ROTOR BEARING SOLUTIONS INTERNATIONAL, LLC

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Fundamentals of Rotor-Bearing Dynamics And Case Histories in the Rotating Machinery Industry Third Annual Short Course

Dates: November 9-12, 2015
Location: Ethos Energy, Houston, Texas
3100 South Sam Houston Parkway E.
Houston, TX 77047

Sponsored By:
Rotor Bearing Solutions International (RBSI)
EthosEnergy, Houston

Industrial Machine Analysis and Fix Case Histories:

Horizontal and Vertical Pumps
Single and Multistage Compressors
Single and Multistage Steam Turbines
Motors, Generators, Alternators
Geared Systems, Gas Turbines
Turbochargers

Topics:

Rotor Problems, Fixes and Repairs
Rigid and Flexible Rotor Dynamics
New API Vibration Specifications and Automated Analysis
Rotor Modeling for Industrial Machines
Fixed and Tilting Pad Bearing Properties and Damage
Annular Gas and Water Seals
Rotor Unbalance, Cracks and Repair with Welding
Stability Problems, Sub-synchronous Vibrations
Spur and Helical Gears, Pump Fluid Forces
Squeeze Film Dampers, Substructure Effects
Rotor Unbalance Response

The Best and Most Comprehensive Rotor/Bearing/Seal Short Course This Year

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Course Description, Objectives, and Lecturers

This fundamental rotor dynamics short course is intended for engineering staff of companies using, repairing or manufacturing rotating machinery of common types. These types include horizontal and vertical pumps, compressors, steam turbines, motors, generators, alternators, geared systems, and gas turbines. The emphasis is on the vibration phenomena exhibited by the machine undergoing high vibration. Numerous industrial machine case histories, high vibration characteristics, causes of the high vibration, and fixes are presented.

In each case history, the important individual components of the machines are described in detail and the influence of each component on the vibration is evaluated. Normally a computer model of the machine is developed by the analyst to better evaluate the cause and the machine fix. This process is described. The use of mathematics in this short course is minimized and, when discussed, is used primarily to indicate technical points of use in the solution.

The lecturers in this short course have extensive experience in the rotating machinery field. Paul Allaire and Tom Smith each have more than 40 years' experience with diagnosing and fixing or repairing industrial rotating machinery problems. The other lecturers and contributing authors also have extensive experience in the field.

Lecturers:

1. **Paul Allaire,** ASME Fellow, *Chief Technical Officer, Rotor Bearing Solutions International (RBSI) , Also, Mac Wade Chaired Professor, University of Virginia, Now Retired – Long Time Director of Rotating Machinery and Controls Laboratory*
2. **Tom Smith,** *EthosEnergy, Houston, Former General Manager Of Turbocare, Houston*
3. **Tim Dimond, P.E.,** *President, Rotor Bearing Solutions International (RBSI), Formerly Principal Scientist of University of Virginia Rotating Machinery and Controls Laboratory*

Additional Contributors:

1. **John Nicholas,** *Former Owner and Chief Engineer, Rotating Machinery Technology, Former Engineering Fellow, GE-Lufkin-RMT*
2. **Mike Swann,** *Former General Manager, Waukesha Magnetic Bearings*
3. **Jianming Cao,** *Directer of Rotor Dynamics, RBSI*
4. **Joy Brinkerhoff,** *Rotating Machinery Engineer, Solar Turbines*
5. **Saeid Dousti,** Senior Fellow, RBSI
6. **Brad Nichols,** Senior Fellow, RBSI

Short Course Agenda

Day 1- Monday, November 9, 2015

8:00-8:30		Registration (On Site)
8:30-8:45		Introduction to Short Course – Scott Hill, EthosEnergy

Session 1 – Introduction to Rotordynamics I

8:45-9:15	**Talk 1**	Introduction to Rotordynamics – Paul Allaire (Allaire's Notes -Section 1.1)
9:15-9:45	**Talk 2**	Introduction to Rotor Dynamic (API) Vibration Specifications – Tim Dimond (Allaire's Notes – Section 1.3)
9:45-10:00		Break (Drinks and Snacks Provided During Breaks)
10:00-10:40	**Talk 3**	Single Mass Flexible Rotor (Jeffcott Rotor) on Rigid Bearings – Paul Allaire (Allaire's Notes – Section 2.1)
10:40-11:15	**Talk 4**	Rotor Modeling, Critical Speeds, Mode Shapes, Campbell Diagrams and Unbalance Response of Compressor Rotor – Automated API Analysis with ROTORAUDIT -Tim Dimond with Jianming Cao
11:15-12:00	**Talk 5**	Vibration Reduction in Overhung Compressor by Reduced Shaft Stiffness – Paul Allaire with Richard Armentrout
12:00-1:00		LUNCH (Provided)

