SEMINÁRIOS PPG-EM / UERJ 2016

PPG-EM UERJ 2016 SEMINARS

Programa de Pós-graduação em Engenharia Mecânica UERJ

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Capa: Cristais de carbonato de ferro ($FeCO_3$) precipitados sobre camada de produto de corrosão craquelado formado sobre o aço UNS K41245 grau T5 (5 % Cr) sob exposição em meio de NaCl/CO2 (Sweet Corrosion). Imagens obtidas por elétrons secundários em microscópio eletrônico de varredura. Foto obtida da página `http://www.ipt.br/solucoes/289-microscopia_e_analise_metalografica.htm`.

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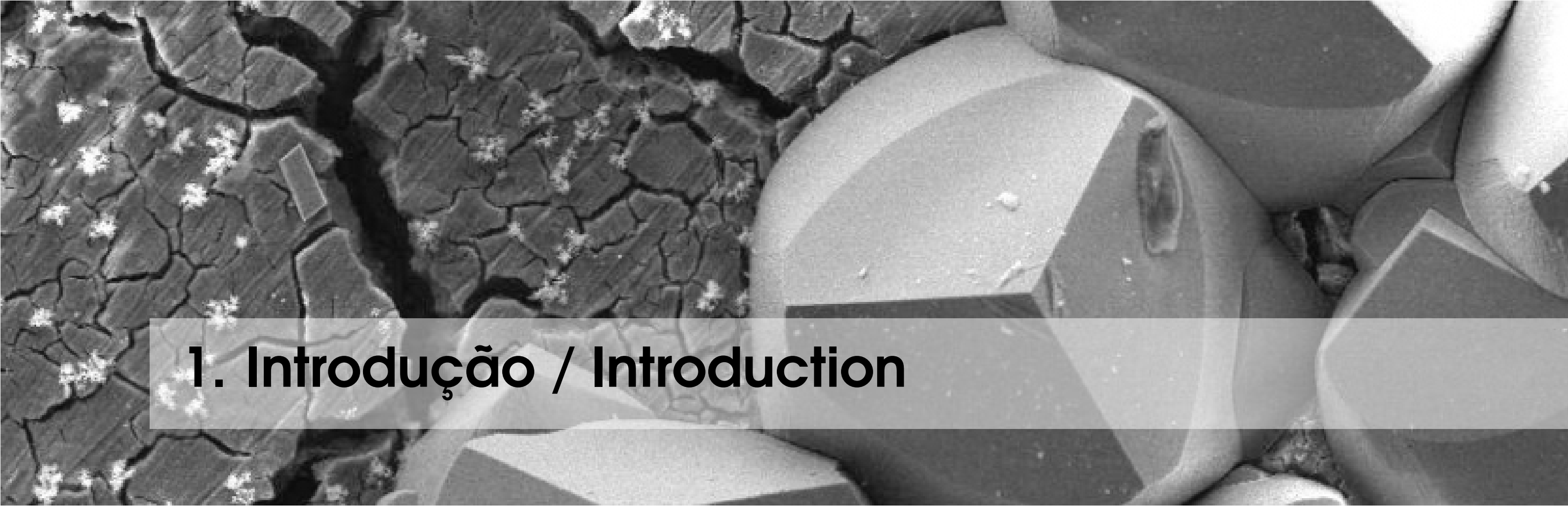
Cover: Crystals of iron carbonate ($FeCO_3$) precipitated over a layer of cracked corrosion products formed on steel UNS K41245 grade T5 (5 % Cr) exposed to NaCl/CO_2 (Sweet Corrosion). Images obtained by secondary electron in a Scanning Electron Microscopy. Picture obtained from webpage `http://www.ipt.br/solucoes/289-microscopia_e_analise_metalografica.htm`.

May 28, 2017

Conteúdo / Contents



1. Introdução / Introduction

A UERJ passou por uma grande crise financeira em 2016, atingido os três setores fundamentais da universidade: graduação, pós-graduação/pesquisa e extensão. O PPG-EM / UERJ manteve suas atividades de pesquisa e educação com a produção de treze seminários realizados neste ano, somando um total de 20 trabalhos de alto nível científico apresentados no contexto de Seminários do PPG-EM. A exposição desses trabalhos contribuiu intensamente para a integração dos grupos de pesquisa do PPG-EM. Os resumos de cada apresentação estão reunidos neste *book*. Dos 20 resumos, 12 artigos compactos (de 2 páginas) foram gerados, os quais compõem também esta publicação.

A motivação que permitiu a continuação das atividades acadêmicas em condições tão adversas foi o esforço contínuo de professores, técnicos e alunos que atuam diretamente no PPG-EM, reforçando que atividades científicas são necessárias para o desenvolvimento econômico, político e social. José Goldemberg, em artigo publicado na revista Science (Goldemberg, 1998), discute qual é o papel da ciência em países em desenvolvimento, analisando diferentes modelos para a rota pesquisa pura $\rightarrow$ desenvolvimento tecnológico $\rightarrow$ produção e mercado. Nos três modelos analisados por Goldemberg, a pesquisa aparece como base para se chegar à produção. Ele argumenta, no entanto, que a pesquisa não deve ser feita de forma estanque e nem tampouco se relacionar exclusivamente com o desenvolvimento tecnológico, mas deve caminhar de forma integrada com tecnologia e produção.

A coordenação do PPG-EM agradece a todos que contribuíram para mais esse ano de produção científica e incentiva todo pesquisador a se manter fazendo ciência objetiva e de alta qualidade, na certeza de que esta é a base para um fututo de desenvolvimento para Brasil.

UERJ underwent a major financial crisis in 2016, affecting several of the three fundamental sectors of the university: undergraduate, postgraduate / research and extension. The PPG-EM / UERJ continued its research and education activities with the production of thirteen seminars held this year, adding a total of 20 high-level scientific papers prepared in the context of PPG-EM Seminars. The exposure of these works contributed greatly to the integration of the PPG-MS research groups. The abstract of each presentation are gathered in this book. Of the 20 abstracts, 12 compact articles (of 2 pages) were generated, which also compose this publication.

The motivation that allowed the continuation of academic activities in such adverse conditions was the con- tinuous effort of teachers, technicians and students who work directly in the PPG-EM, reinforcing what scientific activities are necessary for the economic, political and economic development. social. José Goldemberg, in an article published in the journal Science (Goldemberg, 1998), discusses the role of science in developing countries by analyzing different models for the pure research $\rightarrow$ technological development $\rightarrow$ production and market research route. In the three models analyzed by Goldemberg, the research appears as the basis for arriving at production. He argues, however, that research should not be done in a watertight way, nor should it be exclusively related to technological development, but should be integrated with technology and production.

The coordination of the PPG-EM thanks everyone who contributed to this year of scientific production and encourages every researcher to keep doing objective and high quality science, in the certainty that this is the basis for a future of development to Brazil.

[Gol98] José Goldemberg. "What is the role of science in developing countries?" In: *Science* 279.20 (Feb. 1998), pages 1140–1141. URL: `science.sciencemag.org/content/279/5354/1140` (cited on page 7).

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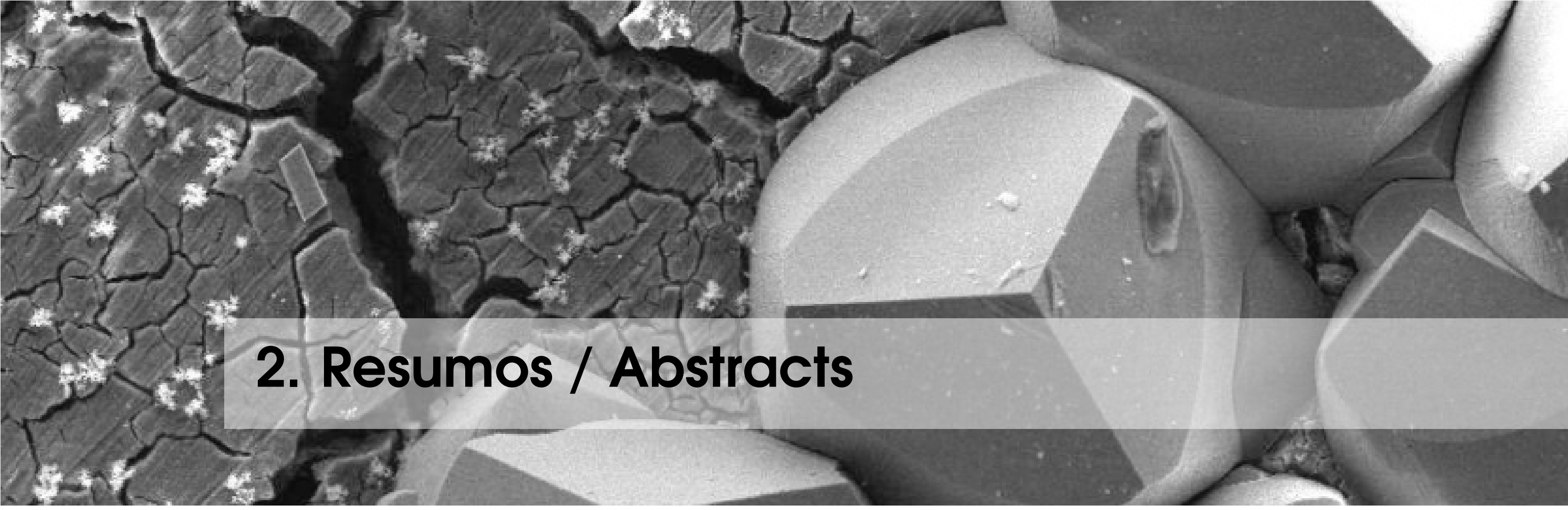

2. Resumos / Abstracts

Neste capítulo são apresentados os resumos dos vinte trabalhos científicos que fizeram parte dos Seminários do PPG-EM em 2016. Os resumos estão organizados segundo a data de apresentação.

This chapter presents the abstracts of the twenty scientific works that participated in the PPG-EM Seminars in 2016. Abstracts are organized according to the date of presentation.

2.1 1° SEMINÁRIO / 14-mar

NUMERICAL SEQUENCES IN SCIENTIFIC COMPUTING: Half Functional Analysis, half Philosophy look

Carlos A. de Moura
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The mathematicians real line is a deep theoretical concept. Its use in computer simulation is backed by the floating point "real" line theory, which has been incorporated to Numerical Analysis since its early days, by Wilkinson and von Neumann. Nevertheless, there exist still some blurred questions about computer simulation of real sequences convergence. These may either puzzle mathematical philosophy dwellers, like R. Hersh, or lead to some worries related to the very convergence proving. The latter ones are backed by Functional Analysis techniques, and may carry out the "false convergence" danger, as will be discussed.

2.2 2° SEMINÁRIO / 7-abr

Validation of experimental rig with emphasis on dynamic phenomenon of rotors

Paulo Roberto Farias
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PPG-EM / UERJ

The dynamic behavior of rotating mechanical systems type shaft-disc-bearing (rotor) is an object of research in mechanical engineering since the early twentieth century. The approach taken in this paper makes use of finite element analyzes. The experimental rig consists of a horizontal rotor driven by an electric motor and a frequency converter, which aims to simulate rotary machines providing a learning environment in rotor dynamics phenomenon that can occur in real machines. The first part of this study is to identify the six main natural frequencies and modes of rigid body vibration. The second part focused on the horizontal rotor, modeled through a specific software developed for analysis of rotors, where you can check the critical frequencies, examine the shapes of vibration modes according to the rotations and generate the Campbell diagram for analyses of other characteristics of system.

2.3 3° SEMINÁRIO / 5-mai

Aplicações de microscopia com feixe de íons focalizados

Suzana Peripolli
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A técnica de Feixe de Íons Focalizados (FIB) é utilizada para a investigação dos mais diversos materiais, com ênfase em caracterização de materiais, e aplicações em micro e nanofabricação.

2.4 4° SEMINÁRIO / 2-jun

Nonlinear dynamics, chaos and control of smart bioinspired systems

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Inspired by nature, researchers are trying to create systems and structures that present adaptive behavior according to its environment. The use of nature as an inspiration has the objective to extract design principles from biological systems. Among many options of smart sensors and actuators, shape memory alloys (SMAs), piezoelectric and magnetostrictive materials are some interesting options. Due to their remarkable properties, smart materials have been used in many areas of human knowledge. This seminar presents some smart material system applications and their thermomechanical behaviors. It is discussed constitutive models that explore phenomenological features of the thermomechanical response of smart materials. This constitutive model is employed in order to describe some interesting behaviors and potential applications of smart devices involving dynamical behavior. Adaptive structures and origami systems are discussed. In this regard, it should be highlighted their rich response including chaos and attractor multistability. Chaos control is also employed showing situations where tiny perturbations can avoid undesirable behaviors.

Radiotracer techniques for industrial and environmental measures

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Radiotracers techniques highlights are to be an absolute and non-destructive measurement. The main application is calculations of flows in pipelines or rivers, and identify problems in industrial mixers. The disadvantages are the specific instruments measures and radioactive aliquot, which require a reactor to proper activation or buying of the radiotracer.

2.5 5° SEMINÁRIO / 7-jul

Update on HVAC design for laboratory

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The concern for the protection of health and safety of laboratory occupants makes the HVAC design extremely restricted. But also, it is essencial to take into consideration the conditions of thermal comfort, temperature

of laboratory work processes and energy efficiency of the system. Soon, choosing the best HVAC system becomes quite difficult, since each laboratory has its own working methods. This study presents a compilation of standards and guidelines for operation, control and assumptions for design the HVAC system. Also, a model is proposed to guide the collect of laboratory data operation, as well is presented a methodology for analyzing the choice of the most efficient air conditioning system. This method takes into account the type and control of air distribution and the configuration of central water chilled.

2.6 SEMINÁRIO EXTRA / 31-ago

The Role of Mathematical and Computational Modelling in Stent Development

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Stents are tiny scaffolds which are used to widen arteries where the blood flow has become restricted. The most common use of stents is in treating coronary heart disease. These stents are now typically coated with a drug to reduce inflammation and are therefore called drugeluting stents (DES). Over the past decade, various generations have emerged which include biodegradable polymer coated, polymer-free and bioresorbable stents. Whilst current DES generally perform well, researchers across academia and industry are engaged in trying to design better stents which can address important concerns such as delayed healing and can be used in patients with more complicated disease.

