1.3.9 Pipe whip simulation

Products: Abaqus/Standard Abaqus/Explicit

This example simulates a pipe-on-pipe impact resulting from the rupture of a high-pressure line in a power plant. It is assumed that a sudden release of fluid could cause one segment of the pipe to rotate about its support and strike a neighboring pipe.

Problem description

The pipes have an outer diameter of 168.275 mm (6.625 in), with a 10.97 mm (0.432 in) wall thickness and a span of 1270 mm (50 in) between supports. The impacted pipe is assumed to be fully restrained at both ends, while the impacting pipe is allowed to rotate about a fixed pivot with an initial angular velocity of 75 radian/sec. We make use of symmetry boundary conditions to reduce the problem size by discretizing only the geometry to one side of the central symmetry plane.

Both pipes are made of steel with a Young's modulus of 207 GPa (30 � 10^6 psi), a Poisson's ratio of 0.3, and a density of 7827 kg/m^3 (7.324 � $10^{�4}$ lb $sec^2 in^{�4}$). A von Mises elastic, perfectly plastic material model is used, with a yield stress of 310 MPa (45 � 10^3 psi).

S4R shell elements are used to discretize the pipes. A higher level of mesh refinement is used near the middle of the pipes, where the impact will take place. The mesh is shown in Figure 1.3.9–1. The contact surfaces are defined over the entire length of each pipe and then grouped into a single contact pair. Kinematic contact enforcement is used for the primary input file, although models that use penalty contact pairs and general contact are also provided. An additional analysis with enhanced hourglass control is performed.

Results and discussion

The deformed shapes at different stages of the analysis, shown in Figure 1.3.9–2 through Figure 1.3.9–4, are in good agreement with the results reported by Ferencz (1989). The results of the analysis with enhanced hourglass control closely match the ones obtained with the default hourglass control.

A time history of the total kinetic energy, internal energy, and plastic dissipation over the duration of the analysis is shown in Figure 1.3.9–5. Near the end of the simulation the impacting pipe is beginning to rebound, having dissipated the majority of its kinetic energy by inelastic deformation in the crushed zone.

The results provided by the analysis based on penalty contact are approximately the same. The analysis costs using the alternative contact methods are increased by 2.5% as a result of a slightly smaller time increment with the penalty method.

Input files

Abaqus/Standard input file

pipewhip_std.inp

Contact pair analysis using S4R elements.

Abaqus/Explicit input files

pipewhip.inp

Contact pair analysis using S4R elements.

pipewhip_gcont.inp

General contact analysis using S4R elements.

pipewhip_enh.inp

Contact pair analysis using S4R elements with enhanced hourglass control.

pipewhip_enh_gcont.inp

General contact analysis using S4R elements with enhanced hourglass control.

pipewhip_s4rs.inp

Contact pair analysis using small-strain shell elements S4RS.

pipewhip_s4rs_gcont.inp

General contact analysis using small-strain shell elements S4RS.

pipewhip_s4rs_gcont_subcyc.inp

General contact analysis using small-strain shell elements S4RS with subcycling.

pipewhip_s4rsw.inp

Contact pair analysis using small-strain shell elements S4RSW.

pipewhip_s4rsw_gcont.inp

General contact analysis using small-strain shell elements S4RSW.

pipewhip_pnlty.inp

Contact pair analysis using penalty contact.

Four additional models are included with the Abaqus release for the sole purpose of testing the performance of the code (file names: pipewhip_medium.inp, pipewhip_medium_gcont.inp, pipewhip_fine.inp, and pipewhip_fine_gcont.inp).

Reference

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Ferencz, R. M., “Element-by-Element Preconditioning Techniques for Large-Scale, Vectorized Finite Element Analysis in Nonlinear Solid and Structural Mechanics,” Ph. D. Dissertation, Stanford University, Stanford, CA, 1989.

Figures

Figure 1.3.9–1 Undeformed mesh.

