T. High-Speed Machining of Titanium

Rahul Aphale
Third Wave Systems, Inc.
Minneapolis, MN
(952) 832-5515

DOE Technology Development Area Specialist: James J. Eberhardt
(202) 586-9837; fax: (202) 586-1600; e-mail: james.eberhardt@ee.doe.gov
ORNL Technical Advisor: D. Ray Johnson
(865) 576-6832; fax: (865) 574-6098; e-mail: johnsondr@ornl.gov

Contractor: Oak Ridge National Laboratory, Oak Ridge, Tennessee
Contract No.: DE-AC05-00OR22725
Subcontractor: Third Wave Systems, Inc., Minneapolis, MN

Objectives

- To improve the material removal rate in machining of Ti-6Al-4V by developing modeling capabilities for various machining processes.

Approach

- Develop drilling modeling capability in the finite element modeling–based tool, AdvantEdge.

Accomplishments

- Delivered and validated drilling capability for titanium workpieces.
- Validated predictions from the AdvantEdge modeling software using drilling test data generated by the University of Michigan.

Future Direction

- Continue to work on reducing computational times and improving accuracy.

Summary

Delivery and validation of drilling capability for titanium workpieces has been successfully accomplished. Third Wave Systems developed the drilling modeling capability in a finite element modeling–based tool, AdvantEdge. Drilling test data generated by the University of Michigan were used to validate predictions from the AdvantEdge modeling software. The agreement between predicted and experimental data was within 15%. Third Wave Systems continues to concentrate its efforts on reducing computational times and improving accuracy.

Task Details

Development of the drilling model was performed for two fluted twist drills via modifications to adaptive meshing and contact algorithms for improvement in overall performance and robustness.

The graphical user interface (GUI) development was performed with the implementation of parametric definition of drill geometry. Twist drills can be defined with either drill design parameters or drill grind parameters (Figure 1). The fundamental information used by the initial mesh generator are the grind parameters, since this is the information

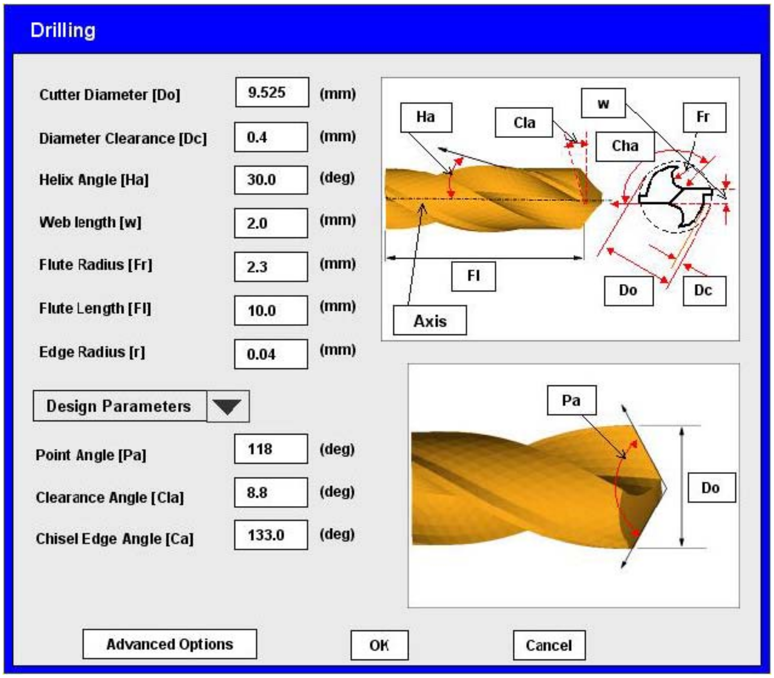


Figure 1. Inputs parameters are shown for drill geometry specification.

used in fabrication. Consequently, a nonlinear set of equations needs to be solved to determine the grind parameters if the user defines the drill geometry via design parameters. The solution of these equations is very fast, taking only a few seconds. Figure 2 shows an example of drilling modeling setup, with chips curling up along the flutes and heat being conducted into chips and deposited on the workpiece.

