T020: Simulations With a Rotating Workpiece

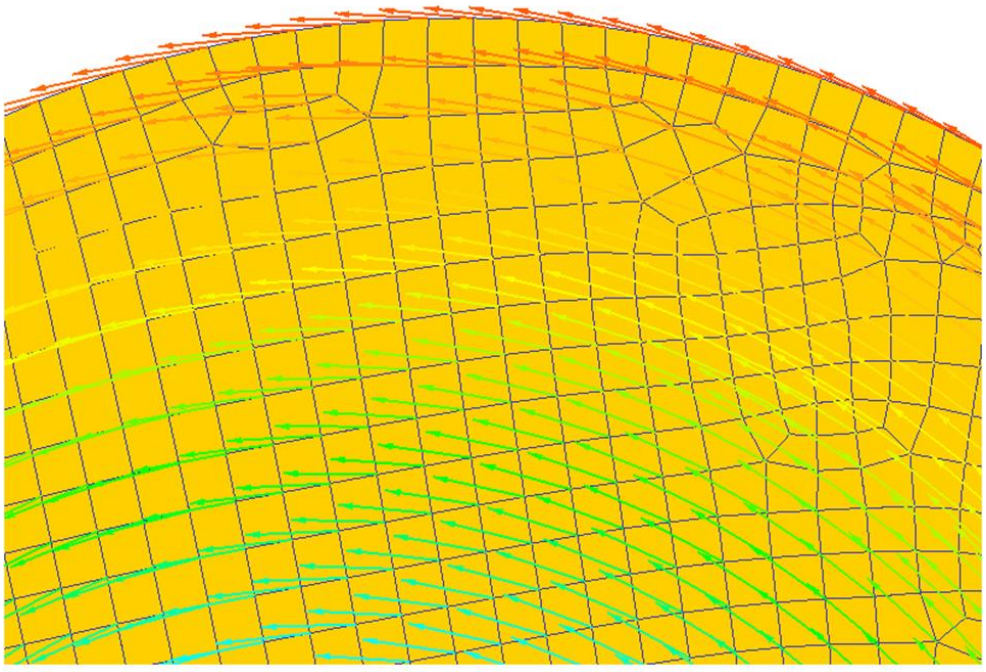
Introduction

This article describes the setup procedures required when modeling rotating workpieces.

Problem Description

There are a number of metal forming operations in which the workpiece rotates between two or more tools during the forming process. These processes include thread rolling, cross wedge rolling, spinning, form rolling, and related processes. In DEFORM, these processes require special treatment to avoid extreme volume fluctuation.

Fundamentally, DEFORM solves for nodal velocity in a rectangular coordinate system. In each time step, the distance and direction a node moves is calculated from the velocity vector, and the time increment. This works well for generally translational deformation. But when there is significant rotational movement, the velocity will be tangent to the surface, so the updated node will be slightly outside the object. The result is substantial volume growth when this updating error is repeated over hundreds of steps as the part rotates.



Solution

There are several methods of managing volume growth in a DEFORM simulation. Each method offers various trade-offs between speed, accuracy, and flexibility. The methods are:

- use a solution technique which inherently considers rotational movement in the solution (elastic-plastic model, rigid-super element solver),
- use a cylindrical coordinate system (triggered by AXIS.DAT file),
- reverse the reference frame – hold the workpiece stationary and rotate the tools around the workpiece.

Elastic-Plastic Solver

Description: No special settings are necessary. Simply specify an elastic-plastic object type.

Advantages: The elastic-plastic solver inherently considers both rotation and deformation within each element, so the velocity prediction is more accurate than a rigid-plastic model when there is significant rigid-body rotation.

Disadvantages: Solution times can be significantly longer than other methods. Convergence may be difficult with some materials and some geometry.

Rigid-Super Element Solver

Description: The Rigid-Super Element (RSE) solver is checked for applicability in every plastic object simulation. By adding a text file (DEF_RSE.DAT, *described later*) to the working directory, the user can tune the conditions under which the solver is active.

Advantages: As with the elastic-plastic solver, the RSE solver inherently considers both rotation and deformation within each element. Solution is extremely fast.

Disadvantages: May not work with some simulations. Rigid zone may restrict deformation in the core of the part.

