ADORE Update Version 7.00

Release Date: October 14, 2016

ADORE 7.00 is a major enhancement to earlier version 6.50. The following is a description of all updates:

1. Code Corrections

ADORE version 7.00 implements the following code corrections:

1. The elastic modulus of 440C in ADORE materials data base, procedure Adra7, is corrected.
2. Minor error in setting initial race displacement, when running ADORE with prescribed displacement is corrected in procedure NoLoadDisplacment, in parent procedure Adra2, is corrected.
3. When using English units the constant in dynamic stress capacity for computation of fatigue life is now set correctly.
4. Line contact procedure Adrc6, when called by cage contacts was providing load per unit contact length, as required for roller/race contacts. In high-speed bearings, this error resulted in excessive radial motion of the cage, which triggered execution termination. This error is now corrected. Note that due to this correction, ADORE solutions after any cage contacts are initiated will be different from those provided by earlier versions of the code.

2. Code Enhancements

2.1 Fatigue Life Modeling

The generalized life modeling procedures introduced in version 6.0, and subsequently enhanced in 6.50, are now further enhanced to provide modified constants in ceramic rolling element stress capacity equation. This results in significantly enhanced life computation for hybrid bearings with ceramic rolling elements.

2.2 Traction Modeling

ADORE version 7.00 introduces a new shear-thinning traction model, where lubricant viscosity is dependent on shear stress. The model is presently implemented for the commonly used MIL-L-23699 type lubricant. In addition a visco-elastic model for this lubricant is also added to the traction modeling procedure. Both of these models are based on experimentally measured viscosity-pressure-temperature relations, which are also included in the traction modeling procedure. This implementation is a major upgrade to the traction modeling procedures in ADORE.

2.3 Modeling of Thermal Interactions

Based on experimental data, the thermal interaction procedure, Adrh1 is completely rewritten

to provide more realistic thermal solutions, which compare reasonably well with available experimental data. Due to some limitations in the current traction modeling procedures in the computation of temperature rise in elastohydrodynamic contacts, there are still some discrepancies in the computation of temperature field across the bearing, although the heat generation results agree fairly well with the experimental data. This enhancement in thermal modeling, along with the continually increasing computing speed in modern computer systems, which now provide simulations over a large number of shaft revolutions in reasonable time, led to the following enhancement of data interface in ADORE, to make all solutions temperature dependent.

2.4 ADORE Data Interface

Within the modular structure of ADORE, ADORE has it own materials data base procedure, Adra7, where properties of the various materials are hard coded. These properties may of course be prescribed as a function of operating temperature. In addition, ADORE can also access user provided materials database, via appropriate code in one of the user programmable routines. Once the materials are prescribed appropriate elastic and thermal parameters are setup in an accompanying procedure Adra71. Appropriate data modules are modified, such as calls to Adra7 and Adrd71 can be made arbitrarily at any time step. This permits both variation in material properties and operating bearing geometry as the operating temperatures change as a function of time. Since the mechanical and thermal time scales are greatly different, the thermal modeling procedure is implemented as follows:

1. Thermal modeling procedure in turned on input record 1.
2. A “skip time” is specified on one of the thermal input records. No thermal interactions are computed during this time and the solutions are simply obtained with the prescribed initial temperatures, which of course are held constant during this time.
3. After the skip time is reached, averaging of bearing heat generation over a prescribed “averaging time” is initiated. When the averaging time is reached, average heat generation if determined and heat flow analysis through the bearing is carried out to compute the temperature field across the baring.
4. At user discretion, defined by selected options for the thermal modeling procedure, the geometrical distortion and materials properties procedure may be called with newly computed temperature of the bearing elements. Thus bearing performance as a function of temperature, with both varying bearing geometry and material properties may be modeled.

This is a major enhancement to ADORE code structure. Due to rather large thermal time scales, integration of equations of motions over very large number of time steps, often corresponding to more than 100 shaft revolutions is required in order to obtain steady-state thermal solutions. Modern computer systems now provide the required speed to obtain such solutions in reasonable computer time.

2.5 Solutions Averaging over substeps

Since thermal modeling requires bearing performance simulations over large number of time steps, effective use of substeps is highly recommended. In earlier versions of ADORE, when integration is carried out over the substeps any output processing is completely skipped over the

substeps. For more precise averaging of thermal parameters, the data processing procedures are enhanced such that the integration procedures, required for computing the average parameters, now include all substeps. Thus the step size for integration is much finer, as a result the computed averages are more precise.

