■ ROTATING MACHINERY AND CONTROLS LABORATORIES ■

ROMAC

FALL, 1994

Message from the Director

Ron Williams

During my first term as ROMAC director, which began in July of 1992, I had a primary goal to ensure that our industrial members received good value return for their membership fees. The ROMAC faculty started to review the research history and future directions for the laboratory. Our administration and budgeting was tightened, and the needs of our members were considered in all planning decisions. We still have more work to do in this area, but it was clear from your responses at the annual meeting that our initial work in this direction has begun to bear fruit.

Our research plans for this year were discussed at the annual meeting in June, and we were pleased with the extent to which our plans coincided with the needs expressed by our members in attendance. Now that my second year as ROMAC director has ended, I am pleased to report that we have continued to try to identify and address the current and future needs of our industrial members. As always, we invite and encourage your suggestions and comments.

We have continued to improve the working environment in our laboratory. Our laboratory experimental engineer, Klaus Brun, is continuing the reorganization of our laboratory space. Last year, we purchased several new personal computers for use by our graduate research assistants in the laboratory. This year we plan to upgrade our computing resources further. We believe that the improved facilities will help our graduate students to be more productive, and we hope to foster a professional attitude about our lab.

This year has brought another change in our administrative support structure. Our long-time conference coordinator and office manager, Sandy Maslen, decided that it was time for a change in her life. She resigned from her position with ROMAC late in the summer, and she has been replaced by Tana Herndon. Sandy will certainly be missed since she carried much of the ROMAC "corporate memory" in her head. However, we were very fortunate to have an individual as competent as Tana to take Sandy's place.

I am also pleased to report that there have been some significant changes in the ROMAC faculty membership. We will miss Bob Humphris who has taken a well earned retirement, but we cannot complain about his departure after all of the good years that he has given to ROMAC. We have again been fortunate to find an excellent replacement for Bob. George Gillies is a Research Professor who has extensive experience with a wide range of research projects, and he has agreed to accept many of the responsibilities that Bob handled so well. We welcome George to ROMAC and we eagerly anticipate great work from him. The other new addition to the ROMAC faculty is an individual known to many of you. Ted Brockett served as our laboratory theoretical engineer for some time, but now he is finishing the requirements for the Ph.D. We are fortunate that Ted has agreed to stay on with ROMAC as a research faculty member. He will continue to provide much of the technical support that he has provided for our members in the past, but he will now start assuming more of the responsibilities that are expected of faculty members.

We have continued to make changes this year that are directed to make better use of our available resources. We continue to seek new members for the ROMAC consortium, but we are not asking any more from our current members. The membership fees for 1995 will remain at the same level ($12,000) as they have been for several years.

We appreciate your support of the ROMAC program, and we welcome any comments or suggestions that you may have to improve our program further. Please contact any of the ROMAC faculty members if you have any questions or suggestions regarding our program.

INDEX

ROMAC Annual Meeting `95

Williamsburg, VA. - June 19-22

The 1995 annual meeting is scheduled to begin with registration on Sunday, June 18, and end on Thursday, June 22. The 1995 meeting has been scheduled much later in the month than the 1994 meeting because of several requests from our members and because we hope to increase attendance further at this meeting.

The annual meeting will be held at The Williamsburg Woodlands in Williamsburg, VA. This hotel was selected because of its conference facilities, resort amenities, and relatively attractive room costs. This hotel provides suites for all of our ROMAC member attendees, and it provides easy access to a wide range of recreational activities for attendees and their families.

Several years have passed since we last had a ROMAC annual meeting at a resort location. We hope that this attractive location will encourage greater attendance, and we also hope that those who attend will be present for more interaction. ROMAC provides significant diversity in our work, and we recognize that few of our members are truly interested in all facets of our research program. We therefore consistently schedule our core work of rotor dynamics at the center of the conference with the specialized topics of magnetic bearings and fluids placed at either end of the conference. This is done intentionally to permit members with more restricted interests to attend only those parts of the conference that are of most interest to them. However, many of our members tell us that one of the most significant benefits of attending the ROMAC annual meeting arises from the interactions that occur among members from different organizations. Since this is of benefit to our members, we want to try to encourage this interaction.

At the 1994 annual meeting, we added an informal hospitality suite in the evenings, and this was generally well received. We will repeat this in 1995. In addition, we hope that members who would otherwise have attended only part of the conference will consider staying for the entire conference. We recognize that some of the topics will not be of interest to everyone, but placement of the conference in a resort location ensures that there will be recreational opportunities available to occupy the interest of attendees during the sessions that are outside of their interests. If you are not interested in magnetic bearings, come to Williamsburg during this time and play golf or tennis, or visit the colonial attractions. You can attend the sessions that apply to you, and you will be able to participate in the valuable interactions with the other attendees. Also, many of you may want to consider bringing family members with you to this meeting since there are so many things to do.

The ROMAC annual meetings have consistently attracted a loyal core of members, but we would like to encourage increased attendance and participation by all of our members. We believe that this year's meeting will offer several special enticements for better attendance.

The accommodations that we have selected should be very pleasant and reasonably priced ($89 per night/single or double). The registration fee will be $550. We understand that the greatest cost of attendance for our member companies is the absence of you, their critical employees. However, we also understand that travel budgets can be tight.

We will also be providing you with information about the many activities and points of interest that are available in the Williamsburg area. There is a wide variety of interesting things to do for those of you who may be accompanied by family.

Registration materials will be sent to our members in March, 1994. Mark your calendars and plan to join us in June.

ROMAC Short Course

Advanced Rotor Dynamics

This course will be offered for the second time next April. It was last offered in March of 1992. The Basics of Rotor Dynamics was held last April. We will be including more on the use of ROMAC computer programs in the advanced course this coming April, including some of the newer programs. We will also be using the ROMAC Scripted Editor and the Shell. As in the past, there will be no registration charge for this course. This may limit the amount of space made available to us by the hotel where arrangements will be made which will in turn limit the number of people who can attend. More information will be provided around the first of the year.

ROMAC Industrial Liaison

Ted Brockett, now a Research Assistant Professor in the ROMAC Laboratories, is still currently responsible for liaison with the industrial members on technical issues with our computer programs. He works directly with other graduate students and the faculty in trying to find answers to your questions. These interactions have resulted in updates and corrections to several of our programs. If you have questions, please call Ted at (804) 982-3049. Computer questions and questions about receiving programs should be sent to our Programmer/ Analyst, Toby Korn at (804) 924-6234.

ROMAC Computer News

W. Tobias Korn

We are continuing our efforts to make ROMAC codes more user-friendly and more easily maintained.

The Scripted Editor and Shell

Development of the ROMAC Shell and Scripted Editor is continuing. See the article on page 13 of this newsletter for more discussion of the ROMAC Shell and Scripted Editor and associated pre-processors and post-processors.

We appreciate the suggestions that we have received thus far, and we welcome your continued input. If you do not yet have a copy of the Shell and Scripted Editor, please let me know.