Traditionally, a purely empirical approach has been adopted by manufacturers in designing new stents. This is an extremely costly process and there have been instances where stents have been shelved at a late stage of development due to poor results. There is a growing recognition within the community that a truly multi-disciplinary approach is required to design the next generation stents, with mathematical and computational modelling playing a key role. Indeed, ideas from several branches of mathematics are required to successfully tackle this problem. Currently, a number of approaches are being adopted, including methods from continuum mechanics and mathematical biology, inverse problem theory, structural and soft tissue mechanics, numerical analysis and multi-objective optimisation. In modelling drug transport, which is the focus of this talk, analytical/semi-analytical and asymptotic approaches to solving coupled systems of advection-diffusion-reaction equations have been considered, moving boundary problems have been defined, and finite difference/finite element methods have been devised to cope with increasing complexity.

The purpose of this talk is three-fold. Firstly, it aims to provide a flavour of the purpose and evolution of stents and the modelling approaches that have been adopted thus far [1]. Secondly, a case study will be presented from our own group, which demonstrates how mathematical modelling has influenced the design of a novel drug-eluting stent [2]. Thirdly, the remaining challenges in the field will be discussed, which if overcome will allow for the design of optimized next generation DES.

2.7 6° SEMINÁRIO / 15-set

Posicionamento aproximado do estado final de sistemas térmicos descritos pela equação do calor linear

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Neste trabalho, será considerado um problema de controle ótimo quadrático para a equação do calor linear em domínios retangulares com condição de fronteira do tipo Dirichlet e nos quais a função de controle (dependente apenas do tempo) constitui um termo de fonte. Também analisa-se a inclusão de uma condição de restrição no valor máximo na norma da energia do funcional de controle. Uma caracterização da solução ótima e obtida na forma de uma equação linear em um espaço de funções reais definidas no intervalo de tempo considerado. Em seguida, utiliza-se uma sequência de projeções em subespaços de dimensão fi

nita para obter aproximações para o controle ótimo, cada uma das quais pode ser gerada por um sistema linear de dimensão fi

nita. A sequência de soluções aproximadas assim obtidas converge para a solução ótima do problema original. Finalmente, são apresentados resultados numéricos para dom ínios espaciais de dimensão 1 e 2.

Otimização estrutural de torre para aerogerador utilizando a interface ANSYS-MATLAB

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Com o aumento do consumo de energia e com a progressiva degradação do meio ambiente, evidencia-se a necessidade de investimentos em pesquisas que busquem aprimorar fontes de energia renovável. A utilização da energia eólica como fonte alternativa é vista como uma ótima opção e vem aumentando gradativamente em diversos países. Neste trabalho é implementada uma técnica de otimização, com base no Algoritmo Genético (GA), através da interface ANSYS-MATLAB. A análise por elementos finitos realizada pelo ANSYS é integrada ao algoritmo executado pelo MATLAB. Este trabalho tem como objetivo a otimização estrutural de uma torre eólica modelo MM92 da Repower, buscando minimizar o volume total da torre respeitando as restrições relativas ao comportamento estrutural: tensão e deslocamento máximos.

2.8 7◦ SEMINÁRIO / 22-set

Teoria espectral em espaços de Hilbert

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Nesta palestra, enunciaremos os principais resultados no estudo dos operadores lineares em espaços de Hilbert, tendo como objetivo apresentar a teoria espectral. Em particular, veremos que os operadores compactos e auto-adjuntos em espaços de Hilbert são diagonalizáveis.

História da análise: o surgimento da matemática pura

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O aluno que cursa as disciplinas de matemática nas universidades de modo geral, não identifica com seu dia a dia, em muitos casos nem mesmo com os conteúdos apresentados na escola. Mas nem sempre foi assim. O próprio conceito de função que conhecemos nos dias de hoje, é datado do século XIX. Quando olhamos para os primórdios do estudo das funções os testos de Newton e Leibniz geralmente para apresentar os conceitos de derivada e integral, vinham acompanhados de descrições físicas. O presente trabalho tem intuito de divulgação cultural e apresenta de forma leve como se deram as transformações do Cálculo informal do mundo físico ao Rigor da Análise Matemática.

2.9 8◦ SEMINÁRIO / 27-out

OpenFOAM e suas aplicações na indústria e na academia

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O OpenFOAM é um software usado para resolver equações diferencias parciais, com enfoque principal na área de dinâmica de fluidos computacional (CFD). O OpenFOAM surgiu em 2004 quando foi aberto o código fonte do FOAM. De lá para cá houve um enorme crescimento de usuários, que além de usar os solvers e utilitários disponíveis no software, participam de seu desenvolvimento. Atualmente, o software dispõe de solvers para solução de físicas bastante variadas e complexas, que vão de escoamentos Newtonianos, não-Newtonianos e viscoelásticos, a escoamentos do tipo incompressível, compressível, turbulento, multifásico, reativo, transferência de calor e massa, etc. O software também é atualmente bastante usado na academia e na industria. Nessa palestra serão apresentados de forma geral aspectos relacionados a estrutura do software OpenFOAM e algumas de suas aplicações na indústria e academia.

Heart diseases and stent technology in brazil: panoramas, outlooks, challenges. how much interdisciplinary is all that?

Gustavo Peixoto
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This talk will present a panorama on heart diseases in Brazil over the last years through facts and figures, especially coronary artery diseases, as well as a summary on the main groundbreaking advances as to the incorporation of drug-eluting stents (DES) both into public and private health care systems in the country. The interplay between interventional cardiology, mathematics and engineering will be addressed. Research issues encompassing hemodynamics, structural mechanics and drug transport will highlight some of the current challenges in stent design. In a word, we pose the question: how much interdisciplinary is all that?

2.10 9° SEMINÁRIO / 10-nov

Avaliação de técnicas não convencionais de análise de vibração, para detecção de defeitos em maquinas rotativas horizontais

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Em termos populares, tem sido dito que: “as máquinas falam e através dos seus sons e vibração podemos ouvir suas queixas e diagnosticar suas doenças”. Este trabalho tem o objetivo de avaliar algumas técnicas não convencionais de análise de vibração para detecção de defeitos em máquinas rotativas. Técnicas especiais como: Full Spectrum, SPM, Orbita, Análise de fase / ODS e Envelope, foram aplicadas numa bancada experimental que permite introduzir diversos defeitos nos mecanismos presentes, como: desalinhamento, desbalanceamento, defeitos em engrenagens, problemas em rolamentos, etc. Os resultados obtidos através de cada técnica foram avaliados e comparados. A análise final é expressa utilizando o método da lógica digital para criação de tabelas comparativas, sendo possível identificar qual técnica é mais eficiente para diagnosticar cada tipo específico de defeito.

Numerical simulation of fins in a high temperature environment

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The present work shows the influence of the dependence between the temperature and the thermal conductivity on the effectiveness of finned surfaces. Numerical simulations are carried out through a sequence of linear problems, possessing an equivalent minimum principle, that has as its limit the solution of the original problem. The presented tools allow the employment of more realistic hypotheses. The problems are simulated

with the aid of a finite element approximation. This work accounts for the the steady state heat transfer process in a rigid fin which experiences convective and radiative heat exchange. The approach employs triangular finite elements. The numerical results are compared with the ones obtained with the usual constant thermal conductivity. Results indicate that thermal conductivity can significantly impact the actual heat transfer response of a fin.

2.11 10° SEMINÁRIO / 24-nov

Solution of extended Grätz problem by Integral Transform with orthotropic duct

Lucas Coelho
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There is a growing interest for applications of heat and mass transfer in orthotropic ducts. Studies have been proposed for investigating the problem and how these issues affect heat and mass transfer characteristics. In the realm of simulation studies for heat transfer in ducts, this paper proposes a comparison between hybrid solution strategies for solving the conjugate heat transfer in a axysimmetric duct made of an orthotropic material, which mechanical properties vary in two main directions, where there is also an internal flow in the channel. The permanent regime has been considered for this problem. The final objective will be the analysis of the temperature distribution for this case. The formulation to be employed is the Integral Transform Technique which in the realm of analytical-numerical methods, has been playing a big role. It deals with expansions of the sought solution in terms of infinite orthogonal basis of eigenfunctions, keeping the solution process always within a continuous domain. The resulting system is generally composed of a set of coupled differential equations which can be solved analytically. An analytical solution is proposed through the application of a matrix method. However, a truncation error is involved since the infinite series must be truncated to obtain numerical results. This error decreases as the number of summation terms (truncation order) is increased, and the solution converges to a final value. Due to the series representation nature of the Integral Transform Technique, the estimated error can be easily obtained, which results in better global error control of the solution. The disadvantage associated with this approach is the need for more elaborate analytical manipulation. This effort can be greatly minimized with the use of symbolical computation. A classic second order Finite Differences Method (FDM) is also developed in this work in order to validate and compare the results. The presented results can serve as guidance for choosing an optimum solution methodology for this type of problem.

2.12 11° SEMINÁRIO / 8-dez

Internet das Coisas: características e desafios técnicos

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LCC/IME/UERJ

A Internet das coisas vai expor dados gerados por um enorme número de dispositivos através de serviços aplicações. Estes dispositivos, como sensores e atuadores industriais e domésticos podem ter diferentes interfaces, protocolos de interação, e semântica dos dados. A integração manual destes dispositivos torna-se inviável. Garantir o acesso escalável, seguro e controlado é também uma questão importante. Nesta apresentação são discutidas características e desafios técnicos para se construir uma infraestrutura de software para a Internet das Coisas e suas aplicações. Também são apresentados trabalhos em andamento no LCC - Laboratório de Ciência da Computação, como "cartão de visitas" para futuras colaborações.

2.13 12° SEMINÁRIO / 15-dez

Bandas de Cisalhamento Adiabático (ABS) como mecanismo de perda de massa por erosão devido a impactos de partículas duras em aço inoxidável duplex UNS S32205 - Simulação por Elementos Finitos.

Maria Augusta Minguta de Oliveira
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PPG-EM / UERJ

Devido as perdas econômicas decorrentes da deterioração de materiais de engenharia em serviço, o estudo da tribologia vem merecendo cada vez mais atenção dos pesquisadores da área de mecânica e de materiais. No caso de desgaste por erosão de superfícies metálicas por impacto de partículas ainda oferece oportunidades de pesquisas, especialmente quanto aos mecanismos que podem explicar os fenômenos relacionados à perda de massa que caracteriza a erosão. Um mecanismo sugerido baseia-se em estudos de balística, onde impactos de projéteis criam inicialmente uma condição de compressão dinâmica localizada, nas superfícies atingidas. Na subsuperfície das áreas de impacto ocorrem transformações estruturais, com a formação das chamadas Bandas de Cisalhamento Adiabático (ASB), que são percursoras de fratura. O presente estudo visa estudar o fenômeno por meio de simulações por elementos finitos, empregando o software ABAQUS. Tal escolha facilitará comparações com resultados experimentais de erosão em aço inoxidável duplex, não só os já obtidos em estudos correlatos, mas também os descritos na literatura, podendo validar as simulações feitas.

Pipes Coatings for Boiler that Generate Steam From Mineral Coal Burning

Pamella Keseller de Campos
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Brazilian thermoelectric plants use the pulverized coal combustion in boilers and the low calorific value of the coals requires a high volume of coal. The pipes in the boilers are subject to high temperature and erosion caused by the gas and particulate fluxes resulting from the burning of the coal. Considering the high ash content in the coal and the metallic parts of the interior of the boiler and especially the water wall pipes which undergo severe wear, a process occurs which reduces the thickness of the pipes and, consequently, Increase the frequency of perforations causing unit unavailability. One way to minimize occurrences caused by pipe wear is to coat critical boiler regions.

Estudo de Escoamento Multifásico com partículas em um canal reto

Rodrigo Moura
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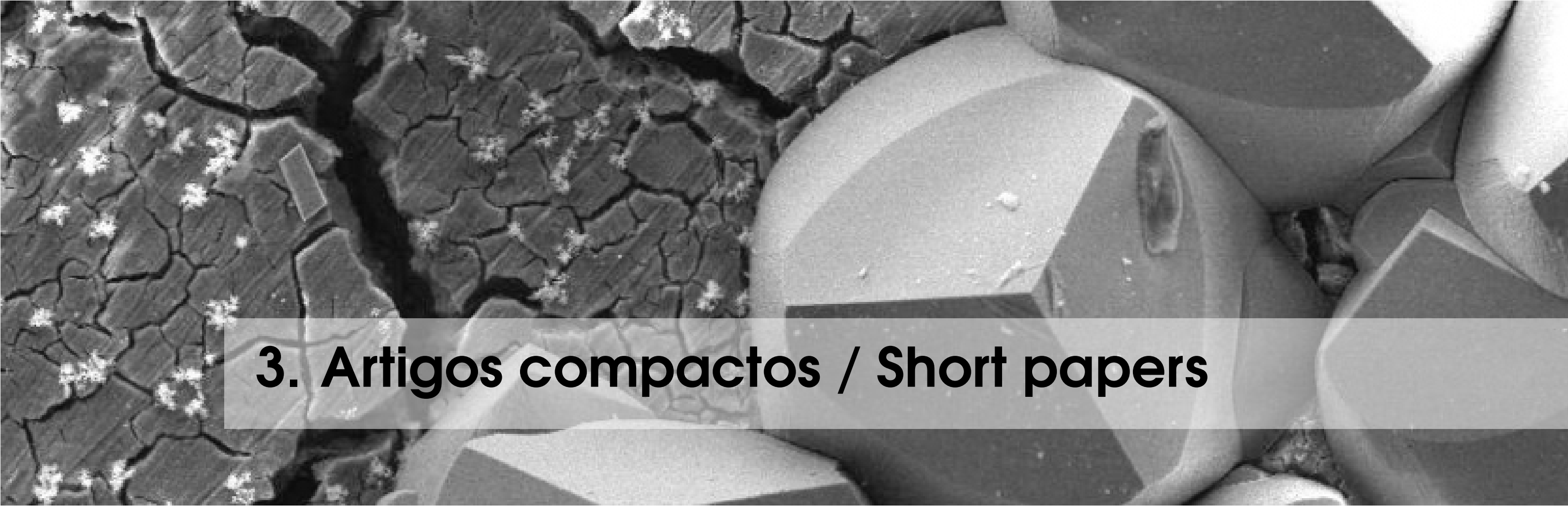
Nesse trabalho é estudado o escoamento multifásico em um canal reto. As equações de Navier Stokes é modelada para um fluido newtoniano para o caso 1D. O efeito turbulento do escoamento é descrito através da implementação dos métodos RANS e k-e para o escoamento. O método de diferenças finitas e utilizado para aproximar e montar o sistema linear das equações resultantes. A influência do escoamento sobre a fase dispersa é modelada utilizando a equação de Basset–Boussinesq–Oseen (BBO) considerando one-way coupling.



