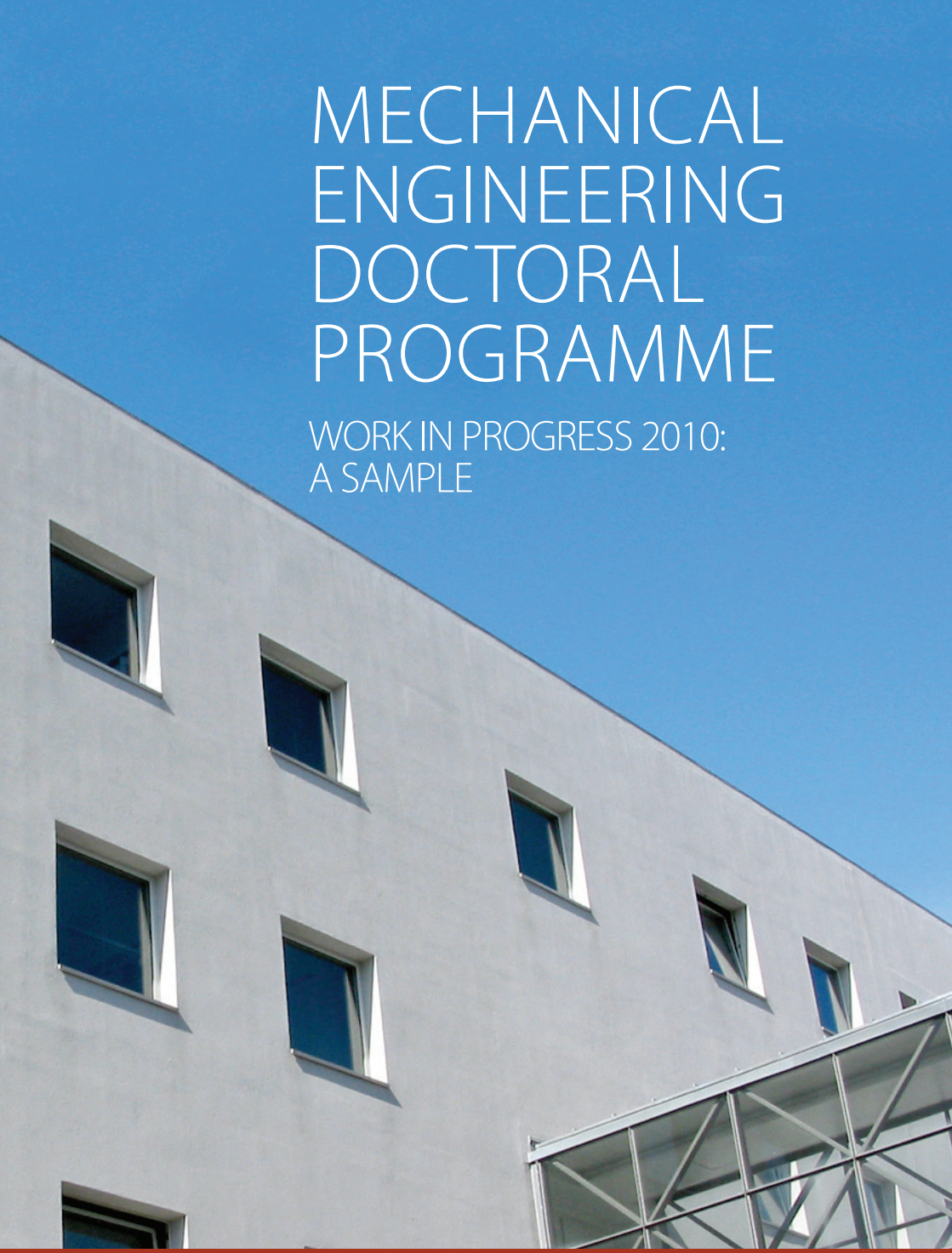
MECHANICAL ENGINEERING DOCTORAL PROGRAMME

WORK IN PROGRESS 2010: A SAMPLE



U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

MECHANICAL ENGINEERING DOCTORAL PROGRAMME

WORK IN PROGRESS 2010: A SAMPLE

Impressão: Maio 2011
Design: SICC/Centro Multimédia
Colaboração: César Sanches, Rosa Silva e Sofia Coutinho

Laboratório de Ensaios Tecnológicos (LET), one of the laboratories involved in the programme; partial view showing a servo-hydraulic testing machine

The Mechanical Engineering doctoral programme (PRODEM) of the Faculdade de Engenharia da Universidade do Porto – FEUP trains leaders in Mechanical Engineering through high level research. It benefits from the tradition of Mechanical Engineering research and education at FEUP and was recently reformatted as a consequence of the Bologna process, also including a component of lectures further to the main activity - research.

Mechanical Engineering R&D at FEUP is carried out in a variety of contexts, particularly R&D Units recognized by the Portuguese Fundação para a Ciência e Tecnologia, based at FEUP itself or in any of the R&D institutes associated to FEUP such as INEGI or IDMEC.

As one of the senior Engineering specialties, Mechanical Engineering represents a vast area of knowledge, permanently rejuvenated through the appearance of new fields of interest and new increasingly powerful numerical and experimental tools.

It is unlikely that any institution will be able to provide research opportunities in all of the possible topics of the field. FEUP, however, does cover a large variety of topics, and this publication, providing very concise information on a sample of doctoral work in progress, will be a testimony in support of that statement.

Nowadays university staff and students got used to rankings and related evaluations. Notwithstanding the controversies that are sometimes associated with these exercises, it is worth pointing out that for example in the 2010 Performance Ranking of Scientific Papers for World Universities [1], the Universidade do Porto ranks 17 in Europe and 62 worldwide in Mechanical Enginering, a fact worth mentioning given that 500 top universities worldwide were considered for this exercise. The status attained by Engineering and related areas at the Universidade do Porto is shown by the inclusion of Civil Engineering, Chemical Engineering and Materials Science in this ranking.

1- Higher Education Evaluation and Accreditation Council of Taiwan, 2010 Performance Ranking of Scientific Papers for World Universities, *http://ranking.heeact.edu.tw/en-us/2010/homepage/*

PRODEM*
DOCTORAL PROJECTS
A SAMPLE

* Acronym of Programa Doutoral em Engenharia Mecânica (Mechanical Engineering Doctoral Programme)

ANALYSIS OF COMPOSITE PLATES AND SHELLS USING MESHLESS METHODS

Ana Maria Azevedo Neves
Master degree in Mathematics, FCUP
FCT scholarship SFRH / BD / 45554 / 2008

Supervisors
António Joaquim Mendes Ferreira, FEUP
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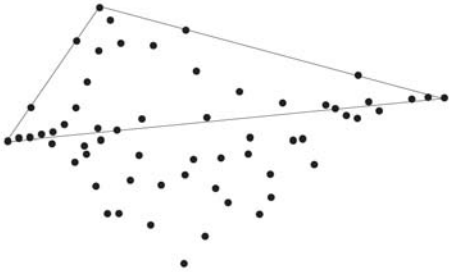
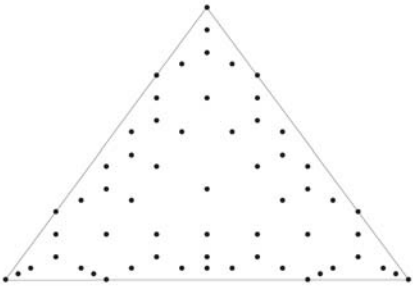
Renato Manuel Natal Jorge, FEUP

Start
Registration in Doutoramento em Ciências de Engenharia, April 2006;
Registration in Programa Doutoral em Engenharia Mecânica, May 2010.





MOTIVATION / OBJECTIVES

Improve the ill-conditioning of the matrix of coefficients.

WORK PLAN

Literature Review.
Implementation of Driscoll and Heryudono's adaptive algorithm for Radial Basis Functions for the bending analysis of plates and shells.

RESULTS

Figures show the final set of points and the deformed shape of an isotropic triangular plate subjected to a uniform load.

SAMPLE PUBLICATIONS

Ana M. A. Neves, T. A. Driscoll, A. R. H. Heryudono, A. J. M. Ferreira, C. M. M. Soares, R. M. N. Jorge, C. M. C. Roque, Adaptive methods for analysis of composite plates with radial basis functions, ***Mechanics of Advanced Materials and Structures***, 2010, in press.

IMPROVED TOUGHNESS OF ADHESIVES FILLED WITH CORK MICRO PARTICLES

Ana Sofia Oliveira Queirós Ferreira Barbosa
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Scholarship of IDMEC in the context of FCT project PTDC/EME-TME/098752/2008

Supervisors
Lucas F M da Silva, FEUP
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Start
March 2010

MOTIVATION / OBJECTIVES

The epoxies are the most common structural adhesives due to their good mechanical, thermal and chemical properties. However, the structure of these thermoset polymers also causes brittleness, with a low resistance to the initiation of cracks and their propagation. There are some solutions available in the literature to improve the toughness of brittle adhesives: addition of a second polymer with a good toughness, use of woven or knitted reinforcement, or inclusion of micro or nano inorganic particles silicates, glass, alumina, etc.). A possible solution, that has never been studied, is cork powder due to its excellent impact energy absorption, beyond having good properties of thermal and acoustic isolation. The cork particles should create obstacles to the propagation of the cracks thus increasing the toughness of the adhesive. The use of this material would give a new application perspective to the cork industry with potential benefits.

WORK PLAN

1st Cork particles characterization
2nd Adhesive-cork specimens manufacture
3rd Adhesive-cork specimens manufacture
4th Modeling

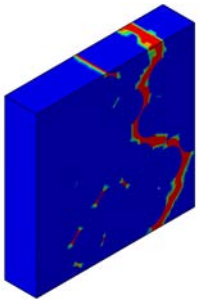
RESULTS

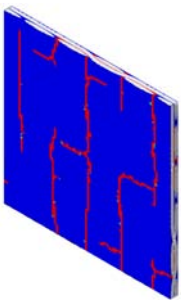
Cork powder samples were analysed in a scanning electron microscope (SEM) in order to measure the size, shape and structure. Contact angle analyses were measured on bulk cork samples using contact angle goniometer. Different wetting liquids were used to obtain the surface free energy. The most uniform and round shapes are not selected yet for the fabrication of the adhesive-cork composites.

ANALYTICAL AND NUMERICAL MODELLING OF DAMAGE AND FRACTURE OF ADVANCED COMPOSITES

António Rui Melro
Licenciatura Mechanical Engineering, pre-Bologna, FEUP
FCT PhD scholarship - SFRH/BD/24045/2005; scholarship of IDMEC in the context of FCT project PDCTE/EME/65099/2003

Supervisors
Pedro P. Camanho, FEUP
Silvestre T. Pinho, Imperial College London
Start
January 2006





MOTIVATION / OBJECTIVES

A better understanding of damage activation and propagation in advanced composite materials at the micro-scale level is envisaged. Numerical analyses will be performed on representative volume elements (RVE) of a composite material.

WORK PLAN

Two constitutive material models, one for each of the composite's constituents – matrix and fibre – are developed. Special attention is given to the non-linear behaviour of epoxies. A continuum damage mechanics formulation is implemented assuring the correct dissipation of energy due to crack propagation. The constitutive models are applied in a RVE of the real material at a micro-scale with a random distribution of reinforcements and periodic boundary conditions. The constitutive model developed for the epoxy matrix is to be applied to the micro-mechanical study of a 5-harness satin weave.

RESULTS

The development of an algorithm for the automatic generation of RVEs has been performed [1]. The two constitutive material models were implemented in the FE software ABAQUS®. The RVE of the 5-harness satin has been developed.

SAMPLE PUBLICATION

[1] Melro, A.R., Camanho, P.C., Pinho, S.T., Generation of random distribution of fibres in long-fibre reinforced composites. ***Composites Science and Technology***, 2008, 68, 2092-2102

ELECTRO MAGNETIC FORMING

Aristóteles Eusébio Teixeira Nogueira da Silva
Licenciatura in Mechanical Engineering at Minho University

Supervisors
Augusto D. C. Barata da Rocha, FEUP
Abel Dias dos Santos, FEUP

Start
September 2008

MOTIVATION / OBJECTIVES

EMF was developed around the 1960's as a shaping, forming and assembling metals process. The work piece is formed by a pulse of electric current which acts as a force, produced by the magnetic field. This process uses a capacitor bank, switches, a forming coil, a field shaper, of constant current power supply, and an electrically conductive work piece. The magnetic field is created by the discharge of the bank capacitor into the forming coil. The work piece is placed very close to the coil so from the magnetic field an eddy current is induced into the work piece. Since the magnetic field was created electromagnetically the eddy current of the work piece is in the opposite direction of the magnetic field of the coil. The interaction of the opposite flowing magnetic fields of the forming coil and the work piece causes a mutual repulsion. The mutual repulsion causes pressure impulse, which causes the metal to be rapidly accelerated and gain high kinetic energy. The kinetic energy forms the work piece by working the metal beyond its yield strength and causes permanent deformation. Despite the fact of being an old process, it is able to treat current problems of advanced manufacturing technology.

The main objective of this project was to develop and enhance the computational tools necessary to model the plastic deformation of metals that have been deformed by the use of electromagnetic forces. The appropriate numerical model will accounts for large strain, higher strain rates and temperature. Effects of other several geometrical and process parameters needs to be included, like, influence of mutual inductance, coil material, field shaper (Fig. 2), work piece material, permeability, etc. Different complex geometries shall be tested to validate the capabilities of the numerical code for future industrial applications.

RESULTS

Computational tools for numerical analysis of the EMF.
The code shall have the capabilities for predict different geometries for future industrial applications.
A new tool design, with hybrid method to reduce the number of set of traditional progressive die.

STUDY OF A HYBRID CONCENTRATING SOLAR POWER PLANT FOR PORTUGUESE CONDITIONS

Bruno André da Costa Coelho
Master in Chemical Engineering, Faculty of Engineering, University of Porto
Gulbenkian Foundation PhD scholarship (104299)

Supervisors
Armando Carlos Figueiredo Coelho de Oliveira, FEUP

Start
November 2008

MOTIVATION / OBJECTIVES

The objective of the PhD thesis is to study concentration solar power plants (CSP) and the viability to integrate hybrid solutions for electricity and chemicals production, under Portuguese climatic conditions.