New Features Added to Codes

We will continue to add the capability for ROMAC codes to accept command line arguments in the DOS environment. We have used command line arguments to input data file names and parameters to redirect output. This will allow batch processing and is a necessary modification to enable programs to work under the ROMAC shell/scripted editor environment. In addition to command line arguments, we are adding a feature to our codes to enable file names and other options which could be entered on the command line or interactively to be listed in a file and specified by placing @filename as the first input to the program. This is done on the command line, or interactively. Since this feature is implemented in standard FORTRAN, those compiling the code on systems which do not provide a command line option capability may enter the name of a file at the first interactive prompt, thus enabling near batch-mode operation.

We are continuing to use standard FORTRAN conventions in our codes, while also taking advantage of the DOS and Windows operating environments. The DOS and Windows versions of our codes will necessarily have some non-standard FORTRAN code in order to take advantage of the DOS command line. In programs where we use any non-standard options, these sections will be commented and are not necessary for the operation of the code. These sections are simply commented out to port the code to a non-DOS system.

Instant Access to ROMAC Codes and Technical Support

In order to make access to ROMAC programs easier for ROMAC members, we have made programs available via FTP (Internet File Transfer Protocol), Internet electronic mail and MODEM dial-in line. Electronic mail is an especially useful tool for providing technical support. If you have difficulty running a program, you may e-mail the input file to us. We are then able to simply extract the data file from the e-mail message and run it here and see first hand the difficulty. Please be sure to let us know if you have at your disposal an INTERNET connection, subscription to Compuserve, America On-Line, MCI Mail, Delphi, BIX, a subscription to some other service that provides electronic mail services, or a MODEM.

If you use a MODEM to dial-in to the ROMAC server, you then have access to ROMAC codes, as well as to electronic mail. You may use the electronic mail service on our server to send mail to ROMAC faculty, staff, other ROMAC member companies, as well as anyone who has access to electronic mail worldwide (including those services mentioned above).

Updates to the ROMAC Shell and Scripted Editor and SED Files

ROMAC Shell Version ß2.3 (12/8/93) (update by W. Tobias Korn): The subroutine which runs the ROMAC Scripted Editor was modified to enable the use of a response file rather than using the command line to input the file names. This version of the Shell must be used with Version 1.2ß or later of the ROMAC Scripted Editor.

ROMAC Shell Version ß2.35 (1/11/94) (update by W. Tobias Korn): Added is the ~l directive in the file ROMAC.GRP to specify that the program being called is able to handle a response file. Due to an unfortunate "feature" related to the access command in Borland C++ Version 3.1, access would not report an error if the file name it attempts to locate is empty. Therefore, a new routine was added to check for this possibility.

ROMAC Shell Version ß2.36 (1/12/94) (update by W. Tobias Korn): If the ASCII editor is not selected, the Shell will automatically prompt for the name. When an external viewer is selected, the Shell will unselect the use internal viewer option.

ROMAC Shell Version ß2.37 (1/12/94) (update by W. Tobias Korn): The name of the Shell Organization file, formerly ROMAC.GRP, is now renamed to ROMAC.ORG to avoid name conflicts with Windows GRP files. This renaming is handled automatically by the Shell.

ROMAC Shell Version ß2.38 (1/13/94) (update by W. Tobias Korn): The SED files are now located in the same directory as the SED.EXE file. If they are not found there, the Shell will check the directory where the program is located for one and attempt to move it to the SED.EXE directory.

ROMAC Shell Version ß2.39 (2/23/94) (update by W. Tobias Korn): A print option was added to the viewer. The print function was written by Eric Maslen.

ROMAC Shell Version ß2.40 (6/16/94) (update by W. Tobias Korn and Eric H. Maslen): If the ORG file is not found, the program displays an error message box and then exits gracefully.

ROMAC Shell Version ß2.41 09/23/94) (update by W. Tobias Korn): When the print option in the viewer was selected, the output file was printed. This has been modified so that the file printed is the one being viewed. This modification was needed since the viewer is used to view help files as well as output files.

ROMAC Scripted Editor Version 1.1β (December 2, 1993) (update by W. Tobias Korn): An initial screen to display program version information was added. Also added was the Swapfile_DEBUG compilation option to display the name of the data file name to pass to the Shell. This is used only for debugging.

ROMAC Scripted Editor Version 1.2β (December 7, 1993) (update by W. Tobias Korn): The capability to use a response file as the first command line argument was added. If the first argument is of the form @*filename*, the file *filename* will be read for arguments to replace those on the command line, one argument per line of the file.

ROMAC Scripted Editor Version 1.21β (December 7, 1993) (update by W. Tobias Korn): Modified the program to automatically rename ROMAC.GRP to ROMAC.ORG as per modifications made to the Shell.

ROMAC Scripted Editor Version 1.22β (December 17, 1993) (update by W. Tobias Korn): Modified the program to look for SED file in the directory where SED.EXE is located rather than looking in the ORG file.

ROMAC Scripted Editor Version 1.23β (June 10, 1994) (update by W. Tobias Korn): Added % comment character specification to SED language as per instructions from Thomas Johnson.

MODFRE.SED Version 1.02 (by Lyle Branagan (PG&E) and W. Tobias Korn): MODFRE is now supported by the ROMAC Shell and Scripted Editor. The new files MODFRE.SED, MODFRE.MAN, and MODFRE.PIF are available. Special thanks to Lyle Branagan for developing this script.

MODFR2.SED Version 1.0 (by W. Tobias Korn): MODFR2 is now supported by the ROMAC Shell and Scripted Editor. The new files MODFR2.SED, MODFR2.MAN, and MODFR2.PIF are available.

THPAD.SED Version 2.0 (September 14, 1994) (update by Lyle Branagan, PG&E): This version is to be used for THPAD Version 2.27a.

Updated ROMAC Programs

The following ROMAC programs have been recently upgraded:

COTRAN/COGRAF Version 3.0 (October 25, 1994) (update by Dr. Zhichu Fang): The Newmark integration algorithm was corrected to give better numerical accuracy and stability. Default data file names have been removed so the user can now specify his/her own data file names. Subroutine MODRED was rewritten for clarity. Several variable names were modified so that potential errors could be avoided. If post-processing of the output is desired, user must now use COGRAF Version 3.0. In COGRAF, unused elements of vector IPN were deleted. The command prompt was modified for aesthetics. A REWIND statement was removed.

CRTSP2 Version 2.32 (August 17, 1994) (update by W. Tobias Korn): The plotting routine GRAPHMOD was modified to correct an error which occurred when the number of stations were the same on both rotors. An extraneous error message, which occurred in CRITMAP when the user selected no plot from the menu, was removed.

CRTSP2T Version 1.1 (March 9, 1994) (update by Theodore S. Brockett): A version number and date were added to the program. Characters in columns 72-80 were removed from the FORTRAN files. Variables declared but not used were removed. The plotting subroutine GRAPH was changed drastically. The "beep" heard after a plot was finished was removed. The newest version of subroutine INIGRF was included. Calls to GEOGRAF subroutine WHERE were corrected by removing the third argument. The statement INTEGER*2 IDEV,NPAGES,GCLOSE,SLTYPE, LTYPE was added to the subroutine GRAPH in order to define the variables correctly. Some spelling mistakes were corrected.