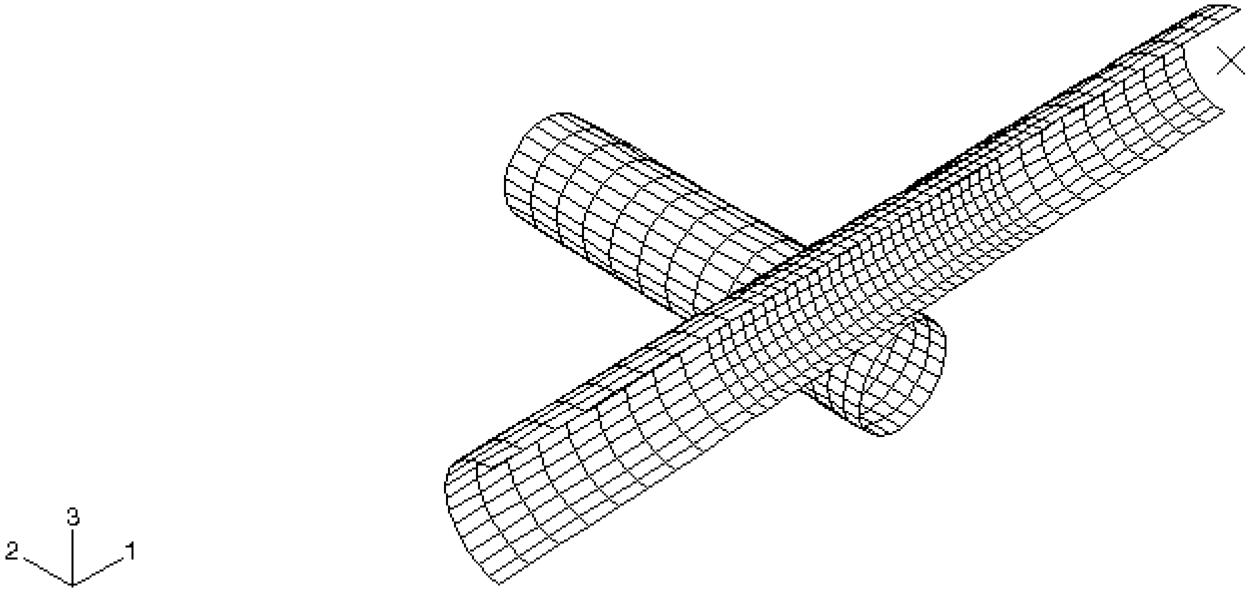


Figure 1.3.9–2 Deformed shape at 5 milliseconds.