WORK PLAN

Among the various CSP technologies, the central receiver system (CRS) is one of the most promising for hybridization. The work plan is to simulate the integration of different hybridization possibilities in different configurations of CRS systems.

SAMPLE PUBLICATIONS

Coelho, B., Oliveira, A. C., Mendes, A., Concentrated solar power for renewable electricity and hydrogen production - a review, ***Energy Environ. Sci.***, 2010, 3, 1398 – 1405.

Coelho, B., Domingues, P., Oliveira, A. C., Mendes, A., SOL-MASS project - solar-biomass dual hybrid 4 MW CRS pilot plant, SolarPaces 2010 proceedings, France, September 2010.

MULTISTABLE COMPOSITE STRUCTURES FOR APPLICATION IN MORPHING AIRCRAFT STRUCTURES

Bruno Miguel Capinha Martins
Graduation in Engineering Physics, Fac. Ciências e Tecnologia, Universidade Nova de Lisboa
Post-Graduation in Aeronautical Technology - Inst. Politécnico de Setubal, Escola Superior de Tecnologia

Supervisors
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Afzal Suleman, IST

Start
September 2009

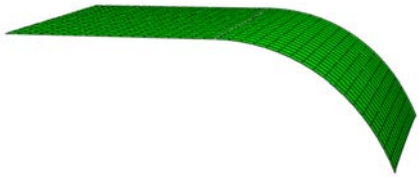


Figure 1. First solution acquired from the cool down phase (Static analysis).

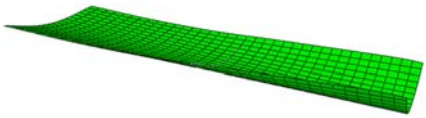


Figure 2. The 2nd solution resulting on the snap-through phenomenon (pseudo-static).

MOTIVATION / OBJECTIVES

Multistable composites are a recent subject with a lot of potential for aerospace industry manly to the sector of unmanned aircraft on observation, reconnaissance, search and rescue operations for civil and military organizations. The major goal of the project consists to implement a skin without transitions or gaps from the leading edge to the control surfaces on the trailing edge - decreasing the drag from those areas - able to answer to all the external and internal solicitations.

With a new morphing concept underway using the more advanced processes in production with the properties of composite materials we have the intention to submit the morphing wing skin for a patent and to use it on other sectors like wind turbine blades, fins, solar panels, etc. The potential and the gains from this project are significant and from it only advantages could emerge to the Portuguese and European industry.

WORK PLAN

A review or state-of-the-art was written with the intention to identify the major adaptive and morphing concepts, materials and actuation system and simulation models. Using an algorithm script to establish the curved fiber orientation along the composite matrix and a computational model on Abaqus/CAE a study about the multistability with curved fiber laminate composites was performed. The following step will be the experimental validation of the results obtained from the simulation by the production of the steered fiber composites and the implementation of the actuation system on the adaptive wing skin. After the validation of the adaptive structure the concept should be integrate to a unmanned aircraft wing to perform aerodynamic and aeroelasticity tests in a wind tunnel.

RESULTS

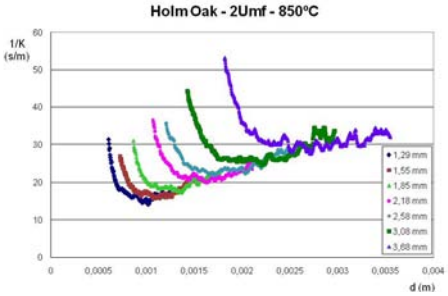
From the models developed using finite element commercial software Abaqus/CAE it was demonstrated the capability of the steered fiber composites with an unsymmetrical sequence to change their shape when actuated by a concentrated external force. More than two solutions were acquired from the simulation using a non-linear analysis, RIKS analysis.

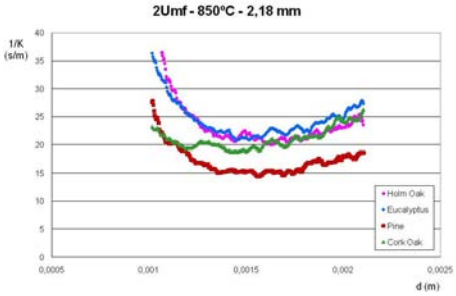
BIOMASS BURNING OF NATIONAL ORIGIN IN A FLUIDIZED BED

Carlos Alberto Catorze Pereira
Master in Mechanical Engineering, Univ. Coimbra
Supported by FCT scholarship under the POPH – QREN program

Supervisors
Carlos Manuel Coutinho Tavares de Pinho, FEUP

Start
September 2007





MOTIVATION / OBJECTIVES

Currently there is a widespread concern about the environmental impacts of fossil fuel use and about the predictable extinction of these resources. This has led to an increased use of biomass as fuel. It is known that the efficiency of burning wood and its derivatives are lower than those obtained in the combustion of fossil fuels, so there is still room for improvement in the utilization of biomass. There is still much research to do in that direction in order to get reliable data on the kinetic and diffusive parameters of the reaction.

This work aims to study the mechanisms of burning biomass of national origin in a fluidized bed. Samples were selected from four different woods (pine, eucalyptus, holm oak and cork oak) and subjected to a pyrolysis treatment before being burned. The study will devote special attention to the analysis of kinetic data of the burning of carbon and to the fluid mechanics of the bed. It will also be taken into account the influence of other factors such as the particle size of char, the fragmentation of particles and the oxygen concentrations in the feeding air.

RESULTS

So far, combustion tests were performed for all particle sizes of all types of char using a fluidization velocity of 2xUmf (Umf is the minimum fluidization velocity) and a bed temperature of 850°C. The data obtained allowed to obtain the overall reaction rate values (K) and the plot of the 1/K versus the diameter of the particles (d). This plot gives diffusion and kinetic information on the mechanisms taking place during the combustion process.

NUMERICAL SIMULATION OF ATMOSPHERIC FLOWS TO FORECAST WIND CHARACTERISTICS FOR APPLICATION IN WIND ENERGY

Carlos Alberto Veiga Rodrigues
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Supervisors
José Manuel Laginha Mestre da Palma, FEUP
Álvaro Henrique Rodrigues, FEUP

Start
Outubro 2006

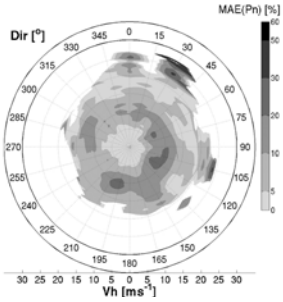

Figure 1. Prevision error. Mean absolute error in the power forecast for the operation of an wind farm

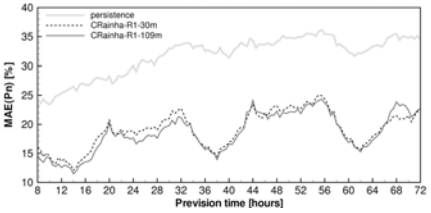

Figure 2. Prevision error. Error as function of direction and velocity in the wind farm reference mast location, but of the function transfer alone (substituting NWP results by field measurements).

MOTIVATION / OBJECTIVES

The need for a better management of the electrical network relies on knowing how much energy can be converted up to 72 hours ahead. The power production from wind farms becomes a critical element because of the difficulty in forecasting the wind characteristics and also due to the large wind power capacity integrated in the Portuguese electrical grid. The state of the art establishes two methodologies: the use of statistical tools and physical modeling. Both are driven by Numerical Weather Predictions (NWP), obtained from regional mesoscale models simulating in large computational grids with resolutions around 9 km.

In this thesis, procedures are investigated on how to implement physical modeling for wind forecasting and how to improve the results from mesoscale models. As the spatial scales at the zones of interest are around 10 km, the flow is numerically simulated with the microscale in-house code VENTOS®, which solves the Reynolds averaged Navier-Stokes equations, modeling the turbulent stresses with the k – ε closure. A first methodology was developed that consisted in establishing a transfer function. This function related the wind characteristics at the location of each wind turbine and a reference location, for where field measurements and weather forecast results were available. This methodology was applied to three wind farms in Portugal, returning mean absolute errors in the generated power around 17% for a 72 hours forecast. By using field measurements, an ideal prediction was produced to remove the forecast inaccuracies introduced by the NWP, returning an average error of 8% and validating the methodology.

Associated with wind forecasting are more fundamental questions related with the typical atmospheric flows that characterize the mountainous locations where wind farms are installed. The physics of the atmospheric boundary layer includes thermal stratification, producing phenomena related to gravity waves such as breaking waves, flow splitting and vortex shedding. These effects are studied in numerical simulations in order to assess their importance at the scales that characterize wind turbines.

LOW VISCOSITY THERMOPLASTIC MATRIX COMPOSITES MATERIALS REINFORCED WITH VEGETAL NATURAL FIBRES

Cristina Maria Nogueira Romão
Master of Science, FEUP
FCT - PhD scholarship - SFRH/BD/40522/2007

Supervisors
José Luís Soares Esteves, FEUP
Celeste Margarida Correia Pereira, INEGI

Start
May 2008

MOTIVATION / OBJECTIVES

Development of high performance reinforced composites using natural fibres and reactive thermoplastics polymers with in-situ polymerization, processed by Resin Transfer Moulding (RTM) technique.

WORK PLAN

State of Art;
Selection of natural fibres and thermoplastic precursors;
Project and development of experimental equipment for the processing of the reactive thermoplastic;
Study of the process variables and processing of the composite material by RTM technique;
Mechanical characterization of natural fibres reinforced composites;
Analysis and discussion of results.

WHEEL/RAIL CONTACT FATIGUE

Daniel Filipe Coutinho Peixoto
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PhD Thesis funded by Gulbenkian Foundation scholarship 104047-B

Supervisors
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Luís A. Ferreira, FEUP
Manuel de Freitas, IST

Start
October 2009

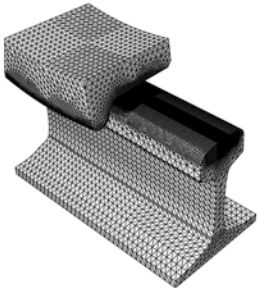

Figure 1. Finite element mesh for the wheel/rail contact analysis.

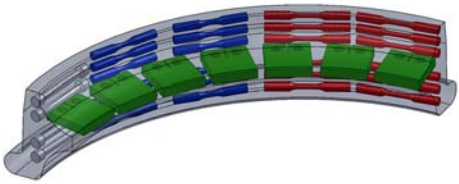

Figure 2. Location of some specimens extracted from ALSTOM AVE wheel.

MOTIVATION / OBJECTIVES

The urgency of the modernization of the railways in Portugal makes essential to train the next generation of experts. The theme chosen for this PhD thesis - modeling of the wheel / rail contact fatigue - will help to solve emerging problems as the damage tolerance of rails and wheels. The trend for new railways steels with increased hardness imply that the wear rates slow down, but simultaneously may facilitate the occurrence of fatigue damage, as in the case of incipient surface damage. There is an increased interest in the application in railways of fitness for purpose or even damage tolerance criteria. Economies of weight and therefore of energy consumption are possible with these approaches, that must be thoroughly validated before they gain acceptance.

WORK PLAN

- Characterization of crack propagation behavior, including tests to be carried out in a tribological twin-disc machine; Identification of typical in-depth residual stress fields for the new generation of rails and for the rolling contact fatigue samples to be tested in a twin-disc machine;
- Derivation of numeric al models for the prediction of damage initiation and propagation, and comparison with experimental data;
- Derivation of inspection intervals based upon the fracture mechanics parameters validated in the previous tasks, in order to demonstrate an innovative damage tolerant approach to the technical management of the railway system.

These tasks are part of the workplan of the FCT project PTDC/EME-PME/100204/2008 "Railways - rolling contact fatigue"

RESULTS

A nonlinear analysis of the stress/strain state resulting of the passage of one wheel on a segment of rail was performed using non-linear 3D finite elements.

SAMPLE PUBLICATIONS

D. F. C. Peixoto, L. A. Ferreira, P. M. S. T. de Castro, O critério de Dang Van para dimensionamento à fadiga: comparação com outros critérios, ***Manutenção***, nr. 101, 2009, pp.22-27

D. F. C. Peixoto, L. A. A. Ferreira, P. M. S. T. de Castro, "Non-linear analysis of the wheel/rail contact", 1st International Congress on Rail Transport Technology, April 12-14, 2010, Zaragoza, Spain.

NUMERICAL AND EXPERIMENTAL INVESTIGATION OF ADHESIVELY-BONDED SANDWICH MATERIAL REPAIRS

Dimitra Ramantani
Licentiate Degree (prior to Bologna process) in Mechanical and Aeronautical Engineering, University of Patras, Greece.
EU Marie Curie Scholarship (MRTN-CT-2005-019198) - MOMENTUM "Multidisciplinary Research and Training on Composite Materials Application in Transport Modes" Research Training Network (10/2006-04/2010)

Supervisors
António T. Marques, FEUP
Marcelo F. S. F. de Moura, FEUP

Start
October 2006

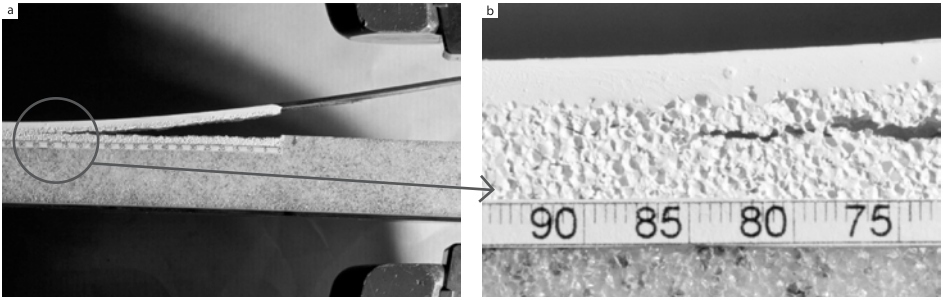

Figure 1. The asymmetric DCB sandwich test and (a) sub-interface crack propagation, (b) mickro-cracks at the crack tip.

MOTIVATION / OBJECTIVES

Sandwich materials are being increasingly used in structures requiring high specific strength and stiffness. Automotive, marine, aeronautical and aerospace industries are their main fields of application. The widespread employment of sandwiches in high responsibility and severely loaded applications introduces an issue regarding the handling of these materials after damage. Repair of sandwich structures is a beneficial alternative to disposal, due to cost saving and ecological reasons. Under this perspective, the development of efficient repair methods is essential.