3. Artigos compactos / Short papers

Doze dos vinte trabalhos são apresentados em artigos compactos, que podem ser lidos neste capítulo.

Twenty of the vinte works are presented as short papers, which can be read in this chapter.

LISTA DE ARTIGOS COMPACTOS / LIST OF SHORT PAPERS:

Paulo Roberto Farias	Validation of experimental rig with emphasis on dynamic phenomenon of rotors
Vitor Ramos	Radiotracer techniques for industrial and environmental measures
Felipe Alfaia	Update on HVAC design for laboratory
Marlon Lopez	Approximate positioning of the final state of thermal systems described by the linear heat equation
Fernando Golçalves	Structural optimization of a wind turbine tower interfacing Matlab and Ansys
Alex Farah	Spectral Theory in Hilbert Spaces
Gustavo Peixoto	Heart diseases and stent technology in brazil: panoramas, outlooks, challenges. how much interdisciplinary is all that?
Marcelo Farias	Evaluation of unconventional techniques of vibration analysis for detection of malfunction in horizontal rotating machines
Rodolfo Sobral	Numerical simulation of fins in a high temperature environment
Lucas Coelho	Solution of extended Grätz problem by Integral Transform with orthotropic duct
Maria Augusta Minguta de Oliveira	Adiabatic Shear Band (ASB) as a mechanism of erosion by impact of solid particles in duplex stainless stell UNS S32205 - characterization and numerical simulation
Pamella Keseller de Campos	Pipes Coatings for Boiler that Generate Steam From Mineral Coal Burning

VALIDATION OF EXPERIMENTAL RIG WITH EMPHASIS ON DYNAMIC PHENOMENON OF ROTORS

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PPG-EM Seminars: season **2016**
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Introduction

The experimental rig consists of a horizontal rotor driven by an electric motor and a frequency inverter, and aims to simulate rotary machines providing a learning environment in rotor dynamics phenomenon that can occur in real machines[1]. The first part of this study is to identify the six main natural frequencies and modes of rigid body vibration of the set of non-rotating parts of the machine. The second part of the evaluation is focused on the rotor, modeled through a software developed specifically for the analysis of rotors, where you can check the critical frequencies, examine ways of modes according to the rotations and generate Campbell diagram for analysis of other resulting characteristics of the gyroscopic effect [2].

Figure 3.1: Experimental Rig

Method

The methodology consists primarily of support the approach of the dynamics of non-rotating parts of the structure supported on springs and also the rotating parts (rotor)[3].

$$M_r\left[\ddot{q}(t)\right]_r + (C_r + G_r)\left[\dot{q}(t)\right]_r + K_r\left[q(t)\right]_r = \left[F_{ext}\right]_r \qquad (3.1)$$

Secondly, tests and simulations were performed with the purpose of obtaining machine characteristics. Simulations and tests:

- Simulation of the 3D model by the finite element method
- Frequency sweep tests
- Tests with initial displacement application
- Tests with application of impact on the discs

Results

The analysis of the dynamics of non-rotating parts has as a result the main modes of machine vibration.

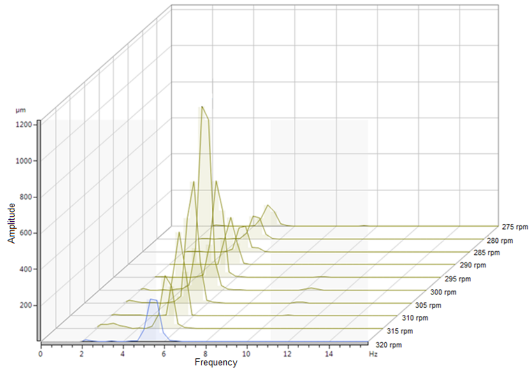

Figure 3.2: Test result to identify the translation mode in X direction. (Frequency sweep tests)

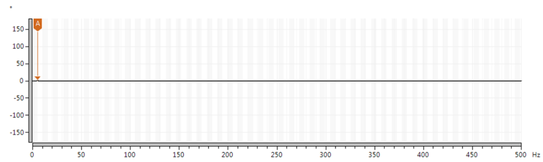

Figure 3.3: Test results to identify the translation mode in X direction. (Phase Spectrum)

Mode	Sweep Test (rpm)	Model Simulation (rpm)	Displacement Initial Test (rpm)	Average
Translation X	300,0	334,2	330,0	321,4
Translation Y	-	-	360,0	360,0
Translation Z	393,6	377,3	390,0	387,0
Rotation Z	431,4	433,8	450,0	338,4
Rotation X	506,4	480,6	510,0	499,0
Rotation Y	675,0	658,0	690,0	674,3

Table 3.1: Experimental and simulation results (non-rotating parts)

The rotor analysis begins with simulation results using the software ROTMEF® developed by CEPEL.

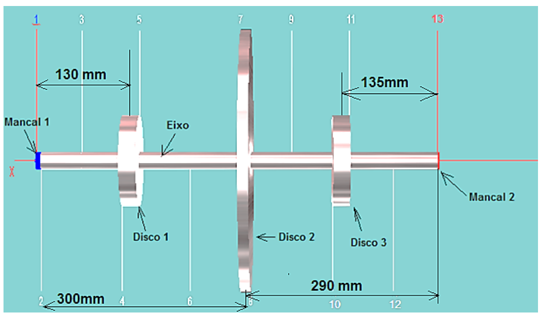

Figure 3.4: Rotor Model

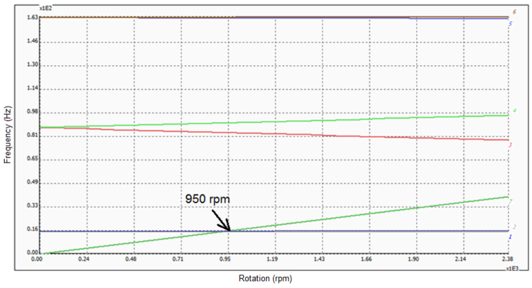

Figure 3.5: Campbell Diagram

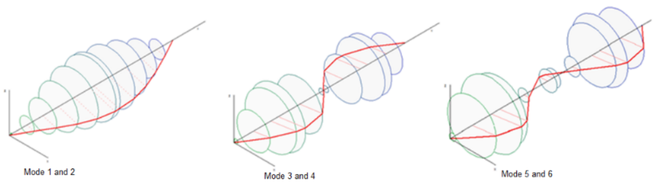

Figure 3.6: Modes Shape

The rotor dynamics analysis shows Full Spectrums and Orbits as a result of processing signals collected during the tests. By analyzing the results identifies the main rotor dynamics phenomena that the horizontal rotor presents.

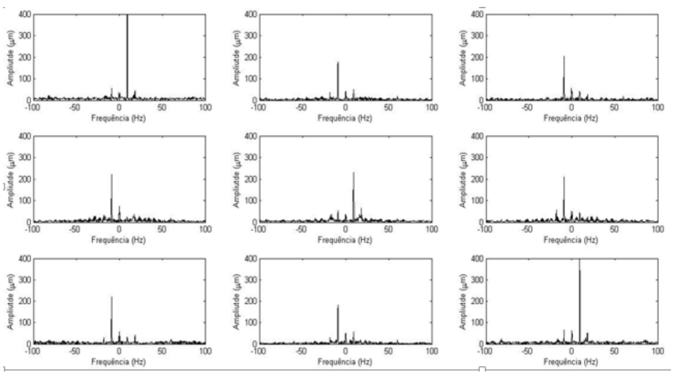

Figure 3.7: Tests results of first configuration in 550 Rpm (Full Spectrum Matrix)

Configuração 1 - 550 rpm - Frequências em Hz

1	Rotação	8,9	4	Rotação	9,1	7	Rotação	8,9
	Modo 1	-16,5		Modo 1	16,5		Modo 1	16,5
	Modo 2	16,5		Modo 2	-16,7		Modo 2	-16,7
	Modo 3	-82,3		Modo 3	-81,9		Modo 3	-82,9
	Modo 4	85,9		Modo 4	86,9		Modo 4	87,7
2	Rotação	8,9	5	Rotação	9,1	8	Rotação	9,1
	Modo 1	-16,1		Modo 1	-16,1		Modo 1	-16,3
	Modo 2	16,7		Modo 2	16,5		Modo 2	16,5
	Modo 3	-86,1		Modo 3	-81,9		Modo 3	-81,9
	Modo 4	91,1		Modo 4	86,7		Modo 4	88,5
3	Rotação	9,1	6	Rotação	8,9	9	Rotação	8,9
	Modo 1	-16,5		Modo 1	-16,1		Modo 1	-16,5
	Modo 2	16,5		Modo 2	16,5		Modo 2	16,7
	Modo 3	-81,9		Modo 3	-83,7		Modo 3	-81,9
	Modo 4	87,7		Modo 4	89,5		Modo 4	85,7

Table 3.2: Tests results of first configuration in 550 Rpm

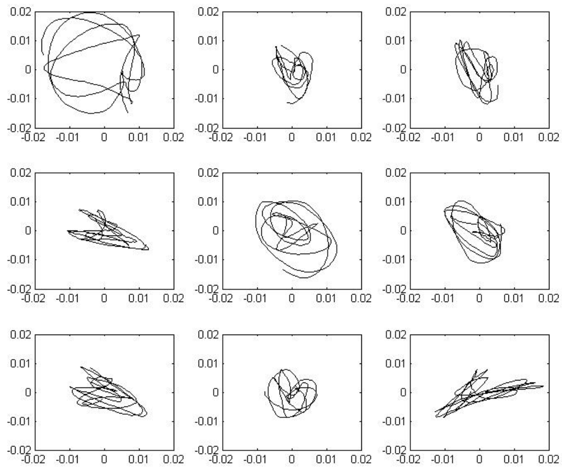

Figure 3.8: Matrix Orbits-Tests Configuration1-550Rpm

Conclusions

In the evaluation of non-rotating parts of the critical frequencies were identified as was also possible to correspondingly validating the first six vibration modes.

With respect to the horizontal rotor and the phenomena that the same features can be seen that the values are quite close to the values generated by Rotmef, then it can be concluded that the tests have expected results and about frequency analysis the gyroscopic effect can be observed and the presence of reverse modes by analyzing the full spectra.

It is considered that the horizontal rotor of the experimental rig has similar characteristcs of a real rotating machine and can be used for research and development in this field of mechanical engineering.

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RADIOTRACER TECHNIQUES FOR INDUSTRIAL AND ENVIRONMENTAL MEASURES

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June 2, 2016

Introduction

Tracers are materials that are added to the system of study in small quantities and are measured by special measures devices. The use of tracers in hydrology is very old, having been the most different types of tracers used sometimes artificially added directly into the system, and others, is used substances own system, from natural processes or accidental spills. The behavior of these tracers have hydrological parameters that characterize the system. Essential condition for this is that the tracer have similar to the system and to be analyzed behavior. Flow and dispersion measurements in rivers are daily practices, measures through various hydrological techniques, the most accurate and those using chemical tracers (fluorescent dyes) or radioactive (radioisotopes). There are many techniques for flow measurements, however, applied to each particular type of system. The dyes are good tracers, but their effectiveness decreases when the medium under study shows change in its pH, salinity, temperature, photo decay (fluorescence decreases with incident sunlight), the fluid viscosity and opacity. Regarding radioactive, the inconvenience is the acquisition of radiotracer that has restricted and controlled use. The choice of tracer is crucial in this study, therefore, a prior study is required for the system after choosing what the best tracer to be applied. The tracer must have physical/chemical characteristics similar to the studied system. There is a specific tracer technique for each type of systems that are found in industries or the environment, such systems have for example: industry mixers; complex systems, whose volumes are defined, such as ducts or partially filled volume variation; also confluent and divergent systems.

The aim of this paper is to present the practicality of tracer techniques, describing the stimulus and response technique applied in studies in systems in industries and the environment. As secondary objective will be described the methodology for flow calculation in transient ducts time.

Tracers

When studying the characteristics of a flow system is normally used to tracer technique consisting in adding a previously marked material, the system being studied it and observed moving in the middle. For the tracer behavior information (labeled population) in the middle represents the actual conditions of the main flow, it is necessary that the tracer must be the same features of the system. The main fluorescent tracers used are: Fluorescein, Rhodamine B. Since the radiotracer commonly used in liquid, Bromine-82, gaseous Iodine-123 and oils, Antimony-124 (IAEA, 1990).

Technical Stimulus Response

The tracer technique known as stimulus-response, where the stimulus is the tracer and the answer are the results of properly set specific meters (input and output system) are applied and can be associated with mathematical operators, where: $X(t)$ the input function (tracer injection); $Y(t)$ the output function (system response to the input stimulus); and $F(t)$ is the transfer function (system action depends on the internal process), as shown in the flowchart of Figure 1 and equation 1.

$$Y(t) = X(t)F(t)$$

Changes caused by the distribution of the tracer in the medium, as it moves through unit are process characteristics, but the

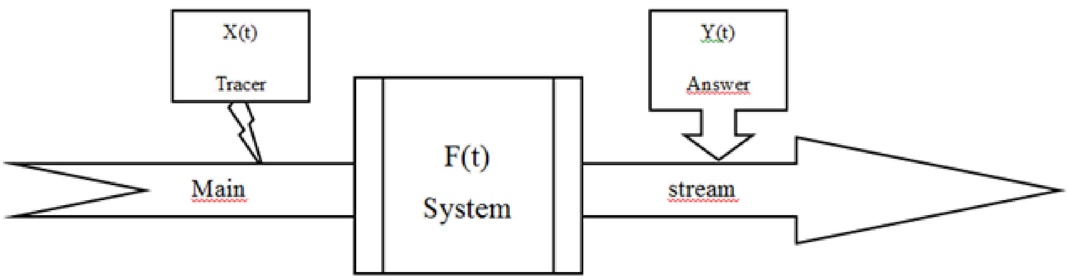

Figure 3.9: Scheme of the mathematical representation of the stimulus-response technique.

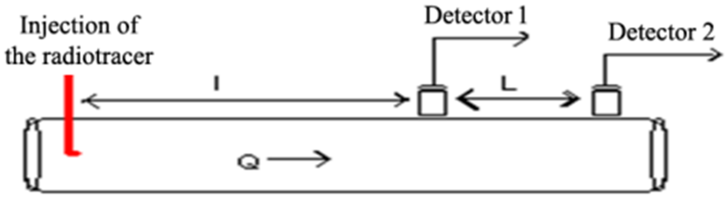

Figure 3.10: Schematic Arrangement of Transient Time methodology.

recorded response $Y(t)$ depends on both the system action, shown by $F(t)$, and the process injection of the tracer, given by $X(t)$. Thus we measured input and response by detectors, and solved the equation 1 for studying the system.

