Forging with sinusoidal dies

This example shows the use of adaptive meshing in forging problems that incorporate geometrically complex dies and involve substantial material flow.

This page discusses:

Products: Abaqus/Explicit

Problem description

Three different geometric models are considered, as shown in Figure 1. Each model consists of a rigid die and a deformable blank. The cross-sectional shape of the die is sinusoidal with an amplitude and a period of 5 and 10 mm, respectively. The blank is steel and is modeled as a von Mises elastic-plastic material with a Young's modulus of 200 GPa, an initial yield stress of 100 MPa, and a constant hardening slope of 300 MPa. Poisson's ratio is 0.3; the density is 7800 kg/m^3.

In all cases the die is moved downward vertically at a velocity of 20000 mm/sec and is constrained in all other degrees of freedom. The total die displacement is 7.6 mm for Case 1, 6.7 mm for Case 2, and 5.6 mm for Case 3. These displacements represent the maximum possible given the refinement and topology of the initial mesh (if the quality of the mesh is retained for the duration of the analysis). Although each analysis uses a sinusoidal die, the geometries and flow characteristics of the blank material are quite different for each problem.

Case 1: Axisymmetric model

The blank is meshed with CAX4R elements and measures 20 × 10 mm. The dies are modeled as analytical rigid surfaces comprised of connected line segments. The bottom of the blank is constrained in the z-direction, and symmetry boundary conditions are prescribed at r=0. The initial configuration of the blank and the die is shown in Figure 2.

Case 2: Three-dimensional model

The blank is meshed with C3D8R elements and measures 20 × 10 × 10 mm. The dies are modeled as three-dimensional cylindrical analytical rigid surfaces. The bottom of the blank is constrained in the y-direction, and symmetry boundary conditions are applied at the x=0 and z=10 planes. The finite element model of the blank and the die is shown in Figure 3.

Case 3: Three-dimensional model

The blank is meshed with C3D8R elements and measures 20 × 10 × 20 mm. The dies are modeled as three-dimensional revolved analytical rigid surfaces. The bottom of the blank is constrained in the *y*-direction, and symmetry boundary conditions are applied at the $x=0$ and $z=10$ planes. The finite element model of the blank and the die is shown in Figure 4. The revolved die is displaced upward in the figure from its initial position for clarity.

Adaptive meshing

A single adaptive mesh domain that incorporates the entire blank is used for each model. Symmetry planes are defined as Lagrangian boundary regions (the default), and contact surfaces are defined as sliding boundary regions (the default). Because the material flow for each of the geometries is substantial, the frequency and the intensity of adaptive meshing must be increased to provide an accurate solution. The frequency at which adaptive meshing is to be performed is reduced from the default of 10 to 5 for all cases. The default number of 1 mesh sweep is used for case 2, and this number is increased to 3 for case 1 and case 3.

Results and discussion

Figure 5 and Figure 6 show the deformed mesh and contours of equivalent plastic strain at the completion of the forming step for Case 1. Adaptive meshing maintains reasonable element shapes and aspect ratios. This type of forging problem cannot typically be solved using a pure Lagrangian formulation. Figure 7 shows the deformed mesh for Case 2. A complex, doubly curved deformation pattern is formed on the free surface as the material spreads under the die. Element distortion appears to be reasonable. Figure 8 and Figure 9 show the deformed mesh and contours of equivalent plastic strain for Case 3. Although the die is a revolved geometry, the three-dimensional nature of the blank gives rise to fairly complex strain patterns that are symmetric with respect to the planes of quarter symmetry.

Input files

ale_sinusoid_forgingaxi.inp

Case 1.

ale_sinusoid_forgingaxisurf.inp

External file referenced by Case 1.

ale_sinusoid_forgingcyl.inp

Case 2.

ale_sinusoid_forgingrev.inp

Case 3.

Figures

Figure 1. Model geometries for each of the three cases.