Additional modifications to contact and mesh adaptation algorithms allow even more chip

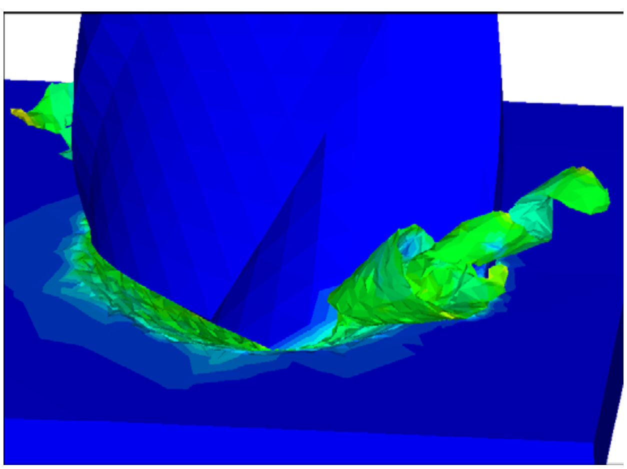


Figure 2. Chip formation for drilling of aerospace alloys. Temperature plots are shown for each chip formed by the two-fluted twist drill.

formation development and drill break-through, . The drill is removed from the analysis, revealing the chip and workpiece with a break-through hole (Figure 3). The adaptation and contact algorithms are able to model both the cutting action of the drill flutes as well as the plowing action of the chisel edge.

In order to model the entire hole drilling process, it is necessary to analyze the entrance, full engagement, and exit stages of the cut. To model full engagement it is necessary to have a pre-drilled hole in the workpiece. This hole has the same geometry as the drill would make in one complete revolution. The drill is then inserted into the pre-drilled hole and programmed speeds and feeds are applied. As the drill rotates it progresses deeper in the hole until it finally breaks out, Figure 4.

Modeling and simulation of indexable drills was performed. Automated initial mesh generation was performed for a number of ISO standard inserts. An example of indexable drilling modeling with rectangular inserts is shown in Figure 5. Inserts are offset from center axis of drill, so each insert experiences a different chip load and cutting speed.

Experimental thrust force and drilling torque data were generated by the University of Michigan (Figures 6–9). The drills used were 3.97 mm in

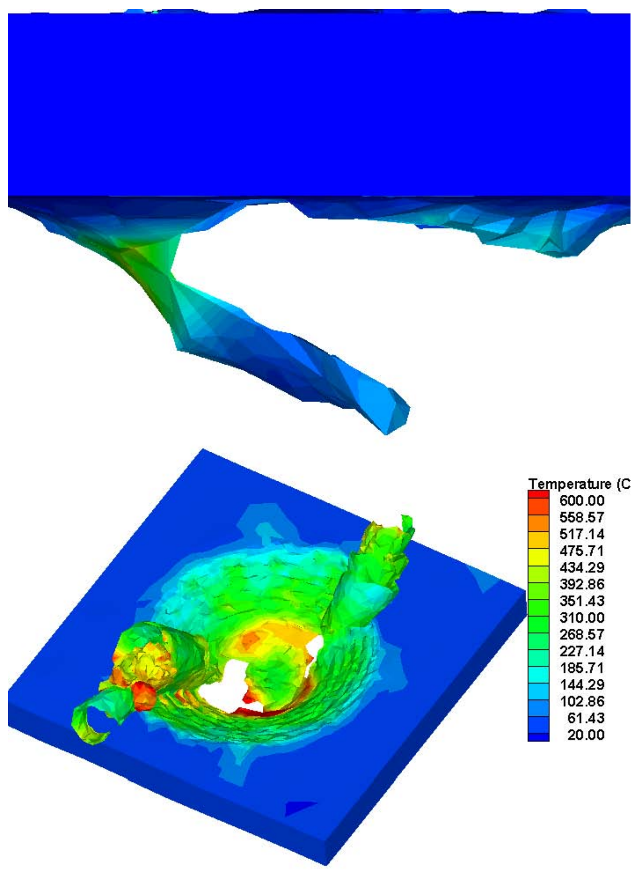


Figure 3. AdvantEdge model of drill breakout shown with drill geometry removed. Burr formation on breakout (top) and chip formation with temperature contours (bottom).