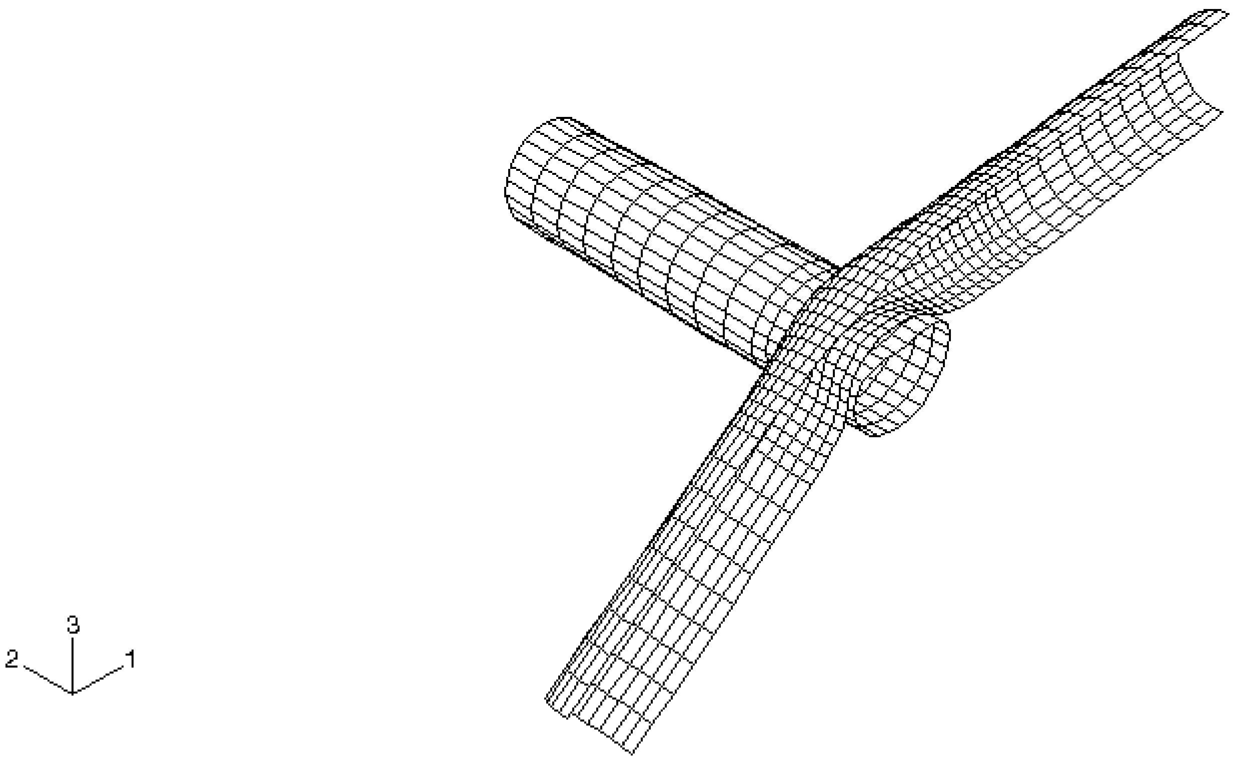


Figure 1.3.9–3 Deformed shape at 10 milliseconds.

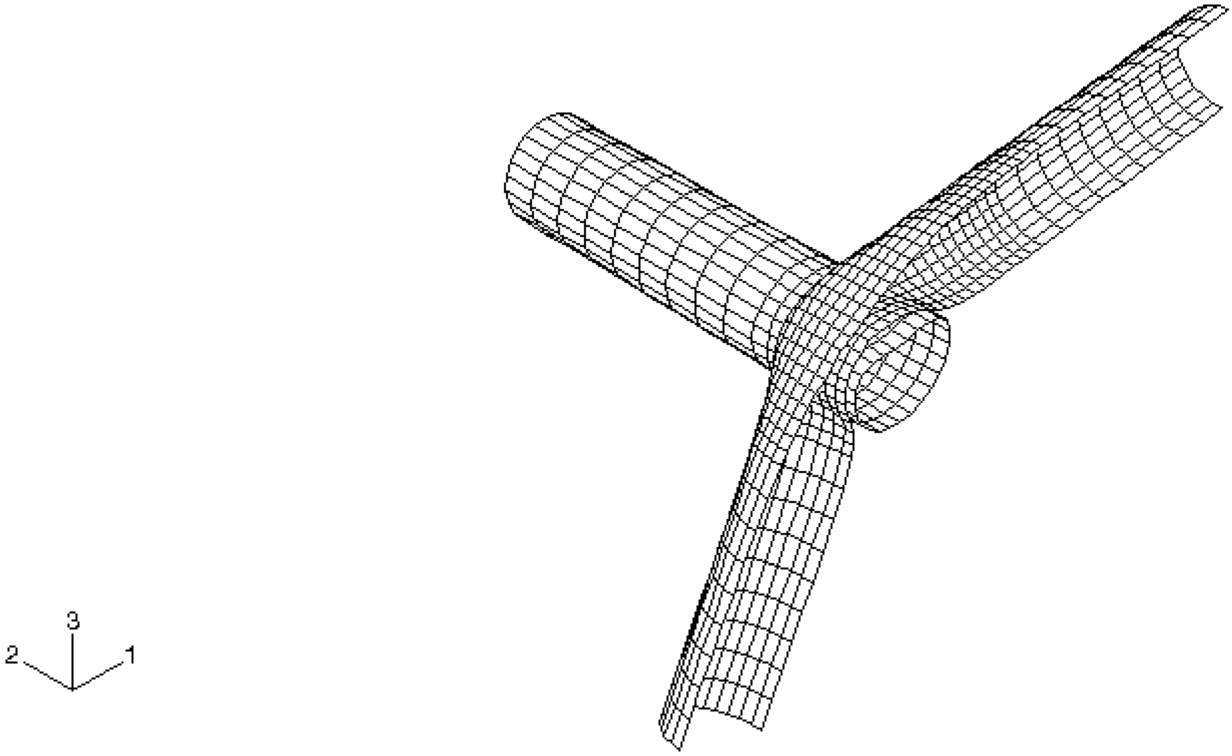


Figure 1.3.9–4 Deformed shape at 15 milliseconds.