Time Transient Methodology

The flow of the fluid is measured from the difference between the tracer pulse signal measured at two different points. It consists of the injection of the tracer and after some distance, are positioned two detectors, which record the passage of the radioactive cloud. For the relationship between the two measurement points and the time difference of radioactive cloud passage between the two detectors is calculated from the displacement velocity of the fluid, and determines the flow rate by the product of fluid velocity and cross-sectional area straight pipe. Figure 2 represents schematically the experimental and equation 2 expresses the flow calculation (Ramos, 2006).

$$Q = \frac{\text{volume}}{\text{time transient}} = \frac{SL}{dt}$$

where S is the cross-sectional area of the duct, L is the distance between detectors and dt is the transient cloud passage time of the radiotracer by the two detectors.

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UPDATE ON HVAC DESIGN FOR LABORATORY

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Introduction

Since the supply crisis of the Brazilian electricity sector in 2001 and 2002 there was a strengthening of national understanding of the need for rationalization of electricity. From this issue, programs and standards have been developed with the aim to guide and standardize best practices in the use of electricity. According to the national energy balance of 2015 (MME, 2015), about 65.1% of electricity consumption is distributed between the industry, the trade and the public sector. A type of building that is present in these three sectors, are the laboratories. Therefore, as the HVAC system is about 40% of energy consumption of a building, good preparation of this type of design become essential for national energy consumption.

Design Methods

According to NFPA 45 (2004) (NFPA, 2004), laboratory HVAC systems can not operate with air return, as it must be avoided the distribution of chemicals. Because of this assumption, the TSI Corporation (2014) (Incorporated, 2014) identifies four types of methodology for the preparation of HVAC projects for laboratories. The methods are:

- Method for constant air volume (CAV): estab that the flow of air blown in the laboratory is constant. And the whole supply air is exhausted by a dedicated exhaust system or equipment such as fume hoods.
- Method for two positions: establishing that the air blown in the laboratory varies with the use of ambient exhaust systems (open or closed).
- Method for Variable Air Volume (VAV): estab that the flow of air blown in the laboratory is variable. And that their demand varies according to the temperature control and the demand for exhaust equipment such as fume hoods.
- Diversity Method: establishes the use of an operating schedule to the VAV method. An example of schedule is shown below.

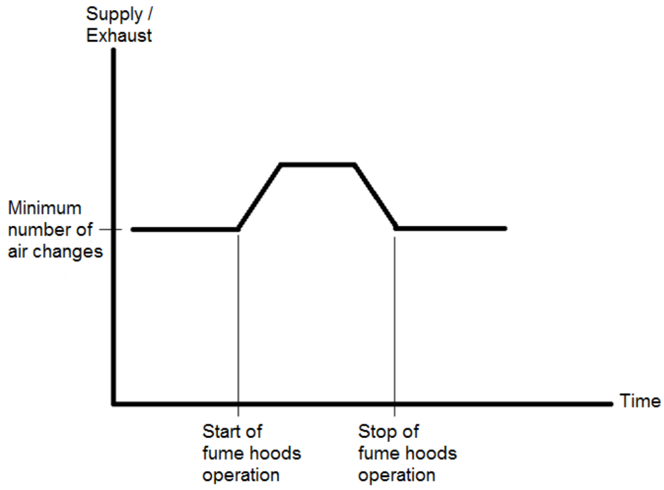

Figure 3.11: Schedule Example

Analyzing the four methods, it is concluded that the CAV is the methodology less expensive, because it has a smaller investment in automation. However, it is demonstrating the less flexibility and larger equipment, as these are designed for the maximum load of the system. Consequently this system has the highest consumption of electricity.

By contrast, the method of diversity is what has the highest cost of deployment. However, it is the one with the best flexibility and lower power consumption because it uses a sophisticated control system and variable frequency in the equipment.

Supply Air Design

The dimensions of the air to be blown in the laboratory is determined by the highest comparative value between:

- Air Changes: the standard NFPA 45 (2004) (NFPA, 2004) establishes the minimum supply air should be 8 volume changes per hour for inhabited environments and 4 trade volumes per hour for uninhabited environment. This analysis is important to ensure the dilution of contaminants in the laboratory.
- Pressurization: establishes the minimum amount required air to direct the supply air between the environments. This method is important because it ensures that laboratory environments are always in depression in relation to administrative environments, so that it can be avoided possible contamination by chemicals.

- Thermal load: establishes the minimum air to be blown to combat the thermal load demand environment. The thermal load is the sum of heats from equipment, lighting, people, envelopment and outside air. And the analysis of this factor ensures room temperature control and thus the thermal comfort of the user.
- Exhaust Demand: the supply air is dimensioned for the need of air to be exhausted in each fume hood. To estimate the exhausted air flow is important to determine the opening area of fume hoods and their simultaneity. Another important factor to be determined is the face speed of the fume hoods, this factor depends on the material being handled. OSHA (2001) (OSHA, 2001) recommended value of 0.5 m/s for volatile and 0.7 m/s to more dense substances.

Energy Efficiency

As the HVAC system uses a large volume of outside air, the use of energy recovery devices is interesting to minimize losses. Therefore, it is recommended to use the following equipment:

- Enthalpy wheel. This equipment uses an aluminum wheel with silica filler to do the heat exchange between the exhaust air (dry and cold) with the outside air (hot and humid). Thus there is a primary combat of the latent and sensible heat;
- Air-air plate heat exchanger. This equipment uses the temperature difference between the exhaust air (dry and cold) with the outside air (hot and humid). Thus there is a primary combat of the sensible heat;
- Heat tube heat exchanger. This equipment uses a capillary tube with titanium dioxide to do the heat exchange between the exhaust air (dry and cold) with the outside air (hot and humid). Thus there is a primary combat of the latent and sensible heat.

Conclusion

From the analysis of the various assumptions that can be used for the preparation of the project, it is concluded that the best approach is to use the diversity method, sizing the supply air by the exhaust demand and use of enthalpy wheels as energy recovery.

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UERJ — UNIVERSIDADE DO ESTADO DO RIO DE JANEIRO
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APPROXIMATE POSITIONING OF THE FINAL STATE OF THERMAL SYSTEMS DESCRIBED BY THE LINEAR HEAT EQUATION

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September 15, 2016

Introduction

Control problems for systems described by *linear evolution equations* (roughly speaking equations involving partial derivatives related to time and space coordinates) have received considerable attention in recent literature, see for example, (Bünsch and Benner, 2012) and its references.

In particular, the basic goal of achieving a desired end state from a given initial state has given rise to various problems of optimal control (in *open loop*) to parabolic equations in general and in particular for the heat equation. Such problems may include different types of boundary conditions (Dirichlet, Neumann and Robin) and the control can be acting on the border of the domain space considered or as a source term in the interior of the domain. Usually, these problems aim to obtain a *control function* defined (in a general sense) in both, a prespecified time interval as on the spatial domain in which the equation is defined, *i.e.* each time the control "signal" assumes a "value" of a function defined throughout the refered space domain.

An *open loop* control system consists of applying a control signal, $u(x,t)$, that is not calculated from a measurement of the output signal (*no feedback*), to a system o process, $\theta(x,t)$, and it is expected that the output of the controlled variable, at the end of a determined time, t_F, reaches a certain specified value, $\theta_{\text{Cont.}}(x,t_F)$.

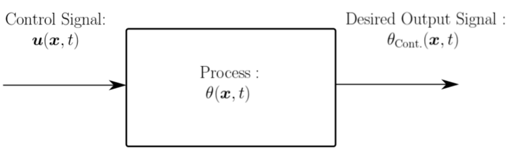


Figure 3.12: A General Open loop control system

Moreover, in view of potential applications, it is interesting to consider the case of control functions depending only on time, (each time the control signal assumes as a "value" a point in $\mathbb{R}^n$ for some n fixed *a priori*), whose action in space is defined by "actuators" used. In this work, it will be considered a quadratic optimal control problem for the linear heat equation in rectangular areas with a Dirichlet boundary condition type and in which the control function (solely dependent on time) is a source term. Also, an example of the $1-$D case with a restriction on the maximum value of u_K and an example of the $2-$D case without this restriction will be presented.

Optimal Control Problem

In order to see the formulation of an optimal control problem applied to the heat equation, for clarity, we take the $1-$D problem which is:
Find u such that

$$\min_{u\in L_2(0,t_F)^m} \mathscr{J}(u) \tag{3.2}$$

subject to:

$$\begin{aligned}
\frac{\partial\theta}{\partial t}-\alpha\frac{\partial^2\theta}{\partial x^2} &= f_u(x,t) \quad \forall x\in(0,L_x),\ \forall t\in(0,t_F)\\
\theta(x,t) &= 0 \qquad \text{for } x=\{0,L_x\},\ \forall t\in(0,t_F)\\
\theta(x,0) &= g(x) \qquad\qquad \forall x\in(0,L_x)\\
\|u\|_\infty &\leq \mu_u, \qquad\qquad \mu_u\in\mathbb{R}_+,
\end{aligned}$$

where $m\in\mathbb{N}$, α,t_F,L_x and $\rho_F\in\mathbb{R}_+$, $\mathscr{J}(u)=\|u\|^2_{L_2(0,t_F)^m}+\rho_F\|\theta_o(t_F;u)-\underline{\theta}_r(x,t_F)\|^2_{L_2(0,L_x)}$ and $f_u(x,t)=f_S(x,t)+\beta_S{}^{\mathrm{T}}(x)\,u(t)$. The function $\theta_o(t_F;u)$ *controlled function*, $\underline{\theta}_r(x,t_F)$ is the *desired final state function* and β_S is the *spatial distribution* function on which the control function acts in order to take the system to the desired state and $\|u\|_\infty=\max|u|$.

Approximate Positioning of the Final State

Since our main interests lies in the field of applications, it will suffice to find a procedure that gives us a reliable approximation, u_K, to the analytical solution, u, of our previous problem. Along these lines we present a suitable approximation. For complete details on how the following results were obtained cf. (Flores, 2014).

Matrix Form of the Approximate Control Function

The approximate control function that satisfies (3.2) subject to the given conditions, in matrix form is given by

$$u_K(\tau)=\overline{\beta}^{\mathrm{T}}_{SK}\blacksquare_K(t_F-\tau)\,\overline{\alpha}_K\in\mathbb{R}^m\ \forall\tau\in[0,t_F], \tag{3.3}$$

where m is the number of signals in the vector $\beta_{Sj}=[\langle\beta_{S1},\phi_j\rangle,\ldots,\langle\beta_{Sm},\phi_j\rangle]^{\mathrm{T}},j=1,\ldots,K$, where $K\leq K_a$ is the number of terms used to calculate the control signal and K_a is the number of terms chosen to calculate the "weak solution" of the heat equation, $\overline{\beta}^{\mathrm{T}}_{SK}=[\langle\beta_S,\phi_1\rangle,\ldots,\langle\beta_S,\phi_K\rangle]\in\mathbb{R}^{m\times K}$, where $\langle\beta_S,\phi_i\rangle=[\langle\beta_{S1},\phi_i\rangle,\ldots,\langle\beta_{Sm},\phi_i\rangle]^{\mathrm{T}}$ for $i=$

$1,\ldots,K$, $\blacksquare_K(t_F-\tau) = \exp[\mathbf{A}_K(t_F-\tau)] \in \mathbb{R}^{K\times K}$, $\overline{\alpha}_K$ comes from the solution of a *Sylvester* matrix equation. The matrix $\mathbf{A}_K = diag(-\alpha(k\pi/L_x)^2)$ and $\{\phi_k\}_{k=1}^{K} = \{\sqrt{2/L_x}\sin((k\pi x)/L_x)\}_{k=1}^{K}$.

Approximately Controlled Function

Since we obtained an approximate control function, u_K, then it is possible to define an approximately controlled function at time t_F, $\theta_{\text{cont.}}$, that also approximates to the analytical controlled function $\theta_o(t_F;u)$. This function is represented explicitly as

$$\theta_{\text{cont.}}(x,t_F) = \Sigma_{k=1}^{K_a}\widehat{C}_{\theta k}(t_F)\,\phi_k(x), \tag{3.4}$$

where $\widehat{C}_{\theta k}(t_F) = \widehat{C}_{Sk}(t_F) + \widehat{C}_{u_K k}(t_F;u_K(\tau))$. Explicitly we have $\widehat{C}_{Sk}(t_F) = g_k\exp[-\alpha(k\pi/L_x)^2 t_F] + \int_0^{t_F}\exp[-\alpha(k\pi/L_x)^2(t_F-\tau)]f_{Sk}(\tau)d\tau$, where $g_k = \langle g(x),\phi_k\rangle$ and $f_{Sk}(\tau) = \langle f_S(x,\tau),\phi_k\rangle$. The term $\widehat{C}_{u_K k}(t_F;u_K(\tau))$ comes from solving a *Sylvester* matrix equation involving the approximate controllable function u_K.

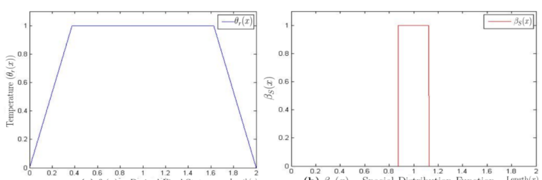
Restriction on the Maximum Value of the Control Function

The restriction $\|u\|_\infty \leq \mu_u$ is distributed throughout the system by means of quadratic programming optimization over the approximate functional $\mathscr{J}(u_K)$ with the given constraint μ_u.

Examples

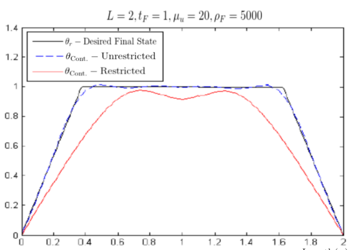
Example for the $1-$D Case with Energy Restriction

Approximate control of the linear heat equation for the $1-$D case with an desired final state function given by $\theta_r(x) = \begin{cases} \frac{8}{3}x & \text{if } 0 \leq x < \frac{3}{8}, \\ 1 & \text{if } \frac{3}{8} \leq x < \frac{13}{8}, \\ -\frac{8}{3}x + \frac{16}{3} & \text{if } \frac{13}{8} \leq x \leq 2, \end{cases}$ and using as spacial distribution function $\beta_S(x) = \begin{cases} 0 & \text{if } 0 \leq x < \frac{7}{8}, \\ 1 & \text{if } \frac{7}{8} \leq x < \frac{9}{8}, \\ 0 & \text{if } \frac{9}{8} \leq x \leq 2, \end{cases}$ with the restriction of $\|u\|_\infty \leq 20$ for $t_F = 1$.

