubes/epoxy nanocomposites were produced using ultrasonication followed by casting. The effects of CNT functionalization on the properties of the nanocomposites were investigated by dynamical mechanical analysis (DMA), hardness and impact mechanical testing. The nanocomposites with functionalized nanotubes showed better DMA and impact results in comparison with the non-functionalized nanotubes.

Keywords*: carbon nanotubes, functionalization, epoxy, composites*

INTERNAL STRESS DEVELOPEMENT DURING THE CURING OF AN EPOXY-VALIDATION BY FIBRE MICROBUCKLING PREDICTION

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Abstract: Fibre waviness phenomenon is well known as resulting from microbuckling instability during the curing of long fibre thermosetting composites. This was observed by video records to happen during the hot stage of the curing [1]. The leading idea of this study is to use fibre microbuckling prediction to validate internal stress estimation during the curing of an epoxy. A modelling for matrix growth during the curing to provide explanations for internal stress development is presented in the first part of the paper and is applied to the curing analysis of a single fibre specimen in the second part which is a perfect internal stress indicator. Thus, couplings induced by the curing between the chemistry, the thermal and the mechanics of the matrix in progress are presented and are taken into account. The solving strategy presented in [2] for the curing of an epoxy sample was applied to the single fibre specimen structure to check for microbuckling instability as observed in [1]. Experimental heating conditions recorded during the microbuckling experiment were reported as boundary conditions to the geometry. The mechanics of the matrix in construction was considered in the framework of elasticity. This approach accounts for fibre instability detection only. Post buckling analyses were not performed at this stage. However, instability appearance predicted by the model is reasonably satisfying with instability detection and offers a first validation for internal stress growth modeling. Corresponding internal stress level observed were found to be around 2 MPa. at fibre instability appearance and tends to be around 50 MPa. at the end of the curing investigated here, which is significant at the hot stage of the curing.

Keywords*: internal stress, epoxy, microbuckling, carbon fibre, cure kinetics*

MECHANICAL CHARACTERIZATION OF ANGLE PLY FIBERGLASS/EPOXY MATRIX COMPOSITES AT DIFFERENT ANGLES

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Abstract: Polymeric composite materials have several advantages when compared to metallic materials commonly used in engineering. Its resistance to corrosive environments, associated with its high strength and specific modulus of elasticity, along with its low density, stimulated the application of these materials in structures that require these characteristics. For an effective use of polymer composites in structural applications, given the numerous possibilities of building the material, broad skills in structural design, fabrication and characterization techniques of mechanical and thermal analysis are necessary for the professional involved with the material. As the mechanical strength and stiffness in a composite can be changed as function of the fiber properties, orientation and the content of the constituent materials, it is especially important for a structural application to determine the composite properties, including those in which the composite is determined as a function of angle of lamination. The aim of this study was to determine mechanical properties of angle-ply composites manufactured by filament winding. The fiberglass/epoxy angle-ply composite was manufactured considering different reinforcement orientations. The coupons were manufactured in the directions of 0º, ±10º, ±20º, ±30º, ±60º, ±70º, ±80º e 90º, related to the loading direction of the test machine. The results showed that mechanical strength decreases for any off-axis angles up to 45º. It was found, for instance, a fall of 28% in strength for only a deviation of 5% from de load direction. For high angles there is no change in the strength and modulus, being these properties determined by the matrix. The fiber content was obtained for all manufactured plates and also the glass transition temperature of the epoxy matrix.

Keywords*: fiberglass, epoxy, composites, off-axis, mechanical characterization*

STUDY OF THE THERMAL EXPANSION BEHAVIOR OF THE COMPOSITE Mg-B (20%)

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Abstract: The composite of Mg-B (20%) has applications related to the aeronautical/aerospace, according to their historical usage reported and evaluated by some authors, and due to its properties, especially regarding the resistance/weight. The focus of the study was to collect detailed behavior of thermal expansion for controlled rates of addition of heat and thermal cycling of work. The results were as expected for this material, i.e., the fibers are more loaded in a range of temperatures and orientations and the matrix is replaced by greater global dominance on other range of temperatures and orientations, which is proven in the course of this experimental study.

Keywords*:* Composites, Magnesium, Boron, Fibers.

USE OF OOF2 TO STUDY THE RELATIONSHIP BETWEEN MECHANICAL PROPERTIES AND THE SPATIAL DISTRIBUTION OF REINFORCEMENT IN COMPOSITE MATERIALS

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Abstract: The use of finite element software for the study of composite materials is an area of research that has enjoyed steady growth in recent years. OOF2 is a free finite elements software oriented to the study of thermal and mechanical response of solid pieces with different and relatively complex bi-dimensional geometries of their cross section. Even though the software is only applicable to bi-dimensional problems, it may be particularly useful for estimating mechanical properties of composite materials reinforced with relatively long aligned fibers, while allowing relating the results with the structural characteristics of the composite (spatial distribution of the reinforcement). To show this and other potentialities of this software for the study of composite materials is the objective of the present work. To achieve this goal, three virtual test samples were designed and studied: bars of composite material with square cross section, reinforced with circular cross section fibers, identical and parallel. Thus, the spatial distribution of fibers and all the parts of the internal structure are completely characterized by the image of the cross section. Different spatial distributions of the fibers were obtained by simulation, to create cross-sectional images of the first three samples. For the third sample a digital SEM micrograph of the cross section of a real composite material was used. Appropriate values of mechanical properties were assigned to constituent materials. The images were then input into OOF2 where an algorithm was used to perform a virtual test on the samples in order to determine the transversal Young's modulus. The virtual test results were compared with theoretical models (rule of mixtures) and beyond, in the case of the third part, with real test results performed on the real piece from which the micrograph had been obtained. The results showed a good agreement with the references of comparison, which validate the proposed use of OOF2 for the study of such composite materials. Stress map images of the cross section of deformed pieces were also obtained and analyzed, as well as profiles of stress on the faces of interest. This type of result can be particularly useful for the study of local internal processes in composite materials, such as crack nucleation and growth, etc.

Keywords: *Modeling, finite elements, OOF2, mechanical properties, composites*

ACCELERATED TESTING METHODOLOGY FOR LONG-TERM LIFE PREDICTION OF CFRP LAMINATES

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Abstract: Carbon fiber reinforced plastics (CFRP) are now being used for the primary structures of airplanes, spacecrafts and others, in which the high reliability should be kept during the long-term operation. Therefore, it would be expected that the accelerated testing methodology for the long-term life prediction of CFRP structures exposed under the actual environments of temperature, water, and others must be established. Recently, we have proposed a general and rigorous accelerated testing methodology (ATM-2) which can be applied to the life prediction of CFRP laminates exposed to an actual load and environment history. Most important condition as the basis of ATM-2 is the fact that the time and temperature dependence on the strength of CFRP is controlled by the viscoelastic compliance of matrix resin. In this paper, the formulations of viscoelastic compliance and time-temperature shift factors of matrix resin are carried out based on the time-temperature superposition principle. And the formulations of long-term life for various load directions of unidirectional CFRP laminates are carried out. The effect of viscoelasticity of matrix resin and failure mechanism on the long term life for various load directions of unidirectional CFRP laminates is discussed based on ATM-2.

Keywords: *Durability, Viscoelasticity, Accelerated Testing, Polymer Composites*

POLYESTER COMPOSITES OF THE HOLLOW GLASS MICROSPHERES

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Abstract: In this study, Polyester/hollow glass microsphere composites have been suggested as a automobile material because of the high mechanical proprieties and the low gravimetric density of the microspheres. Composites were characterized by means of viscosity, density, scanning electronic microscopy (SEM) and mechanical tests. Composites containing hollow glass microsphere were produced by resin transfer molding. Loading the Polyester with microspheres reduces its density and allows use of microspheres made from various compositions of glass. Since the bulk density of the hollow glass microspheres is much less than that of Polyester, the use of a composite reduces the weight of the material, thus decreasing the amount of fuel needed. The mechanical properties of these composites were similars with increase in hollow spheres content.

Keywords*: composites,hollow glass microsheres, resin transfer moulding process (RTM)*

DESIGN AND CONSTRUTION OF A ELLIPSOIDAL COMPOSITE SHELL COVERING A METALLIC GEODESICAL STRUCTURE

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Abstract: This paper describes the structural analysis and construction of a ellipsoidal composite shell. The structural thin shell was modeled with 3 and 4noded shell elements using effective engineering properties derived from a micromechanics theory. The Shell construction and assembling was based in the metallic structure project and the shell was designed divided in segments of about 16 m^2. The methods and dimensioning of those segments is described as well as the assembling and determination of fixing points. The laminate construction, formulation and properties are described. Special auxiliary devices for hand lay up of large parts were developed. The shell elements were fixed in pivots placed at some of the nodes of supporting metallic structure. Corrections due to unexpected deformations in the metallic structure were determined by laser measurement, method that uses laser scanner/point cloud to generate the CAD model of the real structure with a precision of 1mm .