FRESP2 VERSION 2.40 (September 15, 1994) (update by W. Tobias Korn): Modified the program to allow the output to be written directly to a file rather than to standard output (usually the screen). The command line arguments were modified to allow for the input of the output file name and the order was changed. The command line options are now as follows:

FRESP2 *input* output *rotor1*
rotor2 substructure result *plot*

where *input* is the FRESP2 input file, output is the output from FRESP2, *rotor1* and *rotor2* are the modal data files for rotors 1 and 2, respectively, *substructure* is the file with the data for the substructure, result is a file to be generated by FRESP2 of displacement data, and plot indicates whether or not to produce GEOGRAF™ plots. The valid options for plots are Y and N for yes and no, respectively. Also added to this version is the standard FORTRAN capability to use a response file to list the file names and options required, one per line. To use a response file, the input parameter is filled with *@responsefilename*. The file *responsefilename* is opened and the file names and options are read from this file. If certain file names are not required for a particular case, the word NONE can be used as a place holder in the list of arguments. Any required arguments not specified on the command line or response file will be prompted for interactively.

MAGSTAB Version 2.12 (August 31, 1994) (update by W. Tobias Korn): Added report of version number to syntax description.

MODFRE Version 1.11 (August 11, 1994) (update by W. Tobias Korn): Allowed MODFRE to overwrite output files if they exist.

RESP2V3 Version 2.3 (August 23, 1994) (update by W. Tobias Korn): The size of variable arrays used in the program were parameterized to facilitate increasing the capacity of the program. See the file PARAM.INC for sizes and notes on use of the PARAMETERS. A subroutine was added to check certain input variables against program limits. Several FORTRAN file names were changed to better indicate the contents of the file. The version number and date were included in the parameters.

THPAD Version 2.27 (June 15, 1994) (update by Lyle Branagan): This update adds output of convergence errors, better output of non-converged conditions, and opportunities to provide input for hot oil carryover (user inputs a % of hot oil that is mixed at the leading edge of the next pad) and a percentage for cold oil insertion (user inputs a % of leading edge oil that is supplied by cold inlet oil - takes priority over other sources). In the latter case, remaining oil requirements for the leading edge are supplied by oil at the sump temperature.

THPAD Version 2.27a (September 14, 1994) (update by Lyle Branagan, PG&E): This update corrects recent revisions to include hot oil carryover and cold oil injection. This revision does include a change to the input file. If you are using the ROMAC Scripted Editor, you will need to update your THPAD.SED to Version 2.0.

New Computer Programs

THRUST Version 0.9β

Ted Brockett, Lloyd Barrett and Paul Allaire

Program THRUST is a standard FORTRAN-77 computer program used to determine the steady-state operating characteristics of fixed and tilting pad geometry hydrodynamic thrust bearings. The bearing operating characteristics calculated by the program include the film thickness distribution, film temperature distribution, temperature distribution in the pad and runner, and the elastic deformation of the pad and runner. In addition, the power loss and fluid flow requirements are determined by the program. The pad styles that can be analyzed presently include tilting pad (with spherical, line or mechanical pivots), tapered land, parallel tapered land, complex taper, and plain flat land styles. Additional styles will be available in the near future.

The finite element method is used throughout to solve the governing equations. A generalized Reynolds equation is used to find the pressure distribution in the film and includes the effects of cavitation, cross-film viscosity variation, and turbulence. An axisymmetric conduction model is used in the runner while a 3-D conduction model is used in the pad. A 3-D energy equation is used to find the temperature distribution in the film. The resulting temperature gradients at the film-solid interface establish the fluxes into the solids and, therefore, the resulting temperature distribution in the solids. Thermal and mechanical deformation of the pad is calculated using a detailed pad model.

Output files compatible with the plotting package TECPLOT are produced and allow for easy visualization of all calculated results.

TORTRAN2 Version 1.0

R. Scott Orsey, Ted Brockett, and Lloyd Barrett

Program TORTRAN2 is a standard FORTRAN-77 computer program used to determine the transient torsional characteristics of rotor systems. Originally intended to model the startup characteristics of synchronous motor-driven systems, the program is also capable of modeling any set of time dependent torques applied to the rotor with an arbitrary set of initial conditions. Three different applied torque model options are available to the user. The synchronous motor applied torque option allows the user to specify the manner in which the steady and oscillating torque magnitudes vary with the shaft speed. The oscillating frequency varies with the slip frequency in this case. A slightly more general torque input option allows the user to specify the variation of the steady and oscillating torque magnitudes and the oscillating frequency as a function of shaft speed. The most general torque option allows the user to specify the applied torque magnitude at arbitrary discrete points in time with linear interpolation used by the program for points in between. Up to ten applied torques of any type may be applied to the rotor model simultaneously.

The code returns valuable information to the user. Both the torque and maximum shear stress within the elements are available as a function of time in the form of printed results and plots. In addition, a cumulative fatigue analysis is performed on the elements of the model using Miner's rule. The cumulative fatigue analysis returns the maximum number of starts (or cycles) the rotor may experience before failure is predicted to occur. A manual is available to the user to aid in running the code.

MAGSTAB Version 2.11

Eric H. Maslen

MAGSTAB is a fairly simple, stripped down analysis tool for finding the damped planar eigenvalues of a rotor supported in a combination of conventional and magnetic bearings. The code can also be used to generate a state space model in a form compatible with Matlab™ or other matrix analysis software. It assumes the following:

- circularly symmetric shaft and bearings
- conventional bearings are described as simple direct stiffness and damping
- magnetic bearings pair one sensor with each actuator through a linear transfer function
- only one shaft is supported
- an Euler--Bernoulli beam model is used for the shaft with no shear deformation or rotary inertia in the shaft elements; degrees of freedom

with no assigned inertia are removed by static (Guyan) condensation
- components mounted to the shaft, such as disks or impellers, are mounted rigidly and are circularly symmetric
- The standard analysis assumes that the shaft is not spinning.

MAGSTAB will analyze spinning shafts but the analyst should have a clear understanding of the analysis involved when interpreting the results. The eigenvalues computed are not actual eigenvalues of the system, but are useful in forced response analysis.

Program Development

THRUST

Ted Brockett, Lloyd Barrett, and Paul Allaire

ROMAC's hydrodynamic thrust bearing program THRUST is now available as a "Beta" test version. It is capable of analyzing tilting pad bearings with the various pivot geometries, tapered land bearings, parallel taper bearings, and compound taper bearings. Development continues with this code, especially in the area of adding more pad geometries to those that can already be analyzed. Additional development will be considered if interest by the industrial participants is shown. This additional development could include adding analysis capabilities for circular pads, double-acting thrust bearings, hydro-static lift calculations, churning loss models, or additional pad styles or models not yet considered.

SEAL3: Dynamics of Annular Seals in High Axial Flow Incompressible Fluids

Avichal Mehra, Paul Allaire and Hossein Haj-Hariri

Work continues on the development of a new seal code, SEAL3, for the dynamic analysis of seals with high axial flow. The primary application will be for high pressure pump seals. The analysis is an extension of the older code SEAL2 which has been in use for many years and is well regarded by many pump companies and pump users.