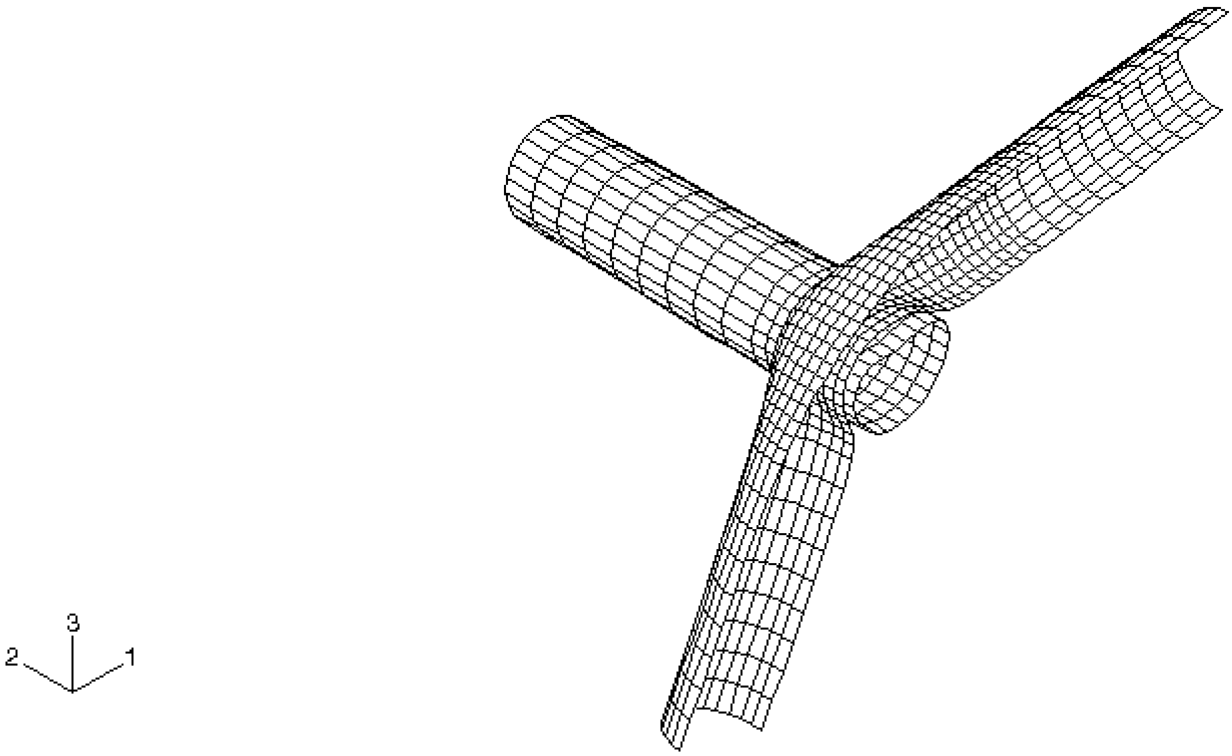
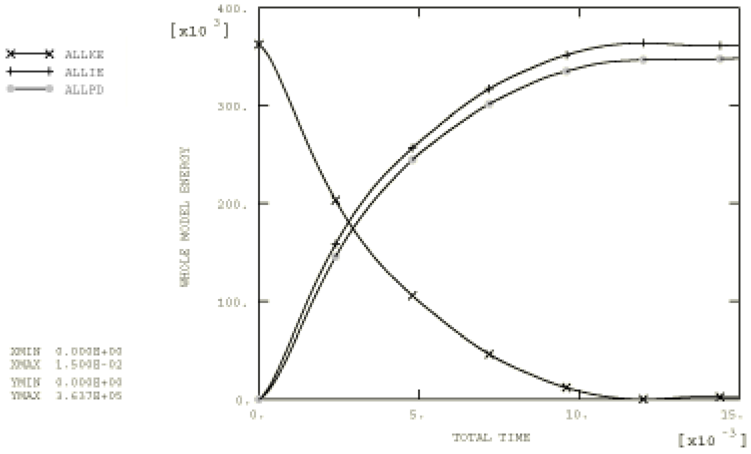


Figure 1.3.9–5 Time histories of the total kinetic energy, internal energy, and plastic dissipation.


ALLKE
ALLIE
ALLPD
[x10 3]
400.
300.
200.
100.
0.
WHOLE MODEL ENERGY
0.
5.
10.
15.
TOTAL TIME
[x10 -3]
XMIN 0.000E+00
XMAX 1.500E-02
YMIN 0.000E+00
YMAX 3.617E+05