Keywords*: composite shell, FEA, FEM*

MECHANICAL BEHAVIOUR OF LIGNOCELLULOSIC COMPOSITES: SUGARCANE BAGASSE FIBERS/HIPS

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Abstract: High impact polystyrene (HIPS) reinforced with mercerized and bleached sugarcane bagasse fibers composites were fabricated to evaluate the influence of chemical treatment on the composite mechanical properties. Tensile and flexural tests were carried out on samples of HIPS and its composites. The fracture surfaces of tensile tests samples were analyzed by scanning electron microscopy (SEM) to correlate adhesion between fiber and matrix with mechanical properties. Tension tests results show that addition of fibers in HIPS matrix improved tensile strength and tensile modulus, on the other hand decreases elongation at break causing fragility of material. Flexural tests show that the addition of fibers improved flexural properties, special for composites reinforced with bleached fibers. From SEM of fracture surface was observed that composites reinforced with bleached fibers presented more effective interface due to fibers roughness surface promoted by chemical treatment.

Keywords*: high impact polystyrene (HIPS), sugarcane bagasse fibers, tensile tests, lignocellulosic composites*

FLEXURAL PROPERTIES OF SISAL AND COCONUT FABRICS REINFORCED EPOXY MATRIX COMPOSITES AFTER CONDITIONING

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Abstract: Epoxy is a thermosetting polymer having excellent thermal and mechanical properties for high performance applications with composites used in aeronautic and wind turbine blades. However, for the application of epoxy resin in natural fibres reinforced composites it is necessary to conduct studies on the absorption of moisture that may affect thermal and mechanical properties. This work involves the moulding of epoxy resin and epoxy resin with vegetable fibres such as sisal and coconut. For moulding it was used a polymeric matrix of the type diglycidyl ether of bisphenol A epoxy resin. The moulding was carried out by compression in a hydraulic press at room temperature. The fibres were previously cut into the dimensions of the metallic mould used. After moulding, two plates of each composite (epoxy/ sisal and epoxy/coconut non-woven fabrics) and the epoxy matrix (unreinforced) were compared. Flexural tests were performed in accordance with ASTM D790. Moreover, it was made the conditioning of some samples in a humid chamber adapted from ASTM D5229M-92. The behaviour of the resin matrix was more brittle to fracture, while the composite suffered greater deformation (strain). The flexural tests after the conditioning showed a decrease in the flexural strength when compared to flexural tests at room temperature. During the flexural tests of the conditioned specimens it was noticed an increase in the deformation of all materials. However, the reduction of mechanical properties of composites was more pronounced due to a decrease on adhesion in the fibre/matrix at the interfacial region because the vegetable fibres increase the moisture content of the composite material.

Keywords: *epoxy resin, natural fibres, flexural tests, moisture content*

EVALUATION OF COMPOSITE SLEEVES FOR REINFORCEMENT OF DENTED PIPELINES ON LONGITUDINAL WELD

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Abstract: The purpose of this study was to determine if composite materials can effectively repair dents on longitudinal weld in high pressure pipelines subjected to cyclic pressure service. Artificial dents with depths of 6% OD were imposed to 18 in. OD, 3/8 in. thick, API 5L X52 tubular specimens. After this, the specimens were repaired with composite materials. This article included the participation of three composite repair manufacturers. The composite repair systems were consisted of fiber E-glass and carbon. Matrix resins included two-part epoxies and water-activated urethanes in a pre-impregnated form. The main purpose of the repair sleeve in this case was to provide a repair procedure installed at room temperature and capable of reducing the stress range at the hot spot in the dent. The goal was to improve the fatigue resistance of the repaired pipeline. Low cycle fatigue tests were performed, both using non-repaired specimen (to serve as the basis for comparison) and the specimens repaired using different systems. The tests were fully instrumented to analyze deformation in each specimen. This paper reports the main results of the tests and the deformation analysis of each repaired specimen, aimed to define parameters which will serve to the design of future cases.

Keywords*: pipeline repair, composite sleeve, dent, damage*

INFLUENCE OF NATURAL GRAPHITE IN THE PROPERTIES OF RECYCLED POLI (ETHYLENE THEREPHTHALATE)

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Abstract

Composites of poly(ethylene terephthalate) recycled and different amounts of natural graphite were developed with the intention of providing a new route to recycled PET with added properties. The composites were developed in an intermeshing co-rotating twin-screw extruder working at 300 rpm and at temperatures in the range 220-275 °C. Low field nuclear magnetic resonance (LFNMR), wide angle scattering diffraction (WAXD), thermogravimetric analysis (TG) and differential scanning calorimetry (DSC) was performed in the powder form to evaluate the materials obtained. The LFNMR analysis did not show some difference of T_1 for PET and composites. By WAXD, it was observed a decrease of peak 2θ around 25° for the composites. The TG analysis showed a decrease on T_{onset} for the composite with 2 wt.% of filler. The DSC curves for the composites it was not observed the T_c peak of portion of PET. These results confirm some influence of filler in the polymeric matrix.

Keywords*: Natural graphite, recycled PET, extrusion*

STUDY OF DIFFERENT PREPARATION METHODS OF COLLAGEN/HYDROXYAPATITE COMPOSITES

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Abstract: This investigation aims to study the influence of preparation method in the production of collagen/hydroxyapatite (HA/COLL) composites. The samples were produced by physical mixture and by *in situ* method. For the *in situ* method, hydroxyapatite was synthesized adding collagen on the solution containig precursors of HA. For the physical mixture, certain amount of collagen was added to the HA previosly synthesized. In both cases the resulting material was lyophilized, in order to obtain powder morphology. The composites were characterized by energy dispersive X-ray spectroscopy (EDX), Fourier transform infrared spectroscopy (FT-IR), wide-angle X-ray diffraction (WAXD), and scanning electron microscopy (SEM). The Ca/P molar ratio - determined through EDX - showed the influence of the addition of collagen in the synthesis of HA. The values were 1,89 (HA) and 2,38 (*in situ*). The FT-IR analysis showed some interaction between the parent materials of the composites. The X-ray diffractograms resolution and intensity of the HA peaks were better presented in the *in situ* method, rather than the physical mixture. This could be ascribed to the increase of the crystallinity of the samples prepared *in situ*. The photomicrographs showed that the preparation method exhibited significant influence in the composite morphology. The morphology of physical mixture composite is embedded in the HA clusters while that produced by *in situ* method showed collagen as platelets involved by HA aggregates.

Keywords*: collagen; hydroxyapatite; composite; in situ synthesis; polymer*

CHARACTERIZATION OF CUPUAÇU SHELL PARTICLES (*Theobroma grandiflorum*) AND THEIR POTENTIAL USE AS FILLER IN COMPOSITES: A PRELIMINAR STUDY

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Abstract: Since the beginning of humanity, materials have been classified according to their chemical and physical properties. However, more recently, there has been a stronger concern regarding the environmental implications of their processing and use. Several approaches have been considered for materials to be further explored, particularly in the field of composites materials. Nowadays, there has been an increasing interest in "eco-composites" and "green composites". New polymer matrices and new sources of fillers have been investigated to produce materials with less environmental impact. The objective of this work is to study the use of cupuaçu shell (*Theobroma grandiflorum*) as filler for polymer matrix composites. Cupuaçu shells were dried at 100° C and then ball milled to reduce particle size. After ball milling, the material was passed through a sieve (2 mm) to separate solid particles from dust. The particle size distribution was measured by means of laser diffraction, using water as dispersing medium. A large variation in particle size was observed, resulting in a standard deviation of approximately 57 µm. The material was also characterized by thermogravimetric analysis (TGA), X-Ray Diffraction (XRD), Differential Scanning Calorimetry (DSC) and Scanning Electron Microscopy (SEM). Scanning Electron Microscopy (SEM) images indicate that the process used results in a wide range of dimensions. Overall, the results suggest that the cupuaçu shell has a potential to be used as filler in polymer composites.

Keywords*: cupuaçu, composites, eco-composite, cupuaçu shell*

THE EFFECT OF SILICON CARBIDE ADDITION INTO FIBREGLASS REINFORCED COMPOSITES

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Abstract: In today's modern world the composite materials have been widely used not only for aerospace/aeronautics, but also automotive, sports and construction industries. The flexural strength of laminated composites depends on the characteristics of dispersive and matrix phases, considering the presence of tensile and compressive loadings. For this reason, the addition of particles into the matrix phase has been investigated to enhance its stiffness and consequently the elastic modulus of the composite. This work investigates a glassfibre composite reinforced with silicon carbide particles. The following responses were evaluated: apparent density, water absorption, flexural strength, modulus of elasticity. The results were compared to those manufactured with no silicon carbide particles. It was observed that the silicon carbide particles provided the increase of the apparent density and flexural strength of the composites.