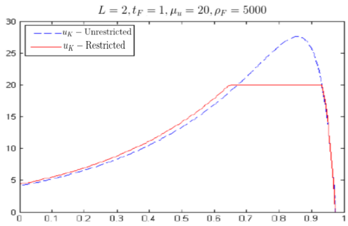


(a) $\theta_r(x)$ – Desired Final State. (b) $\beta_S(x)$ – Spacial Distribution Function

Results for the $1-$D case with restriction.



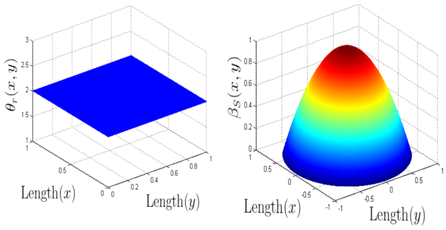
(a) $\theta_r(x)$ – Desired Final State.

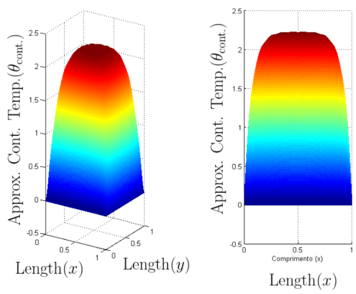


(b) u_K – Approx. Cont. Function

Example for the $2-$D Case without Energy Restriction

Approximation of the desired final state $\theta_r(x,y) = 2$ using the spacial distribution function $\beta_S(x,y) = -[(x-1/2)^2 + (y-1/2)^2 - 1]$ in the domain defined by $[0,1]\times[0,1]$.





Future Work

This model will be extended to cover more general boundary conditions, such as the Robin boundary condition.

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STRUCTURAL OPTIMIZATION OF A WIND TURBINE TOWER INTERFACING MATLAB AND ANSYS

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Introduction

Increasing energy consumption with simultaneous exhaustion of fossil fuels and rapidly progressing natural environment degradation caused countries to support renewable power industry. Current trends show that considerable technological progress related to the wind industry has been achieved over recent years.

Commercial wind turbine towers are about 100 m high and forces acting on them are very large in comparison to other types of towers. This causes the wind turbine tower to be expensive due to the large material consumption. Since wind power plants are manufactured in commercial scale even slightly change in the tower mass can lead to great savings. In accordance with the advance in size of turbines, tower optimization becomes more important, as towers account for 20–30% of the turbine cost.

This work aims to optimize the tower of a wind turbine REpower MM92 integrating the software MATLAB and ANSYS. The tower structure analysis will be carried out with ANSYS, which is a finite element software. The model was programmed in Ansys Parametric Design Language (APDL), taking into consideration the nacelle's weight and the wind loads. From the different optimization algorithms available in MATLAB, the Genetic Algorithms (GA) havs been selected to optimize the tower structure.

GA's can be described as search algorithms inspired from evolutionary biology, thus based on the mechanics of natural selection and natural genetics. They belong to a category of stochastic search methods, with an additional strength that randomized search is conducted in those regions of the design space which offer the most significant potential for gain.

Methodology

The wind turbine tower's structure was manufactured in steel and it has a conical shape. It is initially divided in three parts in order to make the assembly and the transportation easier. The diameter and thickness decrease from the base to the top of the tower.

The numerical model was created based on the Finite Element Method. It was programmed using the software ANSYS, wich became responsible for the static analysis during the process. Obtaining the maximum displacement and stress level was the analysis goal.

Structural optimization

A solution to an optimization problem specifies the values of the decision variables, and therefore also specifies the value of the objective function. This work aimed to optimize the volume by reducing the thickness of the tower, maintaining the diameter and height values. Two variables were adopted in this process:

- B: tower's base thickness
- C: tower's top thickness

The optimization was carried out under some structural restrictions. The constraints applied on the model followed the recommendation of (EUROCODE, 2004).

- Displacement restriction

$$\delta_{max} \leq 152cm \tag{3.5}$$

- Stress level restriction

$$\sigma_{max} \leq 255MPa \tag{3.6}$$

Finally the optimization problem can be stated as follows:

$$\begin{aligned} & \underset{x}{\text{minimize}} && f(x) \\ & \text{subject to} && g(x) \leq \delta_{max} \\ & && h(x) \leq \sigma_{max} \end{aligned} \tag{3.7}$$

Where:

x - Project variables
$f(x)$ - Tower volume
$g(x)$ - Tower maximum displacement
$h(x)$ - Tower maximum stress level

MATLAB-ANSYS interface

The following are the points summarizing the genetic algorithm and the interfacing process of ANSYS and MATLAB:

1. Initially the algorithm creates a random population.
2. This new population then becomes the parameter for ANSYS.
3. ANSYS is then run in batch mode from MATLAB, generating the output files.
4. The output files are read in MATLAB and the constraint conditions are checked.

5. If the check is satisfied then the volume is accepted, else MATLAB returns an invalid value.
6. The algorithm then creates a new sequence of populations. In every step, the algorithm creates a new population by reproducing the individuals in the current generation.
7. Finally the algorithm stops when any one of the stopping criteria is met, wich in this work was the MATLAB's default stop criteria.

Figure (3.23) is a schematic illustration of the structural optimization using the genetic algorithm that is implemented in MATLAB.

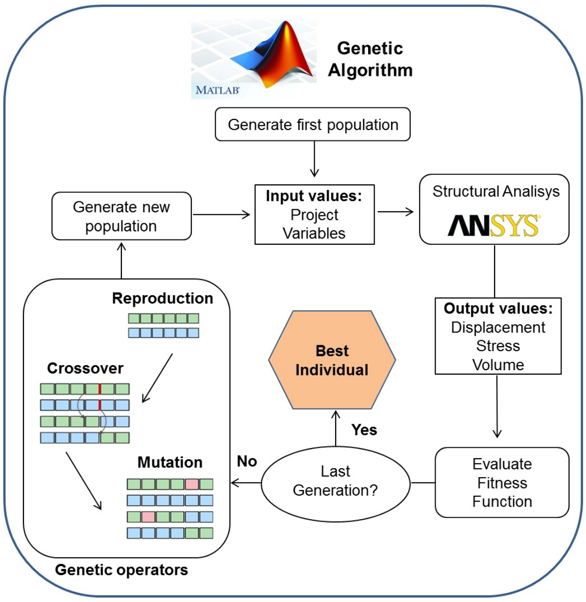

Figure 3.13: Genetic algorithm optimization interfacing MATLAB and ANSYS

Results and Discussion

The genetic algorithm searches for the different feasible thickness values inside the defined search that the space the fitness function is evaluated. The optimized values obtained by interfacing ANSYS and MATLAB using genetic algorithm are shown in Table3.3 and Table 3.4.

Table 3.3 shows that the optimization of the tower structure using the genetic algorithm generated a reduction of 53% of its volume. Thus, achieving less than the half of its original volume.

	Inicial value	Optimum value
B	$30mm$	$11,15mm$
C	$12mm$	$6,21mm$
Volume	$17,91m^2$	$8,41m^2$

Table 3.3: Optimum project variables values

Analysing the results in Table 3.4, it is possible to see that the maximum stress level supported by the tower in the end of the process represents 99.8% of the allowable value. It means that the optimum project variables achieved were satisfactory based on the optimization constraints.

	Optimum value	Allowable value
δ_{max}	$0,876m$	$1,52m$
σ_{max}	$254,6\ MPa$	$255\ MPa$

Table 3.4: Project restrictions values

Conclusions

The tower optimization using the genetic algorithm presented satisfactory results, providing a 53% volume reduction. Thus, applying this process in a large wind farm can be very profitable.

The optimization interfacing MATLAB and ANSYS proved to be an efficacious process. Since the interface demonstrated a high processing time, the projects need to be evaluated, however its behavior proved to be very satisfactory when it comes to structural optimization.

Acknowledgments

The author thanks CAPES for the financial support.

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SPECTRAL THEORY IN HILBERT SPACES

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Introduction

In Linear Algebra courses, we have learned that any linear transformation between spaces of finite dimension can be represented by a matrix. The reciprocal is also true, that is, a matrix defines a linear transformation between finite-dimensional spaces. Besides that, we know that if V is a finite-dimensional Euclidean space, then a linear operator $T : V \longrightarrow V$ is self-adjoint if, and only if, there exists an orthonormal basis of V formed by eigenvectors of T. In this case, the matrix of T in such a base is a diagonal matrix. However, in the case of V is a space of infinite dimension, we can not represent T through a matrix, which makes it difficult to study the operator T. The objective of this mini-article is to present the main results of this theory in infinite-dimensional spaces, in particular, the theorem of spectral decomposition for compact and self-adjoint operators.

Hilbert Spaces

Let E be a vector space of $\mathbb{K}$ (real or complex). The inner product in E is a function

$$\langle\cdot,\cdot\rangle : E \times E \longrightarrow \mathbb{K}$$

that satisfies:

(P1) $\langle x_1 + x_2, y\rangle = \langle x_1, y\rangle + \langle x_2, y\rangle \ \forall x_1, x_2, y \in E$
(P2) $\langle \lambda x, y\rangle = \lambda \langle x, y\rangle \ \forall x, y \in E\,,\ \lambda \in \mathbb{C}$
(P3) $\langle x, y\rangle = \overline{\langle y, x\rangle} \ \forall x, y \in E$
(P4) $\langle x, x\rangle > 0 \ \forall x \neq 0$

The pair $(E, \langle\cdot,\cdot\rangle)$ is called Euclidean space. A Hilbert space is a Banach sapce with induced norm by the inner product.

For instance, $\mathbb{C}^n$ is an Hilbert space (of finite dimension) with

$$\langle x, y\rangle = \sum_{j=0}^{n} x_j \overline{y_j}$$

where $x, y \in \mathbb{C}^n$ and $\ell_2 = \{(x_n)_n \in \mathbb{C}\,;\, \sum_{n=0}^{\infty} |x_n|^2 < \infty\}$ is an Hilbert space (of infinite dimension) with

$$\langle x, y\rangle = \sum_{n=0}^{\infty} x_j \overline{y_j}$$

where $x = (x_n)_n, y = (y_n)_n \in \ell_2$.

Let H be a Hilbert space. A subset S of H is a complete orthonormal system when S is an orthonormal set (that is, they are all unit vetor and orthogonal to each other) of H and $S^\perp = \{0\}$, where $S^\perp$ denotes the orthogonal complement of S. It is possible to prove that a set $S = \{x_i\,;\, i \in I\}$ is a complete orthonormal system in a Hilbert space H if, and only if, satisfies the so-called Parseval's Identity, that is, for all $x \in H$ we have

$$\|x\|^2 = \sum_{i\in I} |\langle x, x_i\rangle|^2.$$

It is important to note that the Gram-Schmidt orthogonalization process remains valid in Hilbert spaces of infinite dimension. In that way, it is always possible to obtain orthonormal bases in these spaces. What we can guarantee is even more: all Hilbert space admits a complete orthonormal system formed by eigenvectors of an operator $T : H \longrightarrow H$, where T satisfies some properties.

Spectral Theory

If V is a finite-dimensional vector space and T is an operator linear in V, then $\lambda \in \mathbb{C}$ is not an eigenvalue of T if, and only if, $(T - \lambda I)^{-1}$ exists. This comes from the fact that a linear operator T over a finite-dimensional space is injective if, and only if, it is surjective. In this case, or T is bijective or T is neither injective and surjective. In addition, T is a continuous operator. On an infinite dimension, the following questions arise: Let E be a normed space and $T : E \longrightarrow E$ a continuous operator in E. If λ is not eigenvalue, then we can state that $(T - \lambda I)$ is surjective? If so, can we say that $(T - \lambda I)^{-1}$ is continuous? We can not always get positivly answers from both questions. In this way we define:

- λ is a regular value of T when $(T - \lambda I)$ is bijective and its inverse is continuous.
- $\rho(T)$ is the set of regular values of T called resolvent set of T.
- $\sigma(T) = \mathbb{K} - \rho(T)$ is called spectrum of T.

If E is a Banach space, the Open Mapping Theorem guarantees that

$$\rho(T) = \{\lambda \in \mathbb{K}\,;\, (T - \lambda I)\,\text{is bijective}\}.$$

In this case, we must consider the concept of compact operators. An operator $T : E \longrightarrow E$ is said to be compact for every bounded sequence $(x_n)_n$ in E, a sequence $(T(x_n))_n$ has convergent subsequence in E. For example, integral operators are compact. Compact operators are very resemble those operators in finite-dimensional spaces since all operator is continuous and, moreover, the following result is worth: If E is a Banach space, $T : E \longrightarrow E$ is a compact operator and $\lambda \neq 0$, then $(T - \lambda I)$ is injective if, and only if, it is surjective. For spaces with infinite dimension, the diagonalization of an operator is presented by the;

Spectral Decomposition Theorem
for Compact and Self-Adjoint Operators:

Let H be a Hilbert space and $T : H \longrightarrow H$ a compact operator and self-adjoint. Then H admits a complete orthonormal system formed by eigenvectors of T. Moreover, there are sequences (finite or infinite) eigenvalues $(\lambda_n)_n$ of T and vectors $(v_n)_n$ such that each v_n is eigenvector associated with λ_n and

$$T(x) = \sum_n \lambda_n \langle x, v_n \rangle v_n.$$

The proof of this result requires exactly the study of the spectrum of these operators and can be found in any of the books cited in Bibliography of this mini-article.

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PPG-EM
PROGRAMA DE PÓS-GRADUAÇÃO EM ENGENHARIA MECÂNICA

HEART DISEASES AND STENT TECHNOLOGY IN BRAZIL: PANORAMAS, OUTLOOKS, CHALLENGES. HOW MUCH INTERDISCIPLINARY IS ALL THAT?

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Introduction

This paper presents a simple panorama on heart diseases in Brazil over the last years through facts and figures, especially coronary artery disease, summarizes the evolutionary trajectory of the drug-eluting stent (DES) technology and its lawful incorporation into Unique Health System - SUS, the public healthcare system in Brazil. Intended to promote a knowledge exchange between medical and applied sciences, the author singles out a couple of data obtained from health surveys regarding facts and figures that support the relevance of the scientific research for DES optimized design. We will see how a plethora of high-complexity challenges is demanding a wholesome handshake among cardiologists, mathematicians and engineers worldwide. Amid viewpoints and ongoing research issues, we hope to answer the question: after all, how much interdisciplinary is all that?

