

**Fundamentals of Rotor-Bearing Dynamics And
Case Histories in the Rotating Machinery Industry**

Dates: October 20-24, 2014

**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
API Vibration Specifications
Rotor Modeling for Industrial Machines
Fixed and Tilting Pad Bearing Properties and Damage
Annular Gas, Water and Oil Seals
Stability Problems, Sub-synchronous Vibrations
Spur and Helical Gears, Pump Fluid Forces
Squeeze Film Dampers, Substructure Effects
Rotor Rubs, Electrical Faults**

**The Best and Most Comprehensive Rotor
Short Course This Year**

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. John Nicholas, Tom Smith and Paul Allaire 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. **John Nicholas**, *Former Owner and Chief Engineer, Rotating Machinery Technology, Former Engineering Fellow, GE-Lufkin-RMT*
4. **Timothy Dimond**, *President, Rotor Bearing Solutions International (RBSI), Formerly Principal Scientist of University of Virginia Rotating Machinery and Controls Laboratory*

Additional Contributors:

1. **Mike Swann**, *General Manager, Waukesha Magnetic Bearings*
2. **Jianming Cao**, *Director of Rotor Dynamics, RBSI*
3. **Joy Martin**, *Rotating Machinery Engineer, Solar Turbines*

Short Course Agenda*



Day 1- Monday, October 20, 2014

8:00-8:30 – Registration (On Site)

8:30 – 8:45 – Introduction to Short Course – Scott Hill, EthosEnergy

Session 1 – Introduction to Rotordynamics I

8:45-9:150 – *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

10:00-10:40 – *Talk 3* – Rotor Vibration Characteristics, Condition Monitoring, Unbalance, Misalignment, Looseness, Vane and Other Frequencies – Tim Dimond

10:40-11:15 - *Talk 4* – Single Mass Flexible Rotor (Jeffcott Rotor) on Rigid Bearings – Paul Allaire (Allaire’s Notes – Section 2.1)

11:15-12:00 noon – *Talk 5* - Critical Speeds, Mode Shapes, Campbell Diagrams and Unbalance Response of Compressor Rotor – Tim Dimond

(Drinks and Snacks Provided During Breaks)

12:00-13:00 Lunch (Provided)

Session 2 – Fixed Pad Bearings and Case History

13:00-13:45 – *Talk 6* – Properties of Fixed Fluid Pad Bearings – Paul Allaire (Allaire’s Notes –Section 4.10)

13:45-14:30 – *Talk 7* – Dynamics of Fixed Pad Fluid Bearings/Plain, Axial Groove, Multilobe, Offset Half – Paul Allaire (Allaire’s Notes – Section 4.11, Part 1)

14:30-15:15 – *Talk 8* – Fixed Pad Bearing Design for High Speed Turbochargers – Tim Dimond

15:15-15:30 Break

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

15:30-16:15 – Talk 9 – Dynamics of Fixed Pad Fluid Bearings/Pressure Dam – Paul Allaire (Allaire’s Notes – Section 4.11, Part 2)

16:15-17:00 – Talk 10 – Steam Turbine/Gearbox/Generator Bearing Case History of Instability in Fixed Pad Bearings and Repair with Pressure Dam Bearings – Tim Dimond

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Day 2 – Tuesday, October 21, 2014

Session 4 – Horizontal and Vertical Pumps/Case Histories I

8:00 – 8:45 – Talk 11 – Practical Rotor Dynamics for Pumps/Stiff vs Flexible Rotors/API Rotor Dynamics Specs for Pumps – Paul Allaire

8:45 – 9:40 – Talk 12 – Lomakin Effect for Pump Seals/Swirl Brake Design/Impeller Diffuser Forces and Nuclear Pressure Injection Pump Case History – Paul Allaire

9:40-10:15 – Talk 13 – Vertical Pump Rotor Vibration Problems and Case History, Tim Dimond

10:00-10:15 – Break

Session 5 – Horizontal and Vertical Pumps/Case Histories II

10:15-11:00 – Talk 14 – Horizontal Boiler Feedpump High Vibration Case History – Tim Dimond

11:00-12:00 - Talk 15 – Vertical Nuclear Main Coolant Pump High Vibration Case Histories – Paul Allaire

12-00-1:00 – Lunch (Provided)

Session 6 – Tilting Pad Bearing Static/Dynamic Properties

13:00-13:45 – Talk 16 – Tilting Pad Bearing Static Properties – Paul Allaire (Allaire’s Notes – Section 4.12, Part 1)

13:45-14:30 – Talk 17 - Tilting Pad Bearing Dynamic Properties – Tim Dimond (Allaire’s Notes – Section 4.12, Part 2)

14:30-15:00 pm – Talk 18 – Compressor Stability in Tilting Pad Bearings – Non-synchronous or Synchronous Tilt Pad Bearing Model? – Tim Dimond

15:00-15:15 pm Break

Session 7 – Compressor/Steam Turbine Instability

15:15-16:20 - Talk 19 – Stability of Jeffcott Rotor with Cross Coupled Effects - Steam Whirl, Alford Forces, Aerodynamic Excitation – Paul Allaire (Allaire’s Notes – Section 2.4)

16:20-17:00 – Talk 20 - Stability of Compressor with Seal Cross Coupling and Optimized Tilting Pad Bearings with Pivot Flexibility – Tim Dimond