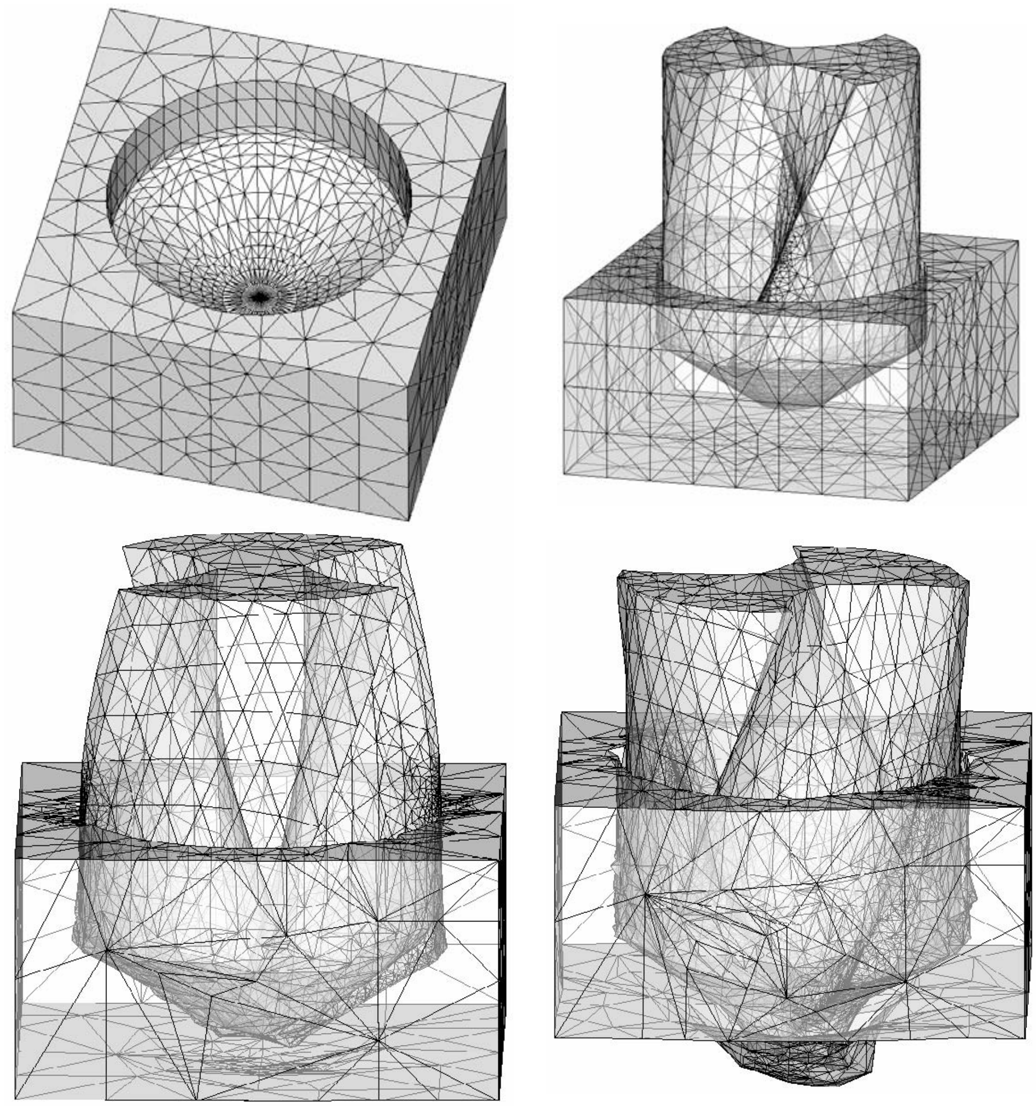
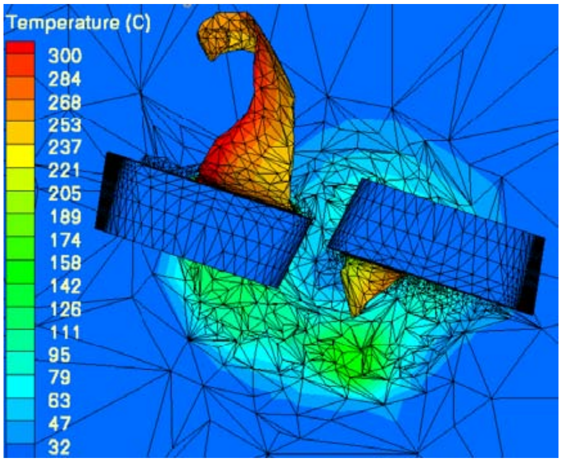