Cardiovascular diseases in Brazil

Coronary artery disease (CAD) and the acute myocardial infarction are among the main causes of obits in South America and especially in Brazil (Polanczyk and Ribeiro, 2009). Cardiovascular diseases (CVD) as a whole were responsible by 28% of them from 1996 to 2011, being the second most relevant cause (see Fig. 3.14). From 2000 to 2005, the National Centre of Cardiovascular Interventions (CENIC), an entity of the Brazilian Society of Hemodynamics and Interventional Cardiology (SBHCI) has registered 154,406 angioplasty procedures. DES were used in 10,426 percutaneous coronary interventions, i.e. 7% of total prothesis implemented in the period. From 2008 to 2012, the number of stent-based angioplasties was 543,937, i.e. an increase of 352% in relation to the previous period. The annual cost for cardiovascular treatment in 2004 was R$ 30,8 billion, of which 36,4% were related to direct medical costs. The estimated direct costs associated with acute coronary syndrome (ACS) for 2011, for example, reached R$ 522,286,726 for the SUS (0.77% of the total government healthcare budget), and the amount of R$ 515,138,617 for the Suplementar Health System. Indirect costs reach R$ 2.8 billion from the societal standpoint, with the total direct and indirect costs of ACS in Brazil for 2011 estimated at R$ 3.8 billion (Teich and Araujo, 2011).[1]

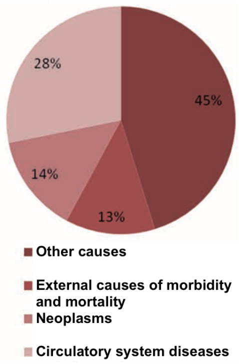

Figure 3.14: Main causes of deaths in Brazil (1996-2011). Adapted from (SUS–CONITEC, 2013).

According to a recent study published by the International Diabetes Federation, Brazil has the highest number of people with diabetes mellitus in South and Central America (ave. 14.3 million). The Diabetes Atlas shows that in the region as a whole, nearly 30,900 children aged < 15 amidst other 45,100 in the region affected by type 1 diabetes live in Brazil. Such index places the country as the third highest in the rank of children with type 1 diabetes in the world, coming after USA and India. In 2015, 247,500 adults died as a result of diabetes in the region. Over 42.7% of these deaths occurred in people aged < 60 and half of the obits occurred only in Brazil (130,700). This figure explains why the country spent at least US$ 21.8 billion to combat diabetes.

Stents, interventional cardiology and applied sciences

Since 1977, when the first angioplasty procedure was performed, several generations of stents have been being devised in growing levels of complexity. Until 2002, bare-metal stents (BMS) were the main devices used in interventional procedures. On the other hand, they were also known to generate inflammations and injuries over the artery walls. From 2003 and on, drug-eluting stents came up with a solution aiming to reduce the restenosis rate while releasing a drug that inhibits the proliferation of endothelial cells. Nowadays, we are getting to a new generation of DES, which appeals to a biodegradable concept based on polymer-free coatings, being classified as macroporous, micro-

[1] To the best of the author's knowledge, DATASUS is the main data source about the health status in the country, which was lastly fed after the National Health Survey 2013. Other figures were obtained in literature. References were omitted due to text limitation, but are available under request.

porous, nanoporous or of smooth surface. Figure 3.15 shows the Scitech Inspiron, a sirolimus eluting stent with abluminal coating and biodegradable polymer in a CoCr platform, the first DES made in Brazil under international standards.

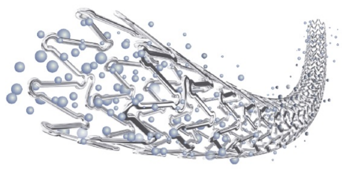

Figure 3.15: Scitech Inspiron: the first DES made in Brazil under international standards. (Source: http://goo.gl/iavAiO)

Although DESs had already been used in Brazilian patients earlier, its incorporation into SUS budget took place only on 2014. By means of its Report 111, the National Commission for Technology Incorporation (CONITEC), governmental entity liable for advising the Brazilian Health Ministry as to incorporation, exclusion or modification of health technologies and clinical protocols into SUS, decided to recommend the incorporation of DESs for a limited class of people and clinical scenarios. Such incorporation was legally concluded on August 27th through Portaria MS 29/2014.

DES design optimization is by far complex and requires much attention not only from the medical community, but also from mathematicians and engineers in several frontlines (e.g. chemical, materials, mechanical) (McHugh, Barakat, and McGinty, 2015). Today, the use of *in vitro*, *in vivo*, *ex vivo*, *in silico* and mathematical models has enhanced understanding of DES mechanisms (McGinty et al., 2015). The challenges, in turn, encompass an interdisciplinary scope that includes, but is not limited to hemodynamics, porous media, fatigue and structural mechanics and CFD. All of them require not only experimental essays, but also theoretical models tailored to a determined situation and validated numerical modelling. In the next section, we navigate over a sea of opportunities regarding DES research.

Interdisciplinary research issues

Here we briefly list a series of issues that have been being investigated by researchers involved with DES. This broad and rich interdisciplinary scope also highlights the remarkable partaking of mechanical engineering for future community's achievements.

- hemodynamics: arterial wall shear stresses and flow metrics; non-Newtonian blood flow models, luminal protrusion and stent apposition;
- chemistry/materials: polymer-free coating; biocompatible materials and drugs; controlled drug release;
- mechanics: porous media properties (tortuosity); fracture, fatigue and structural integrity of stent struts; fluid-structure interaction stent/vessel; drug transport; pulsatile and disturbed flows CFD;
- mathematics: analytical models of drug release;
- manufacturing: laser technology; nanofabrication; design optimization; image processing and CAD modelling;

Conclusions

We have provided an overview on heart diseases and drug-eluting stent technology in Brazil. We assure that, given the wideness of open challenges, the interdisciplinary nature of this research is paramount and require the contribution of different expertises. The future of drug-eluting stents is promising and we hope that the interested reader be stimulated to find an effluent that may debouches into this vast sea of opportunities.

Acknowledgments

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EVALUATION OF UNCONVENTIONAL TECHNIQUES OF VIBRATION ANALYSIS FOR DETECTION OF MALFUNCTION IN HORIZONTAL ROTATING MACHINES

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Introduction

In popular terms, it has been said that “the machines speak and through sounds and vibration we can hear their complaints and diagnose their diseases”. The condition monitoring of rotating machines by measuring and vibration analysis is the process in which a machine is periodically evaluated by measuring and vibration analysis, and their conditions are checked using the vibration signals.

This monitoring can be carried out at three levels: 1- Overall measurement of vibration levels, to know the severity of vibration and compare with preset limits; 2- Frequency spectrum analysis to detect where it comes from vibration and possible defects; 3- Special techniques that can better detail the level, location and type of defect or malfunction. This study aims to evaluate some of these special techniques such as Full Spectrum, SPM spectrum, Orbit, phase analysis / ODS and Envelope. These techniques have been applied on an experimental rig for entering various defects in these mechanisms such as misalignment, imbalance, gear defects, problems in bearings, etc. The results obtained by each technique were evaluated and compared. The final analysis of the results is expressed using the method of digital logic for creating tables of comparative techniques for each type of defect, it is possible to identify which technique is best to diagnose a particular type of defect.

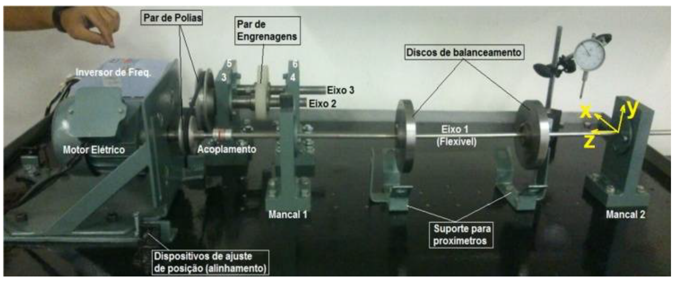

Figure 3.16: Experimental Rig.

Method

Experimental method was used to evaluate the following vibration monitoring techniques:

Conventional: RMS vibration level (severity) and also frequency and time dominium spectrum.

Orbit: The orbit (Bently, 2002) is the trajectory of the shaft center line of the pair of proximity sensors.

Full spectrum: The common frequency spectrum resulting from the application of the FFT transform on the time signal. But the full spectrum (Southwick , 1993) it is the spectrum of an orbit. It’s derived from the waveforms from the pair of proximity sensors , combined with knowledge of the direction of rotation.

Shock pulse: It is a signal processing technique used to measure impact of metals and rolling noise , such as Those found in ball bearings and gears . Unlike common vibration measurement, shock pulse does not measuring movement, but measure the impact that is propagated through the metal ultrasound frequencies.

Envelope: The envelope technique, also referred to as " amplitude demodulation " is the technique of extracting the modulation signal from an amplitude modulated signal.

ODS: It has been defined as deflection of a structure in a particular frequency. However, an ODS can be defined more generally as any forced movement of two or more points on a structure (Brian, 1999).

Phase: It can be regarded as a complement or part of the ODS technique. Certain types of defects generate phase differences known between two or more measurement points, helping to distinguish the specific defect type and the action that should be taken to correct.

Evaluation Method

The **digital logic method** has been used as a tool for the systematic evaluation of vibration analysis techniques. In this procedure , the reviews are arranged such that only two techniques are considered at a time. To determine the relative importance of each technique for each type of defect, comparative tables and results graphs are built.

Results

The results presented here are for the application of the mentioned techniques to defects of : Resonance , Unbalance and damaged bearings.

Resonance: To determine the natural frequencies, mode shapes, critical speeds and resonance, tests were divided into two different approaches: the first considering the entire assembly as a rigid body, and the second considering only the rotor system (disks, flexible shaft and bearings 1 and 2).

In rigid body approach we used 3 methods: Computer simulation MEF, frequency sweep and impact test. In the second approach we used Rotmef Software is a program that was developed specifically for rotor dynamics and software results for various configurations of discs and bearings positions were confronted with experiments that proved the natural frequency values.

Table 1. Results of resonance test of complete Rig.

Freq.	Computer Simulation (rpm)	Changing Rotation speed (Rpm)	Impact test (Rpm)	Modes
1	112,6	-	330	Linear Z
2	333,5	310,2	300	Linear X
3	367,3	387	375	Linear Y
4	440,54	452	450	Rotation Y
5	489,64	505	495	Rotation X
6	699,24	678	675	Rotation Z

Unbalance: The unbalance tests were divided into six stages, two conditions (balanced and unbalanced) for each of the three configurations: Static (B1, B2), dynamic (B3, B4) and balance (B5, B6). For testing of static unbalance was used configuration 1, with only one central disc on the drive shaft 1 between the M1 and M2 bearings spaced at 590mm.

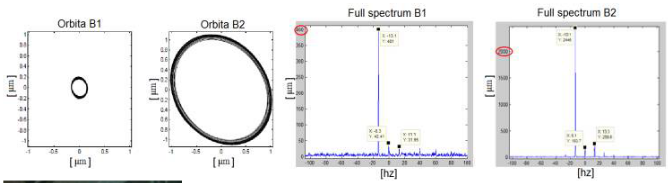

Figure 3.17: Orbit and Full spectrum for static unbalance test B1 and B2.

Bearing test: The defect in the bearing was generated using a small abrasive disc making a tear in the outer race to generate a hole on the inside of the bearing outer race. Rehearsals for bearing were divided into R1 (good bearing) and R2 (defective bearing).

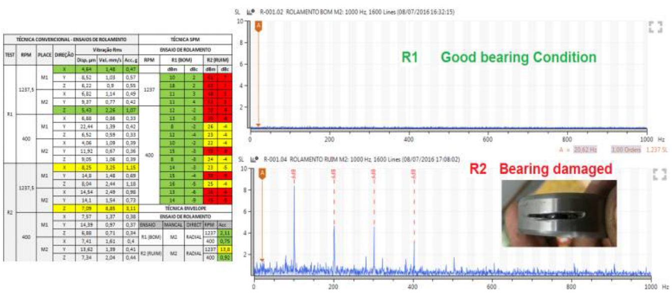

Figure 3.18: Results of bearing faults tests R1 and R2.

Conclusions

Through the preliminary analysis were constructed comparative tables of techniques for each type of defect using the method of digital logic. Through the tables it is possible to identify which technique is best applied to diagnose a specific type of defect. Table 2 and Figure 4 shows one of these tables and their respective graphic, which are examples of the final results in the evaluation of techniques for the selected defect unbalance.

DEFEITO DE DESBALANCEAMENTO	DECISÕES POSITIVAS POSSÍVEIS (N)															Decisões Positivas	Coeficiente relativo de ênfase(α)
TÉCNICAS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
CONVENCIONAL	0	0	1	1	0											2	0,13
FULL SPECTRUM	1					1	1	1	0							4	0,27
ORBITA		1				0				1	1	0				3	0,20
SPM			0				0			0			0	0		0	0,00
ENVELOPE				0				0			0		1		0	1	0,07
ANÁLISE DE FASE / ODS					1				1			1		1	1	5	0,33
Total de decisões positivas:																15	1,00

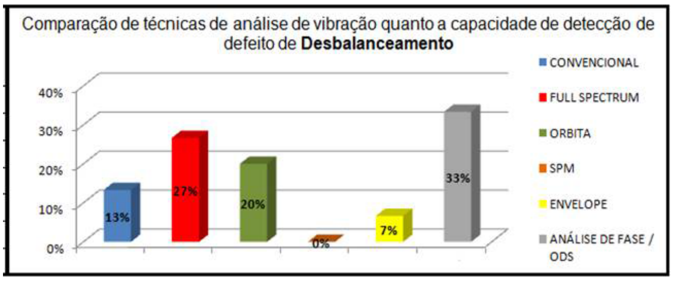

Figure 3.19: Final Graph of techniques evaluation for unbalance detection.

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NUMERICAL SIMULATION OF FINS IN A CONTEXT OF HIGH TEMPERATURES

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Introduction

The present work numerically investigates the coupled heat transfer performance for straight fin arrays including mutual irradiation between radiator elements. Numerical simulations are carried out through a sequence of linear problems, possessing an equivalent minimum principle, that has as its limit the solution of the original problem. This coupled conduction/radiation heat transfer process is an inherently nonlinear phenomenon, where this coupling on the body boundary is mathematically represented by a nonlinear relation between the absolute temperature and its exterior normal derivative, in which the unknown is the temperature distribution in the body. The solution to the problem is given by the limit of a sequence whose elements are obtained from the minimization of functionals. The problem is simulated with the aid of a finite element approximation.