Most of the design approaches of repairs are based on Finite Element Modelling coupled with strength of materials or fracture criteria, which have some limitations. Cohesive Zone Models are an appealing alternative to these methods, overcoming their limitations and exploiting their advantages, by the use of strength of materials criteria to model damage initiation and fracture mechanics to deal with propagation. One of the most important advantages is related to their capacity to simulate onset and non-self-similar growth of damage overcoming the difficulties inherent to stress and fracture based criteria. This methodology, including a mixed-mode formulation, has been extensively used to simulate delamination as well as failure of adhesive bonds in monolithic composite components and has provided results in excellent agreement with experimental and analytical ones. However, the application of cohesive damage modelling in sandwich structures is still limited mostly due to specific difficulties associated to fracture characterization of the debonding between the facesheet and the core under pure and mixed mode loading.

The objective of this thesis is to extend the application of this methodology to sandwiches and to provide a numerical tool able to reproduce the behaviour of repaired sandwich materials and subsequently to define repair design guidelines. Such an attainment, would allow the reduction of costs and time associated to extensive experimentation.

In this work, a bilinear mixed mode (I+II) Cohesive Zone Model implemented in Finite Element simulations via zero thickness interface elements was employed to simulate

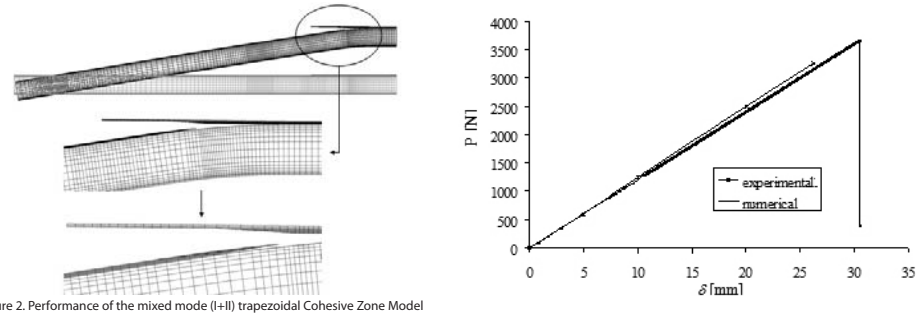

Figure 2. Performance of the mixed mode (I+II) trapezoidal Cohesive Zone Model on the simulation of patch debonding of repaired sandwich structures.

debonding between the facesheets and the core, which is an essential failure mechanism of repaired sandwich structures. Numerical and experimental study of fracture characterization tests of the sandwich interface under pure mode (I and II) (Fig 1) and mixed mode loading were performed. The objective was to obtain the fracture parameters i.e. the fracture toughness and local strength, Gi and σ_i, i=I, II, respectively, of the cohesive laws under pure mode loading and also a propagation criterion characterizing mixed mode fracture. The cohesive laws in pure modes I and II were derived by an inverse methodology. An important outcome of this work was the analytical formulation of a data reduction scheme able to incorporate the complex damaging phenomena of debonding associated to bimaterial interface (facesheet and core mechanical properties mismatch), geometric asymmetry of the test specimen and crack length monitoring (Fig. 1). The formulation of the proposed method is based on sandwich beam theory and measured specimen compliance and it is named Compliance Based Beam Method (CBBM) [1]. For the simulation of debonding of the patch in repaired sandwich materials a previously developed mixed mode (I+II) trapezoidal Cohesive Zone Model able to simulate thin layers of ductile adhesives (Araldite® 2015) in bonded assemblies was employed (Fig 2).

The developed numerical methodology was applied to the fracture behaviour prediction and geometric parameters optimization of repairs in sandwich materials made of thin carbon-epoxy facesheets and a medium density foam. Overlap and also scarf repairs of debonded and perforated sandwich beams were examined experimentally and numerically under bending. Particular emphasis was paid to the fracture mechanisms and failure load. A purely numerical geometric optimization investigation was carried out for both types of repairs. Some of the geometric alterations regarded in the literature to increase the repairs strength are addressed, such as patch overlapping, patch outer and inner chamfering, adhesive filleting at the patch edges and plug filling the repair hole [2].

[1] Ramantani DA, de Moura MFSF, Campilho RDSG, Marques AT. Fracture characterization of sandwich structures interfaces under mode I loading. ***Composites Science and Technology***, 2010;70:1386-1394.

[2] Ramantani DA, Campilho RDSG, de Moura MFSF, Marques AT. Stress and failure analysis of repaired sandwich composite beams using a cohesive damage model. ***Journal of Sandwich Structures and Materials***, (special issue dedicated to selected papers presented at the 8th International Conference on Sandwich Structures (ICSS-8), 6-8 May 2008, Porto, Portugal), 2010;12:369-390.

CHARACTERIZATION OF THE ENERGY POTENTIAL OF SHRUBS, HERBACEOUS AND GRASSES CULTURES

Edmundo Manuel Tavares Marques
Master in Engineering of Lignocellulosic Materials, Viseu
Polytechnic Institute of Viseu scholarship (PROFAD)

Supervisors
Carlos Manuel Coutinho Tavares de Pinho, FEUP
João Luís Monney de Sá Paiva, IPV

Start
June 2009

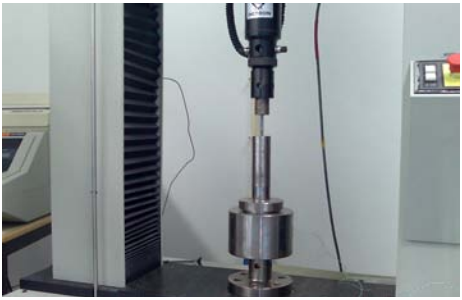

Figure 1. Instron machine with pellet's compression prototype constructed

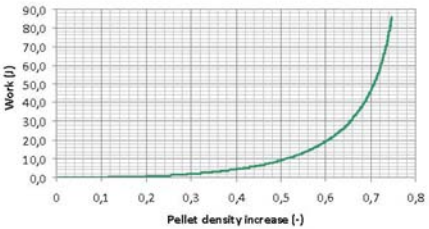

Figure 2 . Diagram of the energy spent versus densification of a 10 mm diameter pellet to 76%

MOTIVATION / OBJECTIVES

Inserted in the contribution for the definition of a reliable agro energy strategy for Portugal, this work intends to characterize the energy potential of autochthonous cultures (shrubs, herbaceous and grass) comparing them with dedicated energetic cultures.

WORK PLAN

Doctoral Program
The state of the art review on the bioenergy use. The Portuguese reality.
Modeling of experimental work. Design, construction and testing of prototype equipment and its instrumentation.
Physical conversion optimization: feedstock selection and its characterization; sustainable model of energy quality densification process.
Thermo chemical process conversion: Combustion of the products previously selected and its energetic performance. Assessment of results and theoretical analysis. Proposal of a strategy for Portugal. Writing of the thesis.

SAMPLE PUBLICATIONS

Marques, E., Paiva, J., M., Pinho, C., 2009, "Using infestant shrubs to bioenergy - preliminary results", Proceedings of COBEM, 20th International Congress of Mechanical Engineering, 15-20 November, Gramado, RS, Brazil

Marques, E., Paiva, J. M., Pinho, C., 2010, "Making pellets from infestant shrubs and cork residues – some preliminary results", European Pellet Conference, 3-4 March, Stadthalle Wels, Upper Austria.

ADHESIVE JOINTS FOR HIGH TEMPERATURE AEROSPACE APPLICATIONS

Eduardo André de Sousa Marques
Mechanical Engineer, Integrated Masters in Mechanical Engineering
Scholarship of IDMEC in the context of project PTDC/EME-PME/67022/2006 – P0716 sponsored by FCT

Supervisors
Lucas F M da Silva, FEUP

Start
February 2008

MOTIVATION / OBJECTIVES

The objective of this project is to design a joint which is suitable for use from low (-80ºC) to extremely high temperatures (+1200ºC), by the combination of two adhesives, one for strength at high temperatures and one for strength at low temperatures. A low temperature adhesive such as a silicone rubber adhesive which is tough at low temperatures and has a high modulus, but which does not degrade at the highest required operating temperature even though it may be very ductile and creep, may be combined with a high temperature adhesive such as a ceramic adhesive, which has high strength at high temperatures but which may be very brittle at low temperatures. Such a joint is needed for applications such as the space shuttle, where ceramic tiles are bonded to the internal aluminium structure for thermal protection on re-entry into the atmosphere. The present technology uses a RTV adhesive, but its low strength at +1200ºC can lead to debonding as appears to have happened in the recent disaster.are still some disadvantages that limit their more extensive use, being the main the lack of reliable design criteria. The broad objective of this PhD study is to contribute for the development of improved design criteria for adhesive joints.

The criteria are based in either a continuum mechanics approach or in a fracture mechanics approach. The PhD study is focused on the latter. The two main objectives are:

1. Develop experimental procedures to determine in a practical and universal way the fracture parameters G_I, G_{II} and G_{I+II};
2. Design common adhesive joints with a fracture mechanics approach to validate the parameters determined in 1.

WORK PLAN

1 · Study of current technical solutions, materials and test procedures.
In this task, existing literature is reviewed to study the current state in the art in the field of thermal protection and high temperature adhesives. Various materials are also studied and compared to assess their suitability for use in the intended application. The loading condition imposed by the real world application are also studied and characterized, allowing the planning of an adequate testing procedure.

2 · Material selection and mechanical property testing
After an initial study, the materials to be used in the experimental procedure are selected and acquired. The

mechanical properties not available in the literature but needed for the simulation are obtained by means of bulk testing of the materials.

3 · Manufacturing and mechanical testing of complete specimen under various loadings
A procedure for manufacturing and testing complete specimens is developed. The manufacturing procedure must be optimized to ensure consistency in the joint geometry and reduce the incidence of defects. A special testing tool is designed and built. Methods to apply temperature gradients are coupled with this testing to allow study of the joint strength under a large temperature envelope. Impact testing is also performed in the specimens to assess their tolerance to damage and capability to absorb energy.

4 · Finite element simulation of specimen and optimization
A finite element model of the joint is created to allow the prediction of joint strength under a large number of loadings. The results of this simulation are compared with the available mechanical testing results to tune and optimize the numerical model. Once the model is satisfyingly predicting the joint strength values, it is used to allow optimizations of the experimental specimens

5 · Mechanical testing of optimized specimen under various loads.
The optimized specimens are manufactured and tested under the same conditions as done in Task 3. The improvements and modifications in joint behaviour are studied and registered.

RESULTS

Manufacturing processes have been developed to ensurue accurate and consistent mixed adhesive joints.
Mechanical testing has demonstrated increase in strength and energy absorbtion for mixed joints in a large range of temperatures.

SAMPLE PUBLICATIONS

E. A. S. Marques, D. F. M. Magalhães, L. F. M. da Silva, "Experimental study of silicone-epoxy dual adhesive joints for high temperature aerospace applications", ***Mat.-wiss. u.Werkstofftech***, 2011, vol. 42, pp 471-477.

E. A. S. Marques, D. N. M. Magalhães, L. F. M. da Silva, "Dual adhesive ceramic-metal joints for aerospace applications", WCARP-2010, France.

COMPUTATIONAL MODELING OF MATERIALS THROUGH MULTI-SCALE TECHNIQUES

Fábio José de Pinho Reis
Masters in Mechanical Engineering, FEUP
Scholarship: FCT SFRH/BD/60887/2009

Supervisors
Francisco Manuel Andrade Pires, FEUP

Start
October 2009

MOTIVATION / OBJECTIVES

The global properties of any material employed in engineering are strongly dependent on the micro-structure. Even though at the macro-scale a ductile metal may be considered isotropic and homogeneous, it is easily stated that there is a large number of particularities at the micro-structure, such as different solid phases, micro-voids and micro-cracks, which play a crucial role on the global behavior of the material. It is also at the micro-structure that preponderant effects and fracture mechanisms, like nucleation, growth and coalescence of voids, propagation of cracks and phase transformation, take place. In a general sense, two approaches have been widely adopted by the scientific community in order to incorporate microscopic effects into the macroscopic behavior of the material. The first one is based on the development of phenomenological equations, which has, on the last decades, achieved important advances and results. However, the phenomenological strategy seems to be close to its limits. The second approach concerns the development of detailed discretization of the micro-structure. However, even though from a theoretical point of view the microscopic strategy is the most accurate solution, it is not reasonable, at the present time, from the perspective of human and computational resources. In order to circumvent these shortcomings, the so-called Multi-Scale Modeling has emerged as an attractive approach. The basic idea behind a coupled multi-scale model is the attachment a Representative Volume Element (RVE) to each infinitesimal macroscopic point, where the micro-structure is then embedded into the RVE. Therefore, the main objective of the doctoral research is to develop and numerically implement new multi-scale models aiming to more accurately describe the deformation and failure of engineering materials.

WORK PLAN

Literature Review;
Formulation of a Coupled Multi-scale Model based on a Variational Formulation;
Elaboration of an algorithm for a Coupled Multi-Scale Model with different RVE boundary constraints;
Development of numerical algorithms in order to optimize a Coupled Multi-Scale Model;
Numerical assessment of the proposed models and algorithms. products previously selected and its energetic performance. Assessment of results and theoretical analysis. Proposal of a strategy for Portugal. Writing of the thesis.

RESULTS

A set of algorithms have already implemented and developed which gave rise to an implicit finite element code exclusively for analyses and simulations at the microstructure. At this moment, it is possible through these algorithms analyze the behavior of RVEs with complex geometries as well as with different constitutive models, such as von Mises, and Lemaitre damage model, when the RVE is subjected either to different boundary conditions or different macroscopic deformation gradients. Regarding with the types of boundary constraints, the most popular and widespread boundary conditions were introduced into the code: Linear Boundary Conditions, Periodic Boundary Conditions and Uniform Tractions on the Boundary.