Keywords: Laminated Composites, Silicon Carbide, Fibre Glass, Hybrid Composites

THE USE OF $CaCO_3$ FILLED RESIN ON THE RTM PROCESS

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Abstract: Resin Transfer Molding (RTM) is one of the most widely known composite manufacturing technique of the liquid molding family, being extensively studied and used to obtain advanced composite materials comprised of fibers embedded in a thermoset polymer matrix. Nowadays, RTM is used by many industrial sectors such as automotive, aerospace, civil and sporting equipment. Therefore, the aim of this study is to investigate the effect caused by the use of $CaCO_3$ filled resin on the characteristics of the RTM process. Several experiments were conducted using glass fiber mat molded in a RTM system with cavity dimensions of 320 x 150 x 3,6 mm, room temperature, constant injection pressure of 0,25 bar and different content of $CaCO_3$ (0, 10, 20, 30 and 40%). The results shows that the use of filled resin with $CaCO_3$ influences the preform impregnation during the RTM molding, however it is possible to make composite with a good quality and low cost. It is important to know all the variables involved in the molding in order to know what it is possible to change to achieve the desired objectives.

Keywords: *RTM, filled resin, $CaCO_3$, filling time, pressure*

DEVELOPMENT OF NANOCOMPOSITES BASED ON EVA AND STRUCTURAL EVALUATION BY LOW-FIELD NMR

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Abstract: In this work a series of EVA/clay nanocomposites have been prepared by solution casting, using two organophilic clays (Viscogel S4 and Viscogel S7). The effect of the nanoclay chemical composition and nanoclay ratio on the structural organization and thermal behavior of EVA/clay nanocomposites were systematically investigated by low-field nuclear magnetic resonance relaxometry, thermogravimetric analysis (TGA) and X-ray diffraction (XRD). The results obtained from XRD showed that all studied systems presented a partially intercalated and partially aggregated structure, however the EVA/S4 systems showed a better nanoparticle dispersion. From TGA was seen that the introduction of nanoparticle into EVA matrix caused a slight decrease on the thermal stability for all EVA/clay nanocomposites, especially for EVA systems containing 5% of nanoclays, which presented a more significant reduction in the initial temperature degradation (Ti) comparing to other systems prepared with the same type of nanoparticle. Analysing the spin-lattice relaxation time and the domains distribution curves, it was possible to find a decrease in the T_1H values for EVA/S4 5% and EVA/S7 5% systems, indicating that a portion of the nanoclays was exfoliated. The results obtained from NMR ralaxometry permitted to study nanocomposites systems in more detail, enhancing the results found in the XRD and TGA analyses.

Keywords*: Nanocomposites, EVA, Low-field NMR characterization, TGA, XRD*

THE EFFECTS OF CHEMICAL TREATMENT AND FIBRE ORIENTATION IN SISAL COMPOSITES

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Abstract: Composite materials are designed to support axial, transverse, shear and combined loadings. The use of natural fibres such as coconut, banana, sisal, bamboo and others has been the focus of much research. The biocomposites present low density, high specific strength and attractive cost, besides the fact the fibres come from renewable sources and are biodegradable. The physic-mechanical properties are influenced by the percentage and orientation of fibres, and fibre-matrix interface. Chemical treatments, such as mercerization, acetylation, heat, have been investigated to improve the adhesion between natural fibres and matrix phase, This work investigates the effect of orientation of fibres and a chemical treatment in the flexural strength of biocomposites made of five unidirectional layers oriented such as, 0°/0°/0°/0°/0° and 0°/90°/0°/90°/0°. The results showed that the chemical treatment was able to enhance the interface adhesion. The composites fabricated as 0°/90°/0°/90°/0° showed a lower flexural strength compared to those composites laminated at 0°.

Keywords: *sisal, laminated composites, orientation, chemical treatment*

EVALUATION OF CRYSTALLINITY FROM POLYAMIDE 6/ORGANOCLAY NANOCOMPOSITES

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Abstract: Polymer/clay nanocomposites have great potential as low-cost, lightweight and high-performance materials because of the physical property enhancements due to their improved mechanical, thermal, electrical and optical properties as compared to their macro- and micro-counterparts. The most representative layered silicate is natural montmorillonite, i.e. natural smectite clay (2:1 phyllosilicate), which consists of regular stacks of aluminosilicate layers with a high aspect ratio and a high surface area. The improved properties of nanocomposites are related to the modification of the structure and dynamics of the polymer at and near the particle surface. Because of the large surface area this fraction of the polymer contributes significantly to the properties of the whole nanocomposite, even at low filler content. In this study, it was evaluated the crystallinity of polyamide 6 nanocomposites with organoclay. The clay was characterized by XRF and XRD. The results of this analysis showed the incorporation of salt in the clay layers, making it organophilic. To obtain the hybrids, were prepared concentrates (1:1) in mixer coupled to a Haake torque rheometer. The mixtures were processed in a twin screw extruder corrotacional Werner-Pfleiderer ZSK 30. The morphology of the hybrids was analyzed by XRD. These results showed that the peak of the organoclay disappeared when incorporated into polyamide 6, apparently indicating that all systems have exfoliated and/or partially exfoliated structure. The crystallinity was studied by XRD and DSC, showing an increase tendency in the systems in relation to pure PA.

Keywords*: Nanocomposites, polyamide, organoclay*

TRANSVERSAL SHEAR CARACTERISATION OF THICK LAMINATED COMPOSITE USING A REPRESENTATIVE VOLUME ELEMENT (RVE)

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Abstract: The determination of accurate behavior of composite laminated plates largely depends on the theory used to model the structure. Most commercial finite element packages use elements based on the classical Kirchhoff plate theory, which neglects the effect of transversal shear. The effects of transversal shear in the final response of a structure increases with the thickness of the laminate, as such, the correct characterization of transversal shear distribution is necessary when studding problems with thick laminate plates such as in the petroleum industry. The introduction of shear correction factors can circumvent this problem by mathematically simulating the transversal shear distribution over the thickness of plates, but are difficult to calculate due its inherited dependence with the layup of the laminate. This paper presents an away to calculate the shear correction factor for unidirectional (UD) carbon-epoxy composites using a representative elemental volume (REV) for the whole laminate.

Keywords*: finite element analysis; representative volume element (RVE); transversal shear*

DYNAMIC MECHANICAL PROPERTIES OF HYBRID CURAUA/GLASS COMPOSITES

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Abstract: In this work, dynamic mechanical analysis of hybrid intralaminate curaua/glass composites was carried out. Variations in the curaua/glass fiber content ratio and the overall fiber volume fraction (20, 30 and 40 vol.%) were studied. Dynamic mechanical properties showed an increase in storage modulus whereas the glass transition temperature showed no significant trend with glass incorporation. Furthermore, a significant increase in overall properties was obtained even without significant changes in glass transition temperature. The composites containing more effective reinforcement showed higher storage modulus along the studied temperature range. Also, hybridization has been successful, and the composite containing 30 vol.% of curaua and 70 vol.% of glass fiber showed a performance similar to that of pure glass composites for all overall fiber volume fractions studied.

Keywords*: Hybrid composites, curaua fiber, dynamic mechanical analysis, viscoelastic properties.*

NON CRIMP FABRICS FOR ADVANCED COMPOSITES APPLICATIONS: A SURVEY

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Abstract: Non Crimp Fabrics (NCF) are materials made of unidirectional plies at different orientations assembled together by a transverse stitching made with a polymer fiber. A NCF can be transformed in a polymer matrix composite by various processing techniques such as RTM, infusion, prepreging, etc. NCF can be seen as a semi-product in the manufacturing process of a composite having several advantages balanced by the extra cost of the semi-product compared to UD. NCF offers many opportunities for creating unique composite applications which are reviewed in the paper. Based on the aforementioned properties, the paper covers some of the potential applications of NCF. A review by large domains is given: aerospace and aeronautics, automobile, energy, civil engineering and sport.

Keywords*: Non Crimp Fabric, Anisotropy, Thin ply, Multiaxial.*

POLYAMIDE 11/TITANIUM NANOXIDE NANOCOMPOSITE

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Abstract: It was studied the effects of chemical modification of the surface of titanium nanoxide (TiO_2) and its addition in the matrix of polyamide 11 (PA11), on mechanical and tribological properties of the PA11/TiO_2 nanocomposite. To modify the surface of the TiO_2 nanoparticles was used 3-aminopropyl trimethoxysilane (ATPMS). To evaluate the efficiency of the surface chemical modification of the TiO_2 nanoxide was used infrared spectroscopy (FTIR). Samples of neat PA11, modified PA11/TIO_2 nanocomposite with ATPMS and unmodified PA11/TIO2 nanocomposite were evaluated mass loss by abrasion, and tensile strength. Infrared spectroscopy allowed to observe the appearance of a peak at 928 cm^{-1} that corresponds to the Titaniun-Silicon-Oxygen (Ti-Si-O-) chemical bonds which indicate that ATPMS reacted with TiO_2 and modified its surface. The addition of unmodified TiO_2 nanoxide reduced volumetric loss by abrasion in 55 % when compared to neat PA11. The surface modification of the TiO2 particles with ATPMS, decreased the volumetric loss by abrasion of the PA11/TiO2 nanocomposite in approximately 70% compared to neat PA11. The tensile tests showed that elastic modulus was higher in the nanocomposite prepared with modified TiO_2 than that prepared with unmodified TiO_2.