The new code will use bulk flow theory for the continuity and momentum equations. Bulk flow theory employs an approximation assuming that the radial velocity component is small so it does not appear in the equations of motion. A perturbation approach has been adopted where the analysis is separated into two parts: (1) shaft centered operation, and (2) perturbed operation. In the first part, the nonlinear equations are evaluated for centered seal operation where there is no circumferential variation of the pressure or velocity components. In the second part, a linearized set of perturbation equations is developed. These are employed to find stiffness, damping and mass dynamic properties of the seal.

Inlet and exit boundary conditions are important in the analysis - inlet and exit pressure boundary conditions as well as inlet swirl effects due to flow along inlet surfaces. Both plan and grooved seals will be considered. Results will be compared to other theoretical treatments and experimental results where available.

Current Research Projects

Fluid Film Bearings and Seals

Assessment of Non - Linear Effects in the ROMAC Bearing Test Rig

Carmen Müller-Karger, Lloyd Barrett, and Ron Flack

Carmen Müller-Karger has completed her MS thesis examining the effects of bearing non-linearity on the measurement of hydrodynamic bearing linearized stiffness and damping coefficients. A report on this work is available as well as the computer programs written as part of this work.

The work involved simulating the complete measurement and calculation process used on the bearing test rig. The simulation process was conducted for a wide range of testing conditions including the size of the imposed orbits and relative magnitude and phase of the dynamic force input for a wide range of Somerfeld numbers. In addition, the effects of residual unbalance and non-synchronous excitation were also examined.

Results of the study correlated well with test results obtained from the rig. The study has also provided insight into conduction future tests to minimize distortion of the measured stiffness and damping coefficients due to non-linear effects.

Tilting Pad Bearings

Karl Wygant, Ron Flack and Lloyd Barrett

The large rigid rotor bearing test rig (70 mm dia. bearings) is being setup for testing of tilting pad bearings. Turbo Components and Engineering, TCE, is currently instrumenting the first of a series of bearings that ROMAC plans to be testing.

The first test bearing is a five pad tilting pad bearing. This bearing consists of a bearing shell and four sets of interchangeable tilting pads. Each set of pads has a different machined clearance. By adjusting the assembled bearing clearance multiple preload and multiple bearing clearance conditions may be examined. This particular bearing has an L/D ratio of 0.75, ball and socket pad pivots, and bronze backed pads. Eight thermocouples are being embedded in specific pads to allow a better understanding of the bearing's thermal properties.

For each bearing clearance and preload the thermal, dynamic, and static characteristics will be determined. These bearing characteristics are to be evaluated at various Sommerfeld numbers and loading conditions (on pad and between pad loads). An uncertainty analysis will then be performed to provide confidence levels for the experimental results.

In the future TCE will be providing additional test bearings. The next bearing that ROMAC plans to have manufactured is a four pad tilting pad bearing of similar design to the current test bearing. In the future various L/D, pad backing materials, and oil feed systems might be examined.

A feasibility study is in progress to explore the potential of testing over a greater range of Sommerfeld numbers and Reynolds numbers. The ability to test over greater non-dimensional speed ranges allows the experimental results to be of benefit to a greater variety of ROMAC member companies.

Flexible Rotor/Bearing Rig

José-Antonio Vázquez, Ron Flack and Lloyd Barrett

The small (25 mm diameter bearings) flexible rotor rig has been modified to incorporate flexible supports. Designs and preliminary tests were presented at last summer's annual meeting. The pedestals have been designed so that support flexibility effects on the unbalance response and stability can be documented. The results from this research will be used for verification of theoretical models and program codes. Tilting pad bearings as well as fixed geometry bearings will eventually be tested.

These new pedestals have been designed in such a way that the operational range of the rig is located above the first critical of the supports. Theoretical studies show that the forced response of the rig with the flexible supports is very different from the rigid case. This system has been designed to modify only the response in the horizontal plane while results in the vertical plane will remain very close to the rigid support response.

A simple finite element model of the pedestals shows results very close to preliminary impact test results. More detailed tests are being conducted on the pedestal to guarantee a good representative characterization of the dynamical behavior of these supports.

The shaft/bearing alignment difficulties discussed at the annual meeting have been successfully resolved. Tests of the assembled rig will begin in the next month.

Calculation of Hydrodynamic Rotordynamic Coefficients for Labyrinth Seals

Avichal Mehra and Hossein Haj-Hariri

Fluid forces developed in the seals are important in modeling the dynamic behavior of turbopumps accurately. The major contribution of this effort is the development of a code for modeling the flow in labyrinth seals and evaluation of relevant dynamic coefficients. Fluid forces due to all orbits around the eccentric position are used in the evaluation of stiffness, damping and inertial coefficients. The flow in the seals is described using the Navier-Stokes equations with an algebraic turbulent model. These equations are expanded by using an appropriate perturbation parameter (e.g., eccentricity). The resulting zeroth and first order equations are solved using a finite-volume formulation.

The zeroth order equations are assumed to be steady and axisymmetric. The velocities near the wall are represented by the logarithmic law of the wall. The temporal and azimuthal dependence of first order equations is removed by assuming periodic solutions and a circular shaft precession orbit. The forces and dynamic coefficients are obtained by integrating pressures and shear stresses on the rotating surfaces. An iterative algorithm which can be applied both to zeroth order and first order equations is adopted, which uses Roe linearization for upwinding and a point-implicit/explicit procedure for discretization. The algorithm can address various configurations including teeth on stator, teeth on rotor, interlocking seals and rotor whirl.

Some initial results for compressible flow through a single cavity labyrinth have been obtained. The flow fields and hydrodynamic forces agree well with the earlier published results for similar geometries. Also, there is excellent agreement between the computed and measured leakage for a given geometry. Efforts are on to verify results of multi-cavity labyrinths against available experimental results.

Fluids

Plexiglas Pump

Daniel Baun, Ron Flack, and Steve Miner

Tests were completed two years ago for the double volute Plexiglas pump. Velocities (from LV data) and pressures were collected. Impeller loads were found for both the single and double volute geometries. As expected, the double volute resulted in much lower loads at off-design conditions. Also from the LV data volute losses and slip were calculated for the double volute case. The efforts are continuing and loads and other characteristics are being predicted for both double and single volutes and are being compared to measurements.

The pump is now being modified and magnetic load cells are being installed which will directly measure the hydraulically generated loads on the impeller. The pump will be configured with two 8 pole planar radial bearings (load cells) on the inboard side and a single 8 pole planar radial bearing on the outboard side. In addition all axial thrust loads will be carried by a single double acting thrust bearing (load cell). The complete instrumentation system, including calibrated differential proximity probes for shaft position sensing, high output Power Amplifiers to drive the bearings, and a PID controller will enable force measurements over a wide frequency and load range. The first two verification tests planned will be the same single and double volute geometries for which LV and pressure data have already been taken. The new system will facilitate the quick measurement of total forces for different volute shapes, impeller geometries, tongue shapes etc. Once interesting geometries are identified, LV and pressure data can be measured to complete the characterization of the flow field.