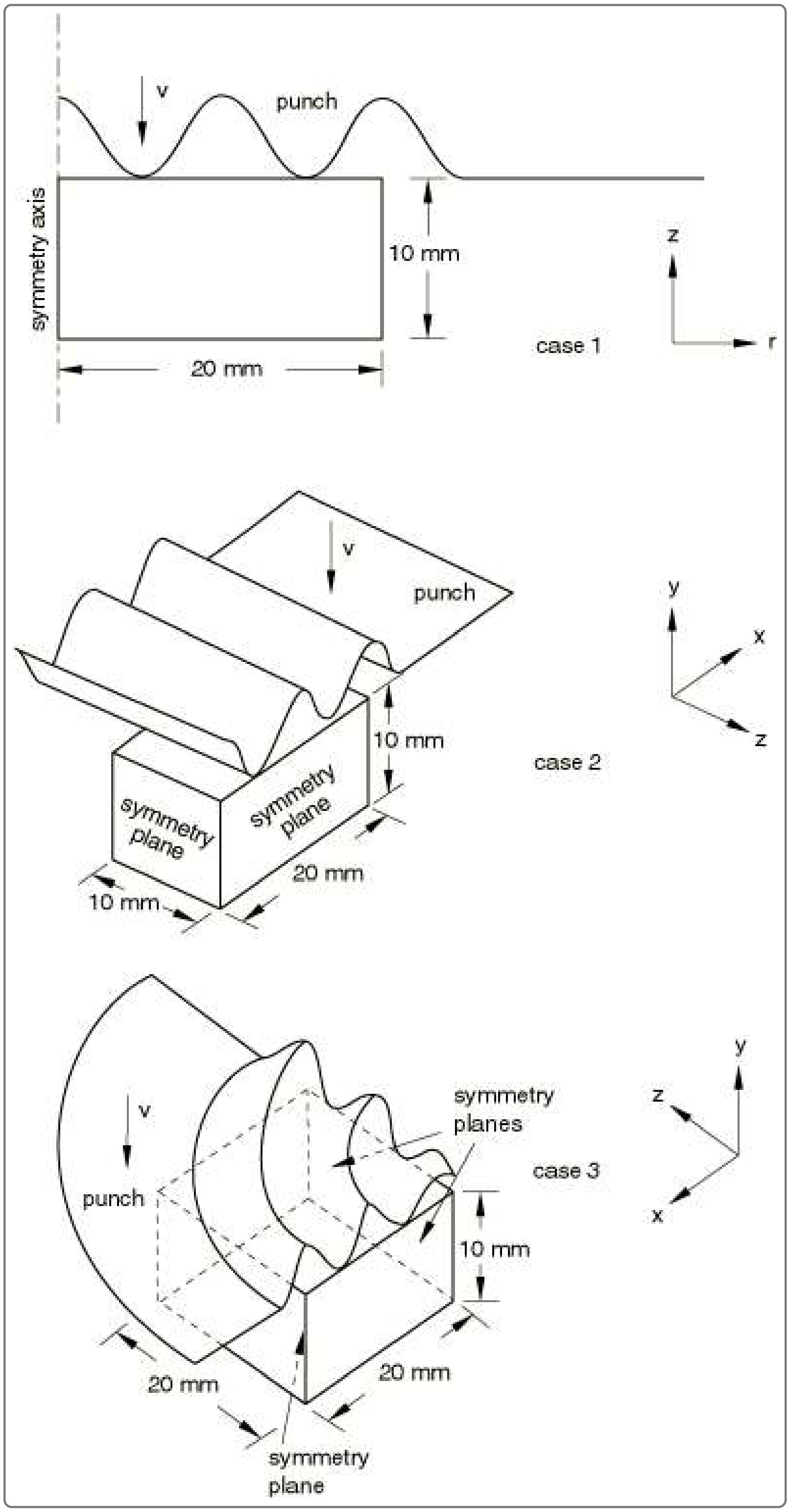

Figure 2. Initial configuration for Case 1.

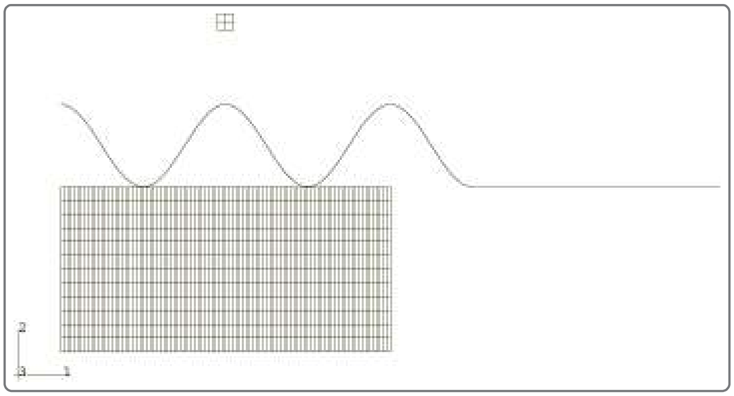

Figure 3. Initial configuration for Case 2.

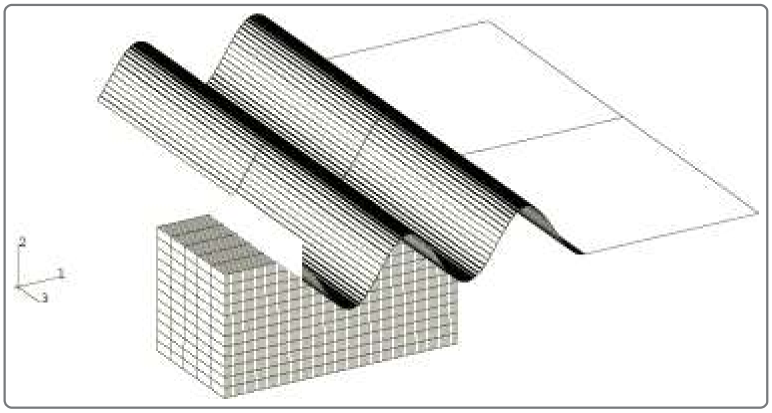

Figure 4. Initial configuration for Case 3.

