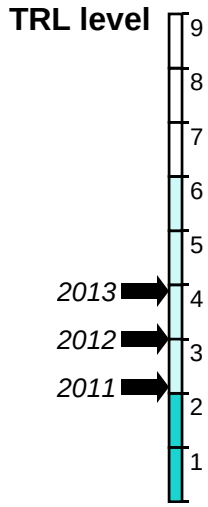
Liquid Impingment Erosion Rig and High Level Info

September 13, 2011

Project Summary/Purpose



Project statement:

- Understand the Liquid Impingement Erosion phenomenon in gas turbine compressors

Project objectives:

- Build LIE Test Rig
- Deliver a long term solution for ISI technology

Justification:

- The understanding of the water erosion phenomena as applicable to gas turbine compressors is fundamental to successful application of the ISI concept.

Team: M. Medraj, P. Bocher, J.E. Klemberg-Sapieha, A. Dolatabadi, J. Siedlikowski, P. Jedrzejowski

Accomplishments/Progress/Status

- Second group meeting was held in August 2011
- Website with reports and meeting minutes is operational
- Periodic link calls are scheduled
- Rig design was reviewed with Frank Heymann
- Compressor blades with 500h ISI are investigated at Concordia
- Rig is delayed till November 2011

Major/Key Milestones:-

Milestone Descr.	Commit. date	Current date	Variance
Rig manufactured	AP9	AP11	+2AP
Rig Comissioned	AP9	AP11	+1AP
Testing procedures issued	AP9	AP9	

Comments:

Upcoming Events/Tasks:

- Rig testing
- Testing specifications issued
- Contract with Frank Heymann

Major Issues/Risks/Support Needed:

- Project management is complex due to the large number of participating institutions.

Green: on time ***Yellow: < 30 days*** ***Red: >30 days***

Failure Analysis – ÉTS

Date: September 14, 2011

Project Summary/Purpose

Project statement:

- Understand the Liquid Impingement Erosion mechanisms in coupons and in gas turbine compressors

Project objectives:

- Analyse the eroded surface of coupons submitted to water erosion tests : coated coupons, Laser Shot peened and Low Plastic Burnished coupons.
- Analyse the eroded surface of real compressor blades submitted to water droplets erosion in service

Justification:

- Identify the erosion mechanisms helps understanding and optimizing the erosion resistance observed with certain coating or surface treatment.

Team: N. Kamkar, F. Bridier, P. Bocher

Accomplishments/Progress/Status

- Qualitative and quantitative analyses of the untreated / rolled samples and Laser shock peened / forged samples
- Investigation on low plasticity burnishing samples and rolled Ti-6Al-4V plate is in progress
- A water droplet erosion mechanisms is proposed from an exhaustive characterization of eroded samples. The cyclic behavior (crack initiation and propagation involved) in the erosion mechanism has been reported.
- Nelly Kamkar's master has been switched to Ph.D.

Major/Key Milestones:-

Milestone Descr.	Estimated date	Revised Date	Variance
Erosion mechanisms analysis of RR coupons	Aug 11	Aug 11	
Microstructure characterization of rolled plate	Sept 11	Sept 11	
Microstructure characterization of blade	Oct 11	Oct 11	
Characterization of LPB samples	Nov 11	Nov 11	
Intermediate report from Nelly Kamkar	Nov11	Nov 11	

Comments:

Green: on time ***Yellow: < 30 days*** ***Red: >30 days***

Upcoming Events/Tasks:

- Complete analyses of laser shock peened and untreated samples.
- Investigation on low plasticity burnishing samples
- Microstructure analyses of compressor blade Ti alloy
- Investigation on blade

Major Issues/Risks/Support Needed:

- The samples we have are in the final stage of erosion however it is very important to have the samples at earlier stages of erosion. Therefore, the experiments on the rig will be very useful.
- Flat samples have rolled microstructure while bolt samples have forged microstructure, which basically are uncomparable. Therefore it is needed to run some experiments on similar samples.

