T017: Ring Rolling Template

Introduction

The following article gives step-by-step instructions for the Ring Rolling Module and summarizes the control files used for ring rolling simulations.

Problem Description

Simulation of ring rolling processes is a complex, time-consuming task when traditional simulation tools and methods are used. The DEFORM Ring Rolling Module was introduced to simplify and speed-up the modeling of these applications. The module includes a preprocessing template for data preparation and a mesh generator developed expressly for simulating this difficult process. It also includes an application-specific finite-element solver with FEM routines specially developed for ring rolling processes. Because of many unique features within the FEM solver, project definition must be performed with the Ring Rolling preprocessor, as described below.

Background Information

A few guidelines should be followed when using the Ring Rolling Module. To optimize performance, a mapped brick mesh is used. The mesh is generated from a 2D profile, and extruded to form a ring.

Use cross-section geometry

It is strongly advisable to use 2D cross-sections of the workpiece and all rolls. DEFORM uses the 2D cross-section to create an analytic revolved geometry surface for the rolls. For ring rolling, this produces more accurate results than a faceted 3D model.

Table

A virtual table is used in DEFORM. If one is present, it will be defined using a control file after setup is completed in the template.

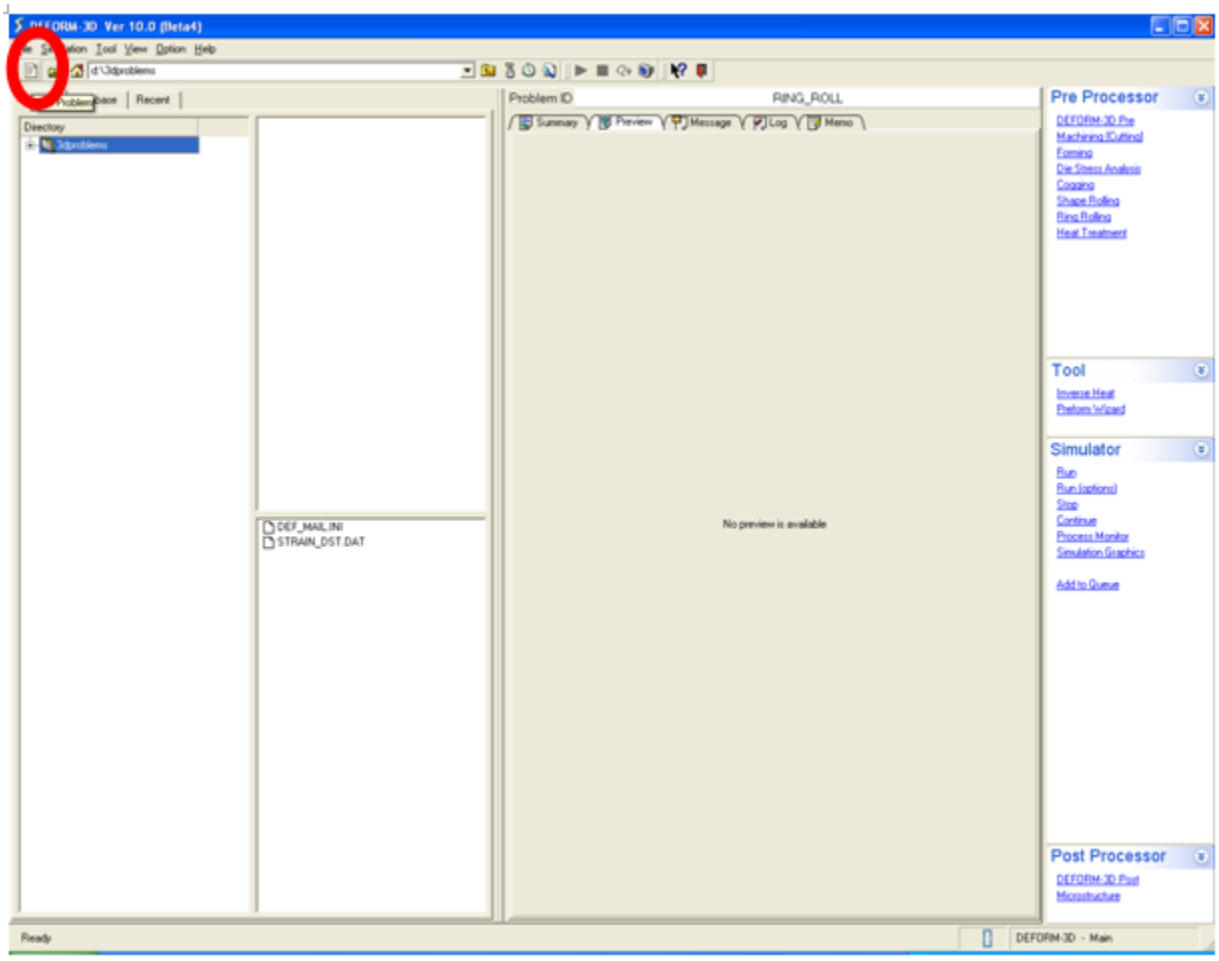
Finalize settings

Because this is a newly developed module, it is necessary to make some small modifications in the standard DEFORM preprocessor, and add some control files

at the end of the setup process. These will be discussed in detail at the end of this document.

Solution

Create a new project from the DEFORM-3D main window.



Select the Ring Rolling template, and specify a project name.

At the Units screen, select English or SI units.

Operation name can be specified if desired.

Temperature Calculations

User has the choice of including or disregarding temperature calculations. If temperature calculations are included, the workpiece temperature will increase with adiabatic work, and decrease with heat loss to the environment. If

temperature calculations are not included, the workpiece temperature will remain constant at the initially specified temperature.

Workpiece Shape