Torque Converter

Klaus Brun, Len Whitehead, and Ron Flack

This is an industrially sponsored problem but has been used to expand our experimental capabilities and understanding of a complex multi-element mixed flow turbomachine. The torque converter internal flow field was mapped in detail for 13 measurement planes in the three different components and two significantly different operating conditions. A method was developed to correlate discrete laser velocimeter measurements taken in the stationary frame to obtain the unsteady velocity field in the rotating frame. "Movies" of this unsteady flow field have been presented at the annual meeting showing a complex jet/wake interaction at the pump-exit/turbine-inlet interface. Also, strong circulatory secondary flows, slip factors, and incidence angles have been measured. The data collected at UVA provides a benchmark for torque converter and other mixed flow turbomachine computational flow codes. Work is currently continuing for 6 different torque converter geometries.

Three Directional Laser Velocimeter

Ron Flack

Two years ago a three directional laser velocimeter was obtained under a separate contract. This was purchased for some very low velocity measurements (approximately 1 ft/min) for fire propensity studies, including free convection. The system is motor driven and fiber optics so the system is quite versatile and adaptive. It is capable of velocities in the supersonic regime. The system is not currently on a ROMAC project and the free convection studies will last until the end of this calendar year. During the next year it will be used for some aero-acoustics measurements in jets (also not a ROMAC project) and also probably for some measurements on a second pump. It is also available for some other turbomachinery flow measurements.

Magnetic Bearings

THE CENTER FOR MAGNETIC BEARINGS

The Center for Magnetic Bearings, part of the ROMAC Laboratories, has again received continuation funding from Virginia's Center for Innovative Technology (CIT). The funding for July 1, 1994 through June 30, 1995 is $49,600. This brings the total CIT funding for the Center to nearly $1,400,000 since July 1989. The Center is one of ten Technology Development Centers funded by the CIT. This funding has supported much of the magnetic bearing development in ROMAC.

Development of A Digital Controller for Magnetic Bearings

Steve Fedigan, Jeff Ebert, Paul Wayner, Feng Shen and Ron Williams

The control of magnetic bearings in rotating machinery can be a demanding industrial application for which processing speed must be sufficient to support fast, flexible rotors. Additional innovations in adaptive and open-loop control are demanding more processing power in embedded controllers. Furthermore, magnetic bearing applications cannot tolerate a controller failure. Therefore, simplex digital controllers are not sufficient to meet advanced needs in magnetic bearing control or, more generally, industrial control.

Work continues in ROMAC to develop a next-generation digital controller which can be configured for multiprocessing or redundancy, in order to satisfy the different demands of magnetic bearing applications. The base processor for the digital controller is the Texas Instruments TMS320C40 digital signal processor. The `C40 is a widely accepted DSP for both control and signal processing, and many tools are available to support this device. The CPU boards are TIM-40 compatible. (TIM-40 is an open standard, designed and supported by Texas Instruments and an industrial consortium.) Each TIM-40 board measures 2.5" by 4.2" and has a local memory of 128 Kbytes of EPROM and 256 Kbytes of SRAM. The CPU boards plug into a motherboard which may be configured for multiprocessing or fault tolerance. The motherboard, in turn, connects to a backplane into which the I/O cards are inserted.

The `C40 has six asynchronous communication channels which may be used to interconnect these chips for multiprocessing. When configured for multiprocessing, the system's four `C40s form a fully interconnected network. At any given time, only one of the devices communicates with the input and output boards, and this is done via the Processor-I/O Link (PIOL). Software may determine how the DSPs actually interact; pipeline or array architectures are possible. Further, each TIM-40 will have its own system and user software. The system software is ROMAC's own real-time multi-tasking operating system which is currently running on the Integrated Controller for Magnetic Bearings. The flexibility and ease of use of this system will allow designers to experiment with the power of multiprocessing.

The system can provide fault-tolerant operation because a majority vote of the processors decides which of the processors controls the PIOL. Fault tolerance is achieved in the PIOL and Channel Bus by traditional encoding methods. The ADC and DAC boards do not need to be fault-tolerant if the sensors and bearings of the application are redundant. So, losing a particular ADC or DAC channel should not cause a breakdown. The system can also detect faults that occur in the bearings. The sensors include current detectors to determine if a coil has current. If a coil has no current then the controller will try to determine whether the coil or the amplifer is faulty. The amplifiers have status lines that are read by the controller to facilitate fault detection.

Development of this controller has been significantly delayed by a combination of aggressive design objectives and conservative design constraints. The original design objective for this system placed most of the burden for fault-tolerant operation upon hardware. This was known to be a very difficult problem when the design began. As the design progressed, this aggressive objective was determined to be barely achievable with currently available technology. Unfortunately, the design compromises that would have been required to achieve this objective were not feasible within the conservative design constraints used.

The original objective of hardware-based fault-tolerance was set aside last Spring in favor of more conventional software-based redundancy and checking. With fully connected computing modules and a majority vote to decide which module controls the PIOL, it should be possible to implement a range of fault-tolerant approaches in this system. This provides greater flexibility than the original hardware-based plan, but the cost is additional software.

The controller is currently being integrated. TIM-40 modules have been assembled and tested. The motherboard has been assembled and tested along with the synchronous backplane bus. The digital to analog and analog to digital interface cards are currently being assembled. Direct digital input and output cards are currently being designed. We plan to have the first working prototype of this controller in the lab before the end of 1994, and there are no obvious impediments to this objective.

Investigation of Magnetic Bearing Inductances

Daniel Noh, Chris Sortore, David Meeker, Eric Maslen, and Paul Allaire

This project, sponsored by Kingsbury Inc., is aimed at providing design level tools which can accurately predict the coil inductances in magnetic bearing actuator or sensor stators. The motivation behind the project is Kingsbury's practical experience that the coil inductances of their commercial products virtually never match the value computed using the classic inductance formulas and parameters. Small changes in coil geometry have unexpectedly large effects on measured inductance.

The work has both a theoretical and an experimental component. The theoretical work was aimed at evaluating the secondary effects which are expected to introduce errors into the simple circuit analysis models usually used to compute coil inductances. The two effects examined were leakage flux and eddy current effects. In studying the effect of leakage, a semi-analytic model was developed (to simplify the resulting finite element analysis) for a high permeability stator and the effective added inductance due to the leakage flux was computed. For the eddy current study, again a semi-analytic model was developed and the effects of the eddy currents on coil inductance were assessed. It must be emphasized that the approach followed in the theoretical study assumed that the two secondary effects are uncoupled. In fact, eddy current losses will tend to increase the leakage flux (by reducing the material relative permeability) so the effects tend to be compounded.

The principal finding of the theoretical study was that leakage is a more significant effect than eddy current losses at frequencies in the 1 KHz to 50 KHz range for low loss laminated structures. Further, the leakage effect will produce an increase in measured inductance (compared to that computed with a no-leakage circuit model) on the order of five to ten percent for typical stator/coil geometries.

