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

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

Application of fiber-optic strain gauges to accurately measure dynamic forces with magnetic bearings for parameter identification

Measuring rotodynamic coefficients for tilting-pad bearings

Predicting and measuring rotor response during dry-friction whip and whirl

Predicting and measuring the characteristics of both radial hydrostatic bearings

Computational analysis of process fluid hydrostatic/hydrodynamic thrust bearings: effects of collar misalignment and prediction of moment-angle coefficients

Seals

Computational bulk flow analysis of Lomakin bearings for cryogenic turbopumps

Computational bulk flow analysis of labyrinth seals for cryogenic turbopumps

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 rotodynamic coefficients

Labyrinth seals—analysis and testing for leakage and rotodynamic coefficients

3D LDA measurement of fluid flow

CFD based rotodynamic coefficients for labyrinth seals and impeller shroud leakage paths

Leakage measurements in brush seals

ROTODYNAMICS SOFTWARE

The TL staff has developed the integrated rotodynamics-software suite, XLTRC2. The structural-dynamics code uses a finite-element/real-component-mode synthesis approach to achieve accurate and speedy analyses. XLTRC2 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 is only available to members of the Turbomachinery Research Consortium. During the past year, Dr. Brian Murphy was contracted to greatly enhance the features of the code to automatically carry out analyses in compliance with API 684 requirements.

XLTRC2 also includes a comprehensive torsional analysis, including transient and steady-state applications for multirotor systems including branched and loop systems.

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 rotodynamic response