Physycal model

Consider a heat sink with longitudinal fin of profile as shown in Fig. 1. The fin is attached to a primary surface at fixed temperature T_b and exchange heat by convection and radiation with the surrounding medium. The convective heat transfer coefficient over the exposed surface of the fin is assumed to be a constant. The heat loss from the tip of the fin compared to the lower part and finned side is assumed to be negligible. The heat conduction is assumed to occur solely in the cross-cut direction.

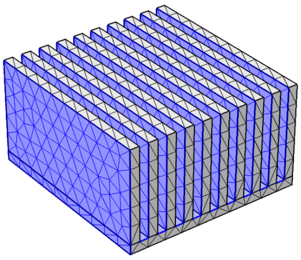

Figure 3.20: Longitudinal convecting-radiating copper fin

The material for the fin is chosen to be copper because of its high thermal conductivity. The investigation of heat transfer on finned surfaces has to be modeled by a bi-dimensional geometry as it is clear from Fig. 2.

Governing equations

The steady-state heat equation in a medium with temperature-dependent, inhomogeneous conductivity, such as straight fin in Fig. 2 is:

$$\frac{\partial}{\partial x}\left(k(T)\frac{\partial \overline{T}}{\partial x}\right)+\frac{\partial}{\partial y}\left(k(T)\frac{\partial \overline{T}}{\partial y}\right) - \frac{2}{\delta}\left[h\left(\overline{T}-T_\infty\right)+\varepsilon\sigma|\overline{T}|^3.\overline{T}\right]=0 \quad in \quad \Omega_1 \tag{3.8}$$

where $k(T)$ is the thermal conductivity of regions Ω_i. The boundary conditions (b.c.) (see Fig. 2) are homogeneous Neumann b.c. on Γ_1, Γ_3 e Γ_4 (adiabatic boundary) and Dirichlet b.c. on Γ_2 (prescribed temperature).

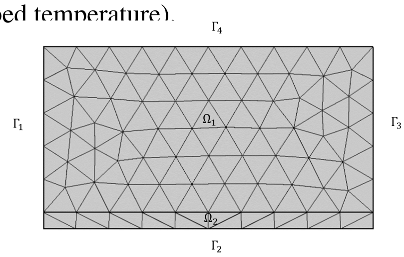

Figure 3.21: Two-region piecewise homogeneous fin

The coupling between the conduction heat transfer, convection and thermal radiant heat transfer is done on the body. For a convex fin surrounded by an atmosphere non-free space:

$$-k\nabla\overline{T}.\mathbf{n}=0 \ \ on \ \ \partial\Omega_1=\Gamma_1 \cup \Gamma_3 \cup \Gamma_4 \tag{3.9}$$

and

$$T=T_{env}(\xi,\eta) \quad for \quad t=0; 1<\xi<H; 1<\eta<Z \tag{3.10}$$

Equation (3.8) employed the term $|T|^3.T$ in place of the term T^4 in order to ensure the coerciveness of the operator in infinite dimension, preserving the physical structure of the phenomenon, analytical details in advisors works.

Kircchoff transformation

If k and q_{cond} are functions of space only, Eq. (3.8) becomes a linear differential equation with variable coefficients. The solution of such an equation requires no additional mathematics. But if k is dependent on temperature and independent of space, however, this equation becomes non-linear and difficult to solve. Usually, numerical methods have to be employed.

Equation(3.8) may be reduced to a linear differential equation by introducing a new temperature ω related to the temperature T of the problem by the Kirchhoff transformation:

$$\omega = f(T) = \int_{T_0}^{T} k(\varepsilon)d\varepsilon \tag{3.11}$$

For the copper empirical curve, there was obtained with the help of least squares method the adjusted curve $k(\varepsilon)$ to be integrated in kirchhoff transformation.

The kirchhoff transformation is showed below

$$\omega = f(T) = \int_{T_0}^{T} k(\varepsilon)d\varepsilon = \frac{c}{(d+1)}.T^{(d+1)} \tag{3.12}$$

in which c and d were obtained with least square method in MatLab curve fitting.

According to

$$grad\omega = kgradT \tag{3.13}$$

The inverse of the above Kirchhoff transformation can be easily obtained as

$$T = f^{-1}(\omega) = e^{\frac{1}{d+1}\log\frac{\omega(d+1)}{c}} \tag{3.14}$$

with $\lambda = \frac{1}{d+1}\log\frac{\omega(d+1)}{c}$, the partial differential equation can be written.

$$div[grad\omega] - \frac{2}{\delta}\left[h.e^{\lambda} + \sigma|e^{\lambda}|^3.e^{\lambda}\right] = 0 \quad in \quad \Omega_1 \tag{3.15}$$

and the boundary condition becomes

$$-(grad\omega).\mathbf{n} = 0 \quad on \quad \partial\Omega_1. \tag{3.16}$$

The positiveness of the thermal conductivity ensures that ω is an increasing function of T, while T is an increasing function of ω.

Variational formulation

In order to ensure the existence of a minimum is necessary and sufficient to show that I, the functional associated to the physical problem is continuous, convex and coercive functional.

The solution of problem in Eq. (3.8) may be reached as the limit of a sequence whose elements are obtained form the minimization of a quadratic functional.

$$I[v] = \frac{1}{2}\int_0^H \int_0^Z \left[\left(\frac{\partial v}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial y}\right)^2\right] dxdy + \int_0^H \int_0^Z \left[\frac{h}{\delta k}(v - T_\infty)^+ \frac{2\varepsilon\sigma}{5Dk}|v|^5\right] dxdy \tag{3.17}$$

The first variation of Eq. (3.17) describes the variational formulation of the problem addressed that may be mathematically represented by the minimization of a functional coercive. The existence of this minimum principle provides an easy and accurate tool for numerical simulations of such heat transfer phenomena.

In other words, the solution ω of problem given by Eq. (3.11) is given by

$$\omega = \lim_{i\to\infty} \Phi_i \tag{3.18}$$

in wich the elements of sequence $[\Phi_0, \Phi_1, \Phi_2, ..., \Phi_i]$ are obtained from

$$div(grad\Phi_{i+1}) = \alpha\Phi_{i+1} - \beta_i \quad in \quad \Omega_1 \tag{3.19}$$

and

$$-(grad\Phi_{i+1})\mathbf{n} = 0 \quad on \quad \partial\Omega_1 \tag{3.20}$$

The auxiliar term β:

$$\beta_i = \alpha\Phi_{i-1} - \left(\sigma|\Phi_{i-1}|^3\Phi_{i-1} - h(\Phi_{i-1} - T_\infty)\right) \quad for \quad i = 0,1,2,... \tag{3.21}$$

where α is sufficiently large positive constant and $\Phi_0 \equiv 0$. This constant is evaluated from an priori estimate for the upper bound of the solution in Eq. (3.11) and ensures a bounded and nondecreasing sequence $[\Phi_0, \Phi_1, \Phi_2, ..., \Phi_i]$.

Results and discussion

This paper introduce the idea of Kirchoff Transformation and sequence of linear problems to find a solution of the steady-state nonlinear fins problem with temperature dependent thermal conductivity. For this, the mathematic analysis will be based on Murray–Gardner assumptions, for analysis come closer to the real-world situation.

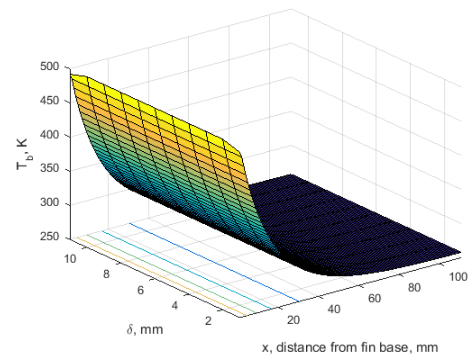

Figure 3.22: Temperature profile for a longitudinal convecting-radiating copper fins with mutual irradiation between radiator elements

Conclusions

Heat transfer analysis is an active and important engineering research field, as it increases the effectiveness of heat exchangers result in considerable technical advantages and especially in cost savings. It is noteworthy that correct and effective design of thermal load demand knowledge of heat transfer phenomena, so that erroneous considerations aren't taken compromising the integrity of all equipment. The present work shows the influence of the dependence between the temperature and the thermal conductivity on the effectiveness of finned surfaces. Results indicate that thermal conductivity can significantly impact the actual heat transfer response of a fin.

SOLUTION OF EXTENDED GRAETZ PROBLEM BY INTEGRAL TRANSFORM WITH ORTHOTROPIC DUCT

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Introduction

There is a growing interest for applications of heat and mass transfer in orthotropic ducts. In the realm of simulation, studies for heat transfer in composite ducts, this paper proposes a hybrid solution strategies for solving the conjugated heat transfer in an axisymmetric duct made of an orthotropic material, which the conductivity vary in three main directions(Li et al., 2009). Since the wall material is anisotropic, the axial diffusion is also considered in this formulation. The final result will be the analysis of temperature distribution for this case. The formulation to be employed is the Generalized Integral Transform Technique (GITT) which in the realm of hybrid analytical-numerical methods, has been playing a big role(Morini, 2000).The Integral Transform Technique is employed as the main solution methodology. The presented results can serve as guidance for choosing an optimum solution methodology for this type of problem.
Keywords:: Axysimmetric duct, Orthotropic material, Conjugate Heat Transfer, Generalized Integral Transform Technique.

Methodology

In order to solve the conjugate heat-transfer problem, one needs to solve the energy equation. The flow is assumed to be hydrodynamically developed but thermally developing, with negligible viscous dissipation and temperature independent of physical properties(Knupp, Naveira-Cotta, and Cotta, 2013). The duct is considered to be axyssimetric, and the fluid flows with a known fully developed laminar velocity profile. The duct solid wall ($a \le r \le b$) has anisotropic conductivity. The inlet temperature is prescribed and there is a fluid flowing outside the duct, resulting in a Robin (third kind) boundary condition at $r = b$. The general formulation of conjugated problem in classical two-dimensional cylindrical coordinates is given by:

$$u(r)\,w_f\frac{\partial T}{\partial z} = \frac{1}{r}\frac{\partial}{\partial r}\left(k_r(r)\,r\frac{\partial T}{\partial r}\right) + \frac{\partial}{\partial z}\left(k_z(r)\frac{\partial T}{\partial z}\right) \quad (3.22)$$

$$T = T_{\text{in}} \quad \text{for} \quad z=0 \quad \text{and} \quad 0\le r\le b \quad (3.23)$$

$$\frac{\partial T}{\partial z} = 0 \quad \text{for} \quad z\to\infty \quad \text{and} \quad 0\le r\le b \quad (3.24)$$

$$\frac{\partial T}{\partial r} = 0 \quad \text{for} \quad r=0 \quad \text{and} \quad z\ge 0 \quad (3.25)$$

$$-k_r(r)\frac{\partial T}{\partial r} = h\left(T - T_f\right) \text{ for } r=b \text{ and } z\ge 0 \quad (3.26)$$

where $u(r)$ is the parabolic fully developed velocity profile, that flows between $(0 \le r \le a)$, w_f is the inner fluid heat capacity, $k_r(r)$ and $k_z(r)$ are the thermal conductivities in direction r and z respectively. T_f is the external environment temperature, T_{in} is the temperature at entrance of channel and h is the heat transfer coefficient.

The following dimensionless groups are defined:

$$K_r(\eta) = \frac{k_r(r)}{k_f};\quad K_z(\eta) = \frac{k_z(r)}{k_f};\quad \tilde{k}_r = \frac{k_{sr}}{k_f};\quad \tilde{k}_z = \frac{k_{sz}}{k_f}; \quad (3.27)$$

$$\xi = \frac{z k_f}{b^2\bar{u}w_f};\quad \eta = \frac{r}{b};\quad \beta = \frac{a}{b};\quad \theta = \frac{T - T_f}{T_{\text{in}} - T_f}; \quad (3.28)$$

$$u^*(\eta) = \begin{cases} 2(1-\frac{\eta^2}{\beta^2}) & \text{if } \eta\le\beta \\ 0 & \text{if } \eta>\beta \end{cases} \quad (3.29)$$

$$K_r(\eta) = \begin{cases} 1 & \text{if } \eta\le\beta \\ \tilde{k}_r & \text{if } \eta>\beta \end{cases} \quad (3.30)$$

$$K_z(\eta) = \begin{cases} 1 & \text{if } \eta\le\beta \\ \tilde{k}_z & \text{if } \eta>\beta \end{cases} \quad (3.31)$$

Where k_f is the fluid thermal conductivity, k_{sr} is the solid thermal conductivity in r-direction, k_{sz} is the solid thermal conductivity in z-direction, $\bar{u}$ is the fluid average velocity $(0 \le r \le a)$, a is the inner radius, and b is the outer radius, Bi is the Biot number, Pe is the Péclet number, $K_r(\eta)$, $K_z(\eta)$, θ, ξ, η and $u^*(\eta)$ are nondimensional versions of $k_r(r)$, $k_z(r)$, T, z, r and $u(r)$ respectively and β is the aspect ratio.

In order to solve this system of equations, an analytical solution is proposed. One can obtain the solution of the modified system by integrating analytically. The eigenvalues and eigenvectors of $\mathbf{M}$ are calculated so that the solution of the components of $\mathbf{y}$ can be written in the following form:

$$y_n(\xi) = \sum_{m=1}^{2n_{\max}} G_{n,m}c_m\exp(\omega_m\xi) \quad (3.32)$$

The solution of transformed potential is obtained, and then the temperature field is calculated by applying the inversion formula and the Nusselt number can be obtained directly from the transformed temperatures using the following expression:

$$\mathrm{Nu}(\xi) = \frac{\sum\limits_{n=1}^{\infty} \bar{\theta}_n \frac{2\beta}{N_n} R'(\beta)}{\sum\limits_{n=1}^{\infty} \frac{\bar{\theta}_n}{N_n} \left[R_n(\beta) - \frac{2}{\beta^2} \int_0^\beta u^* R_n \eta \, \mathrm{d}\eta \right]} \tag{3.33}$$

Results

It is analyzed the local Nusselt number convergence at different axial positions, ranging from 0.01 up to 10, for different Biot numbers and thermal conductivities. Nusselt values were presented for different truncation orders, so that it is possible to analyze the convergence behavior. Converged three digits are noticed for position $\xi = 0.1$, in which k_z=0.5 and k_r=1.5, among 50 and 70 terms in the series, for Bi=1. Meanwhile for position $\xi = 1$, we have three digits converged among 20 and 40 terms in the series. On the second case, it's realized three converged digits for Bi=10, in which k_z=0.5 and k_r=1.5, for position ξ=0.01 among 70 and 100 terms in the series, and at position ξ=0.1, also three digits converged behavior among 10 and 30 terms, and for 60 and 70 terms as well. In other case, for Bi=1 is possible to see that convergence occurs for positions ranging from ξ= 0.1 until ξ=10 just for 2 meaningful digits, except for position ξ=0.1, which we have four converged digits, among 60 and 80 terms. When Bi is increased to 10, there is no convergence of four digits.