Figure 4. Different stages of drilling with pre-drilled holes are shown. (a) The initial pre-drilled hole in the workpiece; (b) the drill and workpiece combined (translucent mesh); (c) drill and workpiece after several rotations of the drill; (d) and drill break out on the bottom side of the workpiece.



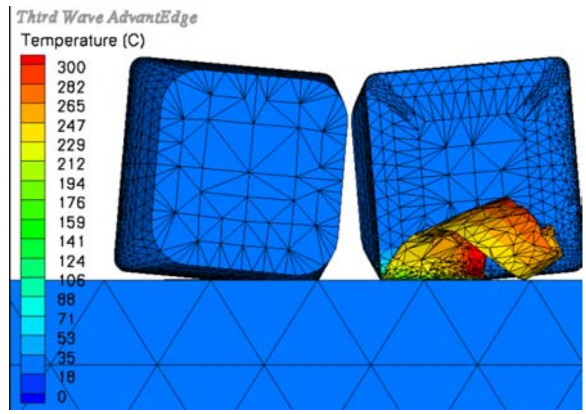


Figure 5. Modeling of indexable drilling is shown with finite element mesh and temperature contours overlaid. Chip formation is seen from the inserts which are offset from center, top view, left; side view, right**.**

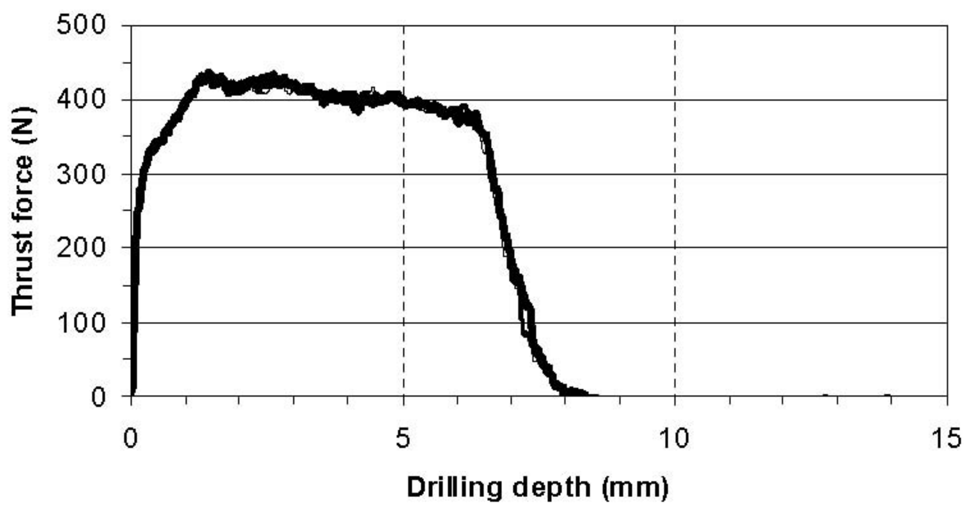


Figure 6. Experimental thrust force data from University of Michigan, for drill diameter of 3.97 mm, 734 rev/min, and 0.050 mm/rev.