Whole part / symmetry: If the part is top/bottom symmetric, the user can model only one half of the part. This significantly reduces problem size, and increases simulation speed. It also adds an additional, possibly artificial constraint to the workpiece, and neglects potential non-symmetric effects such as out of plane instability. It can be extremely helpful in terms of performance, but the user should understand the implications.

Objects

Rolls to be simulated: Ring rolling processes are generally assumed to have a main external drive roll, and an inner pressure roll or mandrel. These “radial” rolls reduce the wall thickness and expand the ring. Depending on the mill configuration, axial rolls may also be used to control the width or height of the ring. If axial rolls are to be used, check the “Axial Rolls” option. For symmetric parts, use 1 roll. For full parts, use 2 rolls. By default the axial rolls are assumed to be directly (180 degrees) opposite the radial rolls.

The FEM solver uses an automatic centering system, so guide rolls are not necessary, and not available at this time.

Workpiece

Assign the initial workpiece temperature. The name can be specified if necessary.

Geometry – 2D cross-section

The initial workpiece geometry must be specified as a 2D cross-section. The cross-section can be defined using a 2D iges or dxf file, or from a 2D primitive or other geometry created in the template.

To make the geometry a *ring* rather than a solid, define the left edge of the profile as the inside radius of the part. In other words, if the ring has a 10” starting Inside Diameter, position the cross-section profile geometry 5” to the right of the vertical axis.

Mesh

The mapped 3D brick mesh is created from a 2D mesh of the cross-section. So the first step in meshing the workpiece is to generate this 2D cross section mesh. Typically a simple geometry can be meshed with 50 elements. An

average ring will be around 100 elements An extremely complex cross-section may require 200 or more cross-sectional elements, but a mesh this large will substantially degrade run times.

After the 2D mesh is generated, generate the 3D mesh. The 3D mesh is automatically compressed circumferentially in the contact areas, and expanded in the non-contact areas. The area away from the contact region is coarsened. 120 sections is generally adequate for this section. Increasing the number of sections will degrade run time without substantially improving performance.

Material

As with all DEFORM simulations, select a material with the appropriate temperature range for the process being simulated.

Main Roll

The user may specify a different name for the main roll.