FRACTURE MECHANICS APPLIED TO THE DESIGN OF ADHESIVELY BONDED JOINTS

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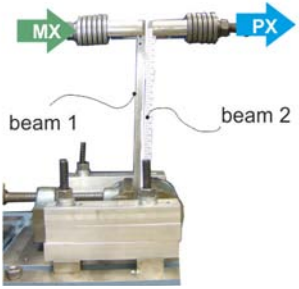
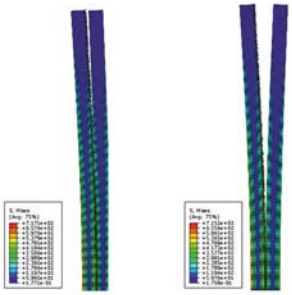
Scholarship of IDMEC in the context of project 314/06 sponsored by FLAD

Supervisors
Lucas F M da Silva, FEUP
Marcelo F S F de Moura, FEUP
David Dillard, Virginia Tech, USA

Start
December 2006





MOTIVATION / OBJECTIVES

The use of adhesively bonded joints is clearly increasing over the last decades due to a number of advantages such as the fact that it enables a more uniform stress distribution and can bond dissimilar materials. However there are still some disadvantages that limit their more extensive use, being the main the lack of reliable design criteria. The broad objective of this PhD study is to contribute for the development of improved design criteria for adhesive joints. The criteria are based in either a continuum mechanics approach or in a fracture mechanics approach. The PhD study is focused on the latter. The two main objectives are:

1 · develop experimental procedures to determine in a practical and universal way the fracture parameters G_I, G_{II} and G_{I+II};
2 · design common adhesive joints with a fracture mechanics approach to validate the parameters determined in 1.

WORK PLAN

1 · Identification and assessment of the existing fracture mechanics tests
The objective of this task is to define a starting point of the PhD study by identifying the limitations of the available fracture tests. Experimental tests according to the standards and procedures described in the literature will be done. These tests will be checked against finite element analysis predictions to ascertain if what is being measured corresponds to the material property that is supposed to be determined.
2 · Numerical and experimental plan with the existing tests to assess the influence of various parameters (glueline thickness in particular)
After the identification of the variables that might have an influence on the strain energy release rate of the adhesive (Task 1), a numerical study will be undertaken in order to help the design of an experimental plan based on the Taguchi method to quantify their influence.

This will be done for different types of adhesives, from very ductile to very brittle. The results will be compared with the original finite element analysis using cohesive and continuum damage models.

3 · Numerical and experimental plan with the new test method and comparison with Task 2

With the results of Task 2, the fracture mechanics parameters that are not properly measured using the existing methods will be known. The existing methods will be improved or a new type of test will be proposed. Experimental tests will be done according to a plan similar to the one designed in Task 2. The results will be compared with the results of Task 2. The results will be compared with a finite element analysis using cohesive and continuum damage models.

4 · Adhesive toughness model in function of mode mixity and glueline thickness

The critical strain energy release rate of different types of adhesives will be determined as a function of the mode mixity from pure mode I to pure mode II. As explained in the State of the art section, the ability of the adhesive to absorb energy depends on the plastic extension which can be constrained if the distance between adherends is smaller than this plastic extension. Therefore, the adhesive toughness needs also to be determined as a function of the adhesive thickness. This needs a statistical analysis of the experimental data obtained in Task 3 and a numerical validation.

5. Design of adhesive joints to validate fracture parameters determined in Tasks 3 and 4

The fracture parameters determined in Tasks 3 and 4 will be validated by an experimental and theoretical programme. Typical adhesive joints where the adhesive experiences various kinds of loading will be tested varying the materials and the joint geometry. The experimental failure loads will be compared with finite element analysis predictions where the failure criterion is based on fracture mechanics.

SAMPLE PUBLICATIONS

Some fracture envelopes have already been obtained and presented.

"Determination of the envelopes for mode-mixity evaluation of adhesive systems", presented at the ACE-X2010 in Paris, France, 8th July 2010

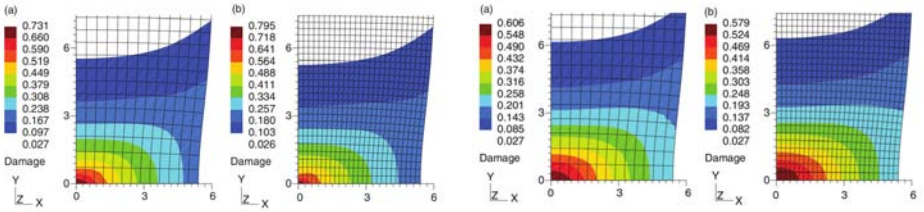
"Determination of the envelopes for mode-mixity evaluation' for adhesively bonded steel", presented at the CIFIE 2010 in Porto, Portugal, 17th March 2010

NON-LOCAL MODELLING OF DUCTILE MATERIALS: FORMULATION AND NUMERICAL ISSUES

Filipe Xavier Costa Andrade
Engenheiro Mecânico, Universidade do Estado de Santa Catarina (Brazil)
Funding under the project ALBAN

Supervisors
José Manuel de Almeida César de Sá, FEUP
Francisco Manuel Andrade Pires, FEUP

Start
October 2007



MOTIVATION / OBJECTIVES

The classical local theory disregards important effects of the microstructure of the material and therefore it cannot correctly describe the localised failure process of ductile materials. Likewise, the mathematical description of the failure phenomenon using the local theory is inappropriate since it inherently suffers from spurious instabilities, leading to a pathological dependency on the finite element mesh. The main objective of the present doctoral research is to develop new constitutive models based on the so-called non-local approach, which incorporates an intrinsic length into the material law and is expected to eliminate the aforementioned instabilities.

WORK PLAN

- Literature review;
- Elaboration of non-local models for the description of ductile damage;
- Development and implementation of numerical algorithms associated with the proposed non-local models;
- Assessment of the developed non-local models through numerical simulation.

RESULTS

Specific algorithms for the non-local approach of integral-type have been developed and proven to attenuate the pathological mesh dependency. The damage variable, which within the local approach presents unlimited localisation upon mesh refinement, has a realistic behaviour when the non-local model is adopted. As a consequence, ductile failure has been more accurately predicted, resulting in more reliable numerical simulations.

SAMPLE PUBLICATIONS

F. X. C. Andrade, J. M. A. César de Sá, F.M Andrade Pires, "A ductile damage nonlocal model of integral-type at finite strains: formulation and numerical issues", ***International Journal of Damage Mechanics***, in press, 2010.

J. M. A. César de Sá, F. M. Andrade Pires, F. X. C. Andrade, "Local and nonlocal modeling of ductile damage", in book "Advanced Computational Materials Modeling: From Classical to Multi-Scale Techniques", Editors: M. Vaz Junior, E. A. de Souza Neto, P. A. Muñoz-Rojas, Wiley-VCH, Weinheim (Germany), 2010.

MULTI-MATERIAL JOINTS FOR HIGH-SPEED TRAIN STRUCTURES

Giuseppe Catalanotti
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PhD candidate, Marie-Curie grant under contract No. MRTN-CT-2005-019198

Supervisors
Pedro P. Camanho, FEUP
António T. Marques, FEUP
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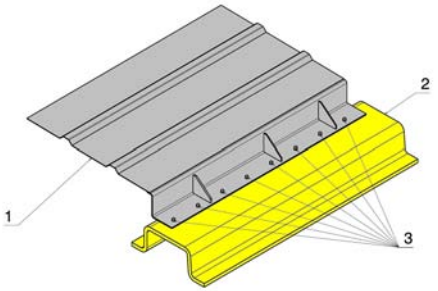
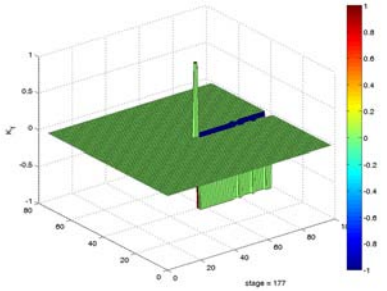
Start
February 2008





MOTIVATION / OBJECTIVES

The use of composites is a vital issue for the railway industry. The advantages are in fact:

- The reduction of weight and consequently of the energy necessary for the transportation;
- The reduction of the cost of manufacturing;
- The reduction of the recurring cost.

Comparing different solutions, only metals, only composites, metal and composites; the hybrid solution gives the minimum manufacturing cost.

WORK PLAN

1 · Experimental tests to evaluate the influence that different geometries, materials and material combinations have on the behavior of the joint;
2 · Definition of a 3D set of failure criteria to evaluate the damage of the composite. Thus to take into account the 3D stress state in the neighboring of the bolt.
3 · Determination of the parameters that define the cohesive laws (CT and CC tests) using digital image correlation;
4 · Numerical results and correlation;
5 · Definition of a 2D FE model to use in a industrial environment.

SAMPLE PUBLICATIONS

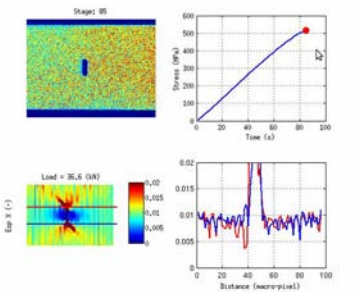
G. Catalanotti, P.P. Camanho, J. Xavier, C.G. Dávila and A.T. Marques, Measurement of resistance curves in the longitudinal failure of composites using digital image correlation, ***Composites Science and Technology***, Volume 70, Issue 13, 15 November 2010, Pages 1986-1993

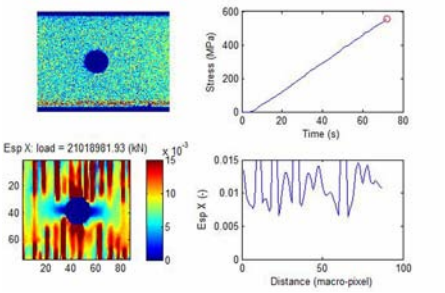
FAILURE MODE INTERACTION IN NOTCHED LAMINATES

Gülsüm Hilal Erçin
Master in Aeronautical Engineering, Middle East Technical University, Turkey

Supervisors
Pedro P. Camanho, FEUP

Start
November 2009





MOTIVATION / OBJECTIVES

In this PhD project, a detailed model for the analysis of composite structures with stress concentrations, such as in the case of open-hole tension and compression, will be developed. Open-hole tension (OHT), open-hole compression (OHC), unnotched Tension (UT), unnotched Compression (UC), Notched Tension (NT) and Notched Compression (NC) test specimens will be designed, manufactured and tested in order to identify the individual failure mechanisms as well as their interactions. A meso-mechanical model using a continuum damage model for ply failure mechanisms and cohesive elements for interlaminar failure mechanisms will be developed, validated, and used in the simulation of the OHT, OHC, UT, UC, NT and NC test specimens. The specimens will be tested and analysed by using fast analysis methods and by a model based on the non-linear Finite Element methods.

Two different laminate configurations will be designed and manufactured using the material Hexcel T800/M21 that will trigger different failure mechanism when tested in OHT and OHC configurations. The first laminate configuration has been designed, manufactured and the specimens are prepared. OHT, UT and NT tests are performed and test results are analysed.

DYNAMIC LOCALIZATION OF OBJECTS IN INDOOR SPACES USING LOW COST COMMUNICATION NETWORKS AND ALGORITHMS BASED ON NEURAL NETWORKS

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Supervisors
Manuel Romano dos Santos Pinto Barbosa, FEUP
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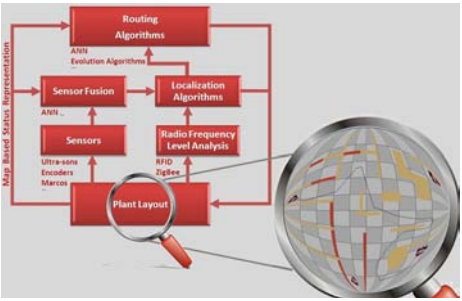
Start
September 2010



MOTIVATION / OBJECTIVES

The work consists in developing new strategies or methods to locate objects moving in indoor spaces using low cost communication technologies. Being a problem of interest for various applications such as identification and tracking of objects and humans in hospitals and industrial environments, the application will target the location of automated guided vehicles inside buildings or industrial facilities. The problem of locating a given object at a given instant of time will be addressed in a recursive manner, considering the knowledge and information management associated with the behaviour patterns of the set of locations over a time interval of each object, individually and the collective set. The handling of this information will be used as a support element to implement a system of dynamic "routing" for the movement of each vehicle in order to optimize the overall system.

WORK PLAN

Being at an initial stage the work plan established so far will be adjusted and further detailed based on work progress. The main phases will include first an identification of the problems involved and their formulation as problems to be considered. Subsequently it is envisaged the need for developing models of the localization and tracking of objects, in order to test and validate the solutions for these problems. The developed solutions will be as well subject to experimental implementation. The localization solutions will then be transferred to the localization and dynamic routing of automated guided vehicles. This will entail the development of simulation models as well as experimental tests.

RESULTS

The expected results are the development of new solutions to dynamic localization and tracking of objects based on low cost wireless network communication technologies and the improvement of dynamic routing algorithms for automated vehicles.

MECHANICAL RESPONSE OF ADVANCED COMPOSITES UNDER HIGH STRAIN RATES

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FCT scholarship under Project PTDC/EME-PME/64984/2006

Supervisors
Pedro P. Camanho, FEUP

Start
May 2007

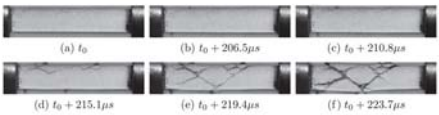


Figure 1. Crack evolution for a high strain rate transverse compression test

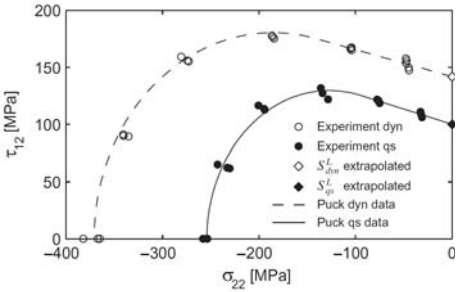


Figure 2. Quasi-static and dynamic failure envelopes for combined transverse compression and in-plane shear loading

MOTIVATION / OBJECTIVES

Improve the predictive capabilities of constitutive material models and failure criteria for fibre-reinforced polymer (FRP) composites by including strain rate effects.
The strain rate effects on the mechanical material response are studied at the meso-scale (ply-level) via an extensive experimental program, making use of state-of-the-art data acquisition techniques such as digital image correlation and ultra high speed photography.

WORK PLAN

Literature review of state-of-the-art experimental methods, results and constitutive models;
Material selection: unidirectional carbon-epoxy IM7-8552;
Quasi-static material characterization (reference test data for the following task);
High strain rate material characterization using split-Hopkinson pressure bar (SHPB);
Implementation of constitutive model and failure criteria, considering the strain rate sensitivity observed in the previous task, into an ABAQUS VUMAT subroutine;
Model validation.

