Turbomachinery Laboratory

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Founded in 1971, the faculty and staff of the Turbomachinery Laboratory (TL) and Texas A&M University continue to address the needs of the pump and turbomachinery industries. We are proud to continue Texas A&M's land-grant charter and tradition of attention to industry's needs in the following three areas:

- Continuing Education and Professional Development
- Undergraduate and Graduate Education
- Basic and Applied Research

CONTINUING EDUCATION AND PROFESSIONAL DEVELOPMENT

With respect to continuing education and professional development, the Turbomachinery Symposium was the initial principal activity of the Laboratory. From a modest beginning on the Texas A&M campus, the symposium has become the principle annual meeting for the users and manufacturers of industrial turbomachinery. The attendance for this meeting has grown to more than 3400, with over 250 exhibiting companies. Because of the continued growth of the Turbomachinery Symposium, the meeting moved to Houston. The papers presented at the symposium are invited by the Advisory Committee from recognized industrial leaders. The high quality and enduring value of these papers have been confirmed by practicing engineers who carefully hoard the symposium Proceedings within their professional libraries, and by the frequency of their citation in other transactions.

In 1984, the TL began a new symposium, the International Pump Users Symposium, which was patterned after the Turbomachinery Symposium, but devoted entirely to pumps. The inaugural Pump Symposium had 520 attendees and more than 50 exhibitors, representing pump manufacturers and users from the petrochemical industry and the utilities. Recent Pump Symposia have shown strong growth and clearly confirm the need for a forum for industrial pump users. The attendance has grown to more than 2500, with over 145 exhibiting companies.

Short courses are offered in advance of both symposia. The Short Courses are offered by experienced turbomachinery and pump users. Some topics covered by recent short course offerings include:

- Hydraulic Design and Analysis of Axial, Mixed Flow, and Centrifugal Pumps
- The Relationship of Vibration to Problems in Centrifugal Pumps
- Fundamentals of Mechanical Seals (Basics)
- Fundamentals of Centrifugal Pump and System Interaction
- Positive Displacement Pumps
- Pump Cavitation—Physics, Prediction, Control, Troubleshooting
- Road to Reliable Pumps
- Centrifugal Compressors 101
- Introduction to Steam Turbines
- Centrifugal Compressors 201
- Combined Cycle and Cogeneration Power
- An Introduction to Babbitted Bearings as Used in Industrial Turbomachinery
- Large Engineered Motors, Generators, and Variable Frequency Drive System Fundamentals for Mechanical Engineers
- Root Cause Failure Analysis in Industrial Turbomachinery
- API 614 (ISO 10438) Fifth Edition

In addition, the TL offers several standalone short courses throughout the year. Recent titles include:

- Dry Gas Sealing Systems
- Compressors—Construction, Performance, Testing, Selection, and Sizing
- Centrifugal Compressor Operation for 21st Century Users
- Reliability Evaluation of Steam Turbine Blades for Process Drives
- Pump Life Cycle Course
- Machine Failure Short Course

More information regarding these courses can be found on the TL website at http://turbolab.tamu.edu.

UNDERGRADUATE AND GRADUATE EDUCATION

At Texas A&M University, faculty expertise related to turbomachinery has traditionally provided equal emphasis on performance and reliability. Our undergraduate program provides students with elective options in turbomachinery performance, fluid and thermal science, vibrations, stress analysis, and other related topics. Our M.S. program provides a balance between performance and reliability with more specific electives in turbomachinery performance, rotordynamics, etc. Most M.S. thesis research projects involve experimental validation of theoretical and computational developments. The emphasis on experimental validations of predictions stands in contrast to many graduate programs around the country. Ph.D. research topics are generally related to ongoing research programs within the Laboratory.

BASIC AND APPLIED RESEARCH

Faculty and staff of the TL carry out research activities for both industry and government. Most of the industrial research support is provided through the Turbomachinery Research Consortium (TRC). Currently, 25 industrial firms provide grants of $20,000 per year to support a broad range of industrial research projects. In addition, grants and contracts from government and private agencies provide continuing support for graduate research and education related to performance, rotordynamics, seals, computational fluid dynamics, torsional vibrations, materials, and finite element analysis. Brief summaries are provided below for some of our current research activities.

