



## Thesis abstracts

*This section presents the abstract of most recent Master or PhD thesis related to aerospace technology and management*

### Characterization and quantification by FT-IR, HPLC and TG techniques of polymers used in plastic bonded explosive

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Thesis submitted for PhD degree in Physics and Chemistry in Aerospace Materials at the Technological Institute of Aeronautics, ITA, São José dos Campos, São Paulo State, Brazil, 2008.

Advisor: Dr. Rita de Cássia L. Dutra

**Key words:** Plastic bonded, Polymer, Characterization, FT-IR, TG, HPLC.

**Abstract:** High explosives are a tool that can be used in many areas of research and are critical components in both conventional and nuclear weapons. The desire to pack more energy into smaller volumes led to the development of Plastic Bonded Explosives (PBX). PBXs were developed to reduce the sensitivity of explosives, and are widely used in both civil and military applications when high performance is required. One method for obtaining an explosive charge is by pressing the explosive coating by means of a hydraulic press, and this represents the most important process in manufacturing high performance explosive charges. Since the weapons may be used in aggressive thermal and mechanical environments, it is important to characterize the PBXs, in order to know their behavior and properties. Therefore, contributing to the research on PBXs, a methodology was developed in this Thesis to characterize and to quantify the polymer content in PBXs by Fourier Transform Infrared Spectroscopy (FT-IR), using High Performance Liquid Chromatography (HPLC) and Thermogravimetry (TG) as reference techniques for the quantitative method. The proposed methodology for the quantification of polymers in PBXs, using the FT-IR technique of ATR and UATR reflection presented excellent results, being faster than the usual methodologies and eliminating the disadvantage of chemical residue generation. The development of the FT-IR methodology, including surface analysis techniques to quantify polymers constitutes a new line of research in our Research Center,

already appears to offer a base for the development of new methodologies applied in the aerospace sector.

### Implementation of radial basis function networks on CMOS and BiCMOS technology

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Thesis submitted for PhD in Electronic Engineering at the School of Engineering - UNESP Ilha Solteira, São Paulo State, Brazil, 2009.

Advisor: Prof. Dr. Nobuo Oki

**Key words:** Neural networks, Radial basis function networks, Integrated circuits, CMOS, BiCMOS.

**Abstract:** In this work, we present the development of radial basis function circuits in CMOS technology. Two one-dimensional circuits, namely  $RBF_1$  and  $RBF_2$ , are proposed for radial basis function realization, and their functionality is demonstrated by SPICE simulations and by their implementation with commercial MOSFET array integrated circuits. Multidimensional capability is demonstrated by the implementation of a bi-dimensional  $RBF_1$  circuit and by SPICE simulation results. In addition, BiCMOS versions are also presented for  $RBF_1$  and  $RBF_2$ . The proposed cells are used in the design of bi-dimensional radial basis function neural networks in AMS 0.35 $\mu$ m CMOS process. In order to test their functionality, the networks were simulated for some applications with good results achieved. The issue of parameter quantization and its influence on the network function approximation capability is also dealt with in this dissertation. We carried out several simulations with different levels of quantization. The results obtained show that the network is capable of learning functions, even with a severe parameter quantization. As expected, the error increases for less bits of quantization. Nevertheless, the parameter quantization decreases the memory size and complexity necessary for network parameter storage, allowing the implementation of compact circuits and being adequate for low power applications.

## Characterization of thermostructural materials based on carbon reinforced with carbon fibers (CRFC) and carbons modified with silicon carbide (SiC)

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**Key words:** Composite materials, Thermostructural composites, Characterization.

**Abstract** In aerospace programs some materials are subjected to high temperatures and an aggressive thermal environment. To achieve these requirements there are a considerable number of resources that involve the development of composite materials based on Carbon Reinforced with Carbon Fiber (CRF) and Modified Carbon, especially with Silicon Carbide (SiC). To obtain materials that resist the thermal demands of a space vehicle, such as a protective structure for atmospheric reentry, or a rocket motor nozzle, or a component that acts as a thermal protection, is of strategic importance to the success of a space program success, such as the Brazilian program now under development. In the present work, some aspects of the usual process to obtain these materials, is examined, emphasizing the possibilities of carbon incorporation in the structure by chemical gas deposition or by liquid impregnation with pitch or phenolic resin. A study of the process variables in the national production of thermostructural composites, coming from three direction (3D) and four direction (4D) preforms, made by spatial arrangement of carbon rods, was undertaken. Thermal and microscopic characterization of the national composites was carried out, in addition to the characterization of four foreign composites originating from traditional producer countries.