Keywords: *Nanocomposites; polyamide 11; titanium nanóxido; tribological properties*

CHARACTERISATION OF SYAGRUS CORONATA (MARTIUS) BECCARI (LICURI) FIBRES

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Abstract: *Syagrus Coronata* (*Martius*) *Beccari* is a native palm from the semi - arid regions of Brazil, it is available in abundance and is still barely known among the scientific community. Licuri offers an opportunity for economic survival to those who depend on its exploration, as well as offering other positive environmental, social and economic aspects. Collected material was deposited in the herbarium. The morphological, biochemical, physical, chemical and mechanical properties of licuri leaf fibres were investigated in this work. The results show that the licuri fibre can potentially be used as reinforcement in composites materials.

Keywords: *Natural fibres, licuri, Syagrus Coronata, characterisation.*

EPOXY THERMOSET TOUGHENED WITH AMPHIPHILIC BLOCK COPOLYMERS

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Abstract: To take full advantage of the properties of epoxy thermosets it is at times necessary to improve its toughness. Usually this is done by adding toughening agents. Typical toughening agents, thermoplastics or elastomers, can do a good job but often this improvement comes at the expense of other desirable mechanical properties (like modulus), thermal properties (like glass transition temperature, T_g) and/or ease of processability of the uncured formulation (undesirable changes in viscosity). This paper focuses on the use of an amphiphilic block copolymer that gives a better balance of improved toughness without tradeoffs to other key performance properties and ease of processability.

Keywords: *Epoxy, Toughening, Composites*

IMPACT LOCALIZATION IN COMPOSITE PLATES WITH DISTRIBUTED PIEZOELECTRIC SENSORS SETUP

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Abstract: The present work had as objective the development of an impact localization methodology applicable mainly to composite material laminates. For such an approach via use of piezoelectric sensors was sought, one that allowed real time monitoring of this kind of structure. Bearing this in mind, different kinds of algorithms were revised, taking into account vantages and advantages, with posterior development of a computational model in MatLab and a methodology of localization based in the main features of the methods studied.

Keywords*: composite materials, impact localization, structural health monitoring*.

INFLUENCE OF THE ADDITION OF NATURAL MICAS IN THE PROPERTIES OF EVA

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Abstract: The ethylene-vinyl acetate copolymers (EVA), classified as a thermoplastic copolymer is widely used in the footwear industry. According to the type and formulation, EVA can be used as flexible or rigid expanded material. The use of mineral fillers has been used for some time in order to modify certain properties of polymeric materials and to reduce production costs. Currently the use of mineral fillers in polymer matrix is its use associated with the use of nanoclays. Mica, a term used to identify a class of the family of layered phyllosilicates, has layered structure, consisting of a central sheet of Al_2O_3 and two tetrahedral sheets of SiO_2. May have the presence of interlayer cations such as Ca^{2+} or K^{2+}. Due to its high aspect ratio, the mica makes it a promising filler to obtain the nanocomposite polymer from exfoliation of its lamellar structure. In this study, to evaluate the effect of adding various types of mica when incorporated in different amounts (2.5, 5.0 and 7.5 phr) in EVA. Was used muscovite mica, with different amounts of metallic cations, including K^{2+} The incorporation of fillers in the polymeric matrix occurred in the melting state in an extruder twinscrew co-rotating. After processing, the samples were compression molded for mechanical characterization (tensile strength resistance), thermal (thermogravimetric analysis (TGA)) and morphology (X-ray diffraction (XRD)). The results of tensile tests indicate that the incorporation of mica in the EVA resulted in a lower elongation in the yield when compared to pure EVA. The addition of different types and amounts of mica to the polymer matrix, when compared, did not significantly influence the results of maximum tension for the composite. The results of the TGA showed an increase of about 2% of the maximum degradation temperature of the samples containing mica compared pure EVA. The maximum rise in temperature of degradation can be associated with increased difficulty of heat conduction and diffusion of gases through the polymer matrix provided by mica. The onset temperature of mass loss of all the samples did not change significantly The authors believe that the mechanical properties are influenced by the weak interfacial interactions between the filled and the matrix, a fact explained by the XRD experiments revealed the presence of agglomerates of the clay in the polymer matrix, indicating the formation of conventional composites

Keywords: composites, ethylene-vinyl acetate copolymers, mica

STUDY OF THE ADDITION OF OMMT IN UV CURING POLYURETHANE COATING

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Abstract: The coatings have great importance in the protection of metal materials when they are exposed to aggressive environments. Technological advances in this area have intensified the research for new materials and technology improvements. Increasing environmental regulations have required that new technologies are developed. Within the new technology of ultraviolet (UV) curing has reached highlighted in recent times because its low emission of volatile organic compounds (VOC), in addition it is a system with low power consumption and also it is an industrial painting process very fast, since the UV cure system is instantaneous. The polymers structured nanoclay recently has been shown attractive due to their enhanced properties when applied to the polymer matrix. The growing development of UV curing coatings technology associated with the development of nanocomposites allowed the combination of the nanoclay and resins UV curing. This study evaluated the behavior of films UV cure polyurethane coatings containing different concentrations (2 and 5 % (w/w)) of montmorillonite Cloisite® 30B (OMMT) in its formulation when applied to carbon steel substrates. The coatings were characterized by adhesion, impact resistance and flexibility resistance. The thermal performance and the structure of the coating films were evaluated by thermogravimetric analysis (TGA) and X-ray diffraction (XRD). Physical characterization of the films showed a weakening of the film with the incorporation of nanoclay. The TGA showed that the clay did not act as a thermal barrier, a fact explained by the XRD analysis, which confirmed the presence of OMMT agglomerates (tactoids), favoring the formation of points of fragility in the film. The authors believe that the reduction in the mechanical resistance of the films and its adhesion to the metal surface is related to the presence of tactoids.

Keywords: *Montmorillonite, polyurethane coating, ultraviolet curing*

MASS EFFECT AND HEATING RATE ANALYSIS IN CARBON FIBER/EPOXY COMPOSITES

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Abstract: The increase of the use of composites in the aerospace industry, including structures with higher requirements to mechanical stress, attracts considerable interest in reducing manufacturing costs thereof. One can consider the cost of composite materials primarily as a function of the raw material, the lamination, the method of manufacturing and the finishing processes. For the aviation industry, the molding process in autoclave is predominant and the time spent in the process of cure is a fundamental variable. The objective of this study was to evaluate the influence of the mass effect and heating rate of the cure in thermal profile, considering a reduction in process time, and in the mechanical properties of carbon/epoxy composites. During the study tests were performed: interlaminar shear, dynamic mechanical analysis (DMA) and damped free vibration. There were evaluated fifteen composite with plain geometry, which are distinguished by the number of layers and the cure cycle applied. The results showed that continuous heating rates from 1,0 °C/min to 3,0 ºC/min until the final temperature of cure, do not cause major variations in the mechanical properties of the final composite, which could allow a reduction in the processing cost.

Keywords*: Exotherm, Mass Effect and Composite Material*

INFLUENCE OF THE CLAY CONTENT ON THE POROSITY OF MEMBRANES OBTAINED FROM POLYAMIDE 6 NANOCOMPOSITES

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Abstract: In the modern world, polymeric membranes are widely used in industries. Some examples of industrial applications are gas separation, filtration, ultrafiltration and reverse osmosis. The control of the morphology of the membrane is very important in the suitable configuration and performance for a specific application. The addition of inorganic nanoparticles in polymeric materials improves the filtration properties of membranes attracting great attention to the development of science and membrane technology. Polymeric nanocomposite films with montmorillonite have received considerable attention, since the nanoparticles increase the barrier properties of films. The objective of this study is to evaluate the content of clay in membranes obtained from polyamide 6 nanocomposites using the phase inversion technique. By XRD, the obtained nanocomposites indicated possibly exfoliated structure, as also shown for membranes. By SEM it was observed that the presence of clay changes morphology of the membrane in relation to PA6 with the presence of a larger quantity of pores along the surface. Two contents of clay (3 and 5 wt.%) were used and the higher content caused an increase in pore density, but contributed to a significant decrease in the same. Along the cross section it can be visualized the presence of an asymmetric morphology, where the selective layer has very small pores in relation to the porous support. With the presence of clay has been seen that the thickness increased proportionally with the clay content. Already the pores of the porous layer had a significant decrease of the diameter. For all membranes obtained from nanocomposite it was verified the formation of macropores near the surface, that can be attributed to precipitation with a delay due to the increased viscosity of the solution, making it difficult the diffusion of solvent and nonsolvent in the formation of membrane structure. In general, asymmetric microporous membranes were obtained and the presence of clay modified formation, size and distribution of pores along the membrane.

Keywords*: membranes, polyamide 6, montmorillonite*

FLEXURAL BEHAVIOR OF SISAL/CASTOR OIL-BASED POLYURETHANE AFTER UV RADIATION

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Abstract: A solution to reduce the pollution caused by large-scale employment of polymers is the use of biodegradable polymers as polyurethane derived from castor oil. Besides displaying a good set of mechanical properties, natural fibers such as sisal are low in cost, abundant, non toxic, non-abrasive and thus, can be used to improve the mechanical strength of biodegradable polymers. Composites were made by compression molding, without thermal treatment. The aim of this work was to investigate the effect of UV radiation on the flexural behavior of castor oil derived polyurethane/sisal composites. Three points bending test results indicate the flexural strength decrease after UV radiation.