Turbomachinery Performance

- Development of computational programs for both compressible and incompressible, radial-flow turbomachines
- Testing pumps for two-phase flow performance and vibration characteristics

Combustion

- Chemical kinetics of fuel blends at engine pressures and temperatures
- Flame speed and ignition measurements in mixtures with high water content
- Nanoparticle additives for tailoring the burning rate solid composite propellants
- Formation and characterization of soot grown at engine conditions
- Detonation wave formation and propagation into a confined volume
- Shock-tube studies of low vapor pressure fuel combustion

Rotordynamics and Reliability

- Measurements of responses to imbalance (100,000 rpm) and shock loads in a test rotor supported on gas bearings for oil-free turbomachinery
- Experimental characterization of the rotordynamic (nonlinear) performance of automotive turbochargers supported on floating and semifloating ring journal bearings
- Experimental tests for identification of rotordynamic coefficients in fluid film bearings, gas damper seals, and brush seals
- Development of high temperature magnetic bearings
- Flywheel stress and vibration
- Computational transient (linear and nonlinear) response of turbocharger rotors supported on floating-ring bearings. Identification of limit cycle amplitudes and whirl frequency ratios
- Measuring rotordynamic coefficients for tilting-pad bearings
- Coupled lateral-torsional rotordynamics
- Rotordynamics of a twin-screw pump with two-phase flow
- Marrying the output of ANSYS® to *XL*TRC^2 for speedy analysis of general housing structures
- Developing a new rotordynamic analysis algorithm for the Morton Effect
- Calculating in-rotor temperatures for fixed-arc and tilting-pad bearings to support Morton-effect rotordynamics analysis

Seals

- Predicting rotordynamic coefficients for a see-through labyrinth seal for real-gas properties and steam
- Computational analysis of gas tilting pad bearings, spiral-groove face seals and herringbone bearings for oil-free turbomachinery
- Annular, honeycomb, labyrinth, and hole-pattern gas seals—analysis and high-pressure (70 bar supply pressure) testing for leakage and rotordynamic coefficients
- Labyrinth seals—analysis and testing for leakage and rotordynamic coefficients
- 3D LDA measurement of fluid flow
- CFD based rotordynamic coefficients for labyrinth seals and impeller shroud leakage paths
- Leakage measurements in brush seals

ROTORDYNAMICS SOFTWARE

The TL staff has developed the integrated rotordynamics-software suite, *XL*TRC^2. The structural-dynamics code uses a finite-element/real-component-mode synthesis approach to achieve accurate and speedy analyses. *XL*TRC^2 can perform steady-state response calculations for synchronous or nonsynchronous excitation, stability analysis, and time-transient nonlinear calculations. The finite-element base means that multirotor systems can be handled readily, e.g., flexible-rotor/flexible-housing vertical pumps, dual-rotor/flexible-housings, etc. The basic code is enhanced by an extensive support library for calculation of bearings, gas seals, liquid seals, impeller stages, etc. The time-transient feature can be used to examine nonlinear response, e.g., blade loss, bearing-dead-band effects, etc. The code is highly efficient and runs on a range of operating systems. Developments are currently underway to allow a direct transfer of housing modal data into the code. This feature will allow external structural dynamic analysis of complicated housing structures using codes such as ANSYS®. This code has been extended to include torsional-lateral coupling and a new algorithm for predicting Morton-effect behavior.

*XL*TRC^2 also includes a comprehensive torsional analysis, including transient and steady-state applications for multirotor systems including branched and loop systems. During 2009, Dr. Brian Murphy was contracted to greatly enhance the features of the code to automatically carry out analyses in compliance with API 684 requirements.

*XL*TRC^2 is only available to members of the Turbomachinery Research Consortium. An online blog feature is provided to rapidly identify “bugs” and their corrections plus continuing upgrades.

FUTURE PROGRAMS

Several of the following programs are being planned for the future.

- LDV measurement capability for compressible and incompressible flow fields (compressors and pumps)
- Visualization of the flows around blade surfaces and tips
- Visualization of bubbly flows (air entrainment) in squeeze film dampers
- Use and improvement of magnetic bearings for parameter identification in centrifugal compressors
- Examining the use of much longer balance piston or division-wall seals in centrifugal compressors to enhance performance and rotordynamic response