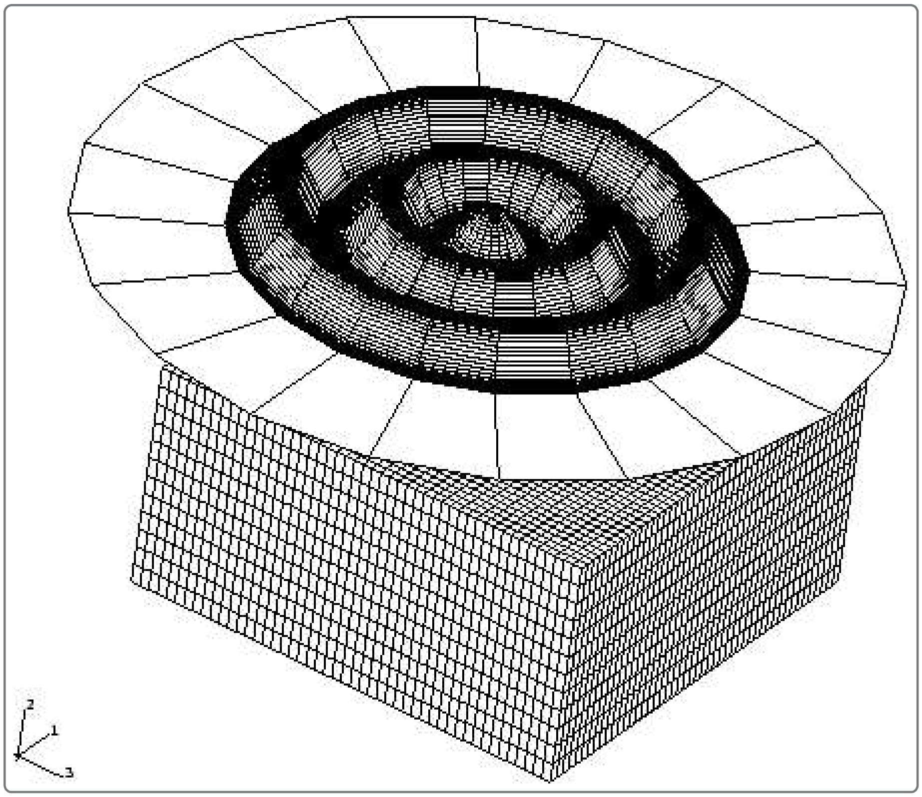

Figure 5. Deformed mesh for Case 1.

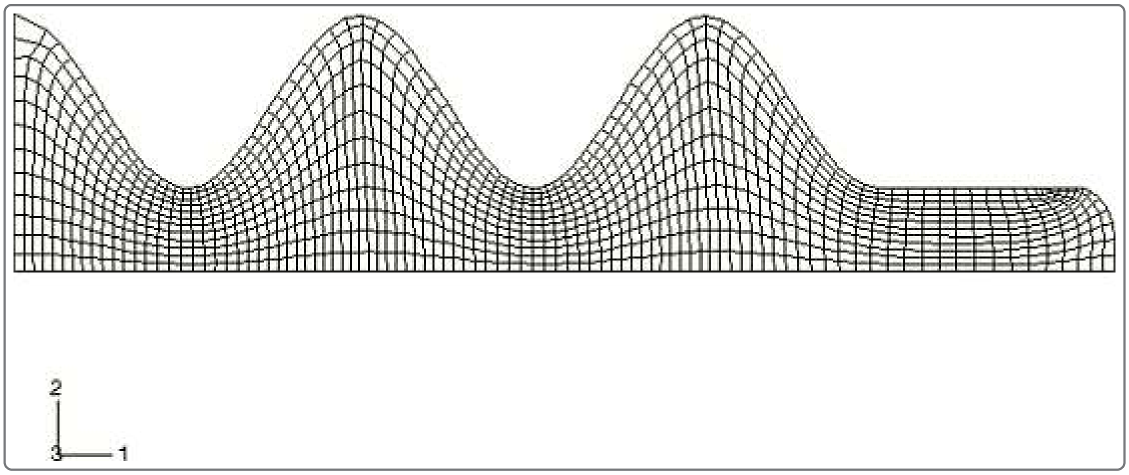

Figure 6. Contours of equivalent plastic strain for Case 1.