Keywords*: castor oil, sisal, polyurethane*

MECHANICAL CHARACTERIZATION BY NANOINDENTATION OF POLYURETHANE DERIVED FROM CASTOR OIL REINFORCED WITH SISAL

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Abstract: Composites of sisal fibers and polyurethane derived from castor oil were investigated by nanoindentation and nanoscratch tests. These mechanical tests were employed to obtain information of the mechanical properties of polyurethane/sisal interface. It was observed that a series of experimental factors affect a good analysis of the mechanical properties of sisal polyurethane interface. The roughness of the surface is one of the most important limiting factors, since the measurements are made in nanoscale. Another point to consider is the random aspect of sisal fiber distribution that changes the mechanical stress distribution during loading, or scratching. Stress concentration at polyurethane/sisal interface is an important factor of mechanical behavior during normal operation. The nanoscratch tests permits to investigate the effect of an external concentrate stress at polyurethane/sisal interface. Images obtained from scanning electron microscopy after the nanoscratch tests reveal cracks at polymer/sisal fiber interface.

Keywords*: hardness, castor oil, composite*

THERMAL ANALYSIS OF SISAL COMPOSITES

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Abstract: The interest on the development of ecologically viable materials, especially with less environmental impact, either with the use of recycled materials or using materials from natural sources propels research involving polymeric composites reinforced with natural fibers. The use of polymer composites reinforced with sisal fibers are being considered to application as reinforcement of timber structures. Nowadays, the fibers with larger structural applications are glass and carbon fibers but the use of natural fibers is an economical alternative and present many advantages such as biodegradability, low cost and having its origin from a renewable source. Castor oil, a triglyceride vegetable with hydroxyl groups, was reacted with 4,4' diphenylmethane diisocyanate (MDI) to produce the polyurethane matrix, one of the three matrices used in this work, the others resins were epoxy and phenolic. All the composites were processed by compression molding. This research studies thermal behavior and its respective mechanism of thermal decomposition at three composites: sisal/castor oil based polyurethane, sisal/phenolic and sisal/epoxy. Samples of sisal fibers, polyurethane, phenolic and epoxy resins and the respective composites were characterized by thermogravimetric analysis (TG/DTG). Only the resins were analyzed by differential scanning calorimetry (DSC). Thermogravimetric curves showed that epoxy resin was the greatest stability material followed by sisal/epoxy composite.

Keywords*: thermal analysis, polymeric composites, sisal fiber, castor oil based polyurethane resin, thermogravimetry (TG)*

STUDY OF MECHANICAL PROPERTIES OF HIGH DENSITY POLYETHYLENE/MONTMORILLONITE NANOCOMPOSITE RECYCLED BY EXTRUSION

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Abstract: Nanocomposites of organoclay in a polymeric matrix are of current research and commercial interesting. The incorporation of organoclay in nanometer scale in a matrix of high density polyethylene aims to improve the mechanical, thermal and barrier**,** besides increasing the dimensional stability of the material. Few studies address the effects of recycling on this material. For treat is a commodity price is subject to market fluctuations**,** so recycling becomes important to reduce the use of virgin resin**,** reducing costs and increasing competitiveness, besides reducing the impacts of both the holding of raw material as the discharge of the final product**.** This study examines the effect of the melt intercalation and reprocessing by extruding organophilic montmorinllonite polymeric in a matrix of high density polyethylene**.** Further this treatment; melt flow index, mechanical tensile tests**,** and differential scanning calorimetry analysis were conducted**.** The results show that the presence of an organoclay improves the mechanical behavior**,** without thereby is responsible for the degradation caused by several thermal cycles through the extruder. The melt flow index showed that the presence of the clay was not directly responsible for the degradation of the material**.**

Keywords*: nanocomposite, organoclay, polyethylene, recycling*

STUDY OF CHEMICAL TREATMENTS OF CARBON FIBERS

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Abstract: Carbon fibers are the most used type of reinforcement in composites that required best structural performance (e.g. high tensile strength, high elastic modulus, and low specific weight in comparison with glass fiber). Carbon fiber has low intrinsic affinity with polymer matrices, and surface treatment with acids (e.g. HNO_3, HCl, CH_3COOH) or other agents (e.g. $KMnO_4$, $K_2Cr_2O_7$, NaClO, H_2O_2) can introduce functional groups and increase fiber surface area. Several factors such as acid concentration, exposure time, temperature and treatment method can effectively influence the outcome of these treatments. The aim of this work is to study the influence of two chemical treatments in the physical (apparent density and diameter), surface (AFM and contact angle) and mechanical (tensile strength and elastic modulus) properties of PAN-based carbon fibers. Acetone P.A., glacial acetic acid P.A., hydrogen peroxide P.A., sodium hydroxide, and white glycerin were used as received. The CF were pre-treated with acetone to remove its sizing, being called *Neat CF*. Two surface treatments were carried out: (i) CH_3COOH for 1 h at 80 °C, (ii) H_2O_2 for 1 h at 80 °C. The treated fibers were called 100% CH_3COOH 1 h (T80) and H_2O_2/NaOH 1 h (T80), respectively. The fibers were characterized by density, contact angle and diameter measurements, also AFM and tensile properties. The density is directly related to fiber diameter. AFM and the optical micrographs of the liquid glycerin microdroplet in the treated carbon fibers, shown that is can modify your surface with relative ease, in order to evaluate the wettability and promote a better performance of its interfacial properties. 3D AFM images also show that minor amount of more wide streaks (100% CH_3COOH 1 h (T80)) results in smaller contact angle and roughness values versus to H_2O_2 treatment that show a larger amount of smaller streaks (results in higher contact angle and roughness values). The tensile tests show that the CF can be treated without having a pronounced decrease in their tensile properties (such as for 100% CH_3COOH 1 h (T80)). In short, rougher surface results in higher contact angle and lower tensile properties values for the studied fibers.

Keywords: *carbon fibers, chemical treatments, surface properties, wettability, tensile properties*

MICROMECHANICS-BASED FATIGUE LIFE PREDICTION OF COMPOSITE MATERIALS

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Abstract: A micromechanics-based approach for fatigue life prediction of polymeric matrix composites, called MMFatigue, was proposed in this work. The micro structure of a unidirectional lamina was described by micromechanical unit cell models, such that time-varying micro stress in fiber, matrix, and interface were calculated from ply-level fatigue loading. A unique fatigue model was employed for each constituent to convert multi-axial micro stresses to a uniaxial time-varying equivalent stress. Next, a modified Goodman formulation of constant life diagram (CLD) was utilized to define constituent effective stress, which is a function of the mean value and amplitude of equivalent stress, as well as constituent strengths. The time-independent effective stress and fatigue life was correlated through experimentally obtained S-N curve for each constituent. Finally the linear damage accumulation rule (Minor's rule) was utilized to consider the overall damage in each constituent caused by different fatigue loading schemes. MMFatigue is able to predict individual constituent failure in each ply within a multi-directional laminate, and the comparison between prediction and test data of various laminates showed satisfactory agreement. The fatigue behavior of carbon/glass hybrid laminates was also discussed. At the end, the CLD of a multi-directional laminate was generated to demonstrate the predictive capability of MMFatigue.

Keywords: *polymer matrix composite (PMC)*, *micromechanics*, *fatigue*, *life prediction*

FLEXIBLE POLYMER COMPOSITES WITH NATURAL FIBERS

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Abstract: Residue management has become a major problem in modern society, especially solid residue with potential toxic effects. Thus was studied flexible polymer composites with natural fibers developed from 100% recycled materials. These composites used residues poly (vinyl butyral) (PVB) as matrix and natural fibers of leather and wood flour. The two composites (PVB/Leather and PVB/Wood flour) were processed in an extruder equipped with a Maillefer screw. After extrusion, the PVB/leather and PVB/Wood flour composite plates were compression-molded. Increasing the leather content in the composites led to a significant increase in the tensile modulus and a reduction in the tensile strain at breaks. The Shore hardness of the composites increased with the wt% of leather. The SEM analysis revealed good interfacial adhesion between the PVB matrix and the leather fibers. The tensile tests showed that the tensile strength and Young's modulus of the composites increased with the content of wood flour. Positions of good interfacial adhesion with continuity of the interface were observed. The good adhesion at the interface of the PVB/wood flour composites without the addition of coupling agents or compatibilizers may be due to a good interaction between the PVB matrix and the wood fibers.