Day 3 – Wednesday, October 22, 2014

Session 8 – Compressor High Vibrations and Case Histories I

8:00-8:30 – Talk 21 – Aerodynamic Cross-Coupling – A Brief Overview – John Nicholas

8:30-9:15 – Talk 22 – Rotordynamic Design of Centrifugal Compressors in Accordance with API Specifications – John Nicholas

9:15-10:00 – Talk 23 - Compressor Instability Due to Internal Seals and Solution – Paul Allaire (From Joy Martin, Chester Lee of Solar Turbines)

10:00-10:15 Break

Session 9 – Compressor High Vibrations and Case Histories II

10:15-11:00 – Talk 24 – Gas and Liquid Labyrinth, Honeycomb, Hole Pattern Seals – Advanced Analysis Methods and Improvements – Paul Allaire

11:00-11:45 – Talk 25 – High Vibration and Fix in Pipeline Compressor Fix with Damper – Paul Allaire

12:00-13:00 – Lunch (Provided)

Session 10 – Rotor Problems and Repairs I

13:00-13:30 – Talk 26 – Bearing Redesign – Tom Smith

13:30-14:15 – Talk 27 – Better Rotor Balancing – Principles and Repairs – Tom Smith

14:15-15:00 - Talk 28 – Rotor Repair with Welding and Coatings – Performance Improvements – Tom Smith

15:00-15:15 Break

Session 11 – Rotor Problems and Repairs I

15:15-16:00 – Talk 29 - Characteristics and Repair of Rotor Cracks, Tom Smith

16:00 - Tour of Ethos Energy Facility

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Day 4 – Thursday, May 23, 2014

Session 12 – Motors, Generators and Alternators I

8:00-8:45 – Talk 30– Case History and Lateral Rotordynamic Assessment of Large Alternator/Flywheel Rotor – Tim Dimond

8:45-9:15 - Talk 31 – Electrical Faults and Characteristics of Motor Vibration Problems - Paul Allaire

9:15-10:00 – Talk 32 – Torsional Analysis of Large Alternator/Flywheel Rotor with Motor Excitation and Fatigue Life - Tim Dimond

10:00-10:15 – Break

Session 13 – Motors, Generators and Alternators II

10:15-11:00 – Talk 33 – Motor Excitation of Structural Vibration Problem and Fix –Paul Allaire

Session 14 – Steam Turbines and Case Histories I

11:00-12:00 – Talk 34 - Eliminating a Rub Induced Start-Up Vibration Problem in an Ethylene Drive Steam Turbine – Case History – John Nicholas

12:00-13:00 pm – Lunch (Provided)

Session 15 – Steam Turbines and Case Histories II

13:00-13:45 – Talk 35 – Identification of Steam Turbine Rotor Rub and Bowing Characteristics of Rotating Machinery – Paul Allaire

13:45-14:30 – Talk 36 – Squeeze Film Damper Construction and Operation/Use of O-Rings as Centering Springs – Tim Dimond

14:30-15:00 – Talk 37 – Retrofitting a Large Steam Turbine with a Mechanically Centered Squeeze Film Damper – John Nicholas

15:00-15:15 - Break

Session 16 – Introduction and Industrial Applications of Magnetic Bearings

15:15–16:00 – Talk 38 – Introduction to Magnetic Bearings – Paul Allaire

16:00–16:45 – Talk 39 – Trends in Upstream Oil and Gas Applications with Magnetic Bearings - Tim Dimond (with Mike Swann)

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Day 5 – Friday, October 24, 2014

Session 17 – Geared Systems and Case History

8:00–8:45 – Talk 40 – Modeling of Geared Systems Including Bearings and Shaft Dynamics – Tim Dimond

8:45–9:15 - Talk 41 – Tilting Pad Journal Bearing to Solve a High Speed Pinion Vibration Problem – Case History – John Nicholas

Session 18 – Nonlinear Dynamic Modeling of Industrial Rotors

9:15–10:00 - Talk 42 – Nonlinear Transient Analysis of Compressor on Tilting Pad Bearings and Squeeze Film Dampers – Tim Dimond

10:00–10:15 – Break

Session 19 – Modeling of Gas Turbine Engines

10:15–11:00 - Talk 43 – Rotordynamic Modeling of Gas Turbine Engines – Rolls Royce AE3007– Tim Dimond

11:00–11:30 - Talk 44 – Rotordynamics of Gas Turbine Engines: Updates on Squeeze Film Dampers – Tim Dimond

Session 20 – Thrust Bearings

11:30–12:15 - Talk 45 – Design and Analysis of Thrust Pad Bearings, Tim Dimond

12:45 - End of Short Course

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

Registration and Fees

Advanced registration for the short course should be sent to Dr. Tim Dimond at tim.dimond@rotorsolution.com or Rotor Bearing Solutions International (RBSI), 3277 Arbor Trace, Charlottesville, Virginia, 22911. Additional information is given on the Rotor Bearing Solutions International website at www.rotorsolution.com. The RBSI telephone number is 434-632-8469 or 434-284-1850 (cell). The Ethos Energy contact person is Scott Hill – his cell phone number is 713-203-7236.

The fee for the course for the first person from a company is \$1,500, with advanced registration or \$1,600 on site. The fee for the second or third person from the same company is \$1,200 per person or \$1,300 on site. Seating for the short course at Etho Energy 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.

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 32.5 PDHs (professional development hours) will be provided for attendees of the short course.

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.