SAMPLE PUBLICATIONS

Koerber, H., *et al.* High strain rate characterisation of unidirectional carbon-epoxy IM7-8552 in transverse compression and in-plane shear using digital image correlation. ***Mechanics of Materials,*** (2010), doi:10.1016/j.mechmat.2010.09.003

Koerber, H., Camanho, P.P. Characterisation of unidirectional carbon-epoxy IM7-8552 in longitudinal compression under high strain rates. DYMAT2009 (2009), doi:10.1051/dymat/2009025

ANALYTICAL AND NUMERICAL MODELING OF THE BEHAVIOR OF GEOMATERIALS

Helder David Fernandes Miranda
Master degree in Civil Engineering, FEUP

Supervisors
Francisco Pires, FEUP

Start
September 2009

MOTIVATION / OBJECTIVES

The geomaterials are extremely common in nature and in engineering applications. Typical examples are construction materials, rocks and soil. Despite the importance of these materials, their behavior, especially close to collapse, is still not well understood. The macroscopic collapse of the geomaterials is characterized by complex degradation phenomena that exhibit a highly anisotropic behavior due to their heterogeneous microstructure. During the deformation process, several degradation mechanisms, as the formation of crack bands, may occur and the material can no longer be considered as continuous media.

Therefore, the correct description of deformation of these materials requires the use of sophisticated mathematical and numerical models to predict their behavior when subjected to various stresses.

In particular, the use of numerical tools based on the Discrete Element Method has been highlighted in recent years and has enormous potential given that the inherent complexity of the deformation of geomaterials (location, formation of discontinuities, etc..) Emerges naturally from the method without be necessary to program these phenomena explicitly. The Discrete Element Method is based on simple contact laws and requires a limited number of parameters allowing extremely rich model behaviors. Therefore, the overall aim of this study is to explore and develop models of discrete elements for the simulation of phenomena with a discrete nature in geomaterials.

Taking as its starting point a three-dimensional model of discrete elements, we increase the complexity of the model to improve its forecasting capacity.

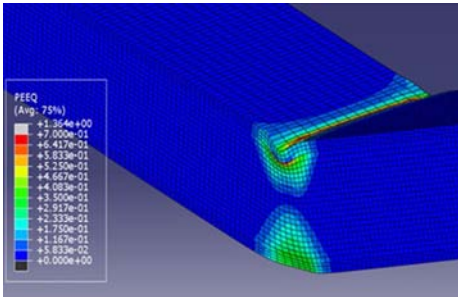
These models are extended to the macroscopic scale through continuous homogenization techniques.

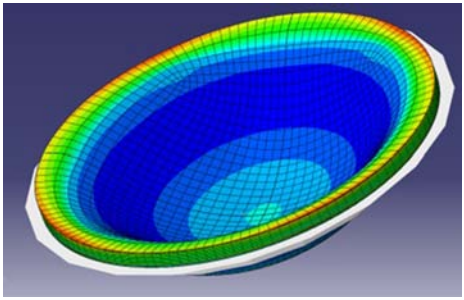
STUDY OF HYDROFORMED SANDWICH SHELLS WITH METALLIC FOAM CORES

Helder Tiago Carriço Mata
Master Degree in Mechanical Engineering, Univ. Porto
Funding provided by Ministério da Ciência, Tecnologia e Ensino Superior - Fundação para a Ciência e a Tecnologia and by ERDF/ESF (FEDER/FSE), under grant PTDC / EME – TME / 098050 /2008

Supervisors
Renato Natal Jorge, FEUP

Start
September 2009





MOTIVATION / OBJECTIVES

The main goal of this project is the development and evaluation of an innovative system able to perform reliable panels of sandwich sheets with metallic foam cores for industrial applications, especially in automotive and aeronautical industries. The forming process will be based on the hydroforming techniques which are largely used nowadays in uniform sheets.

WORK PLAN

Establishment a numerical model:

- Define and understand a constitutive model applicable to this type of material;

Simulation of mechanical tests for this material:

- Implement this model in a finite element software;
- Simulate mechanical tests to evaluate the behavior of such materials;

Validate experimental tests simulated:

- Perform the tests experimentally;
- Compare numerical and experimental results.

SAMPLE PUBLICATIONS

H Mata, RM Natal Jorge, AA Fernandes, RAF Valente, "Study of sandwich shells with metallic foam cores", ***International Journal of Material Forming***, 3:903-906, 2010;

H Mata, RM Natal Jorge, AA Fernandes, RAF Valente, "Study of sandwich shells with metallic foam cores", Conference ECCM2010, Paris.

FILAMENT WINDING PROCESS SIMULATION USING THE FINITE ELEMENTS METHOD

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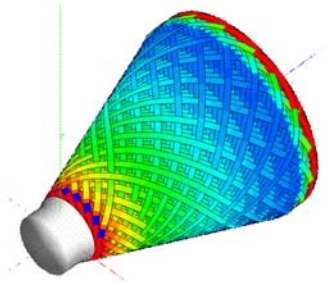
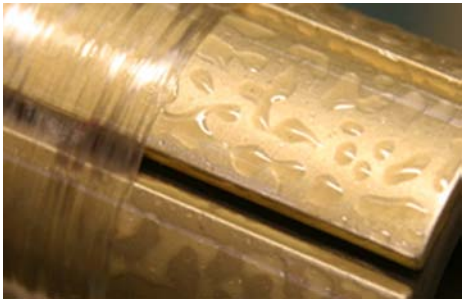
Mechanical Engineer, MSc

Supervisors
António Torres Marques, FEUP
Francisco Manuel Andrade Pires, FEUP

Start
June 2007





MOTIVATION / OBJECTIVES

The physical phenomena occurring during the filament winding process and their influence in the final quality of the manufactured parts are not deeply studied. Thus, detailed information on the process optimum configuration leading to better final properties is still lacking.

This doctoral project aims to establish a multiphysical numerical model, based on finite elements methods, able to properly simulate the influence and interactions between several identified process sub-phenomena. This deeper knowledge will allow the global process optimization.

WORK PLAN

1 · State of the art review;
2 · Development of analytical sub-models;
3 · Implementation of numerical algorithms;
4 · Int. of numerical algorithms in commercial FEM code;
5 · Experimental validation;
6 · Publication of results;
7 · Writing of PhD thesis.

RESULTS

A filament winding process model has been established [1]. Features that are specific of this manufacturing process were also studied and included in the model [2]. Experimental validation is ongoing.

[1] Hugo Faria, Agnieszka E.Z. Rocha, Helder D. Miranda, Francisco M.A. Pires, António T. Marques, Numerical modelling of the filament winding process, ICCM17, 27-31 Jul 2009, Edinburgh.

[2] H. Faria, V. Gomes, F. M. A. Pires, A. T. Marques, Stress-strain modelling in wound laminates under processing conditions, ECCM14, 07-10 Jun 2010, Budapest.

DEVELOPMENT OF AN INNOVATIVE ECODESIGN BASED FRAMEWORK FOR MACHINE TOOL DESIGN / REDESIGN

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Supervisors
Ana Reis, FEUP
Augusto Duarte Campos Barata da Rocha, FEUP

Start
September 2009

MOTIVATION / OBJECTIVES

Industries are facing pressures to improve the environmental performance of its activities. These pressures are expressed in a variety of ways, including the development and implementation of various policies and regulations related to products environmental performance.

In recent years, there has been a trend for the development of simplified methods for LCA (Life Cycle Assessment), in reality this has been a central theme for research in this field. The simplified methods are not compatible with the ISO 1404X standards, so if the aim is to perform public comparisons of products or marketing activities the Full LCA should be the option to follow.

There is a clear opportunity for development of methodologies dedicated to a narrower range of products, like machine tools, or services that ensure the significance of the study, its compatibility with existing and in preparation standards and directives and constructed to facilitate and automate the complex tasks of inventorying and compilation of information.

The aim of this project is to develop an innovative methodology for full environmental impact assessment of machine tool (Full LCA – Life Cycle Assessment). The methodology to be developed will be especially suited to the high complexity that can be a machine tool, will be technologically driven and based on a model that covers the main components commonly found in such equipment. The developed tools will anticipate the results typically achieved after the final Detail Design stage of the equipment to the earliest stage of Product Architecture Design.

To construct the full LCA methodology for machine tools, models will be created in order to clearly identify the environmental inflows and outflows of machine tools and subsystems / components processes. These models will be implemented within an application that could be a base for a more integrated software application to be developed in following project.

The benefits include facilitating LCA study opening the possibility of having a full LCA in early phases of machine tool design, substantially reducing the weight of a typical Full LCA analysis in terms of resources and time involved and full integration of environmental considerations into machine tool design. The methodology permits to evaluate with extreme precision the influence of different design solutions since all cross influences are considered and maintain compatibility with ISO 1404X standards and other standards or directives in order to ensure public comparisons and presentation of results and support marketing strategies.

This project will integrate this methodology in a case study. It is assured the collaboration of a metal working machine tool manufacturer in order to have access to all the necessary data.

RESULTS

There is a working undergoing (case study) with an industrial company relating the redesign of a machine tool using ecodesign methodologies and tools aiming to develop a product with reduced environmental impact but, at the same time, maintaining the same performance process level.

One line of research related to ecodesign and energy and environmental efficiency of processes has been introduced under the pole of competitiveness PRODUTECH for funding under the QREN and COMPETE program.

SAMPLE PUBLICATIONS

J. P. Pereira, A. R. Reis, A. A. Fernandes, "Integration of ecodesign practices in the product development process using policy deployment tools", Proceedings of the First International Conference on Integration of Design, Engineering and Management for innovation IDEMI'09, Porto, Portugal, September 14-15, 2009.

J. P. Pereira, A. R. Reis, A. B. Rocha, 2009, 'An innovative framework for integration of ecodesign practices in the product

development process of machine tools', Proceedings of EcoDesign2009 - 6th International Symposium on Environmentally Conscious Design and Inverse Manufacturing, Hokkaido, Japan, December 7-9.

J. P. Pereira, A. R. Reis, M. I. Oliveira, A. B. Rocha, 'Modeling of mechanical systems for environmental impact assessment in design stage', paper submitted for publication in the Journal of Life Cycle Assessment. (under revision)

J. P. Santos, M. Oliveira, F. G. Almeida, J. P. Pereira, A. Reis, 'Improving the environmental performance of machine-tools: influence of technology and throughput on the electrical energy consumption of a press-brake', paper submitted for publication in the Journal of Cleaner Production. (under revision)

GEAR MICROPITTING PREDICTION USING THE DANG VAN HIGH-CYCLE FATIGUE CRITERION

José Augusto de Sousa Ferreira Brandão
Master in Mech. Engng., FEUP
Scholarship of INEGI in the context of FCT project PTDC/EME-PME/66185/2006

Supervisors
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Manuel J. D. Castro, ISEP

Start
September 2008

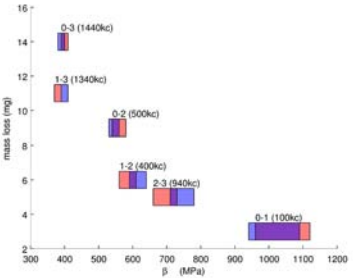

Figure 1. Mass loss predicted against β damage number

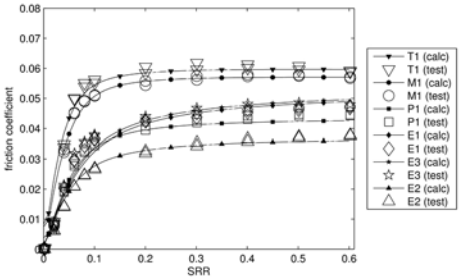

Figure 2. Predicted against measured traction curves of 6 oils

MOTIVATION / OBJECTIVES

Improvements in gear design, materials and surface treatment, as well as improvement in lubricant formulations, have allowed gears to operate at ever higher speeds and power densities. These improvements have greatly diminished the occurrence of the most destructive gear tooth damages, in particular the fatigue damages originated in the subsurface of a gear tooth flank. As a result, surface originated fatigue damage phenomena, in particular micropitting, have gained importance in the determination of the life of a gear.

Micropitting comes from the propagation of fatigue cracks that initiate at the surface of the gear and progress, first inward and then outward, until a surface micro-pit of roughly 100 µm in width by 10 µm in depth is produced. When the distribution of these micropits becomes widespread on the teeth flanks the gearing precision is lowered in consequence of which the incidence of vibration, noise and related problems is increased. In the worst case, the micropit cracks may progress in depth until even more serious problems, such as spalling, are caused.

As a contribution to the understanding and mitigation of this phenomenon, this work is intended to provide a model for the prediction of micropitting.

WORK PLAN

Development of a contact fatigue model for the prediction of micropitting in gears, taking into account the following data, tests and phenomena:

- Mechanical and thermal properties of the gear material;
- Rheology and thermal properties of the lubricating oils;
- Surface roughness of gear tooth flanks caused by the surface finishing processes and by running-in;
- Residual stresses in the flank surface and subsurface;
- Contact stresses between mating gear teeth in full film, mixed and boundary lubrication regime;
- Multi-axial fatigue criterion for surface hardened materials;
- Micropitting tests and their analysis;
- Correlation of the predictive micropitting model and the micropitting tests.

RESULTS

The numerical model is mostly in place [1,2], a number of micropitting tests have been performed and have been favourably compared with the numerical results. In particular, the micropits predicted by the model amount to mass-losses that correlate well with the mass losses observed during the tests (Fig. 1).

A representative set of six industrial, fully formulated gear oils have been submitted to traction tests and from these the rheological properties have been extracted [3]. As can be observed in Fig.2, the traction curves obtained from the rheological parameter based calculations are very close to the measured ones. Additionally similar tests were conducted to ascertain the behaviour of the oils in mixed lubrication regime.

SAMPLE PUBLICATIONS

[1] J.A. Brandão, J. H. O. Seabra, J. Castro, Surface initiated tooth flank damage. Part I: Numerical model, ***Wear*** 268 (1-2) (2010) 1–12.

[2] J. A. Brandão, J. H. O. Seabra, J. Castro, Surface initiated tooth flank damage. Part II: Prediction of micropitting initiation and mass loss, ***Wear*** 268 (1-2) (2010) 13–22.