2.6 Bearing Stiffness Computation

The bearing stiffness computation, which has been based on prescribed race displacement increment in all past versions of ADORE, is now changed to define the displacement increment as a percentage of inner race elastic deflection at rolling element #1 position, which should be the heavies loaded rolling element. This provides a more realistic stiffness computation. Note, however, that the applied load coordinates should be selected such that rolling element #1 is indeed the heaviest loaded rolling element, whenever stiffness computation is desired.

2.6 ADORE Print Output

A new thermal subsection is added under the Applied Parameters section to present summary of thermal analysis whenever a thermal interaction analysis is carried out. Also, the Run Statistics section now includes average value of key performance parameters over a selected number of time steps. The purpose is to provide reasonable values of steady-state time-averaged performance parameters.

2.7 ADORE Plot Output

In the "Overall Performance Parameters" data set, corresponding to file SOL7, a new plot is added to provide heat distribution resulting from thermal analysis.

3. ADORE User Manual

ADORE users manual has been updated to document the newly defined inputs

4. ADORE Input Facility, AdrInput

The input facility AdrInput has been appropriately modified to provide newly required input data. Note that older data sets may not work with ADORE version 7.00. However, the old input data sets may be opened with new AdrInput facility to convert the data files for use with ADORE 7.00

5. ADORE Plot Facility, AdrPlot

As discussed above, ADORE version 7.00 added a new plot in the Overall Performance Parameters data set.

6. ADORE Animation Facility, AGORE

There are no modifications to the plot (AdrPlot) and animation facilities (AGORE).

7. Test Cases

As usual the input data, print output and all plot data sets are included in these subdirectories in the program media. These examples must be run and checked after installation of the program. All outputs, at least at step 0, must match against the supplied output.

8. Program File Contents:

Program updates are distributed on a CD in normal data format. The files may be easily extracted from this disk on any computer system and then transferred to appropriate system for which ADORE is licensed for.

The media contains the following three subdirectories and a **readMe.pdf** file, which provides latest update information and instructions for quick installation on the Windows machine:

Disk1

Update700.pdf: A pdf file containing notes of the latest updates (this file

adoreInput.txt: A text file containing details of ADORE input data.

adoreManual.pdf: ADORE user's manual.

Ball: Subdirectory containing ball bearing test case.

Roller: Subdirectory containing roller bearing test case.

TaperedRoller: Subdirectory containing tapered roller bearing test case.

AdrxExamples: Subdirectory containing few of the user programmable examples.

Disk2

***.f files:** ADORE FORTRAN-90/95 source files.

makeIntel.txt: Makefile for Windows 7 machine with Intel Fortran compiler.

makeLahey.txt: Makefile for Windows 7 machine with Lahey Fortran compiler.

makeUnix.txt: Makefile for Intel compiler on a Unix operating system.

Disk3

setup.bat: Setup batch file to compile adrInput, adrPlot and AGORE on Windows system.

adrInput.bat: Batch file to execute adrInput.

adrPlot.bat: Batch file to execute adrPlot.

agore.bat: Batch file to execute the graphics animation facility, AGORE.

Java: Subdirectory containing all Java source files.

9. Program Installation

Quick installation steps are outlined in the readMe.txt file supplied on the program disk. More detailed installation instructions are included in the users manual.

9.1 ADORE Installation

Make files are provided in Disk2 directory for easy installation of ADORE for both the Intel

and Lahey compilers for a Windows machine. The nmake command available with these compilers may be used to compile and create an executable code. In addition a make file is also included for a Unix operating system, running an Intel FORTRAN compiler. This file may also be used on a Macintosh computer, since Mac OS is essentially based on Unix.

In case of other computing platforms and/or operating systems, any of the supplied make file may be appropriately edited and used for ADORE installation.

9.2 Installation of Java facilities adrInput, adrPlot and Agore

Edit the setup.bat file in Disk3 subdirectory to correct the paths to all source files and the Java Development Kit. Execute the updated setup file to compile and install these facilities.

The setup files for the three applications may then be edited to update the paths and installed in appropriate directory compatible with the environmental variables, which provide access to all executables.

10. Contact Information

In the event of any questions and/or technical support please contact:

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