Keywords: *Wood flour; leather residue; PVB; composites; mechanical properties.*

COUPLING AGENTS AND THEIR INFLUENCE ON MORPHOLOGICAL AND MECHANICAL PROPERTIES OF COMPOSITE PLA / BURITI

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Abstract: Increasingly, the concern for the environment has stimulated the search for alternatives using biodegradable polymers. Studies for the preparation of composites using a biodegradable polymer and a natural fiber is of interest and environmental technology, particularly when using a coupling agent may promote desirable characteristics for a particular application and subsequent disposal, taking into account their biodegradability. In this study, composites of poly (lactic acid) (PLA) with natural fibers buriti and coupling agents and Trietoxivinilsilano and Triacetin with different mass percentages (2.5 and 5.0), were developed and characterized. It was tested in the composite fibers buriti ground at a concentration of 20% in mass. The composites were processed in two extruders, single and double screw. The mechanical properties of composites were evaluated by testing the tensile strength and flexural and morphological properties were evaluated by scanning electron microscopy (SEM). Results were promising, since we were able to maintain the mechanical properties of composites with 30% fiber, similar to pure PLA, attributed to interaction obtained between fiber / matrix using a simple treatment, the base distilled water, in fiber buriti, using Triacetin coupling agent with which had the best result.

Keywords: *composites, poly (lactic acid), fibers buriti, properties, coupling agent.*

A NEW TRANSVERSELY-ISOTROPIC ELASTIC-VISCOPLASTIC CONSTITUTIVE MODEL FOR FIBER REINFORCED POLYMERS

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Abstract: A new 3D transversely-isotropic elastic-viscoplastic constitutive model for unidirectional fiber reinforced polymers and for short fiber reinforced thermoplastics is presented. The model is able to represent the fully nonlinear mechanical behavior under multi-axial loading conditions and triaxial stress states. The experimentally observed different yielding behavior in uniaxial tension and compression perpendicular to the fibers, in uniaxial tension and compression transverse to the fibers and under transverse and in-plane shear stress states can be regarded. In the presence of high pressures the glass transition temperature of the epoxy resin drops from above 80° to operating temperature, which results in a change of the mechanical properties of the lamina [4]; the elastic parameters are reduced and the epoxy resin exhibits pronounced yielding under high pressure. It is shown, that this effect can be approximated with the plasticity model. The constitutive equations are derived in the framework of isotropic tensor functions using structural tensors and transversely isotropic invariants. The mathematical concept of this invariant approach allows an easy consideration of anisotropy and triaxiality and enables furthermore a coordinate system independent representation of the constitutive equations. A non-associated flow rule is applied in order to give realistic predictions of volumetric plastic strains. Strain rate effects are regarded using a 1-parameter visco-plastic formulation (Perzyna-Type). The elastic-viscoplastic model is validated by the simulation of quasi-static and dynamic off-axis compression tests of the unidirectional carbon-epoxy IM7-8552 [5] and by the simulation of uniaxial compression tests of unidirectional 45° and 90° specimens superimposed with various values of hydrostatic pressure [4]. It will be shown that all pre-failure nonlinearities observed in the off-axis compression tests can be predicted with the new elastic-viscoplastic material model. Furthermore, the triaxial tests presented in [4] can be approximated by just controlling the biaxial compression hardening behavior.

Keywords: *Composite structures, Constitutive modeling, Failure, Triaxiality, Viscoplasticity*

INFLUENCE OF THE ADDITTION OF FUNCTIONALIZED MWCNT ON MECHANICAL PROPERTIES ON EPOXY/CARBON FIBER AND EPOXY/CARBON-ARAMID FIBER COMPOSITES

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Abstract:

We investigated the effect of the inclusion of carbon nanotubes (CNT) on the mechanical properties and wear behavior of epoxy/carbon and epoxy/carbon-aramid composites in this study. Epoxy/carbon and epoxy/carbon-aramid composites with 0 wt.% CNT and 0.3 wt.% CNT were manufactured by RTM, amino functionalized multi-walled CNT (MWCNT) were used to modify the matrix. Tensile, compression, two rail shear, Charpy impact tests and Pin On Disc (POD) were performed on the four composites. The EP/CAF composites showed better impact resistance than the ones containing carbon woven. The addition of CNTs improves the shear modulus in 5% for EP/CF composites and 6% for EP/CAF. The results also show that the dynamic friction coefficient is independent of the CNT content, and the specific wear rate shows no improvement with the selected test parameters.

Keywords*: Nanocomposites, mechanical properties, wear, RTM.*

DAMAGE IDENTIFICATION IN COMPOSITES STRUCTURES USING ARTIFICIAL NEURAL NETWORK

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Abstract: Aircraft companies are increasing the amount of composite materials in the primary structure of its airplanes. This kind of material has several advantages when compared with metallic materials; however the identification of damages is still a challenge. This area is conventionally called Structural Health Monitoring (SHM), and one topic that receives the most attention in the technical literature is the feature extraction. Feature extraction is the process of identifying damage-sensitive properties, derived from the measured vibration response, which allows one to distinguish between the undamaged and the damaged structure. The best features for damage detection are typically application dependent. This paper proposes the application of artificial neural network (ANN) for damage classification in composite materials. ANN is part of one science usually called as artificial intelligent (AI). This technique can be applied efficiently for pattern classification, including nonlinear system. During the last two decades there were many new proposals for damage identification. There are in the literature many good reviews about this topic; however, many of these techniques are based on linear system. Structural cracks, caused by fatigue or load excess, are essentially nonlinear systems. Besides the damage, other sources of nonlinearities include the material, the boundary conditions and the geometric aspects. In this sense ANN could be an interesting choice. The paper concludes with an experimental test in a composite material and the results showed that ANN classified properly structural damages.

Keywords: *Artificial Neural network, Structural health monitoring, Composite material, Damage detection*

DYNAMIC FRACTURE OF FIBRE METAL LAMINATES UNDER BLAST: ANALYSIS AND EXPERIMENT

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Abstract: Fibre metal laminates (FMLs) are hybrid material systems based on stacked arrangements of several thin metal layers bonded with layers of a fibre-reinforced composite material. They offer high strength and stiffness to weight ratio, and excellent fatigue resistance when compared to monolithic aluminium or polymer composite. In this paper a computationally efficient predictive model that can capture the dynamic non-linear behaviour of FMLs using the finite element code Abaqus/Explicit is presented. Numerical predictions are in good agreement with experimental data on the back face-displacement and post-damage observations.

Keywords*: Fibre metal laminates, Glare, blast finite element analysis, failure criteria*

INFLUENCE OF THE ORGANOCLAY ON THE RHEOLOGICAL BEHAVIOR OF POLYPROPYLENE

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Abstract: The rheological behavior under Oscillatory regime of Polypropylene (PP)/Clay composites was investigated. PP/clay composites containing 1 to 10 part per hundred (phr) of organoclay were obtained by extrusion followed by injection molding. The rheological measurements were carried out under nitrogen flow at 200º C. Rheological properties showed that the clay did not affect the processability of polypropylene at strain rates above 10 s^{-1}. Except for the concentration of 5 phr, which has a stronger pseudoplastic behavior, there is an increase in the viscosity at low shear rates. The storage modulus (G ') increased with the increase in the clay content.

Keywords: *Polypropylene; Clay; Nanocomposites; Rheology.*

HYBRID NANOCOMPOSITES BASED ON PLA/CELLULOSE/SILICA SYSTEMS

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Abstract: The goal of this work was to investigate the production and properties of nanocomposites based on poly(lactic acid) (PLA) employing microcrystalline cellulose (MCC) and organophilic silica (R972) as nanoparticles. The nanocomposites were obtained by solution casting method in the film form. Each nanoparticle type was incorporated at 3% wt. in relation to the polymer matrix weight. In this experiment, four films were obtained (PLA, PLA/MCC, PLA/R972 and PLA/MCC/R972). The films and materials used in its attainment were investigated by X-ray diffractometry, nuclear magnetic resonance and by Fourier transform infrared spectroscopy. The results showed that each nanoparticle, added individually or both combined, acted differently on the final properties of the films. It was observed that cellulose can act as nucleating agent on the crystallization of PLA. Silica promoted an increase in rigidity, due to the strong intermolecular forces, while MCC addiction promoted an increase in the molecular mobility of the polymeric chains. The film PLA/MCC/R972 showed the highest crystallinity degree and a T_1H value between the parameter's values founded for PLA/MCC and PLA/R972 films. The results indicated that silica acts by decreasing the surface tension between PLA and cellulose.

Keywords*: biodegradable polymers, nanocomposites, cellulose, silica*

TOWARDS AN INTEGRATED XFEM-CE APPROACH FOR THE MODELING OF MATRIX CRACKS AND DELAMINATION INTERACTIONS

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Abstract: This paper proposes a novel approach integrating the extended finite element method (XFEM) and cohesive elements (CEs) for modeling three-dimensional (3D) delaminations and matrix cracks, and their interactions in progressive failure of composite structures. Currently, delaminations are mostly modeled through the use of CEs and some matrix cracks are modeled by the XFEM. However, delaminations and matrix cracks have strong interactions and occur at different length scales. Thus, computational techniques that work for one mode of failure do not necessary work for another mode, and *vice versa*. For this reason, combining two or more computational techniques is challenging but necessary because these failure modes compete with each other and the sequence of occurrence in progressive failure is also important. In this work, a consistent methodology that combines the XFEM and CE methods enable the competition and interaction of delamination and matrix cracks to be modeled explicitly and simultaneously in a single finite element model. The 3D modeling of delamination propagation and matrix cracking in a cross-ply composite laminate is demonstrated. It is found that an XFEM-based enrichment scheme for the cohesive elements is necessary in order to properly model the interactions between the delamination and matrix cracks.