[3] Brandão, J. A., Meheux, M., Seabra, J. H. O., Ville, F., Castro, J.,Traction curves and rheological parameters of fully formulated gear oils, Nordtrib 2010, Lulea, Sweden, 2010 .

DAMAGE ANALYSIS OF STRUCTURAL ADHESIVE BONDED JOINTS

José Manuel Neto Salgueiro Marques
Master of Science, FEUP
FCT - PhD scholarship - SFRH/BD/50214/2009

Supervisors
José Luís Soares Esteves, FEUP

Start
May 2009

MOTIVATION / OBJECTIVES

Fatigue mechanical analysis of aluminum structural adhesive bonded joints, utilizing two different adhesives in the bond line, with different mechanical properties to improve the behaviour of the adhesive joint.
Damage analysis of the adhesive bonded joints.

WORK PLAN

State of the art;
Fracture mechanics analysis of adhesive bonded joints;
Mechanical characterization of bonded joints in fatigue;
Experimental stress measurement with electrical strain gages;
Analyse and discussion of results.

VIBROACOUSTIC OF DISTRIBUTED VIBRATING STRUCTURES: ANALYTICAL/NUMERICAL MODELING, EXPERIMENTAL VALIDATION AND ANALYSIS

Luís Carlos da Silva Mendes Cardoso
MSc, Mechanical Engineering, FEUP, 2010.
Scholarship *(Bolseiro de investigação),* INEGI (in the context of Programa de Financiamento Plurianual of Fundação para a Ciência e a Tecnologia (FCT)).

Supervisor
José Dias Rodrigues, FEUP

Start
July of 2010

MOTIVATION / OBJECTIVES

In many applications of mechanical engineering designs, like passenger compartments of automobile, trains or aircraft vehicles, when a proper vibroacoustic design is not guaranteed severe vibration and noise problems can occur. To avoid these problems, a comprehensive understanding of the vibroacoustic phenomena in body compartments is required at the design stage for a detailed analysis and an improved design.
The main aim of this research is to contribute to the understanding of the underlying physics of sound radiation phenomena produced by distributed vibrating structures. Emphasis is put in the analysis of the vibroacoustic coupling problem and in the development of control strategies.

WORK PLAN

- Development of an analytical model of a vibroacoustic system consisting in a rectangular cavity with five rigid walls coupled to an elastic rectangular plate;
- Assess the coupling fluid-structure interaction in the system in order to predict the acoustic radiation and sound field generated by the vibrating structure;
- Development of a numerical model through the software Actran/VA;
- Experimental validation of the models developed;
- Incorporate passive and active technologies to attenuate the vibroacoustic response, namely, through the use of viscoelastic materials as well as piezoelectric actuators.

RESULTS

With this research it is expected that the developed analytical and numerical tools and models lead to a better understanding of the interaction fluid-structure in the vibroacoustic problem in order to optimize the variables involved in the mechanical design. It is also expected that reduction technologies of the vibroacoustic response will be investigated

L.C. Cardoso, C.M.A. Vasques, J. Dias Rodrigues (2010) Effect of viscoelastic damping technologies on the vibroacoustic behavior of a coupled rectangular acoustic cavity-plate system in Encontro Nacional de Materiais e Estruturas Compósitas (ENMEC2010), edited by A. J. M. Ferreira, 15 pages, September 6-8, Porto, Portugal (CD Rom edition)

HIGH TEMPERATURE ADHESIVES FOR AEROSPACE APPLICATIONS

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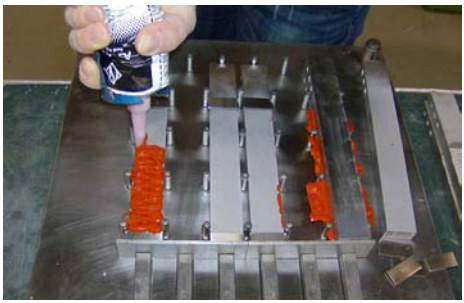
FCT PhD scholarship SFRH/BD/61880/2009

Supervisors
Lucas F. M. da Silva, FEUP

Start
September 2007



MOTIVATION / OBJECTIVES

The main goal of this project is to investigate the mechanical behaviour of two different types of adhesives, one for strength at high temperatures and one for strength at low temperatures, which will be used in aerospace applications. A suitable methodology of fracture characterization of high temperature adhesives as a function of temperature will be performed. All these properties will be subsequently used to predict failure of adhesive joints for high temperature aerospace applications.

WORK PLAN

1 · Literature review;
2 · Selection of the materials;
3 · Mechanical characterizations of high temperature adhesives;
4 · Determination of the adhesive fracture toughness as a function of temperature;
5 · Numerical modelling of high temperature adhesively bonded joints;
6 · Experimental validation;
7 · Elaboration of PhD thesis and scientific papers.

RESULTS

The mechanical properties of two high temperature adhesives were measured over a wide range of temperatures. The cohesive parameters experimentally determined at different temperatures allowed the definition of cohesive laws that would be subsequently used in FEM simulations to model the fracture of bonded structures for high temperature applications.

Banea M.D., da Silva L.F.M., Campilho R.D.S.G., Temperature dependence of the fracture toughness of adhesively bonded Joints, ***Journal of Adhesion Science and Technology***, 24, 2010, p. 2011-2026.

Banea M. D., da Silva L. F. M., Mechanical characterization of flexible adhesive, ***Journal of Adhesion***, 85 (4-5), 2009, p. 261-285.

CONTINUOUS-DISCONTINUOUS MODEL FOR DUCTILE FRACTURE

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Mestre em Engenharia Mecânica, Faculdade de Engenharia da Universidade do Porto
FCT scholarship: SFRH / BD / 43798 / 2008

Supervisors
José M. A. César de Sá, FEUP

Start
October 2008

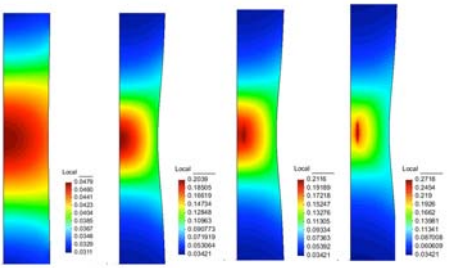

Figure 1. Damage evolution: (a) and (b) before the crack; (c) and (d) after the crack.

MOTIVATION / OBJECTIVES

The behavior of ductile metallic materials can often be described by plastic damageable models, known as the Continuum Damage Mechanics.

In terms of numerical simulation, the continuum models can be implemented in a regular finite element formulation providing a successfully simulation of the hardening part of a material's traction curve. Nevertheless, these models are incapable of modeling material failure up to rupture realistically, as they allow spurious damage growth.

In other hand, fracture may be due to initiation and propagation of discontinuity surfaces within the structure. In recent years, the simulation of crack growth became highly predictive in this framework due to the development of numerical strategies such as the Extended Finite Element method (XFEM), however, as a discontinuous model, it is incapable of predicting the initiation of new cracks.

Therefore, the main objective of this work is to build a model combining a continuous approach with a discontinuous XFEM approach, in order to describe material failure in a complete way.

WORK PLAN

- Literature review;
- Selection of continuous models for the description of ductile damage;
- Elaboration of an XFEM element for non-linear problems (discontinuous formulation);
- Elaboration of a ductile damage based criterion for crack initiation and propagation;
- Development and implementation of a numerical model combining the continuous approach with the discontinuous formulation.

RESULTS

A numerical model combining XFEM with Lemaitre's model for Continuum Damage has been built. The damage variable evolves until reaching a critical value and then a crack is inserted through the XFEM. Damage starts concentrating at the crack tip and material failure is modeled in a realistic way (figure 1).

SAMPLE PUBLICATION

Mariana R. R. Seabra, J.M.A. César de Sá, F.X.C. Andrade, F.M Andrade Pires, "Continuous-discontinuous formulation for ductile fracture", ***International Journal of Material Forming***, in press, 2010.

RIMCOP INDUSTRIAL PROTOTYPE: PROJECT, CONSTRUCTION AND OPERATION

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Mechanical Engineering degree, Inst. Politécnico de Leiria, Escola Sup. Tecnologia e Gestão de Leiria
FCT scholarship SFRH/BD/45621/2008

Supervisors
José Carlos Lopes, FEUP
Paulo Bártolo, IPLeiria

Start
September 2008

MOTIVATION / OBJECTIVES

The Reaction Injection Molding (RIM) is used to process thermosets polymers, and its main applications are automotive, medical and construction sectors, mainly for low to medium production series. Although the industrial relevance and the advantages of the RIM technology, there is still a long way to go regarding the process enhancement, namely on the process reliability.

The goal of this project is the theoretical and fundamental study of the RIM process aiming to optimize it by implementing a new mixing concept introduced at FEUP, the RIMcop® - RIM with control of oscillation and pulsation. It is also intended to achieve a better knowledge of the physical-chemical transformations in curing process and the development of a simulation strategy which allows the optimization of different phases in RIM. This work covers several domains of science that are relevant to RIM, mainly polymer science, computation and fluid mechanics.

WORK PLAN

1 · State of the art of Reaction Injection Moulding (RIM) process
- Existent RIM equipment in market;
- Characteristics of different mixing analysis methods;
- Analysis of several curing models;
- Analysis of mathematical modelation of RIM process;
- Analysis of existent project rules for polyurethanes moulds;

2 · Development of a industrial RIMcop® prototype;

3 · Curing kinetic studies;

4 · Formulation of new project rules for polyurethanes moulds.

Run	$\overline{\Delta p}$	E_c
	[bar]	[MPa]
1	0.32	9.32
2	0.68	16.1
3	0.64	16.2
4	0.29	14.1
5	0.05	22.1

Table 1 – Results

RESULTS

This work has implemented the new technology for control of mixing in RIM, which is one of the novelties in RIMcop®. The heart of the RIM process is the mixing of two monomers in a mixing chamber. The mixing control is based on the dynamic monitoring of the static pressure in the monomer feeding lines to the mixing chamber injectors, which is the variable used to assess mixing It is being demonstrated in this work the use of this control variable, $\overline{\Delta p}$,and for different values of it different mechanical properties were achieved. The better mechanical performance of the part coincides with the best balancing of the monomers feed streams static pressure, i.e., closer to zero (Table 1). [1] For this stage, future work will focus on the implementation of new formulations in the RIMcop® technology and the testing of the use of the control variable, $\overline{\Delta p}$.

N. Gomes, R.J. Santos, M.M. Dias, A.F. Gouveia, C. Costa e Sousa, A.J. Mateus, P.J. Bártolo, J.C.B. Lopes; Assessment of the effect of controlling mixing using RIMCop® technology on the production of polyurethanes - Proceedings RPD 2010, Industrial Knowledge for Innovation. Marinha Grande: September, 2010. Paper 1009.

CRASHWORTHINESS OF SANDWICH MATERIALS USED IN LIGHTWEIGHT VEHICLE STRUCTURES

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Master in Mechanical Engineering, FEUP
Scholarship of IDMEC

Supervisors
António Augusto Fernandes, FEUP
António Joaquim Mendes Ferreira, FEUP

Start
May 2009

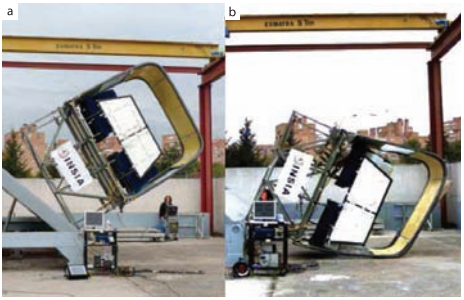

Figure 1. Roll-over test(a) and structure after the test(b).

Figure 2. Structure after test.

MOTIVATION / OBJECTIVES

The motivation for this program is derived from research gaps identified in the execution of the European project "LITEBUS - Modular Lightweight Sandwich Bus Concept", related with the crashworthiness of composite sandwich structures. Further numerical and experimental studies are needed to understand the brittle behavior of fiber reinforced plastics and how its energy absorption properties can be improved to satisfy the stringent requirements of international regulations such as UN-ECE regulation 66 (used as case study).

WORK PLAN

The methodology is based on a multilevel approach to vehicle analysis. The whole system is divided into its various components. Components that directly or indirectly influence the vehicle's crashworthiness will be chosen. Materials will be selected and manufacturing processes will be proposed for the production of those components. The envisaged materials will be characterized (coupon level approach). The results will be used in the numerical modeling and study of the crashworthiness of the components (component level approach). Prototype components will be produced and tested to validate the models. The methodology is focused at coupon and component level. Thus, the work plan is:

- Literature survey;
- Materials characterization;
- Numerical modelling and experimental validation at coupon level;
- Numerical modelling and experimental validation at component level.

RESULTS

The literature review is in progress.
Several numerical studies using both commercial and proprietary software are in progress.
The design of experiments is currently being done.

Note: The numerical modeling and experimental validation at system level (whole vehicle) is out of scope of this program.

EXPERIMENTAL AND NUMERICAL STUDIES OF SOFT BIOLOGICAL TISSUES

Pedro Alexandre Lopes de Sousa Martins
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FCT Foundation PhD scholarship SFRH/BD/41841/2007

Supervisors
Renato Manuel Natal Jorge, FEUP
António Joaquim Mendes Ferreira, FEUP
Maria Teresa da Quinta e Costa de Mascarenhas Saraiva, FMUP

Start
January 2004

MOTIVATION / OBJECTIVES

The female pelvic region comprises one of the most complex regions of the human anatomy. However, this region remains understudied from a biomechanical perspective. The need to augment the available knowledge on this region of the human body becomes more pressing due to the tendency of life expectancy to increase (especially in the developed world). Age is an important issue on the etiology of pelvic floor disorders such as pelvic organ prolapse and urinary incontinence. Age is an important issue on the etiology of pelvic floor disorders such as pelvic organ prolapse and urinary incontinence. This situation has led in the last few years to multidisciplinary efforts in the form of mixed collaborations of engineers and medical doctors.
This thesis addresses an experimental and analytical work on soft tissues of the female pelvic cavity, aiming to improve the available knowledge on pelvic floor diseases.

WORK PLAN

Determination of the biomechanical and physical properties of the tissues, structures and prostheses (used in prolapse and incontinence surgeries) of the female pelvic cavity.
Elaboration of material models (hyperelastic, hyper-viscoelastic), adequate to describe the nonlinear mechanical behavior of the soft tissues from the female pelvic cavity.