The experimental component of the project focuses on precise measurement of coil impedance as a function of frequency and amplitude of applied voltage. The technique which has been developed is based on acquiring the applied voltage and resulting current waveforms for the test coil wired in series with a known, stable reference resistor. The voltage is generated by a wide bandwidth linear power amplifier driven by a programmable sine wave generator. The voltage and current waveforms are measured simultaneously by a digital storage oscilloscope and transferred to a microcomputer. The computer then convolves the measured waveforms with sine and cosine waves of the known generator frequency to determine the fundamental magnitude and phase of the impedance as well as to measure the harmonic content of the current waveform to assess nonlinearity. By using the computer to control the signal generator and the oscilloscope, the measurement can be made repeatable and a very large number of measurements can be made unattended.

Thus far, the experimental component has concentrated on perfecting the measurement technique and benchmarking it with air core inductors which have previously been characterized independently. The testing procedure has been found to be quite successful in meeting its objectives: the measurements are repeatable and appear to be quite accurate. Only a few measurements of actual iron core inductors have been made to date and the results have not yet been digested.

Compressor Magnetic Bearings Audit

Chris Sortore, Robert Rockwell, Eric Maslen, Lloyd Barrett, Paul Allaire, Carl Knospe, and Ted Brockett

NOVA Gas Transmission, Ltd. (NGTL) of Calgary, Alberta has thirty-two gas line compressors supported in magnetic bearings. The compressors range in size from 10,000 HP to 30,000 HP. This is certainly the largest single owner application of magnetic bearings in the world. Last year, NGTL commissioned a a study by the A. D. Little Company to help in assessing the performance of its investment. This report indicated some problems with the implementation and management of the technology in the NGTL units. NGTL decided to engage in a technical audit of their installed equipment in cooperation with the magnetic bearing manufacturers, S2M of France, and MBI of Roanoke VA, and one of the compressor manufacturers, Cooper Industries of Mt. Vernon Ohio. NGTL commissioned the University of Virginia to join the audit group and help in the technical assessment and selection of improvements to the system and also in technical coordination of the effort including production of the final report.

The objective of the audit process underway at the University of Virginia is three-fold. First, the actual performance of the installed magnetic bearings has to be assessed. This preliminary audit report was completed in mid-October for review by NGTL management. Second, a formal audit procedure is to be developed which can be applied by a magnetic bearing customer (in this case, NGTL) in order to determine, independently of the vendor, whether the bearing performance is acceptable. A side result of this capability is a better ability to adequately specify required magnetic bearing performance. Finally, NGTL personnel will be trained in the application and interpretation of the audit procedure. This last step is seen as critical in establishing the confidence level within NGTL's engineering division to continue to support this critical equipment.

Progress in this project has included very extensive testing of four compressors on site in Canada, reduction of this data, and development of new analysis methods as mandated by the project. The preliminary audit report which was presented in mid-October addresses bearing capacity, controller performance, auxiliary bearing performance, and system thermal performance.

Bias Linearization of Magnetic Bearings

David Meeker and Eric Maslen

The forces produced by a generic attractive radial magnetic bearing can be described by quadratic polynomials of the currents supplied to the bearing's coils. Usually, there are two forces and eight currents associated with each bearing, implying a multiplicity of ways to realize some set of desired forces. Bias linearization is a method for picking currents to achieve some arbitrary desired forces. Three sets of currents (associated with biasing, horizontal force, and vertical force) can be chosen in such a way that the quadratic current to force relations are transformed into bilinear forms in terms of the magnitudes of the biasing current and control current for each force direction. When the biasing component is held constant, a linear current to force relation results.

Bias current linearization is already commonly used in many industrial bearings. However, use up to this point has been limited to bearings in which symmetries in design made it possible to intuit the proper biasing and control currents. The conditions for generalized biasing and the associated computational methods have enabled sets of linearizing currents to be chosen for any arbitrary geometry. Of particular interest is the instance of a standard bearing with failed coils. Because failed coils produce a loss of symmetry, a proper set of biasing currents is not obvious. With the generalized biasing methods, a set of currents that preserves linear operation can be derived off-line for each failure configuration. If a failure is detected, the set of currents computed for that configuration is employed. For an eight pole bearing, optimal coil currents have been computed to control the bearing for every failure configuration of up to three coils failed.

This year, reliable computational routines have been developed which can choose optimal biasing currents for any bearing in which bias linearization is possible. In addition, a summary of the bias linearization approach is to be published in the IEEE Transactions on Magnetics. In the near future, the application of bias linearization to bearings with failed coils will be tested on an industrial-sized rig (the Mobil test bearings) at the ROMAC laboratory.

Self Sensing Magnetic Bearings

Daniel Noh and Eric Maslen

Conventionally, active magnetic bearings are paired with displacement sensors for feedback control due to their inherent instability. Sensors used in magnetic bearing systems are most often eddy current probes which have restrictions on where they can be placed in the system. Moreover, expensive sensors can represent a good portion of the total cost of magnetic bearing systems. Finally, the sensor requires its own wires (typically at least two per sensed axis, often four or more) and these wires can involve costly and unreliable connectors as well as contributing to the overall bulk of the system. The self-sensing active magnetic bearing is appealing for these reasons.

The term "self-sensing" in this research means that the bearing has no separate displacement sensor. It is expected that the sensorless bearing will not have as good performance as one with a displacement sensor. Therefore, self-sensing magnetic bearings could be used in the low-cost/performance applications or where there is a need for a reduction in total wire count. The displacement of the suspended object can be estimated by either electrical current or magnetic flux in the coil. It is normally called current feedback control if current is utilized, which is exploited in this research. The basic idea of the proposed inductance estimation method is to estimate the inductance from the switching waveform of which the high frequency component contains the information on gap displacement. The method differs from the existing approaches in that it uses a nonlinear parameter estimation technique and thus is better able to accommodate such effects as hysteresis and eddy current.

The method is verified both by computer simulation and by experiment with a test rig. The stability analysis on the linearized model shows that the estimator can be stabilized by a simple PI controller. Preliminary experimental results demonstrate a good match to simulation results. Future testing will investigate how the performance of the estimator is affected by nonlinear effects such as hysteresis, saturation, and eddy currents. Ultimately, the performance of the self-sensing bearing will be evaluated in terms of frequency spectra, which will be compared with those measured with either eddy current or optical position sensors or known bandwidth and linearity.

Magnetic Bearings for Textile Spindles

Randy Hammond, Roger Fittro, Robert Rockwell, Paul Allaire, Eric Maslen, Lloyd Barrett, and George Gillies

Magnetic bearings are being developed for use in a specialized textile spindle for yarns such as nylon and rayon. The purpose of the textile spindle is to apply heat to the yarn and a tension to cure it at high speeds (8,000 meters/sec.). The purpose of this research project is to design, construct and test magnetic bearings to further enhance the performance of these high quality heated rolls. Phase I - Feasibility Study which started on May 1, 1994, was completed in October 1994.