In the thrid case, the convergence of 2 digits is not obtained at position ξ= 0.01 among 20 and 100 terms in the summation. But this occurs for Bi=10. And also 2 digits from 10 until 100 terms at position ξ=0.1, that does not happen for when Bi=10. For both tables it was not still noticed fully-converged six digits.

This effect of range of convergence rate seems to be strongly dependent on both the Peclet number and the Biot number. For larger Pe values, notably better convergence rates are seen and it also seems to improve for larger Bi values. In second and in the fourth case, in spite of larger Peclet Number, a low convergence rate occurs in the entrance of channel in which in which k_z=1.5 and k_r=0.5. In all cases we can see a worse convergence rate for Pe=1 due to greater influence of the axial diffusion term. On the other hand when Péclet number increases for 10, the convergence rate improves considerably. For all tables, at the entrance of channel at position ξ= 0.01, is verified the worst convergence rate due to the boundary condition discontinuity.

Results presented have been analyzed mainly for different Biot and Peclet numbers, according the axial position (ξ), truncation orders ($n_{\max}$) and two combinations of $\tilde{k}_z$ and $\tilde{k}_r$. The Nusselt number is chosen for the convergence analysis due to its importance in this kind of heat transfer problem. We will consider axial diffusion as reference only. One can confirm what the literature claims about Nusselt local number to be equal to 3.66 for larger ξ, Peclet numbers, Biot Numbers and negligible duct wall. One should note that for larger Bi the boundary condition approaches to the prescribed temperature in $\eta = 1$. The result is that neglecting the axial diffusion, due the high value of Peclet number, the local Nusselt number converges to 3.66.

Conclusions

This paper presented a semi-analytical solution for the conjugate heat transfer problem in a duct with anisotropic wall material considering axial diffusion. It was shown the convergence behavior of local Nusselt. In this work, the axial diffusion has been considered and the solution methodology was based on the Generalized Integral Transform Technique, and a simple eigenvalue problem with analytical solution was employed for the transformation. Although a coupled ODE system was obtained, the equations could be solved analytically by rewriting this system in a modified form and employing a matrix method. The results were verified by comparisons with the datas from the literature and it achieved good agreement. A convergence analysis of the solution showed that very good converge rates are seen for larger Peclet, Biot and aspect ratio values. On the other hand, a worse convergence behavior was seen for the beginning of the duct length. This is due to the boundary condition discontinuity at the entrance of the channel. A worse convergence behavior was also observed for smaller values of Peclet and Biot. Regarding the convergence analysis, illustrative results were presented, showing the variation of the local Nusselt number with axial positions for different values of Peclet, Biot, β and thermal conductivities.

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ADIABATIC SHEAR BAND (ASB) AS A MECHANISM OF EROSION BY IMPACT OF SOLID PARTICLES IN DUPLEX STAINLESS STELL UNS S32205 - CHARACTERIZATION AND NUMERICAL SIMULATION

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Introduction

Due to economic losses related to the deterioration of engineering materials in-service, the study of Tribology has been receiving increasing attention from researchers in the field of mechanics and materials. In the case of wear by erosion, that caused by the impact of hard particles on surfaces of ductile metallic materials still offers opportunities for research, especially on the mechanisms that can explain the phenomena related to the loss of mass that characterizes erosion.

This project aims to simulate erosion on a flat UNS S332205 duplex stainless steel surface, by means of individual and successive impacts of spherical and rigid Alumina particles, using a commercial software ABAQUS. The target material, the impacting particles and the software where chosen due to previous experimental and simulation works (Molter and Lucena, Santos, 2014, 20015).

Erosion

Several models were formulated to explain the behavior of metal surfaces with both ductile and brittle behavior under hard particle impacts. For ductile materials, a well-accepted model presently predicts that the initial impact of a particle may cause only localized plastic deformation on the surface of the material. However, successive impacts at the same point may produce a hardening of the material at the bottom of such craters, also forming edges or lips on the sides of the craters or on the side opposite the impacts. In the end, removal of these lips would characterize erosion, i.e. loss of mass.

A suggested mechanism for the final detachment of these parts was based on ballistic studies, on what projectile impacts initially create a condition of localized dynamic compression on the affected surfaces (Figure 1). In the subsurface of the impact areas, structural transformations occur, with the formation of the so-called Adiabatic Shear Bands (ASB). The presence and coalescence of voids in these bands would give rise to cracks along them, which are precursors of fracture. This is one of the most accepted mechanisms to explain mass loss.

Much of the contributions made in this field come from experiments in laboratories, which can be very costly and time-consuming. Using the finite element method and the Johnson Cook's failure criterion (Johnson and Cook, 1985), it is possible to model erosion in materials, saving time and money.

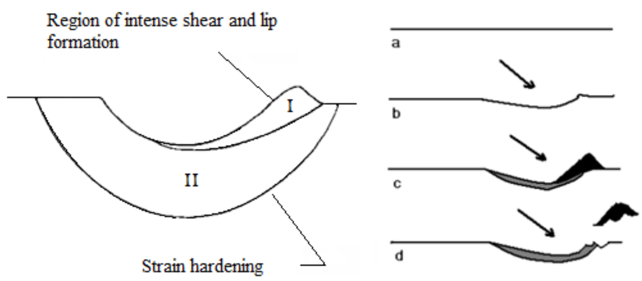

Figure 3.23: crater formed by dynamic impact of particles. Extracted from (Shewmon and Sundararajan, 1983).

Results of the simulations can be validated by those of some previous experimental studies, where the presence of ASB was observed by SEM in the eroded surface of that material, impacted by alumina particles. In this way, graphical outputs of the software can confirm the resulting plastic deformation in the craters of the eroded material, its hardening and the lip formation at the edges of the craters, besides to show the stress and strain values that characterizes the formation of the shear band, which is precursor to failure and a possible mechanism for this type of erosion.

Materials and Methods

Target material

Duplex stainless steel is a relative new material that has been replacing other stainless steels, mainly the austenitic ones, in diverse applications, as in the industry of oil and gas. However, concerning its behavior under erosion, a very few amount of information is available in literature. In the previous experiments, the chemical composition and the mechanical properties of the target material are:
- yield stress (0,2 %): 586 MPa;
- ultimate tensile stress: 784 MPa;
- elongation in 50 mm: 34 %;
- hardness: 20 HRC .

In simulations, the parameters of the Johnson & Cook formulation were as closer as possible to those of this material.

Impacting Particles

It is being considered Alumina particle as erodent once, it promotes a higher rate of material removal due to its high density, hardness and angularity, when compared to particles of quartz and silicon carbide for the same test conditions (Desale, Ghandi, and Jain, 2006).

The erodent particles were polyhedral alumina, with variable morphology and 150 micron average size (100 mesh). In simulations, erodent particles were spherical, rigid, 10 mm diameter.

Software

Modeling of the erosion process was performed using a finite element solver ABAQUS™/EXPLICIT version 6.12-1.

Methodology

Numerical simulation will be carried out in ABAQUS software in order to study the ASB formation and to predict the UNS S32205 stainless steel behavior in erosion, using the Johnson & Cook constitutive model. The Johnson & Cook failure criteria is based on the elastic-plastic material behavior (Johnson and Cook, 1985), and considers ductile failure and the effects of temperature, strain and strain rate.

The Johnson & Cook parameters to be considered in this work are respectively: A (550 MPa), B (750 MPa), n (0.20), m (1.0) and C (0.0014), adapted from (Santos, 20015). Values of melting temperature (1700k) are from (Johnson and Cook, 1985) and reference temperature (293k) is the room temperature. These values approximate those of the UNS S32205 duplex stainless steel.

The working sample of the target will be a plate with 100x100x10THK (mm) and the erodent particle a rigid sphere of 10 mm diameter, velocity of 50 m/s and impingement angle of 30 degrees. Successive and individuals impacts will be simulated and results are expected to be in graphics form or in images.

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PIPES COATINGS FOR BOILER THAT GENERATE STEAM FROM MINERAL COAL BURNING

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Introduction

About 28% of the installed capacity of electric power generation in the Brazilian electric sector comes from thermoelectric generation (ANEEL, 2015). Brazilian thermoelectric plants that use coal as a thermal source use boiler pulverized combustion technology (Tolmasquim, 2016). The low calorific value of Brazilian coals requires a high volume of coal to obtain the appropriate temperature conditions in the boiler. The heat released at the burning of the coal is transferred to the water circulating in the tubes that surround the boiler furnace, transforming it into superheated steam. Tubes forming what is called a "water wall" in which water circulates to be transformed into the steam that will drive the turbine are subject to high temperature, aggressive environment and erosion caused by the gas and particulate fluxes resulting from the burning of coal. From the material point of view, considering the high percentage of ashes present in Brazilian coal, the metallic parts of the interior of the boiler and, in particular, the pipes of the water wall, suffer heavy wear due to the composition of the ashes. This process of attacking the metal surfaces, potentially, is able to reduce the thickness of the pipes and, consequently, increase the frequency of occurrence of perforations causing the unavailability of the unit. The unavailability of the boiler causes substantial losses to the generators for lost profits. If the make changes on the design of the boiler (burning coal, gas flow, positioning of burners, etc.) is not possible, one way of minimizing occurrences caused by pipe wear is the detailed investigation of the wear on the walls of the pipes caused by the impact of particles present in the ash of burnt coal and the research of metallic or composite coatings in the critical regions of the boiler. In this context, the objective of this work is to develop and characterize a coating made of material composed of the inorganic refractory ceramic adhesive system and a carbon fiber for steel pipes subjected to the impact of coal particles resulting from the incomplete combustion of the same, in boilers used in thermoelectric plants that use Brazilian mineral coal.

Materials and methods

The initial tests used a coating composed of a carbon steel sheet with a chemical composition similar to carbon steel used to make water boiler pipes in Brazilian boilers (approx. 0.2%C), resistant ceramic adhesive High temperature Three Bond and carbon fiber with bidirectional frame designation RC 200T / 1270. The resin and carbon fiber assembly was placed on the carbon steel plate previously prepared (sanded with 600 metallographic sandpaper and cleaned with acetone) according to two different preparation schemes. Fig. 1 shows the arrangement of the materials for forming the two coating schemes. After assembly, the samples coated with both schemes were heated for 45 minutes at 150° C in an EDG 1800 3PS oven. Adhesion tests were performed on the assembly according to ASTM 4541 (ASTM, 2002) which establishes minimum technical requirements for the Pull-Off test.

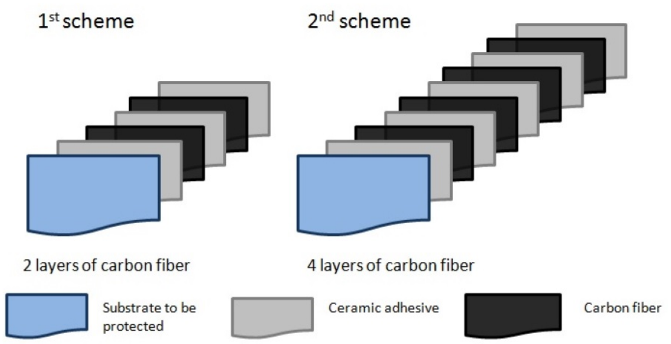

Figure 3.24: Schematic assembly of the two proposed coating schemes for the water wall piping of thermoelectric boilers.

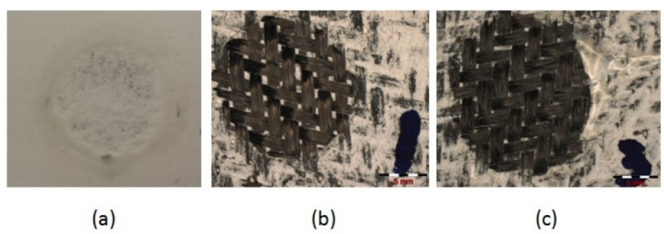

Figure 3.25: Figure 2: (a)Aspects obtained from the adhesion test for the substrate with only the first layer of ceramic adhesive. The nature of the Cohesive B failure was observed.(b) Result of the first protection coating assembly scheme. Nature of the type C failure.(c)Result of the second protection coating assembly scheme. Nature of failure: type C.

Were used the Positest AT-A: Automatic Adhesion tester from Defelsko. Tests were initially done only on the substrate covered with ceramic adhesive and, later, in the assemblies, as Fig. 1.

Results and discussion

The adhesion test performed on the substrate coated with only one layer of ceramic adhesive showed average binding strength of 25 MPa. The nature of the force was cohesive B. It means that the ceramic adhesive actually adhered to the surface of the substrate in a manner considered stable by ASTM 4541 (ASTM, 2002). Fig. 2 presents the aspects obtained for the surface of the steel coated with the ceramic adhesive resin and after the adhesion tests. The purpose of these tests was to verify the behavior of the steel – resin system in an individual way, without the influence of the carbon fiber. The succession of the individual steel-resin system was followed by adhesion tests on the coatings shown in Fig. 2 (b) and (c). The two-layer carbon fiber scheme had a mean adhesion strength of 1.27 MPa (1 MPa - spool 1 and 1.54 MPa - spool 2) and nature of failure type C - cohesive of the last layer - Fig. 2 (b). The four - layered carbon fiber scheme as shown in Fig. 2 (c) had a mean adhesion strength of 1.93 MPa (1.66 MPa - spool 1 and 2.20 MPa - spool 2) and a C - type cohesive nature of the last layer. The results were similar for both schemes.

Conclusions

The preliminary adhesion tests were similar in nature to all proposed schemes: cohesive failure type C. According to ASTM 4541 (ASTM, 2002), this nature of failure is desirable, since cohesive failure indicates that in the event of any damage being caused to the coating , It will not detach itself from the substrate (force of an adhesive nature) and it will be protected.

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