Session 2 – Fixed Pad Bearings and Case History

1:00-1:45	**Talk 6**	Properties of Fixed Fluid Pad Bearings – Paul Allaire (Allaire's Notes –Section 4.10)
1:45-2:30	**Talk 7**	Dynamics of Fixed Pad Fluid Bearings/Plain, Axial Groove, Multilobe, Offset Half – Paul Allaire (Allaire's Notes – Section 4.11, Part 1)
2:30-3:15	**Talk 8**	Dynamics of Fixed Pad Fluid Bearings/Pressure Dam – Paul Allaire (Allaire's Notes – Section 4.11, Part 2)
3:15-3:30		BREAK

Session 3 - Fixed Pad Fluid Film Bearing Dynamics and Case History

3:30-4:15	**Talk 9**	Rotordynamics of High Speed Turbochargers in Fixed Pad Bearings – Tim Dimond with Saeid Dousti
4:15-5:00	**Talk 10**	Steam Turbine/Gearbox/Generator Bearing Case History of Instability in Fixed Pad Bearings and Repair with Pressure Dam Bearings – Tim Dimond

Day 2 – Tuesday, November 10, 2015

Session 4 – Horizontal and Vertical Pumps/Case Histories

8:00-8:45	**Talk 11**	Practical Rotor Dynamics for Pumps/Stiff vs Flexible Rotors/Wet and Dry Critical Speeds and Nuclear Pressure Injection Pump Case History (Allaire's Notes – Section 7.1) – Paul Allaire
8:45-9:40	**Talk 12**	Vertical Pump Rotor Vibration Problems and Case Histories – Submersible Pumps, Nuclear Main Coolant Pumps (Allaire's Notes – Section 7.2) – Tim Dimond
9:40-10:15	**Talk 13**	Horizontal Pump Vibrations/API 610 Specifications, Sulzer Pump Examples, Boiler Feedpump Vibration Case History (Allaire's Notes – Section 7.3) – Paul Allaire
10:00-10:15		BREAK

Session 5 – Tilting Pad Bearing Static and Dynamic Properties I

10:15-11:00	**Talk 14**	Tilting Pad Bearing Static Properties (Allaire's Notes – Section 4.12, Part 1) – Paul Allaire
11:00-11:30	**Talk 15**	Tilting Pad Bearing Dynamic Properties (Allaire's Notes – Section 4.12, Parts 2&3) – Tim Dimond
11:30-12:00	**Talk 16**	Tilting Pad Bearing Selection for Best Bearing Design (Allaire's Notes – Section 4.12, Part 4) – Paul Allaire
12-00-1:00		LUNCH

Session 6 – Compressor/Steam Turbine Instability Issues

1:00-1:45	***Talk 17***	Stability of Jeffcott Rotor with Cross Coupled Effects - Steam Whirl, Alford Forces, Aerodynamic Excitation – Paul Allaire (Allaire's Notes – Section 2.4)
1:45-2:20	***Talk 18***	Stability of Six Stage Compressor with Seal Cross Coupling and Optimized Tilting Pad Bearings with Pivot Flexibility – Automated API Analysis with ROTORAUDIT - Tim Dimond with Jianming Cao
2:20-3:00	***Talk 19***	Unbalance Response of Six Stage Compressor and Optimized Tilting Pad Bearings with Pivot Flexibility – Automated API Analysis with ROTORAUDIT - Tim Dimond with Jianming Cao
3:00-3:15		BREAK

Session 7 – Compressor/Steam Turbine Instability

3:30-4:20	***Talk 20***	Rotordynamic Design of Centrifugal Compressors in Accordance with API Specifications – Comparison of Historic (Kaybob and Ekofisk) and Modern Compressors – Paul Allaire with John Kocur and John Nicholas
4:20-5:00	***Talk 21***	Compressor Instability Due to Internal Seals and Tilting Pad Bearing Solution – Paul Allaire with Joy Brinkerhoff and Chester Lee of Solar Turbines

Day 3 – Wednesday, November 11, 2015

Session 8 – Motor, Generator and Alternator Case Histories

8:00-8:45	**Talk 22**	Case History and Lateral Rotordynamic Assessment of Large Alternator/Flywheel Rotor – Tim Dimond
8:45-9:15	**Talk 23**	Shipboard Generator Subsynchronous Vibration Fix with Bearing Change - Paul Allaire with Richard Armentrout
9:15-10:00	**Talk 24**	Torsional Analysis of Large Alternator/Flywheel Rotor with Motor Excitation and Fatigue Life - Tim Dimond
10:00-10:15		BREAK