Keywords*: XFEM-CE integrated approach, XFEM, Cohesive elements, Composites, Delamination, Matrix cracks*

PARAMETRIC SENSIBILITY STUDY OF A PUCK-MATZENMILLER'S THEORY BASED MODEL

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Abstract: This works presents a parametric sensibility analysis of a computational tool based on the theories proposed by Puck and Matzenmiller to predict damage propagation, using Progressive Failure Analysis (PFA). It is important to note that even on a mesoscale level, the subroutines separates the failure mechanisms concerning the fiber and the matrix (inter-fiber) and treats them under different approaches. Material elastic and ultimate properties are obtained from standardized experimental tests while for specific parameters, new procedures have been developed. From common tension and compression [0]n; [±45]n; [±67:5]n tests, a package of subroutines analyzes raw experimental data providing these parameters. Additionally, numerical models are calibrated and literature data are adopted. Calculus kernel is coded in FORTRAN (UMAT/URDFIL) and linked to Abaqus. A high order plane stress material model is employed and different governing laws are applied for fiber and inter-fiber damage. Also, a non-local criterion is used to provide spatial regularization and thus avoid due-to-convergence numerical issues. The main goal of this work consists on analyzing the level of sensibility the model when occurs changes of relevant parameters.

Keywords*: Composite Structures, Progressive Failure Analysis, Damage Propagation, Finite Element Analysis*

MECHANICAL EVALUATION OF A THERMOSET POLYMERIC MATRIX

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Abstract: A composite material can be defined as a set of two or more different materials combined on a macroscopic scale, to act as a unit, to achieve a set of properties superior to the individual phases. The composites can emphasize some features and minimize others undesirable by appropriate combination of its components. In general, composites can be divided into two main groups: laminate and particulate. A laminate consists in a matrix (usually polymer) reinforced with continuous fibres, which can be unidirectional or bi-directional. The fibres provide an orthotropic characteristic to the composites, meanwhile the particles provide an isotropic behaviour due to their randomly dispersion. In both cases, the matrix phase is essential for the adhesion of phases and loading distribution, sometimes supporting tensile, compressive or shearing efforts. As a result, several modes of failure of a composite are related to the mechanical properties of the matrix. The polymeric matrices used in most engineering composites can be classified as thermoplastic and thermosetting polymers. The epoxy and polyester are most often used as a matrix of laminated composites due to their superior mechanical properties compared to thermoplastic, being less sensitive to temperature variation. Not only the mechanical properties of dispersive phase, but also the matrix phase are critical for the structural design of a polymeric composite. This work focus on the mechanical evaluation of epoxy resin by the use of different test methods, such as: tension, compression, bending and dynamic micro hardness. The elastic properties were statistically compared, revealing the values in tension are inferior to bending, compression and hardening. The compressive and flexural moduli were statistically equivalent. Linear regressions were obtained to correlate the Young modulus under different test methods. The Young modulus of the matrix phase must be properly set and considered on the structural design of composite materials.

Keywords: *epoxy matrix, mechanical behavior, experimental analysis*

MULTI-SCALE MODELING OF VARIABLE ANGLE BRAIDED TEXTILE COMPOSITES AND ITS VALIDATION

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Abstract: Textile reinforced composites are widely used in the aerospace, defense and automobile industries for their ability to provide high strength-to-weight ratios in more than one direction and resistance to delamination. Braided textiles, though less commonly used, have certain unique features that make them a good option for direction-specific structural stiffness. This study seeks to implement a multi-scale modeling methodology starting from micro-, meso- to macro-level, leading to prediction of the elastic behaviour of braided textile composite structures. The three-pronged approach involves first, converting fiber properties to matrix infused yarns; second, partitioning the structure into regions of similar braided textile unit cell geometries for which elastic mechanical properties are determined; and third, using these region-specific elastic mechanical properties as inputs to simulate the macro-level braided textile structure's elastic- mechanical response to non-standard loads. This approach is demonstrated through the finite element (FE) simulation of the flexural bending of a braided textile composite aerofoil section with foam core. To begin with, the structure is divided into smaller zones of different braid angles measured directly of the fabricated structure. Subsequently, matching unit cells were built and analysed to get the elastic constants, which are then used to conduct an FE analysis of the aerofoil structure under three-point bending. An experiment is also carried out to validate the simulation. The strain values on the aerofoil surface and the deflection of the aerofoil tips due to bending were used as measures of performance. It is seen that the FE simulations correlates well with experimental results in predicting the behaviour of the aerofoil structure and the small discrepancies that exist can be reduced by using a more detailed simulation approach. Thus, the proposed strategy can be used successfully for predicting the elastic behaviour of braided textile structures.

Keywords*: Braided textile composite; Unit cell: Finite element modeling*

Author Index

Abrahão, A.B.R.M. 77 86
Affatato, L. 67
Agrawal, P. 29 147
Albuquerque, E.L. 14 59 63
Allen, D.H. 3
Almeida Jr., J.H.S. 56 82 125
Almeida, A.E. 5
Almeida, R.Z.H. 48 49
Almeida, S.F.M. 5 12 23 33
Alvarez, A.A. 38
Alves Jr., C.A. 32 52
Alves, T.S. 98
Alziati, C.L. 129
Amado, F.D.R. 56 125
Amato, V.S. 28
Ambrogi, V. 35
Ambrósio, J.D. 127 141
Amico, S.C. 2 4 25 56 82 83 92 96 104 105 120 125 139
Ancelotti Jr., A.C. 17 53
Andrade, D.L.A.C.S. 88
Angelo, M.V. 150
Angrizani, C.C. 56 82 83
Aragão, B.J.G. 40
Arakaki, F.K. 16 22 30 44
Araújo, E.M. 43 29 47 58 60 61 84 123 134
Araújo, J.A. 26
Araújo, P.M.A.G. 60 61
Avella, M. 24 95
Avolio, R. 24
Azevedo, E.C. 135 136
Azevedo, R.S. 121
Balarim, C.V.M. 127
Baldi, G.C. 127
Baldissera, A.F. 74
Bandeira, C.F. 9 34 37 77
Barbosa, R. 98

Barcella, R. 104 105 120
Bastian, F.L. 31
Batista, F.B. 151
Batista, N.L. 87
Becker, C.M. 104 105
Benini, K.C.C.C. 113
Bezerra, A.F. 99
Bezerra, D.C. 58
Bezerra, V.M.F. 25
Blunk, S. 136
Boiczuk, J.S. 135 136
Bom, R.P. 32 52
Bomio, M.R.D. 81
Bonadies, I. 24
Bonato, C. 142
Borges, L.M.S.A. 38
Borges, P.H. 75
Botaro, V.R. 103
Botelho, E.C. 9 34 37 77 78 79 80 85 86 87
Bottene, A.C. 48 49 57
Bowen, C.R. 102
Brambilla, V.C. 142
Brandalise, R.N. 142
Bravim Jr, J.C. 79
Brisighello, R.R. 93
Brito, G.F. 29 147
Brocks, T. 54
Burkhart, T. 85
Butler, R. 90
Calado, J.F. 88
Camanho, P.P. 70
Canedo, E.L. 97 98
Caratin, R.L. 71
Cardoso, A.M. 26
Cardozo, N.S.M. 131
Carfagna, C. 24 35 95
Carreira, L.G. 116
Carvalho, A. 73
Carvalho, F.J.X. 73 112
Carvalho, G.A. 131
Carvalho, L.H. 97 98 99 100
Carvalho, M.J.C. 41

Carvalho, O. 107
Carvalho, R.F. 128
Cavalcanti, W.S. 99
Ceballos, D.A.C. 64
Cerruti, P. 35 95
Cestari, S.P. 101
Cha, R.K.H. 152
Chang, F.K. 145
Chen, Z. 152
Chia, E.S.M. 152
Christoforo, A.L. 36 119 151 122
Cidade, R.A. 31
Cimini Jr., C.A. 130
Cioffi, M.O.H. 54 82 83 89 113 137
Claro Neto, S. 135 136
Cocca, M. 24
Coelho, L.A.F. 27
Colombo, C.R. 47
Correa, O.V. 68 69
Costa, A.C.F.M. 58 60 61
Costa, A.P. 77 86
Costa, D.I.G. 14
Costa, D.S. 21 39
Costa, L.C. 141
Costa, M.L. 9 34 37 77 85
Costa, R.B. 97
Cota, F.P. 119
Coutinho, M.G.F. 97
Cunha, B.B. 147
Cunha, C.A. 68 69
Cunha, F.G.C. 51
d'Almeida, J.R.M. 108 109
D'Elia, M.A.G. 57
Darros, A.B. 114
Del'Arco Jr., A.P. 26
Detomi, A.C. 102
Dettloff, M.L. 129
Di Lorenzo, M.L. 24
Di Maio, R. 35
Diniz, M.F. 34
Dodwell, T.J. 90
Donadon, M.V. 5 12 23 33

