ADORE Update Version 8.51

Release Date: January 4, 2021

Following the rigorous development of minimum energy hypothesis in version 8.10, the enhancements in this version include further developments in handling rolling element angular velocity and bearing misalignment. The lubricant data base is also extended to include several new lubricants.

1. Code Enhancements

The following enhancements constitute the key elements of the current update.

Treatment of Angular Velocities: While all angular motions in ADORE are modeled in body-fixed coordinate frames, the initial angular velocity of rolling elements is computed in rolling element azimuth frame as commonly done in quasi-static analysis. In this version, an additional transformation matrix from the inertial azimuth to rolling-element-fixed principal coordinate frame is introduced and the initial angular velocity is now set along the primary principal axis along with the initial transformation angles which orient the rolling element principal axis. Although this does not result in any change in numerical values of the solution components at zero time, time domain integration of equations of motion does result in some numerical improvement which yields a slightly higher permissible time step for prescribed truncation limit. Thus, although the numerical results at time equal to zero are closely identical to those obtained in version 8.10, the simulation time over a prescribed number of time steps is now slightly higher as a result of this update. For this reason, there may be a small difference in numerical solutions at the final time step in the various test cases.

Bearing Misalignment: In all earlier versions of ADORE bearing misalignment was simply added as additional rotation to the rotation resulting from bearing element motion. Although such a treatment is analytically simple, there are certain numerical accuracy issues which sometimes impose convergence problems, particularly in roller bearing with line contacts, where the contact zone in numerically segmented in several incremental strips in accordance to a selected order of numerical quadrature. This treatment is now refined by introducing an independent bearing misalignment matrix, which can, in fact be time-varying in most generalized simulation. This facilitates realistic modeling of misalignment in both cylindrical and tapered roller bearings. Separation of initial misalignment angle from rotation of the rolling element due to element motion, also permits the use of the equilibrium constraint while obtaining dynamic performance simulation. The assumption is of course that the rolling element mass center travels on the path determined by radial/axial equilibrium of rolling element with the interacting races while the rotational motion is simulated by the equations of motion,

Initial Position of Bearing Elements: With the above introduction of misalignment matrix, the procedure which sets the initial position of rolling elements had to be basically rewritten. Thus, the initial position of rolling elements relative to the races is now precisely set such that the rolling elements are just touching the races with no contact load. One of the races is then moved by a small amount to generate a contact load and provide estimate of bearing stiffness. This stiffness is then used to set the initial position of bearing elements before calling the iterative procedure to carry out the equilibrium analysis. Again, this modification in numerical procedure may account for some insignificant changes in numerical results when comparing the results with those obtained with the earlier version 8.10.

Tapered Roller Bearing Geometry: In ADORE, geometry of a tapered roller has always been based on the roller diameter at large end of a truly tapered roller with conical surfaces. In case of partly crowned rollers the actual roller diameter at large end is actually slightly less than this value due to crown drop off. While rewriting the rolling element geometrical parameters section of the initial rolling element position procedure the tapered roller geometry is now updated so that the input roller diameter is the actual diameter of the roller at the large end including the reduction due to crown drop off. Note that since the input diameter value in the tapered roller bearing test case is unchanged some minor differences in numerical results, when compared to the results obtained with earlier version, are seen.

Roller/Flange Interaction: Following the introduction of distinct roller misalignment matrix, the derivative of roller/flange contact force with respect to roller misalignment angle has been more precisely updated in the roller/flange interaction procedure. This update has resulted in a notable improvement in modeling of bearing misalignment in tapered roller bearings.

Minimum Energy Hypothesis: Implementation of minimum energy hypothesis in quasi-static equilibrium solutions has been updated for two specialized cases of angular contact ball bearings: (1) radially loaded ball bearings, and (2) ball bearings with zero traction. For radially loaded ball bearing the orientation of ball angular velocity is already defined to be parallel to the shaft axis and under zero traction, the ball angular velocity is simply set in accordance to the race control hypothesis.

Lubricant Data Base: The lubricants data base in ADORE has been updated to include traction modeling for the following additional lubricants. All models are based on independently measured rheological data with shear thinning effects:

- PAO-100 at contact pressures above 1 GPa.
- PAO-600 at contact pressures above 1 GPa.
- PAO-650 at contact pressures up to 1 GPa.
- FVA-3 mineral oil.
- Krytox 143AZ lubricant.

2. ADORE User Manual

Although the traction code in lubricants data record 10.0 has been updated to include the above lubricants, ADORE user manual has not yet been updated. Please refer to the input facility AdrInput for up-to-date data description.

3. ADORE Input Facility, AdrInput

The input facility, AdrInput, has been updated to include the newly defined lubricants on input data record 10.0.

4. ADORE Plot Facility, AdrPlot

There are no modifications to the plot facility Adrplot in this version.

5. ADORE Animation Facility, AGORE

There are no modifications to the animation facility (AGORE).

6. Test Cases

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

7. Program File Contents:

The program media, supplied electronically in the media file Adore851.zip, contains the following four subdirectories and a readMe.pdf file, which provides latest instructions for quick installation on the Windows and Macintosh machines:

Disk1

Update851.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 cylindrical 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 machine with Intel Fortran compiler.

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

makeUnix.txt: Makefile for Intel compiler on a Unix and/or Macintosh system.

Disk3

Java: Subdirectory containing all Java source files.

Disk4

For convenience, this subdirectory contains immediately usable executable files for both Windows and Macintosh operating systems. Of course, all executables may be created by compiling the source codes supplied in Disk2 and Disk3 directories. The contents of Disk4 directory are as follows:

Windows: Windows subdirectory

Adore851.exe: Adore executable
AdrInput.jar: AdrInput (Java executable)
AdrPlot.jar: AdrPlot (Java executable)
Agore.jar: Agore (java executable)

Mac: Macintosh subdirectory

Adore851: Adore executable (Unix executable for Mac)

AdrInput.jar: AdrInput (Java executable)
AdrPlot.jar: AdrPlot (Java executable)
Agore.jar: Agore (java executable)

While ADORE is a command line application and it must be executed on a command line in appropriate directory containing the input data file DATA.txt, the java applications may be executed by a simple double click on the application icon. On command line the application may be executed by invoking the following command:

java -jar *jarFileName*

where *jarFileName* may be AdrInput.jar, AdrPlot.jar or Agore.jar. Of course, the path for the jar file must be satisfied.

8. Program Installation

Quick installation steps are outlined in the readMe.pdf file supplied in the program folder. More detailed installation instructions are included in the users manual.

8.1 ADORE Installation

Make files are provided in Disk2 directory for easy installation of ADORE with both the Intel and Lahey compilers on 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 be used on a Macintosh computer, since Mac OS is based on Unix.

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

8.2 Installation of Java facilities AdrInput, AdrPlot and Agore

The freely available **NetBeans 8.2** Java Development IDE is used to create the java executable jar files as supplied in the Disk4 directory. **NetBeans 8.2** may be freely downloaded from Oracle website. This requires Java 1.8 Java Development Kit, which is also available from Oracle website. The Java JDK must be installed before installing NetBeans.

The jar files so created with **NetBeans 8.2** are self-contained and do not require specification of any classpath statements. Also, since most Java applications are platform independent, the jar files may be used on both Windows and Macintosh operating system.

Please see the user manual or the readMe.pdf file for more details on using **NetBeans 8.2** for compiling the java applications.

9. Contact Information

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

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