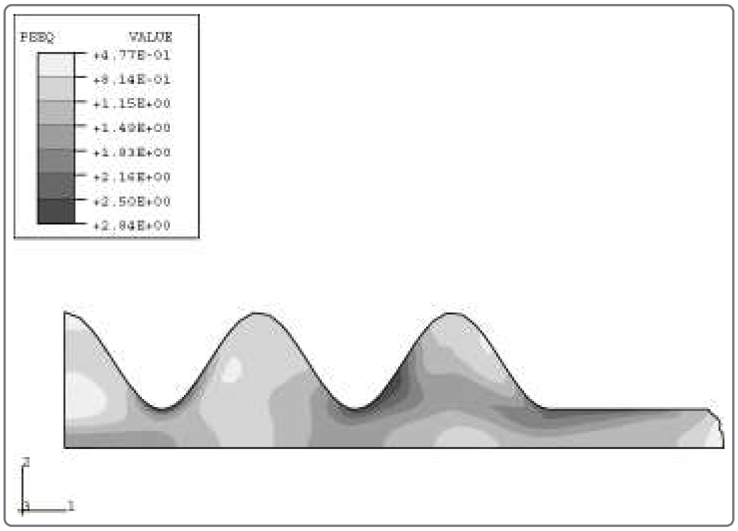

Figure 7. Deformed mesh for Case 2.

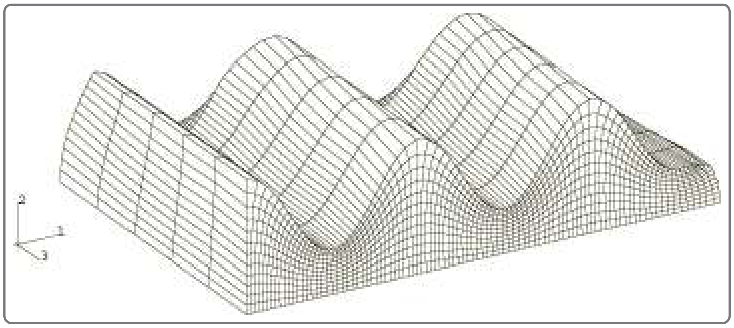

Figure 8. Deformed mesh for Case 3.

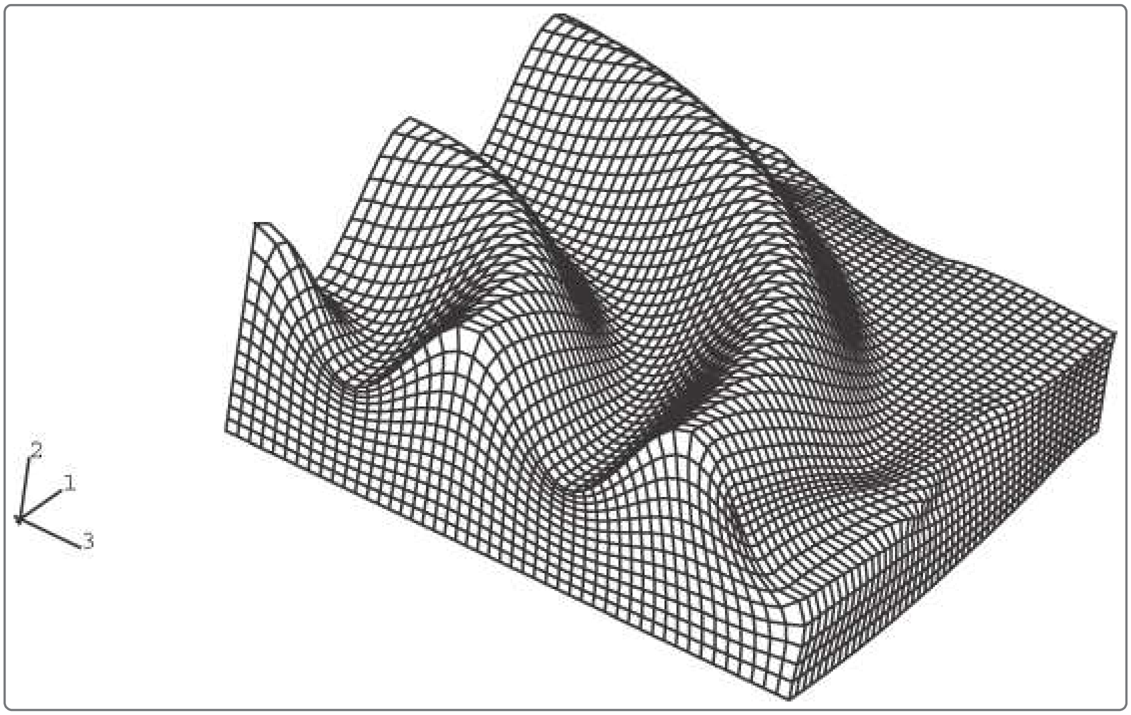

Figure 9. Contours of equivalent plastic strain for Case 3.