Dossin, R. 132
Ducati, C. 35
Edwards, E.R. 78
Errico, M.E. 24 95
Faluhelyi, P. 15
Farah, J.C. 17
Faria, A.R. 5
Faria, M.C.M. 79
Faria, T.P. 16 22 30 44
Fernández, C. 144
Ferrazza, J.F. 135 136
Ferreira, C.A. 74 132
Ferreira, G.F.O. 19 20 62
Ferreira, G.V. 15
Ferreira, L.B.M. 46
Ferreira, M.C. 96
Ferro, O.A.G. 8
Figueiredo, R.M.J. 96
Flores, P. 144
Fonseca, J.C.F. 51
Fonseca, V.M. 50 51
Fook, M.V.L. 100
Fornari, A.M.D. 125
Freire Jr., R.C.S. 46 66
Freire, G. 112
Fujiyama, R.T. 21 39 41
Fulco, A.P.P. 81
Furukava, M. 47
Galucio, A.C. 150
Gama, D.A. 65
Gama, D.B. 88
Garay, A.C. 92 96
Gatti, M.C.A. 93
Gavazzi, A. 16 22 30 44
Gentile, G. 24 35 95
Gomes, P.P. 8
Gomes, V.N.C. 47
Gonçalves, A.R. 42
Gonçalves, V.O. 17
Gonella, L.B. 111
Grandidier, J.C. 106
Guenther, B.S. 38

Guerra Neto, M.D. 50
Guido Damilano 112
Guimarães, J.M.F. 21 39
Ha, S.K. 140
Harry, R. 126
Helfer, A.L. 139
Hodzic, A. 146
Huang, Y. 140
Hunt, G.W. 90
Hunter, G. 129
Hwang, B.S. 76
Iha, K. 87
Ito, E.N. 47
Iulianelli, G.C.X.V. 121
Jacob, G.C. 129
Jesus, D.S. 138
Ji, X. 152
Jin, C. 140
Jochum, C. 106
José, N.M. 128
Joshi, S.C. 152
Junges, J. 7
Kailer, A. 91
Karasinski, E.N. 27
Katoh, H. 110
Khatri, A.M. 152
Kim, J.B. 76
Klen, M.B. 80
Koide, R.M. 72
Komatsu, L.G.H. 18
Koplin, C. 91
Kostov, K.G. 78
Lahr, F.A.R. 10 13
Lana, L.D.M. 115
Lapa, C.M. 55
Lauke, B. 85
Laurindo, C.G. 31
Lavoratti, A. 2
Leão, R.M. 26
Lecomte-Beckers, J. 144
Lee, H.G. 76
Leitão, E.S. 107

Leite, A.M.D. 123 134
Leoratto, M. 111
Lepienski, C.M. 136
Lesko, J. 129
Levy-Neto, F. 15 64
Lima, A.G.B. 120
Lima, E.P.R. 64
Lima, J.H.B 50
Lima, L.N.S. 99
Lima, N.B. 68 69
Lino, A.S. 94
Lira, H.L. 134
Lopes Jr., V. 145
Lopes, L.E. 57
Loriot, T. 126
Lucas, A.A. 141
Lucena, A.F.L. 65
Luersen, M.A. 72
Lugão, A.B. 18 28
Luz, F.F. 120
Luz, S.M. 26
Luz, T.S. 121
Machado, F.L.A. 81
Maino, I.B. 132
Malinconico, M. 95
Mano, V. 122
Marconcini, J.M. 47
Marinho, G.S 50
Marinkovic, B. 108
Marinucci, G. 71 107
Marlet, J.M. 34 133
Marmo, A. 112
Marques, F.D. 62
Marques, R.C. 117
Martins, T. 20
Massard, T. 126
Mattoso, L.H.C. 47
Mazur, R.L. 80
Medeiros, E.S. 47
Medeiros, K.M. 84
Medeiros, R. 62 124
Medeiros, S.N. 81

Medeiros, V.N. 123
Mello, W.L.N. 48 49
Melo, A.B.L. 151
Melo, A.J.L. 51
Melo, J.D.D. 81 118
Melo, T.B.N. 23
Melo, T.J.A. 29 43 47 84 123 147
Mendes, L.C. 94 101 116 117
Mendes, P.A.A.E. 12
Mendonça, A.S.G.B. 118
Mendonça, R.M. 118
Menezes, P C.F. 58 84
Meniconi, L.C.M. 127
Milanese, A.C. 137
Miléo, P.C. 42
Missagia, Z.M.V. 36 119
Miyano, Y. 110
Mohamed, G. 146
Monteiro, V.E.D. 65
Montrieux, H.M. 144
Moon, J.B. 76
Moraes, A.G.O. 139
Moraes, D.H. 59
Morais, D.D.S. 47
Moreira, W.S. 1
Nakada, M. 110
Narita, N.E. 16 22 30 44
Nascimento, C.A.M. 40
Nascimento, M.F. 13
Neves, R.M. 131
Nóbrega, K.C. 134
O'Connell, C. 129
Oishi, S.S. 78
Oliani, W.L. 18
Oliva, M.C. 35
Oliveira, A.M.R.S. 128
Oliveira, F.H. 92
Oliveira, I.R. 120
Oliveira, J.A . 25
Oliveira, M.J.A. 18 28
Oliveira, S.A.C. 33
Ornaghi Jr., H.L. 2 4 125

Paciornik, S. 109
Padial, A.G. 68
Paese, L. 92
Paiva, J.M.F. 103 114
Palma, R.S. 133
Panosso, G. 63
Panzera, T.H. 36 45 75 102 119 122 151
Pardini, L.C. 17 53 55 77 86 133
Park, J.S. 76
Parkes, P.N. 90
Parra, D.F. 18 28
Paskocimas, C.A. 47 81
Paz, R.A. 123 134
Pelegrini, K. 142
Pereira, Y.D.F. 118
Perrut, V.A. 115
Perry, N. 126
Persico, P. 95
Pessan, L.A. 123
Petry, G. 115
Pham, H.Q. 129
Piazza, D. 111 131 132
Pires, P.F.S. 147
Poletto, M. 7
Polidoro, T.A. 131
Portela, A.M.A. 93
Portella, E.H. 4
Prado, V.J.S. 16 22 30 44
Prisco, L. 108
Ramanathan, L.V. 68 69
Ramos, J.T. 104 105
Rebouças, I.G. 66
Regiani, I. 6
Reinecke, H. 91
Reis, E.G. 32 52
Rezende, M.C. 8 34 37 80
Ribeiro, A.L.A. 130
Ribeiro, G.L. 117
Ribeiro, M.L. 19 20 62 124
Rocha, G.J.M. 42
Rodrigues, A.R. 81
Rodrigues, W.T.S. 47

Rodríguez, R.Q. 59
Rolfes, R. 143
Romanzini, D. 2 4
Rubinger, C.P.L. 45
Rubio, J.C.C. 75
Sanial, P. 126
Santana, R.M.C. 7 11
Santos, A.M. 135
Santos, A.S.F. 47
Santos, F.A. 148
Santos, H.F. 119
Santos, J.J.S. 6
Santos, J.C. 36 119 122
Santos, J.J.M. 118
Santos, P.T.A. 60 61
Santos, P.T.A. 60 61
Santos, R.M. 102
Sartorato, M. 19 20 124
Sayeg, I.J. 69
Schiavon, M.A. 45 102
Scienza, L.C. 132
Sene, T.S. 27
Shiino, M.Y. 89
Silva, C.C. 46
Silva, D.F. 43 94
Silva, D.A.L. 10 13
Silva, E.M. 97
Silva, E.O. 28
Silva, F.W. 139
Silva, L.J. 75
Silva, M.W.S. 100
Silva, S.M. 9 34
Silva, S.M.L. 88
Silva, T.R.G. 58 84
Silva, V.R.V. 36
Silveira, J.L.L. 38
Silveira, M.E. 151
Soares, A.R. 108
Sollero, P. 14 59 63
Sousa, B.F. 45
Sousa, C. 70
Sousa, S.S. 122

Soutis, C. 146
Souza, D.F.S. 25
Souza, D.J.P. 50
Souza, F.V. 3
Souza, J.A. 92
Souza, J.F. 74
Souza, S.D.B. 77 86
Souza, W.O. 17
Souza, W.A. 40
Steier, V. 91
Suleman, A. 70
Sun, X.S. 149
Tan, V.B.C. 149
Tarpani, J.R. 33 93
Tavares, M.I.B. 121 148
Tay, T.E. 149
Theophanis, T. 129
Thomas, N.I.R. 128
Tita, V. 19 20 62 124 150
Turakhia, R.H. 129
Turella, T. 11
Ueki, M.M. 138
Untem, F.O. 37
Valença, S.L. 51
Valiente, H. 109
Vandepitte, D. 19 20
Varanda, L.D. 10 13
Vasconcelos, G.C. 40
Verghese, N.E. 129
Vieira, K. 122
Vieira, L.M.G. 122
Visentini, C.B. 139
Vogler, M. 143
Voorwald, H.J.C. 89 113 137
Yeo, B.T.B. 152
Zanol, E. 111
Zattera, A.J. 2 4 7 11 82 83 111 131 132 142
Zimmermann, M.V.G. 11