Cylindrical Coordinate System

Description: Velocity field is calculated in a cylindrical coordinate system rather than rectangular. This coordinate system is defined by adding a text file (AXIS.DAT, *described later*) to the working directory. Depending on settings used, workpiece may be forced to rotate or allowed to rotate freely.

Advantages: This method stabilizes the part to rotate around a pre-defined axis. Helpful in processes such as cross wedge rolling where the workpiece can be difficult to stabilize.

Disadvantages: Requires rotation about a stationary axis. Cannot be used in processes where the rotation axis changes.

Reversed Reference Frame

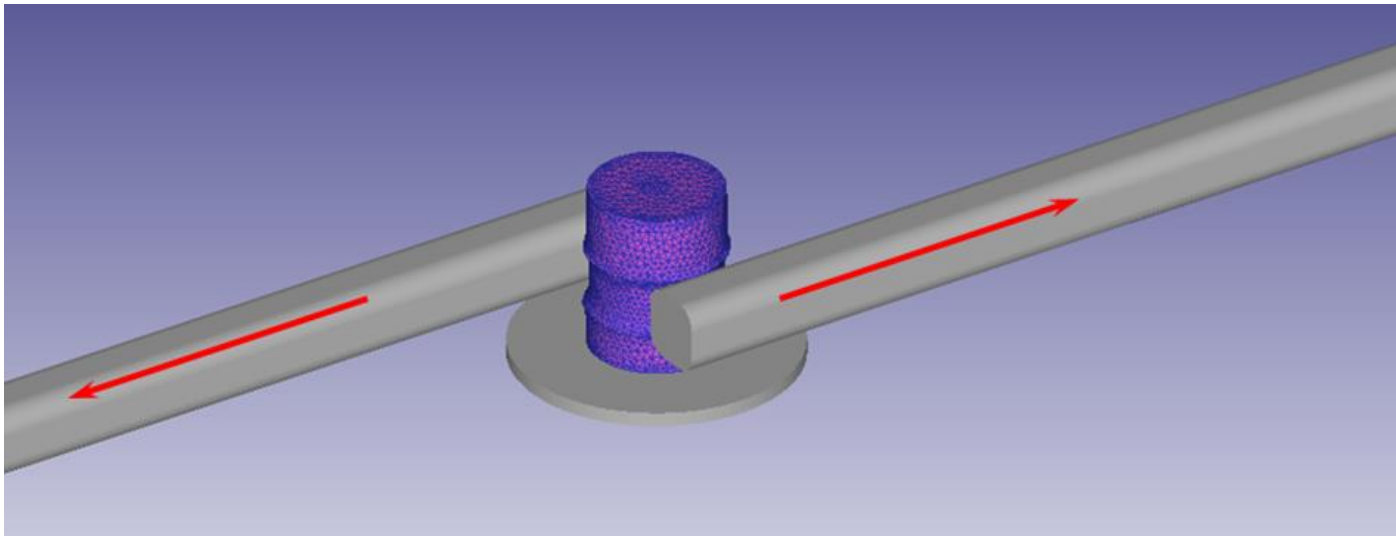
Description: By holding the workpiece stationary and rotating the tools around the workpiece, the rotational updating problem is eliminated. DEFORM features a rotating reference frame for orbiting tools which also translate towards the orbit axis.

Advantages: Eliminates rotational updating issues while maintaining very fast solving times.

Disadvantages: Requires rotation about a stationary axis. Defining correct tool movement can be complex and confusing.

Related Information

Example Case. A simplistic rotating workpiece simulation was constructed to illustrate differences in rotational updating schemes. The general configuration is shown below:



The initial workpiece was 200mm in diameter, and 230mm long. It undergoes two full revolutions. In the selected configuration, reversing the reference frame and rotating the tools was not possible.

Note that volume compensation is NEVER recommended for simulations where the workpiece has a large free surface, and was not used for any of these simulations.

Results are summarized in this table:

	Final length (growth)	Volume change (%)	Run time (h:mm)
Elastic-Plastic	234mm (+4mm)	-0.4%	3h 56min
Cylindrical coordinates	232mm (+2mm)	-0.2%	4h 08min
Rigid Super Element	230mm (No Change)	-1.8%	2h 5 min

Note that Elastic-plastic models and the cylindrical coordinate system method give similar results and similar run times. The RSE method is nearly twice as fast, but also looses significantly more volume. It may be appropriate for a “quick look” simulation, but other options are likely more accurate.