Water Impingement Modeling - Concordia

Date: Sep. 15, 2011

Project Summary/Purpose

Project statement:

- Modeling of Liquid Impingement Erosion on Compressor Blades

Project objectives:

- Modeling drop-solid interaction at high speed impacts
- Finding critical stresses in the solid and their location

Justification:

- Capturing the fluid-solid interaction is essential in calculating the damage characteristics in the solid via impacts of liquid droplets
- Current state-of-the-art models are limited to 2-D cases while droplet erosion is a 3-D phenomenon

Team: Dr. Ali Dolatabadi , Mohsen N. Marzbali

Accomplishments/Progress/Status

- Spray flow was modeled by Lagrangian tracking method and the droplet distribution and velocity was calculated.
- Low speed impacts of single droplets were modeled by VOF using the information from Lagrangian tracking of the spray. (report issued at RR)
- The existing models have been reviewed and their capacity in modeling fluid-solid interaction were evaluated, a literature review is submitted
- A combined fluid-solid solver will be set up to capture the drop-solid interaction. The Volume of Fluid (VOF) method will be used to model the droplet and Finite Element Method (FEM) for the solid. The results can be used for stress analysis in the solid.
- The effect of water droplet impact on elastic solid will be investigated to calculate the deformation/damage of the material.

Major/Key Milestones:-

Milestone Descr.	Commit. date	Current date	Variance
Discrete Phase Modeling of water impingement	01/11/11	15/09/11	-1.5 months
Volume of Fluid Modeling for single Impact	31/07/12	15/09/11	-10.5 months
Water Impingement Modeling: literature review	31/08/11	15/09/11	+0.5 months
Coupled Modeling of drop-solid Interaction	31/12/12	15/09/11	-15.5 months
Substrate Deformation Modeling	01/08/13	15/09/11	-22.5 months

Comments:

First milestone was accomplished during MITACS project

Green: on time ***Yellow: < 30 days*** ***Red: >30 days***

Upcoming Events/Tasks:

- Liquid droplet impacts at moderate and high velocities on solid substrates will be simulated using incompressible and compressible solvers and the results will be compared to each other for every impact case.
- The stress distribution in the solid will be calculated by using the pressure distribution in the liquid obtained from drop impact model (one-way coupling).
- The solid elasticity will be added to fluid-solid interaction model to obtain the pressure in the droplet and the stress in the solid simultaneously (two-way coupling).

Major Issues/Risks/Support Needed:

- The Discrete Phase Modeling of the water spray was carried out during MITACS project and a few improvements were suggested for future work. It is at Rolls-Royce discretion whether this work is going to be continued or not. Due to IP issues it has to be done on RR's premises.

LIE - Multilayer & Composite Coatings - Concordia

Date: Sep. 15, 2011

Project Summary/Purpose

Project statement:

- Developing coatings with improved water erosion resistance

Project objectives:

- Develop multilayer & composite coatings
- Stress wave analysis

Justification:

- As dynamic rather than static load, the droplet impact behaves as stress wave in the coatings and blades. The multilayer or composite structure will be helpful to destroy the shock wave, and improve the erosion resistance.

Team: Wei Chen (Alex) [PhD student], Mamoun Medraj [Supervisor]

Accomplishments/Progress/Status

- In-situ TiC-TiB2 / TiAl3 coating experiment is initiated.
- The plan of laser cladding (and laser peening) experiment was finalized with Jiangsu University (China). Samples are under preparation now.
- Stress wave analysis, using triangle wave instead of rectangle wave, is proceeding.

Major/Key Milestones:-

Milestone Descr.	Commit. date	Current date	Variance

Comments:

Upcoming Events/Tasks:

- A vacuum tubular furnace, used for boronizing, was selected and will be available in 4-6 weeks.
- Boronizing experiment (for dual-layer TiB_2/TiB coatings purpose) will be initiated once the furnace is available.

Major Issues/Risks/Support Needed:

- PVD coating experiment
  Still waiting for response from Patt Tech., and ZCCCT (China).