RESULTS

An experimental set-up was built and an intensive testing program was conducted to obtain the mechanical properties of the female pelvic cavity. Based on the mechanical properties a model for soft vaginal tissue was developed, on the basis of a hyperelastic concept. The work aims to help practitioner medical doctors to choose prosthesis in order to match the real tissue properties.

SAMPLE PUBLICATIONS

P. Martins, E. Peña, B. Calvo, T. Mascarenhas, M. Doblaré, R. M. Natal Jorge, and A. Ferreira. Prediction of nonlinear elastic behaviour of vaginal tissue: experimental results and model formulation. ***Computer Methods in Biomechanics and Biomedical Engineering***, 13(3):327–337, June 2010

P. A. L. S. Martins, R. M. Natal Jorge, C. Salema, T. H. Roza, A. J. M. Ferreira, M. P. L. Parente, M. Pinotti, T. Mascarenhas, A. Santos, L. Santos, and A. L. Silva-Filho. Vaginal tissue properties versus increased intra-abdominal pressure: a biomechanical study. ***Gynecologic and Obstetric Investigation***, DOI: 10.1159/000315160, 2010

DUCTILE DAMAGE PREDICTION IN SHEET METAL FORMING AND EXPERIMENTAL VALIDATION

Pedro Manuel Cardoso Teixeira
Master in Mechanical Engineering, University of Porto
FCT PhD scholarship SFRH/BD/31341/2006

Supervisors
Abel Dias dos Santos, FEUP
José Manuel de Almeida César de Sá, FEUP
Francisco Manuel Andrade Pires, FEUP

Start
December 2006

MOTIVATION / OBJECTIVES

The increasing use of numerical simulation in metal forming processes has raised new challenges and demands for development of these numerical tools. An extensive effort has been devoted to the development of robust analytical tools and mathematical models capable of virtually reproduce (or simulate) metal forming processes. Despite the great advances already achieved, describing the material's response by the use of conventional models can lead to an erroneous description of the real process, particularly in the cases where internal damage, associated with large plastic deformations and triggered by the initiation and growth micro-cracks and cavities, has a prominent role in the constitutive behavior. Therefore, the establishment of criteria that may predict the onset, location and growth of these micro-cavities and cracks, and that can bridge the gap between microscopic analysis and suitable models for product development has been a priority for many researchers.

The main objective of the present work is to contribute to the improvement and development of reliable failure prediction models for the simulation of metal forming processes by using a Continuum Damage Mechanics approach, emphasizing issues related to continuum modelling as well as to the computational aspects relevant to the application of the proposed models in large scale numerical simulations.

WORK PLAN

- Experimental testings of classical and complex sheet metal applications;
- Development of a failure model accounting for the evolution of internal damage of the material and its effect on the constitutive behavior;
- Implementation of developed damage models based on a scalar (isotropic) and on a tensorial (anisotropic) variable within a finite element environment using different coupling strategies;
- Enhancement of the isotropic damage evolution law by introducing distinct damage evolutions for states of tension or compression.
- Comparison of numerical and experimental results in order to evaluate and validate the developments.

RESULTS

Numerical tools and methodology to predict when and where ductile failure will take place inside the stamped part during processing.

SAMPLE PUBLICATION

P. Teixeira, A. D. Santos, F. M. Andrade Pires, J. César de Sá, "Finite element prediction of ductile fracture in sheet metal forming processes", ***Journal of Materials Processing Technology***, Volume 177, Issues 1-3, pp. 278-281, 2006

P. Teixeira, J. M. A. César de Sá, A. D. Santos, F. M. A. Pires, A. B. Rocha, "Prediction of forming limits based on a coupled approach between anisotropic damage and necking models", NUMIFORM 2010 - 10th International Conference in Numerical Methods in Industrial Forming Processes, Pohang, Korea, pp. 253-259, 13-17 June 2010

ADHESIVELY BONDED FUNCTIONALLY GRADED JOINTS

Ricardo João Camilo Carbas
Master in Mechanical Engineering, FEUP
Scholarship of IDMEC in the context of FCT project PTDC/EME-PME/098571/2008

Supervisors
Lucas F M da Silva, FEUP
Gary Critchlow, Loughborough University

Start
March 2010

MOTIVATION / OBJECTIVES

The main advantage of adhesive joints is that the stress distribution is more uniform than with the other traditional methods of fastening such as bolts or rivets.
Single lap joint is the type of joints most studied, but the stress distribution in the adhesive along the overlap is in fact not uniform, being concentrated at the ends of the overlap.
With this project we want to develop ways of reducing these concentrations for more efficient adhesive joint strength. We intend to get an adhesive functionally modified with properties that vary gradually along the overlap allowing a true uniform stress distribution along the overlap.

WORK PLAN

1 · Experimental process to obtain a graded joint - Identification of the most practical and efficient technological process to obtain a graded joint through experimental tests;
2 · Graded joint optimization - The graded joint will be optimized through numerical simulations;
3 · Manufacture of the optimized graded joint - The optimized graded joint will be manufactured in the simplest way;
4 · Optimized graded joint testing - The graded joint concept and manufacture will be experimentally validated through testing.

RESULTS

The adhesive stiffness would lower along the overlap, being maximum in the middle and minimum at the ends of the overlap.
The process that will be tested in this project is a differentiated adhesive cure. If the adhesive can have several degrees of cure, then a gradient in the rigidity of the adhesive along the overlap can be obtained.

A MULTISCALE MODEL FOR SEMI-CRYSTALLINE POLYMERIC MATERIALS

Seyed Mohsen Mirkhalaf Valashani
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FCT scholarship number SFRH/BD/74027/2010

Supervisors
Francisco Manuel Andrade Pires, FEUP

Start
March 2010

MOTIVATION / OBJECTIVES

Semi-crystalline polymeric materials are increasingly used in structural, medical and electronic applications. Nevertheless, in spite of the importance of these materials and the vast body of experimental data available, the relation between their complex microstructure and the overall mechanical properties is not fully understood. The use of multi-scale approaches, which transfer information between different scales, can provide a deeper physical insight into their mechanical behaviour. In addition, multi-scale models offer the possibility to tailor new materials by manipulating the microstructure via numerical simulations. The main goal of the present research is to develop a multiscale constitutive model for predicting the large-scale (macroscopic) response of semi-crystalline polymeric materials. The influence of micro structural parameters, such as the crystallinity ratio or the elastic distortion constant of polymer chains, on the macroscopic response will be naturally incorporated on the model developed and numerically simulated. The following scientific and technical objectives are foreseen:

- The determination of the material parameters of an existing macroscopic constitutive model by fitting the homogenized response produced by finite element solutions of a single Representative Volume Element (RVE) under prescribed macroscopic strain paths.
- The development of new macroscopic constitutive laws capable of capturing the homogenized response of a finite element-discretized RVE.
- To perform fully coupled two-scale finite element analyses where the macroscopic equilibrium problem is solved simultaneously with one RVE equilibrium problem for each Gauss quadrature point of the macroscopic mesh. In this case, the constitutive law at each Gauss point is defined by the homogenized response of the corresponding discretized RVE.
- To enhance the modelling of the micro-scale by including advanced formulations for material and geometric non-linearities in order to capture macroscopic localization phenomena and structural size effects.

The multiscale model to be developed should be able not only to reproduce the experimentally observed behaviour of semi-crystalline polymeric materials but also give a deeper physical insight into the microstructure of the amorphous phase, which is not fully understood at present.

MULTI-SCALE MODELING OF HEXAGONAL CLOSED PACK (HCP) MATERIALS WITH SPRING-BACK PREDICTION

Shenghua Wu

Fellowship project PTDC/EME-TME/105688/2008

Supervisors
Francisco Manuel Andrade Pires, FEUP
Abel Dias dos Santos, FEUP
Augusto Barata da Rocha, FEUP

Start
September 2008

MOTIVATION / OBJECTIVES

Due to the requirements of reducing significantly part weights in Automotive, Electronic and Aerospace manufacturing industries, the use of lightweight materials, such as magnesium, becomes nowadays more and more important. These materials have hexagonal closed-pack (HCP) crystal structure, in which the dislocation movement is essentially restricted to the basal planes of the crystal. As a consequence, it is thus normally required thermal activation to increase the number of active slip systems and, in this way, increase magnesium's ductility and formability.

The objectives of this research include the development of new constitutive material models to study Hexagonal Closed-Pack materials and to study the effect of temperature on their formability. These constitutive models will be applied on sheet metal forming applications including spring-back analysis. Also, experimental equipment is to be developed in INEGI concerned with experimental work, needed for validation of numerical results and developments.

WORK PLAN

- Review of experimental methods and equipments to study magnesium alloys at warm forming including springback analysis.
- Proposal of different tooling for experimental work and its design; follow-up of manufacturing process of proposed equipment.
- Definition of tasks and methodology of experimental work.
- Simulation of experiments by FEM, incorporation of numerical developments like using different constitutive models and temperature to face particularities of magnesium warm forming.
- Validation of numerical results by comparison with obtained experimental data.

SAMPLE COMMUNICATION

Shenghua Wu, "Prediction of damage in sheet metal forming by using Ito-Goya model", Seminar presentation, Department of Mechanical Engineering, Faculty of Engineering, University of Porto, February 25, 2010.

PRODUCTION AND PROCESSING OF NATURAL FIBER COMPOSITES

Sónia Marisa Maciel Leitão Correia
MSc in Industrial Maintenance, FEUP

Supervisors
António Torres Marques, FEUP
João Francisco Silva, ISEP

Start
November 2009

MOTIVATION / OBJECTIVES

The motivation for this work is to add value to natural fibers that are considered waste, using them as reinforcement on composite materials.

WORK PLAN

- Literature Review
- Selection/Characterization of promising natural fibers. These fibers should be selected from the wastes resulting from forest cleaning.
- Production of laboratorial scale samples for testing of composites made with the selected fibers and thermosetting resins.
- Production of laboratorial scale samples of composites made with the natural fibers and common thermoplastic matrices (ex. PP, PE, PVC).
- Mechanical, thermal and rheological testing of the obtained composites.
- Relevant properties optimization of the obtained natural fiber composites.
- Production of composite samples using major composite processing techniques.
- Economical evaluation of the obtained natural fiber composites.
- Conclusion and thesis writing.

RESULTS

New natural fiber composites with acceptable mechanical properties, produced from wasted fibers, using traditional composite processing technologies.

GEOMETRICALLY NONLINEAR VIBRATIONS OF 3D BEAMS ROTATING IN ONE PLANE

Stanislav Dimitrov Stoykov
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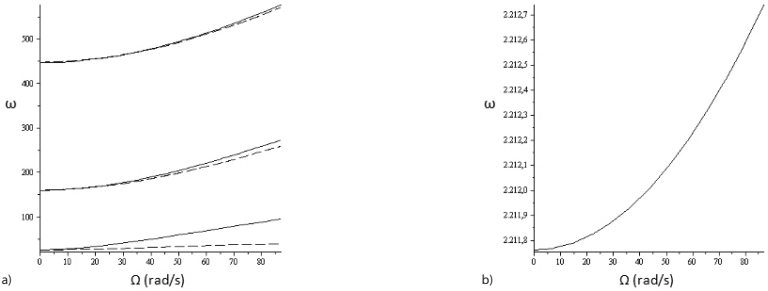
FCT scholarship SFRH / BD / 35821 / 2007

Supervisors
Pedro Leal Ribeiro, FEUP

Start
November 2007



Variation of the natural frequencies with the speed of rotation Ω of beam with rectangular cross section.

(a) First three bending natural frequencies: line - frequencies of transverse displacement perpendicular of the plane of rotation (flapwise), dash - frequencies of transverse displacement in the plane of rotation (lagwise).

(b) First torsional natural frequency of the beam.

MOTIVATION / OBJECTIVES

During recent years, stability problems in wind turbine structures have obtained increasing attention due to the trend towards larger, lighter and more flexible structures. As the length of the turbine blade increases and its weight decreases, large vibration amplitudes become more frequent. These vibrations violate the small displacements assumption and give rise to a nonlinearity known as geometrical nonlinearity.

The goal of the research to be carried out in this PhD is

- To develop a 3D beam finite element with hierarchic basis functions; the element may experience flexure in any plane, torsion, warping and longitudinal vibration. Geometrical type of nonlinearity should be taken into account in the stiffness and the inertia forces due to the rotation must be included in the inertia terms.
- To adopt numerical methods to solve the nonlinear equation of motion that results from the application of the finite elements to dynamics. Methods in time and frequency domain should be considered.
- To achieve a better understanding of the dynamic behaviour of rotating blades. Nonlinear free vibrations and couplings of the modes should be studied. Then, forced vibrations, due to harmonic and aerodynamic forces, and stability should be analysed.

WORK PLAN

- Develop a new 3D beam finite element with rectangular cross section for isotropic materials. Geometrical type of nonlinearity and bending-torsional coupling should be considered. Different models should be compared and validated and the most accurate should be chosen.
- Analyse free periodic vibrations of 3D beams. Determine the bifurcations diagrams, bifurcation points and secondary branches. Investigate if coupling between modes occurs due to internal resonances and describe the modes. Since the beam is 3D, coupling is likely to occur between flexure modes of different planes or between flexure and torsion.
- Analyse periodic forced vibration of 3D beams, determine the frequency response functions due to harmonic exci-

tations. Study the stability of the solutions employing Floquet's theory.

- Develop the 3D beam element into a rotating 3D beam element. For that purpose, the rotation should be taken into account in the inertia terms. Acceleration of Coriolis should be included in the model.
- Analyse free and forced vibration of rotating 3D beams, investigate the influence of the speed of rotation into the mode shapes and the amplitudes of vibration. Harmonic and aerodynamic forces should be applied.
- Develop the 3D rotating beam element to composite materials and to beams with non-symmetric cross sections. Cross sections of wind turbine blades should be considered. The dynamic behaviour of wind turbine blades, which is important for the design, should be analysed.

SAMPLE PUBLICATIONS

S. Stoykov, P. Ribeiro, Nonlinear forced vibrations and static deformations of 3D beams with rectangular cross section: The influence of warping, shear deformation and longitudinal displacements, ***International Journal of Mechanical Sciences*** 52 (2010) 1505-1521.