There are several problems associated with the high performance designs. The roll is operated at approximately 300° C and at high rotating speed. The present spindles are supported in ball bearings. The overhung textile roll with large yarn tension subjects the bearing closest to the heated roll to high bearing forces and high temperature operation. Generally, ball bearings have temperature limits, in the range of 120° C, due to peak operating temperatures in the lubricating oil as well as speed/force limitations due to Hertzian contact stresses in the balls. Many ball bearing failures have been experienced in the bearing near the heated roll. The textile industry would like to move in the direction of even higher temperatures and speeds.

The final important consideration is the monitoring of the tension in the textile yarn during the curing. A variation of tension of less than 10% can render a full batch of yarn worthless. The textile industry desires to have a means of monitoring this tension if possible.

Magnetic bearings have the capability to operate at much higher temperatures (up to at least 500° C) and approximately twice the speed of ball bearings. A completely new heated roll design has been developed by a joint design team of the University of Virginia and Dienes to take advantage of the magnetic bearing capability. It incorporates a single magnetic bearing to replace the bearing closest to the heated roll but retained the existing ball bearing at the other end.

The design will make it possible to operate the rotor at higher speeds and temperatures than previously. The expected bearing life is years longer than present ball bearings. Further, the monitoring of the coil currents provides for on-line monitoring of the tension in the yarn during operation which will improve quality control.

NASA Spin-Test Rig for Measuring Power Losses in High Speed Bearings

Mary Kasarda, Paul Allaire, Eric Maslen, and George Gillies

Construction was begun over the Summer on all of the major system components needed to assemble a NASA sponsored spin test rig capable of measuring the rotational power losses in a rotor spinning at speeds of up to 50,000 rpm. The purpose of the test rig is to conduct comparisons of rotor losses on different magnetic bearing configurations: planar radial vs. axial (homopolar) magnetic path bearings, eight pole vs. sixteen pole bearings, silicon iron vs. Hyperco 50 materials, 14 mil vs. 7 mil lamination thickness, and other parameters. All test bearings will be configured to have the same pole face area so that equivalent bearings are considered. The types of losses are magnetic losses (rotating hysteresis, alternating hysteresis, and eddy current) and windage losses. The cylindrical rotor, suspended by two magnetic journal bearings, is driven up to speed by twin electric motors located outboard of the bearings and is then allowed to coast down. At full speed, the rotor will be functioning at DN levels above 4,000,000 and the windage loss-mechanisms acting on the rotor will be reduced by operating the system in an evacuated chamber.

The vacuum system to be used in this arrangement is designed to exhaust the rotor's chamber pressure down to the crossover point between viscous and free-molecular flow of the residual atmospheric gases. It consists of a mechanical roughing pump as the first stage, with cryopumping provided by a liquid nitrogen-cooled cold trap constituting the second stage of pumping. The vacuum chamber itself is a large cylindrical enclosure rolled from a plate of aluminum, with flat endcaps sealed to the enclosure by o-rings installed at the interfaces. A variety of feedthroughs have been designed into the system to facilitate measurements of the rotor's position, speed, and temperature during the experiments.

There are several unique features to this system that will make it useful in providing previously unattainable types of data. First, the motor windings are mounted on a mechanism that will enable them to be pulled away from the rotor after it is levitated and operating at full speed. By doing so, any drag torques due to magnetic couplings between the rotor and the motors will be eliminated. Second, non-contacting infra-red thermal sensors will be used to monitor the temperature increase of the rotor during each experimental run. There will also be a set of thermocouples mounted at key points on the bearing stators and the motors to measure the temperatures of the stationary components. In this way, the relative increase in the rotor temperature can be determined, thus helping to evaluate the size and type of loss mechanisms at work during spin up and spin down. The rotor position will be detected by Kaman Corp. proximity probes, the signals of which will be used to drive the feedback circuit that stabilizes the magnetic bearings during operation. Finally, both homopolar and heteropolar magnetic bearings will be employed, as will rotors of different materials, thus making it possible to evaluate the loss mechanisms at work in each case.

Data describing the rotor's linear displacements, angular speed and surface temperatures will be recorded by computer for subsequent off-line analysis. A number of interesting experiments are planned, all with the ultimate goal of being able to quantitatively test predictions of power loss mechanisms at work on the rotor, independent of atmospheric windage.

Mobil Test Rig

Patrick Depret-Guillaume and David Lewis

Significant advancements have been made on the three magnetic bearing test rigs funded by Mobil Research and Development Corporation. The ring sensor has been bench tested and is capable of measuring three independent sets of X and Y displacements. It has approximately 250 mV/mil sensitivity over a range of 40 mils. The sensor is mounted and will be compared with the eddy current sensors in late October. Redesign of the mechanical parts of the test rig is complete. The rig now has lip seals in place of the o-ring seals at the rotor-stator interface. The rig alignment is satisfactory and the bearings will be doweled in place. The power amplifiers have been converted from 3 A/V to 1A/V. Later, the amplifiers will be optimized for better high inductance performance. The third generation digital controller now has 24 output channels and 8 input channels. This number of output channels provides for the control of three radial magnetic bearings (8 pole each) with independent coil current control on each pole. PD control has been implemented. By late November, the following items will be finalized: the motor drive, water circulation loop, load application devices, load measure devices, and backup thrust plates.

Future work includes ring sensor testing with canning in place, independent controllers for each bearing, other controller types, amplifier high inductance tuning, experimental bench marking of rig characteristics, water testing of submerge motor characteristics and fourth generation controller integration (see separate progress report). Lastly, fault tolerant controllers, bearings, and sensors will be developed.

Rotor Dynamics

Interaction Between Lateral and Torsional Rotor Vibrations

Scott Orsey, Lloyd Barrett, and Ted Brockett

Scott Orsey is continuing his work with ROMAC. Scott is a undergraduate student and has been accepted into the Engineering School's Accelerated Bachelors/Masters Degree Program. He is currently finishing his undergraduate courses and has started taking graduate courses.

Scott's Masters thesis continues work he has performed while developing TORTRAN2. There has been interest expressed by several ROMAC industrial members on being able to calculate the combined effects of lateral - torsional vibrations and ways to appropriately model gear interactions between rotors. Scott is addressing these issues for his MS research.

Currently we are performing a literature search to determine what work has been accomplished in this area and to assess those aspects of the problem that are most important. We will be using this information to determine the course of the research and what the initial computer program efforts will be. One goal of the research is to determine what linear models may be used to represent this interaction and how these models can be included in existing ROMAC analysis programs. Even if the lateral - torsional interaction is small, there remains the question of how to appropriately model gear stiffness for lateral vibration analysis of coupled rotors.

Additional information from Industrial members on actual problems encountered that appear to involve interaction between lateral and torsional vibrations would be helpful to us.

Design and Optimization of Bearings

Deb Dhar, Lloyd Barrett, and Carl Knospe

Deb Dhar (Ph.D.) has nearly completed his dissertation and computer program implementing an algorithm for determining magnetic bearing controller transfer functions or hydrodynamic bearing stiffness and damping coefficients that satisfy a user specified stability acceptability function. This function specifies the desired minimum logarithmic decrement for modes within a user determined range of frequencies, and thus "optimizes" the stability of many modes simultaneously.

The method uses an optimization search strategy to find acceptable designs within constraints on the design parameters which consist primarily of ranges of values for the stiffness and damping coefficients and coefficients of magnetic bearing controller transfer functions.