Comments on roll geometry

Because DEFORM uses an analytic description of the revolving roll face, it is important wherever possible to use a 2D cross-section and allow the 3D shape to be developed in the ring rolling template. If a 2D geometry is not available, it may be extracted from the 3D profile using the slicing feature in the standard DEFORM-3D preprocessor. Contact DEFORM support for more details.

Geometry-2D (Cross-Section)

The roll geometry is defined from a geometry primitive, or an imported .igs, .dxf, or GEO (DEFORM geometry format) file. The screen vertical axis is the axis of symmetry, and the roll cross-section should be drawn on the right side of this axis.

Geometry-3D

The 3D geometry is primarily for display purposes. 100 sections is adequate. Generate the 3D geometry, and inspect . If the orientation is not correct, it may be necessary to go back to the 2D geometry cross-section.

Position

Use object positioning to be sure the workpiece is positioned against the main roll and centered properly, and the mandrel is positioned against the ID of the ring.

The easiest way to position the mandrel is to use interference, and check the box “Don’t move object outside bounding box.”

Movement

Assuming that the axis of the main roll is fixed, and the angular velocity is constant, it should only be necessary to define the constant rotational speed. Note speed is in radians/sec. To get radians per second, multiply RPM by 0.105.

Mandrel

The user may give a new name.

2D and 3D mandrel geometry…

…details are pretty much the same as the main roll. Center the roll on its own axis. Global positioning will be handled at the next step.

Positioning

Be sure the mandrel is touching the ID of the workpiece. The easiest way to position the mandrel is to use interference positioning in the +Y direction. Be sure the box “Don’t move object outside the bounding box…” is checked.

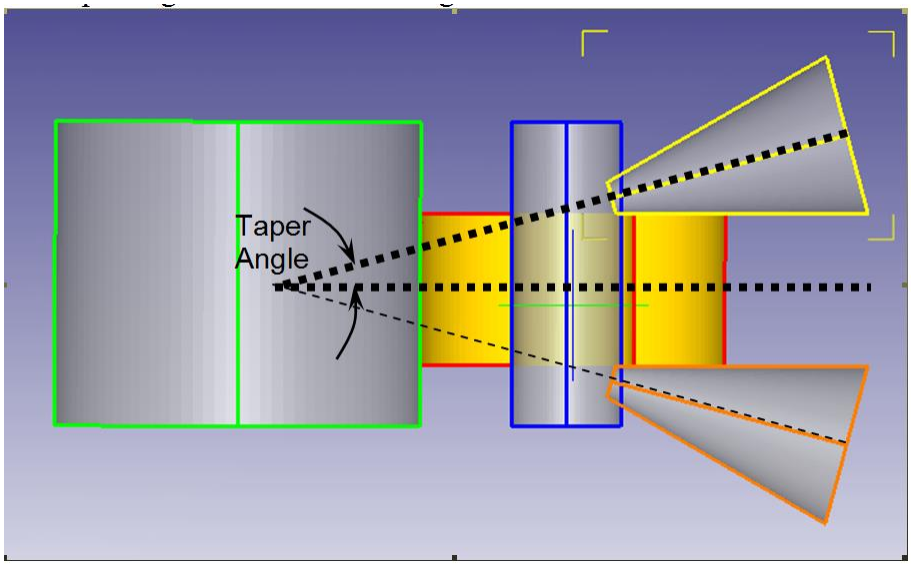
Movement

Mandrel translational movement should be speed controlled, and the movement should be smooth. Controller outputs from actual processes which have substantial oscillation may cause numerical stability issues in the simulation. It is best to create a smooth speed control curve with a minimal number of points which gives the correct displacement vs time behavior.

Mandrel rotation is normally not driven. To set free rotation of the mandrel, assign torque control with a constant 0 torque.

Axial Rolls

The taper angle is the elevation angle of the axial roll axis. So it is ½ the cone angle.



The cones should be drawn with the axis of rotation vertical (along the y axis in the 2D drawing space) and with the cone point up. There is a “symmetry” option for the rolls, which allows the user to define symmetric geometry and positioning. It does not imply symmetric movement controls, so one roll can feed down while the other remains stationary.