S. Stoykov, P. Ribeiro, Nonlinear free vibrations of beams in space due to internal resonance, ***Journal of Sound and Vibration*** (2011), doi:10.1016/j.jsv.2011.04.023

POWER LOSS IN GREASE LUBRICATED ROLLING BEARINGS

Tiago Cousseau
Master in Mechanical Engineering, UP
Scholarship funded by FCT (Fundação para a Ciência e Tecnologia) through the project PTDC/EME-PME/72641/2006.

Supervisors
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Armando José Vilaça Campos, ISEP

Start
April 2009

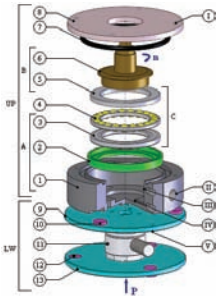


Figure 1. Bearing assembly schematic view

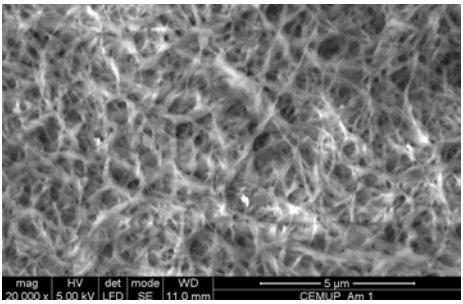


Figure 1. Grease's thickener structure

MOTIVATION / OBJECTIVES

Since energy sources are no longer available as before, the reduction of energy consumption and the increase of the efficiency in mechanical transmissions are mandatory. Beyond that, the use of biodegradable products has been induced due to the environmental concerns.

Approximately 90% of all rolling bearings are lubricated with grease. However, the behaviour of the grease in a lubricated contact is not yet fully understood, mainly in terms of power loss and wear. In this sense, different types of greases have been studied in order to characterize the influence of grease formulation on the coefficient of friction, on the friction torque, on the form-film ability and on fatigue wear for different types of rolling bearings, with special attention on the biodegradable and low-toxicity greases.

WORK PLAN

Characterize experimentally the properties of different greases and of the corresponding bleed and base oils (viscosity, complex modulus, flow capacity, etc.).

- Evaluate the friction torque, operating temperature and bearing wear in grease lubricated thrust ball bearings using a modified 4-Ball-Machine and ferrographic techniques.
- Measure the friction coefficient and the film thickness through optical interferometry in a ball-on-disc device for the greases and the corresponding bleed and base oils.
- Relate grease formulation (thickener, base oil / bleed oil) with film thickness, friction coefficient in full film lubrication, friction torque and bearing wear.
- Optimize a bearing friction torque model for a thrust ball bearing 51107 in order to evaluate the friction considering grease formulation.

RESULTS

The influence of the grease formulation have already been related with the bearing wear and with the rolling and sliding friction torque through some parameters, such as, the bleed oil viscosity, the nature of the base oil and the interaction between thickener and base oil. Some results have published in refs. 1 and 2.

SAMPLE PUBLICATIONS

[1] Tiago Cousseau, Beatriz Graça, Armando Campos, Jorge Seabra, Friction torque in grease lubricated thrust ball bearings. ***Tribology International***, 2010 (JTRI 2295), doi:10.1016/j.triboint.2010.06.013. In press.

[2] T Cousseau, B M Graça, A V Campos and J H O Seabra, Influence of grease formulation on thrust bearings power loss. ***Proc. IMechE, Part J: J. Engineering Tribology***, 224(9), 935-946 (2010).

CONTACT MODELLING OF SOLIDS WITH EVOLVING DISCONTINUITIES

Thiago de Carvalho Rodrigues Doca
Mechanical Engineering, Univ. Brasilia, Brazil
FCT scholarship SFRH/BD/66617/2009

Supervisors
Francisco Manuel Andrade Pires, FEUP

Start
January 2009

MOTIVATION / OBJECTIVES

The numerical treatment of contact problems requires the formulation of kinematical relations and constraints, constitutive equations at the contact interface, variational equations and its discretization using special finite elements within the contact area. The mathematical formulation of contact problems leads to variational inequalities. Hence special algorithms have to be constructed for the solution of such problems.

The primary goal of the proposed research work is to develop computational contact strategies for the finite element simulation of problems with evolving cracks. Firstly, emphasis will be given to the assessment of currently available contact algorithms in several well known analytical and numerical benchmarks. A series of problems supported by experimental data will also be performed and critically analysed. Particular attention will be given to the newest surface interpolation methods, i.e. Mortar method and Nagata patches method. The results of this study will guide the following developments. The next stage will comprise the analysis and development of contact detection algorithms that are able to follow the evolution of multiple cracks. After this procedure, the contact between continuous regions will be addressed. Here, the modelling of sharp corner to corner contact, which is particularly challenging, will be addressed.

The modelling framework to be developed will be applied to several scientific and practical problems whose behaviour can not be interpreted without consideration of the complex contact conditions present .

WORK PLAN

Phase I · Study of the classical methods for contact detection and enforcement of constraints;

Phase II · Development of the newest computational methods for contact mechanics in order to solve problems with evolving discontinuities.

RESULTS

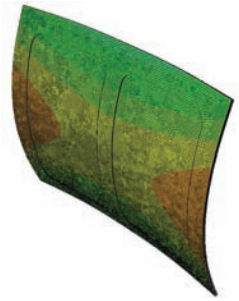
Computational code containing the two classical contact detection methods, as also the Penalty method, the Lagrange method and the Augmented lagrangian method of enforcement of constraints

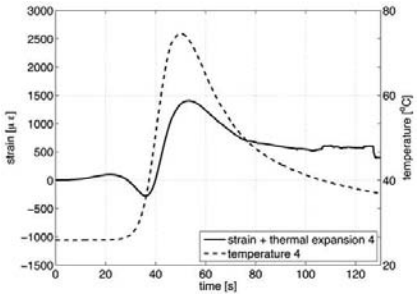
INTEGRATED DESIGN SOLUTIONS FOR LIGHTWEIGHT STRUCTURES: FSW, RESIDUAL STRESSES, DAMAGE TOLERANCE CRITERIA

Valentin Richter-Trummer
Master in Mechanical Engineering, UP
PhD Thesis funded by FCT scholarship SFRH / BD / 41061 / 2007

Supervisors
Paulo M S T de Castro, FEUP
Jorge F dos Santos, GKSS, Germany
Pedro Vilaça, IST

Start
March 2008





MOTIVATION / OBJECTIVES

Great interest is dedicated to the use of welding in aircraft, aiming at moving from riveted structures with hundreds of thousands rivets per aircraft, to integral monolithic structures, with economies in part count, fabrication time, weight and cost. Friction stir welding is a key process currently being considered for critical structures as fuselage panels. Two related problems require attention:

- The damage tolerance of the resulting structures is not as well understood as in the case of the conventional manufacturing method, namely because of residual stress fields;
- It is not possible to predict part distortion in aeronautics and aerospace components to the required level of accuracy when considering component tolerances.

The proposed thesis aims at an integrated multidisciplinary approach to the prediction and resolution of these problems. Research is conducted in the areas of material processing, manufacturing and design, so that a proof of concept can be obtained.

WORK PLAN

The work is divided into several different aspects of the integral design concepts.

Among others, work is performed in the area of damage tolerance of welded components, temperature and strain monitoring during welding using fibre Bragg grating sensors, distortion due to welding and high speed machining of integral structures and residual stresses introduced by welding and their redistribution due to high speed machining.

RESULTS

Good results have been already achieved in most of the areas investigated, particularly FBG monitoring of FSW, and full field residual stress evaluation using the contour technique; some results are already published in refs. 1,2. Further publications are available online or are being prepared.

SAMPLE PUBLICATIONS

[1] V. Richter-Trummer, S. O. Silva, D. F. C. Peixoto, O. Frazão, P. M. G. P. Moreira, J. L. Santos, P. M. S. T. de Castro, 'Fibre Bragg grating sensors for monitoring the metal inert gas and friction stir welding processes', ***Measurement Science & Technology***, 21:p. 085105 (2010). doi: 10.1088/0957-0233/21/8/085105.

[2] V. Richter-Trummer, S. M. O. Tavares, P. M. G. P. Moreira, P. M. S. T. de Castro, 'Friction stir welding of aluminium alloys and damage tolerance of integral monolithic structures', ***Mechanika***, 73(5):pp. 18–22 (2008).

CONCLUDING REMARKS

This publication compiles the contributions received from Mechanical Engineering doctoral candidates to a questionnaire conducted at the end of 2010. It consists of a very concise presentation of a sample of on-going doctoral projects. Some of these are at a very early stage of development, whereas a few are, at the end of 2010, more advanced or close to conclusion.

Reflecting the wide scope of the Mechanical Engineering field and the international outlook of this doctoral programme, this sample includes doctoral candidates accepted on the basis of previous degrees including:

- Aeronautical Engineering, Middle East Technical University, Turkey
- Aerospace Eng (Luft- und Raumfahrttechnik, Dipl.-Ing.), Universität Stuttgart, Germany
- Applied Mathematics, Sofia University 'St. Kliment Ohridski', Bulgaria
- Automation, Instrumentation and Control, FEUP, Portugal
- Chemical Engineering, FEUP, Portugal
- Civil Engineering, FEUP, Portugal
- Engineering of Lignocellulosic Materials, IPV, Viseu, Portugal
- Engineering Physics, Universidade Nova de Lisboa, Portugal
- Industrial Design, FEUP, Portugal
- Industrial Maintenance, FEUP, Portugal
- Mathematics, FCUP, Portugal
- Mechanical and Aeronautical Engineering, University of Patras, Greece
- Mechanical Engineering, 'Dunarea de Jos' University of Galati, Romania
- Mechanical Engineering, Azad University, Arak Branch, Iran
- Mechanical Engineering, FEUP, Portugal
- Mechanical Engineering, Universidade de Brasília, Brazil
- Mechanical Engineering, Universidade de Coimbra, Portugal
- Mechanical Engineering, Universidade do Minho, Portugal
- Mechanical Engineering, Università degli Studi di Palermo, Italy
- Metallurgical and Materials Engineering, FEUP, Portugal
- Physics, FCUP, Portugal
- von Karman Institute, Belgium

In the context of the internationalization of the programme, the participation of doctoral candidates from Austria, Brazil, Bulgaria, China, Germany, Greece, Iran, Italy, Romania and Turkey is noted and especially valued.

The Mechanical Engineering doctoral programme of the Universidade do Porto seeks to expand cooperation with third parties on the basis of voluntary, bottom-up partnerships solely based on shared scientific and technological interests. In this context, researchers and academic staff of the following institutions, R&D organizations and companies are involved as supervisors or co-supervisors in this sample of on-going projects:

- ALSTOM Transport, France
- FEUP, Porto, Portugal
- IST Lisbon, Portugal
- FMUP, Porto, Portugal
- GKSS, Germany
- Imperial College London, UK
- INEGI, Porto, Portugal
- IPLeiria, Leiria, Portugal
- IPV, Viseu, Portugal
- ISEP, Porto, Portugal
- Loughborough University, UK
- Technical University of Malaysia, Malaysia
- Virginia Tech, USA

As already mentioned, the present sample includes projects at very different stages of advancement. Towards the end of 2010 results of this sample of projects were already presented at international and Portuguese conferences, as well as published in a variety of periodicals as:

- Composites Science and Technology
- Computer Methods in Biomechanics and Biomedical Engineering
- Energy & Environmental Science
- Gynecologic and Obstetric Investigation
- International Journal of Damage Mechanics
- International Journal of Material Forming
- International Journal of Mechanical Sciences
- Journal of Adhesion
- Journal of Adhesion Science and Technology
- Journal of Materials Processing Technology
- Journal of Sandwich Structures and Materials
- Journal of Sound and Vibration
- Manutenção
- Materialwissenschaft und Werkstofftechnik
- Measurement Science & Technology
- Mechanics of Advanced Materials and Structures

- Mechanics of Materials
- Mechanika
- Proceedings of the Inst. of Mech. Engineers, Part J: Journal of Engineering Tribology
- Tribology International
- Wear

A doctoral programme relies upon a stimulating research environment and supervisors who are active researchers and permanently seek new relevant projects and research opportunities. Many different sources of funding are used, complementing FEUP's own contribution. In the case of the present sample of projects, these include:

EU ALBAN project, code E07D401751BR
EU Marie-Curie contract MRTN-CT-2005-019198
FCT PDCTE/EME/65099/2003
FCT PTDC/EME-PME/098571/2008
FCT PTDC/EME-PME/100204/2008
FCT PTDC/EME-PME/64984/2006
FCT PTDC/EME-PME/66185/2006
FCT PTDC/EME-PME/67022/2006
FCT PTDC/EME-PME/72641/2006
FCT PTDC/EME–TME/098050/2008
FCT PTDC/EME-TME/098752/2008
FCT PTDC/EME-TME/105688/2008
FCT SFRH/BD/24045/2005
FCT SFRH/BD/31341/2006
FCT SFRH/BD/35821/2007
FCT SFRH/BD/40522/2007
FCT SFRH/BD/41061/2007
FCT SFRH/BD/41841/2007
FCT SFRH/BD/43798/2008
FCT SFRH/BD/45554/2008
FCT SFRH/BD/45621/2008
FCT SFRH/BD/50214/2009
FCT SFRH/BD/60887/2009
FCT SFRH/BD/61880/2009
FCT SFRH/BD/66617/2009
FCT SFRH/BD/74027/2010
FLAD project 314/06
Gulbenkian Foundation PhD scholarship 104047-B
Gulbenkian Foundation PhD scholarship 104299
POPH QREN
PROFAD IPV

Reflecting the perceived need for continuous improvement of doctoral programmes, several policy documents have been recently published; among those originated in Europe, particular notice was taken of the "*The European Charter for Researchers; The Code of Conduct for the Recruitment of Researchers*", published by the European Commission in 2005 (doc. EUR 21620), as well as the 2010 document of the EUA - European University Association "*Salzburg II recommendations - European universities' achievements since 2005 in implementing the Salzburg principles*". The continuous improvement of PRODEM, in the light of such policy recommendations and of the experience accumulated, is a permanent concern of the programme.

PRODEM is always pleased to receive enquiries from prospective doctoral candidates worldwide, and to discuss with companies possible research projects and other forms of partnership.

Paulo M. S. Tavares de Castro*

* programme director since its operation in the context of the Bologna process (July 2007), up to the beginning of 2011.

INDEXES

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U.PORTO

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