Two programs, PREDES (a pre-processor) and ACCDES (the optimization code) are presently undergoing testing and evaluation at ROMAC before release.

Rotor and Support System Identification using Time Domain Methods

Ping Zhong, Lloyd Barrett, and Carl Knospe

Ping Zhong is continuing his Ph.D. dissertation research in the area of identification of rotordynamic system parameters applying time domain signal processing techniques to vibration data obtained in the field or on the test stand. He has developed one computer program, MODID, that is nearly ready to release to the industrial membership.

MODID 1.0 is a Microsoft Windows program for modal parameters identification. It employs the Backward ARMA model method and uses a Singular Value Decomposition or Minimum Norm solution to automatically choose system orders and cancel the noise effects. Program features include:

- Automatic order selection
- Identification of modal parameters, such as
  - Natural Frequencies
  - Modal damping
  - Mode shapes (depending on how many measurement locations are used).
- Identification of well damped modes which are difficult to detect using FFT and other frequency domain techniques.
- Identification of closely spaced vibration modes which are also difficult to detect using frequency domain techniques. Time domain techniques like the ARMA model method have much higher frequency resolution. This is especially valuable for closely spaced structural resonances.

The program manual is currently in preparation, and the program is being used internally to check it out and to more fully understand its capabilities and limitations so we may provide advice and tips to the industrial members on the use of the program. For example, simulated time transient data for machine start-up and shut-down is being used to characterize the ability of the program to identify the damped natural frequencies and logarithmic decrements.

Ping is also working on the development of procedures for identifying specific rotor parameters such as bearing coefficients. These methods will be tested both with simulated time transient data and with test data obtained from test rigs in the laboratory, such as the rig being modified for flexible bearing supports.

Flexible ROTOR/Bearing Test Rig

José-Antonio Vázquez, Ron Flack, and Lloyd Barrett

As described in the Fluid Film Bearings and Seals Research section, José-Antonio Vázquez is continuing modifications to the small (25 mm diameter bearings) flexible rotor test rig. This rig is being modified to incorporate flexible bearing supports. The flexible supports have been designed and built and are being incorporated into the test rig. Tests will be conducted to measure the effects of the bearing supports on the unbalance response and stability of the flexible rotor with both fixed lobe and tilting pad bearings.

The data obtained from the test will be used to further verify ROMAC forced response and stability computer programs such as FRESP2 and ROTSTB. Time domain test data obtained from the rig will also be used to assess the capability of MODID to determine rotor - support characteristics from test data.

Enhancements to the ROMAC Shell and Scripted Editor

Eric Maslen, Lloyd Barrett, Toby Korn, and Ted Brockett

The ROMAC shell and scripted editor have been very well received by the ROMAC member companies and appear to be widely used. We will continue to work on both debugging and enhancement for the foreseeable future. Toby has sent out announcements of several changes to the shell to fix bugs or functional inconveniences and we believe that both codes are now nearly ready for release in a non-beta form.

Originally intended as an extension to the scripted editor, the OSED was developed over the past year as a stand alone application which translates data or output files from a standard (code-native) format into one selected by the user. The primary objective of this code is to automate generation of customized report formats, including customized systems of units. In addition, the OSED can be used to support neutral data formats for existing or future file post-processors. A beta version of the OSED will ship this Fall, along with a detailed user's manual. Note that, with the shipment of the OSED, complete units conversion is now supported in the analysis cycle; the scripted editor supports units conversion when developing the data files and OSED supports units conversion in the output files. This should eliminate a large portion of the software modification currently done by our users.

Planned modifications to the scripted editor (SED) include:

- addition of an IF THEN ELSE language construct in the editor generator. This will permit much better support of codes with significant conditional sections in the data file, such as RESP2V3.

- addition of a language construct to support linking with specialized external "pop-up" editors. A simple mechanism has been devised to allow the editing script to specify an alternative code for editing some portion of the data. This editor would be a stand-alone application written either by ROMAC or by the end user. The external editor would be invoked from within the scripted editor by positioning the cursor on the data to be edited and pressing a control key identified within the editing script and shown in the margin of the editor window. Without closing the scripted editor, the pop-up editor would appear on the screen, overlaid over the scripted editor, allowing specialized editing of the selected data.

An example application of this feature is in specifying the added inertia associated with a disk in CRTSP2 or ROTSTB. This normally requires specification of a translational mass and polar and transverse inertias. Instead, a pop-up editor could be written which would allow entry of disk dimensions and would then compute these derived properties for insertion into the data file.

- porting of the scripted editor to Microsoft Windows. Presently, the scripted editor runs as a DOS application under Windows. This works functionally and permits us to support both Windows and DOS with a single version of the code. However, most users are running the scripted editor from the shell under Windows. Codes running under Windows are generally much easier to understand and operate if they are written as real Windows applications, taking advantage of the Windows interface elements. Further, much of the support for windowing and other I/O functions presently provided by custom written code in the scripted editor could be eliminated with a true Windows version.

In addition to the scripted editor modifications, a fundamental modification to the shell is underway where the multiple document interface (MDI) will be adopted. With this, the shell will function as a desktop with any number of analyses running on top of it at any given time. That is, multiple analysis processes can be defined by the user by opening multiple analysis windows. Within each window, the interface is very similar to the existing analysis window (in the present version of the ROMAC shell). The only significant added feature to the analysis window will be better support for data post-processing. The new code will be backward compatible with the organization file (ROMAC.ORG) used in the present version of the shell.

Finally, we continue to work on auxiliary tools like ROTORVAL, the rotor model validator. The next tool to be released late this fall is a modeshape/forced response plotter compatible with CRTSP2, ROTSTB, FRESP, RESP2V3, TWIST2, and other rotor analysis codes. Other planned tools include geometry sketchers for bearing codes (fluid film or magnetic bearings), and a critical speed map/Campbell plot generator. Suggestions for other potentially useful tools, especially of a graphical nature are actively solicited.

Equipment Donations

Keep ROMAC in Mind

If you have any surplus instrumentation lying around which you're about to discard or are not using, please consider a donation to our ROMAC labs. It may be quite useful in our experimental research in fluids, rotordynamics and magnetic bearings. Such usable and relatively recent equipment as FFTs, oscilloscopes (DSO or analog), DVF-2 or DVF-3, 386 PCs, and any type of transducers (position, pressure, acceleration, etc.) would be greatly welcomed and appreciated, especially since our equipment budget is always quite small. In return, you may get an immediate capital write-off on taxes from the gift donation.

For More Information

We want to hear from you

Write to ROMAC at the address given below. The telephone number to reach our Office Manager is (804) 924-3292. Our FAX number is (804) 982-2246. We can receive Internet electronic mail at romac@virginia.edu.

Your inquiries, comments, and suggestions will be appreciated. Updates to keep our Industrial Contact List current are always welcome.

ROMAC
Dept. of Mechanical, Aerospace & Nuclear Engineering
School of Engineering & Applied Science
University of Virginia
McCormick Road/Thornton Hall/ MEC 105
Charlottesville, VA 22903-2442 USA