## Fluid-structure coupling on unstable vortex shedding phenomena in confined chamber

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2007.

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**Key words:** Fluid mechanics, Instability, Vortex shedding mechanism, Fluid/structure coupling.

**Abstract:** Analysis of a segmented flow field in a confined chamber was carried out in order to estimate the role of the vortex shedding sources. Specific attention was given to the potential interaction between vortex shedding that arises from the thermal inhibitor and vortex generation issuing from the injecting walls. Experimental investigations were carried out with an adapted cold gas experimental set-up and specific analyses studied the fluid/structure potential role of the two vortex sources of instability. Two different fluid/structure analyses were considered. First, a forced flapping movement induced by an adapted mechanical system made it possible to force the thermal inhibitor motion. A flexible obstacle was also analyzed in order to ascertain the potential passive control of instability. With a forced coupling, it was found that the wall injection vortex shedding dominated as source of instability while introducing a flexible obstacle provided a significant reduction in instability. The degree of this reduction was found to be linked to the thickness of the obstacle and the considered Mach number of the flow field. It strongly depended also on the internal geometry i.e. that directly controls the interaction of the vortex sources.

## Evaluation and modeling of porosity type defects in solid propellant grains

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Thesis submitted for Masters in Engineering at Technological Institute of Aeronautics, ITA, São José dos Campos, São Paulo State, Brazil, 2008

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**Key words:** Solid propellant, Rocket motor, Porosity.

**Abstract:** This work presents a study carried out on bubble form imperfections and their influence on the burning evolution of the propellant grain. It discusses some of the main types of defects that can be found and the inspections and tests that can be carried out to detect and measure them. It also describes some types and forms that these defects may have and, based on their geometrical characteristics, a classification is proposed for further analysis and modeling of their burning evolution. Finally, this study covers a tension analysis evaluation for the S-30 motor propellant grain with and without the existence of defects. This study can be applied generally to other motors.

## Ablative carbon-phenolic composites additivated with carbon nanoparticles

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**Advisor:** Professor Dr. Koshun Iha

**Key words:** Carbon-phenolic composites, Carbon nanoparticles, Ablation.

**Abstract:** The development of solid rocket motor propellant began in Brazil, in the 70s. A solid propellant rocket motor is exposed to high temperatures, high pressures, high erosion rates, big thermal shocks without any conventional cooling system. Under these critical operating conditions, ablative polymeric composites and rubber liners are used for thermal protection of the motor's steel shell. Phenolic composites are normally used as ablative materials. Cotton, asbestos, carbon and silica woven cloths have been used in the last three decades as reinforcement for these composites. Lately, carbon woven cloth usage has received special preference. The main goal of this work was to produce and characterize pre-pregs and carbon-phenolic composites additivated with carbon nanoparticles. The literature shows that similar materials are used in high performance solid propellant rocket motors, such as in the solid rocket motor nozzle of the Space Shuttle. Three grades of carbon particles were used as additive in the phenolic matrix: micronized natural graphite, acetylene grade carbon black and furnace grade carbon black. Pre-pregs, were produced using a pilot impregnation equipment and three different additive concentrations 5, 10 and 15 per cent w/o were used. Pre-pregs without additive were also obtained. Eighty one specimens of carbon-phenolic composite were compression molded, nine for each carbon particle grade, plus nine for the phenolic composite without additive. X-ray diffraction and Raman spectra were obtained both for the additives and for the reinforcement. The concentrations of the matrix, reinforcement and additives in the pre-pregs produced were measured together with flow and volatiles content. In the composite, the density, void content, heat transmission coefficient, linear thermal expansion coefficient, Iosipescu shear resistance, and oxyacetylene and plasma ablation resistance were evaluated. The results showed that composites additivated with carbon nanoparticles have better ablative performance than unfilled material. Moreover, the limits for each additive in the impregnation process were obtained.

## Proposal of a risk management

## method for use during rocket development projects in the Brazilian Air Force Institute of Aeronautics and Space

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**Key words:** Risk, Risk management, Space vehicles development, project management.

**Abstract:** This dissertation, proposes a method intended for managing risks during rocket development projects in the Brazilian Air Force Institute of Aeronautics and Space. After a bibliographical search and a study of best practices, several details were identified regarding risk management methods used in the main space agencies around the world and the specific characteristics of risk management applied to space vehicle development and to systems engineering. The proposed method intends to guide the activities of planning, the elaboration of a risk management plan, the activities of risk identification and analyses, the elaboration of risk response plans and other activities to do with tracking and control of project risks. To gauge the effectiveness of the proposed method, it was tested in a case study, related to development of the VS-15 rocket. As a result, the method was considered applicable, given that it makes it possible to keep a record, in an ordered manner, of several characteristic risks and to remove the adverse effects of unknown risks during the project life. The proposed method was considered feasible, even though it proved to require highly detailed and discriminating planning, especially in relation to human resources dedicated to risk management, the physical space necessary to archive the paperwork, the established timeline for these activities and the inherent costs. The proposed method was considered acceptable, within the limits of this work.