Session 9 – Motor/Compressor High Vibration Case History and Morton Bearing Heating Effect

10:15-11:00	**Talk 25**	Motor/Compressor Train Excitation of Structural Vibration Problem and Fix –Paul Allaire
11:00-11:45	**Talk 26**	Morton Effect in Overhung Compressor Instability – Paul Allaire with Saeid Dousti
12:00-1:00		LUNCH

Session 10 – Rotor Problems and Repairs I

1:00-1:30	***Talk 27***	Bearing Redesign – Tom Smith
1:30-2:15	***Talk 28***	Better Rotor Balancing – Principles and Repairs – Tom Smith
2:15-3:00	***Talk 29***	Rotor Repair with Welding and Coatings – Performance Improvements – Tom Smith
3:00-3:15		BREAK

Session 11 – Rotor Problems and Repairs I

3:15-4:00	***Talk 30***	Characteristics and Repair of Rotor Cracks, Tom Smith

16:00 - Tour of Ethos Energy Facility

Day 4 – Thursday, November 12, 2015

Session 12 – Geared Systems and Case History

8:00-8:45	**Talk 31**	Modeling of Geared Systems Including Bearings and Shaft Dynamics – Tim Dimond
8:45-9:15	**Talk 32**	Tilting Pad Journal Bearing to Solve a High Speed Pinion Vibration Problem – Case History – Paul Allaire with John Nicholas

Session 13 – Steam Turbine High Vibrations and Squeeze Film Dampers I

9:15-10:00	**Talk 33**	Retrofitting a Large Steam Turbine with a Mechanically Centered Squeeze Film Damper – Paul Allaire with John Nicholas
10:00-10:15		BREAK

Session 14 – Steam Turbine High Vibrations and Squeeze Film Dampers II

10:15-11:00	**Talk 34**	Eliminating a Rub Induced Start-Up Vibration Problem in an Ethylene Drive Steam Turbine with Squeeze Film Damper – Case History – Paul Allaire with John Nicholas

Session 15 – Modeling of Gas Turbine Engines

11:00-11:30	**Talk 35**	Gas and Liquid Labyrinth, Honeycomb, Hole Pattern Seals – Advanced Analysis Methods and Improvements – Paul Allaire
12:00-1:00		LUNCH

Session 16 – High Pressure Compressor Instability and Unbalance Response

1:00-1:30	**Talk 36**	High Pressure Six Stage Compressor Instability and Unbalance Response With Seal Cross Coupling, Tilting Pad Bearings and Squeeze Film Dampers/Flexible Substructure – Automated API Analysis with ROTORAUDIT – Tim Dimond

Session 17 – Introduction and Industrial Applications of Magnetic Bearings

1:30-2:15	**Talk 37**	Introduction to Magnetic Bearings – Paul Allaire
2:15-3:00	**Talk 38**	Rotor Drop Analysis of Auxiliary Bearings in Magnetic Bearing Supported Flexible Rotating Machines – Paul Allaire with Jianming Cao

3:00 - End of Short Course

Small Agenda Changes May Occur In the Final Short Course Talks and Notes

Registration and Fees

The course fees are as follows:

	Advance Registration	On Site
First Person from an organization	$1,600	$1,700
Second and Third Person from same organization	$1,400/person	$1,500/person

Seating for the short course at EthosEnergy is limited so early registration is recommended. On-site registration payments can be made with cash or credit card. If requested in advance via a purchase order, billing to an individual company will be accepted.

Advanced registration for the short course can be paid by the following methods:

Purchase Order or Check Addressed to:
Dr. Tim Dimond
Rotor Bearing Solutions International
3277 Arbor Trace
Charlottesville, Virginia, 22911
+1-434-632-8469
tim.dimond@rotorsolution.com

Additional information is given on the Rotor Bearing Solutions International website at www.rotorsolution.com.

The EthosEnergy contact person is Scott Hill – his cell phone number is 713-203-7236.

Lecture Materials and Continuing Education Credit

The material for all talks will be provided to attendees on a memory stick. Detailed questions on the course topics in particular and magnetic bearings in general will be answered. Certificates for 30 PDHs will be provided for attendees of the short course upon request.

Conference Hotel

A hotel near the Ethos Energy, Houston site will be booked soon. The lectures will be held in the Ethos Energy conference room and guest rooms reserved in the hotel. The attendees are responsible for registering at the hotel on their own. More detailed information about the hotel and room reservation information will be available soon on the RBSI website.