LSP and LPB - Concordia

Date:2011/09/15

Project Summary/Purpose

Project statement:

- Water erosion resistance surface treatments using Low Plasticity Burnishing and Laser Shock Peening.

Project objectives:

- Optimize the LSP and LPB parameters in order to obtain much deeper and larger residual stress.
- Investigate the mechanical properties improved by LSP and LPB, and how they contribute to water erosion resistance.
- Evaluate the water erosion resistance of the samples been LSP and LPB treated with RIG.
- Analyse the erosion mechanism.

Team: Dr. Medraj, Alex Chen, Tuan Nguyendinh, Mohammad Sadegh, Dina Ma

Accomplishments/Progress/Status

- **LPB Parameter Settings for the first round**

1. Ball Size: 6mm and 13mm;
2. Normal Force: 6mm-----150bar;
   13mm----200~250bar;
3. Number of Passes: Single pass and multiple passes(2~3);
4. Feed: Varies from ball size, 0.1~0.2mm/rpm;
5. Spindle Velocity: 150r/min.

- **LPB Tool**

HGx-9 and HGx-19 are chosen, both are available for manual and CNC lathe.

- **Sample Cutting**

Water jet cutting is chosen to cut the plate material into T and L shaped sample after LPB processing.

Major/Key Milestones:-

Milestone Descr.	Commit. date	Current date	Variance
Place the order of LPB Tools	**Sep.30**	**Sep.15**	

Comments:

Upcoming Events/Tasks:

- Testings before LPB and LSP: XRD, SEM, Vickers' hardness (load=0.05kg,duration=15s).
- Training for access to the machine shop.
- Place the order of LPB tool.
- Planning to send flat samples when they are ready to JiangSu University(China) to do the first round of LSP processing.

Major Issues/Risks/Support Needed:

- Suitable LPB tool ordering is a little time consuming.

Hard Coatings - Polytechnique

Date: Sep 15, 2011

Project Summary/Purpose

Project statement:

- Understanding the Liquid Impingement Erosion phenomenon

Project objectives:

- Deposit hard nanocomposite nitride coatings by HiPIMS technique

Justification:

- Nanostructured coatings prepared by HiPIMS should provide better protection against liquid impingement erosion than coatings prepared by other PVD or CVD techniques

Team: J. Sapieha, O. Zabeida, M. Panjan

Accomplishments/Progress/Status

- Installation of new HiPIMS power supply to the deposition system
- Studying influence of pulsing parameters on the glow discharge
- New master student Etienne Billot, joints the project

Major/Key Milestones:-

Milestone Descr.	Commit. date	Current date	Variance
Literature review on the damage caused by droplet impingement			
Literature review of nanostructured coatings			
The effect of substrate and interface on water erosion			
Deposition of nanocomposite coatings			

Comments:

Upcoming Events/Tasks:

- Implementation of optical emission spectrometer for monitoring plasma conditions

Major Issues/Risks/Support Needed:

- Malfunctioning of deposition system could delay time schedule of targeted objectives

Green: on time ***Yellow: < 30 days*** ***Red: >30 days***

Validation Activites - Concordia

Date: 15 September, 2011

Project Summary/Purpose

Project statement:

- Study laser cladding/nitriding and oxynitride coating for water erosion resistance.

Project objectives:

- Fabricate adherent, uniform, thick coatings with high hardness.
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Business justification:

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Team: professor Mamoun Medraj, Thuan Dinh Nguyen

Accomplishments/Progress/Status

- A thick TiN coating on Ti-6Al-4V alloy was made by laser nitriding.
- Purchase of an oxynitriding equipment is in progress.

Major/Key Milestones:-

Milestone Descr.	Commit. date	Current date	Variance
Laser nitride coating fabricated			

Comments:

Upcoming Events/Tasks:

- Improve uniformity, microstructure and smoothness of TiN coating.
- Do laser cladding.

Major Issues/Risks/Support Needed:

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Green: on time