## Application of the ammonium perchlorate particle packing study, and the use of a model for optimizing high performance composite propellant formulations based on HTPB and aluminum

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**Key words:** Particle packing theories, Propellant, granulometry, Dibutyl thin laurate-DBTDL.

**Abstract:** The aim of this work was to obtain formulations of AP/PBLH/Al-based propellant, in which the solid content was higher than that currently in use. The increase in the solid fraction enhances the rocket-motor thrust. However, it needs to adhere to a set of criteria, which were also subject of this work. These criteria are grounded in particle packing theories, which have been used as a tool for defining modality, distribution, granulometry and solid loading. Some trials were also performed to ascertain the applicability of a linear packing model. The model on trial proved to be applicable and the theoretical predictions agreed with experimental results. A further correlation model was proposed in this work to correlate the end-of-mix viscosity data at 50, 55 and 60°C under atmospheric pressure. Another correlation model was also proposed to correlate experimental data of Young modulus at 25°C. Both equations succeeded in correlating the experimental points. Ballistic properties were then determined for pressures ranging from 4 to 10 MPa. The effect of the order of addition of the bonding agent and aluminum were also evaluated. The best results were obtained when aluminum and the bonding agent were added at the beginning of the mixing process. The cure catalyst was also changed for DBTDL in the following trials in order to speed up the cure process. The tests carried out with 5 ppm of DBTDL displayed the best results for end-of-mix viscosity and further propellant properties. The use of high packing particle systems in conjunction with 5 ppm of DBTDL as cure agent permitted solid loading up to 88 per cent, far higher than the 84 per cent used in VLS propellant. Moreover, mechanical and ballistic properties of these propellants are suitable for the ongoing projects at IAE.

## Evaluation of the applicability of FT-IR and thermal analysis techniques to the characterization and elastomer quantification

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**Key words:** Elastomers, Characterization, FT-IR, Thermal analysis.

**Abstract:** The control of the qualitative and quantitative aspects of elastomer characteristics is very important. Therefore, the development of simple methodologies that allow characterization of these compositions is attractive to researchers in different areas of industry. This study evaluated the applicability of IR transmission techniques, ATR-Universal (UATR), TG and dynamic mechanical analysis (DMA) in the characterization and quantification of elastomeric compositions. Mechanical properties are used to complement this study. Pyrolysis and infrared spectroscopy (PIR-G/FT-IR) are used to investigate gaseous products of rubbers. The results demonstrate that this method is suitable to identify the different elastomers and elastomer blends, including rubbers that present similar IR spectra of pyrolysed liquid products. NBR samples with known contents of acrylonitrile (AN) were prepared at IAE laboratories. They were used as reference samples to construct an analytical curve to determine the content of AN in NBR by new methods of transmission (pyrolysis) and UATR/FT-IR techniques. Analytical curves permit the determination of the contents of AN in NBR samples of similar composition. TG/IR coupled technique is evaluated in the qualitative and quantitative aspects for some types of rubbers. Similarities and differences are observed in relation to known methodologies.

## Dependability requirements analysis process for space software

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**Key words:** Dependability, Software, Requirements.

**Abstract:** Given that software is beginning to assume an increasing number of functionalities in space systems, it is fundamental that the specification requirement activity should play a decisive role in the efforts to obtain a satisfactory and safe project. In critical aerospace systems, where ambiguity, non-completeness, and lack of requirements can cause serious accidents resulting in economic, material and human losses, it is necessary to treat the subject carefully. One of the ways to assure quality in space projects concerning safety, reliability and other dependability factors is to use techniques and safety factors

to identify non-functional requirements during the project start phases, such as the system specifications. It is believed that the definition of what are the most important quality requirements for aerospace applications at IAE, and the most appropriate dependability techniques to evaluate them will produce maturity and stability for both the requirements and the project during its conception phase. The objective of this work is to develop a process to identify dependability quality factors in the development of software for space applications during its requirement specification phase. This work consists of a presentation of the most adequate dependability attributes for space vehicle software at IAE, and of an investigation of what are the most adequate safety analysis techniques to evaluate them so as to produce the most complete, consistent, and reliable requirements.