DEFORM features “adaptive movement control” for the axial rolls. The rotational speed and axial translation away from the main roll are calculated during the simulation to match ring rotation and expansion. These settings will be specified in a control file.

So to define axial rolls, first draw or import the upper axial roll. After 3D geometry is created, the initial positioning will be generated. At this point, DO NOT position the axial roll at this time. We will first create the lower axial roll.

Axial Roll #2

In the “Object” page for axial roll 2, check the “Use Symmetry” option. Click and the lower axial roll will be created.

Positioning

Click “Object Positioning”, then “Coupled Positioning.” Check the upper axial roll in the Coupled Positioning dialog, then close that dialog. Position the rolls radially (along the Y axis).

If necessary, uncheck coupled positioning and position the upper or lower roll axially.

Contact

When the “define inter-object conditions” is clicked, the default inter-object relationships will be created. Friction of 0.7 to 1 is typical for non-lubricated hot processes. Friction for a lubricated cold process will typically be lower – in the range of 0.1.

Be sure to “Generate All” contact before exiting this dialog.

Stopping Controls

Stopping can be based on outer ring diameter, time, or mandrel movement. If multiple controls are set, the first trigger to be reached will stop the simulation.

Step and Remeshing Controls

Many ring rolling processes will exceed 10,000 steps. It is advisable to set the number of steps to 99,999 steps (maximum allowable in DEFORM) so that it stops on a user defined control rather than on step count.

The time step is determined automatically. The default value of 0.01s is normally a good starting point.

It is not necessary to use scheduled remeshing.

Generate Database

Generate the database. After database generation, some additional settings will be assigned in the main DEFORM preprocessor.

Close the template, and open DEFORM-3D Pre, and load the ring rolling database.

Target Volume

In the DEFORM-3D main preprocessor, select object properties. Set Target Volume “Active in FEM” and use the “Calculate Volume” tab to find and assign the ring volume.

Regenerate Database

Go to database generation in the main preprocessor, and regenerate the database. You will receive a warning about overwriting existing step -1. Click “yes” to overwrite this step. Exit the preprocessor.

Related Information

Control Files

DEFORM uses control files to modify simulation settings which are not accessible through the preprocessor. They may be created using a text editor such as notepad or obtained from DEFORM support staff. Be sure that there is a return character at the end of the last line, or it will create problems reading the file on a Windows system.

The files should be placed in the same folder as the DATABASE (.DB) file. Each time a new problem is created, these files will need to be copied in.

DEF_RRE.DAT
Line 1: 6 ring rolling
Line 2: 0 default;
0 Roll geometry generated by revolved 2D section in ring rolling template
1 Otherwise – (attempt to extract profile from 3D shape)
Line 3: 0 default;
0 curved sectional mesh is allowed
1 always flat plane
Line 4: 0 2 0 2 2 0 default; the center control scheme
Line 5: 0 default;
0 standard movement
1 adaptive rotational movement of axial rolls,
2 (recommended) option 1 plus adaptive radial movement of axial rolls – following ring diameter
-2 adaptive radial movement of axial rolls with defined rotational velocity
Line 6: 20 default; the frequency of checking any die node penetration into the workpiece
Line 7: 0.0 default; the mass density

For most simulations, the DEF_RRE.DAT file should look like

6
0
0
0 2 0 2 2 0
2
20
0.0

DEF_TABLE.DAT

Line 1: 1 number of tables – always 1
Line 2: nnn.nn Z position of table

So for a table located at a global height of -100mm, the DEF_TABLE.DAT file should look like

1
-100.0

DEF_RRS.DAT

A special file for railroad wheel rolling – a unique variant of ring rolling.

1 - *workpiece object number*
5 - *total number of rolls*
2 1 - *object number, object type*
5 2 *1 – tread / OD roll*
6 2 *2 – web roll*
3 3 *3 – top axial roll*
4 4 *4 – bottom axial roll*