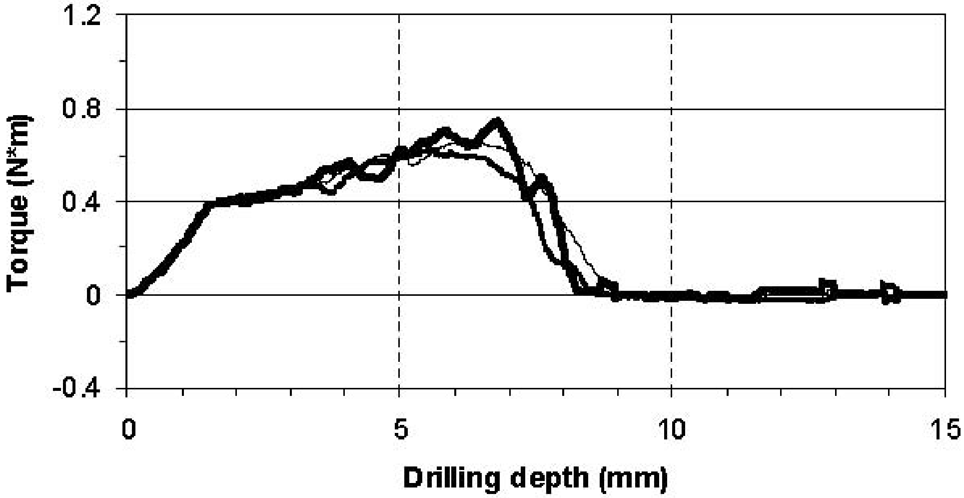


Figure 7. Experimental torque data from University of Michigan, for drill diameter of 3.97 mm, 734 rev/min, and 0.050 mm/rev.

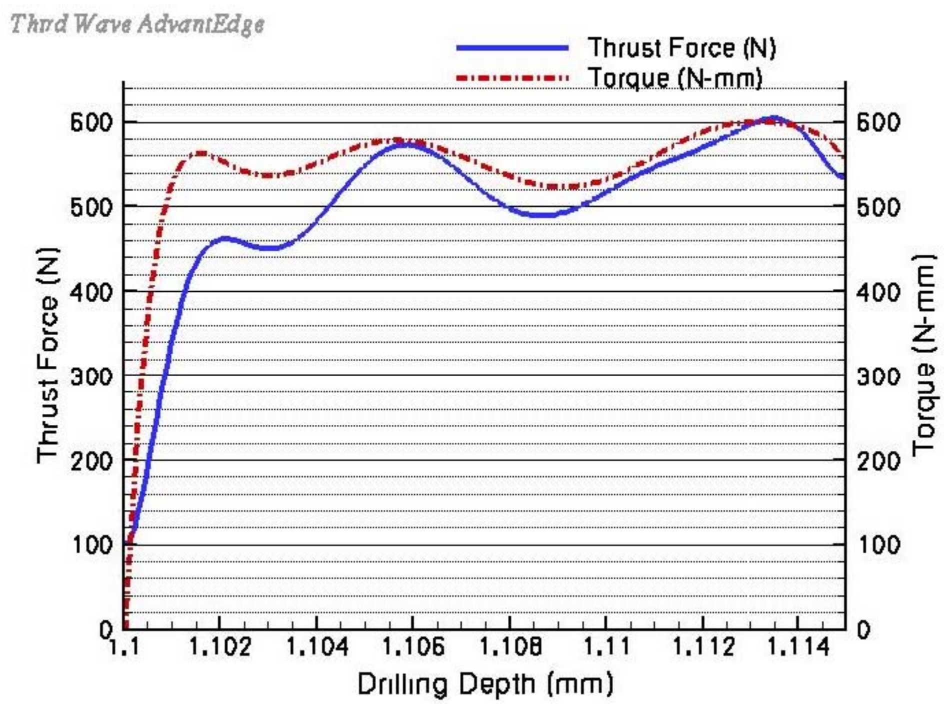


Figure 8. Model predicted torque and thrust force.

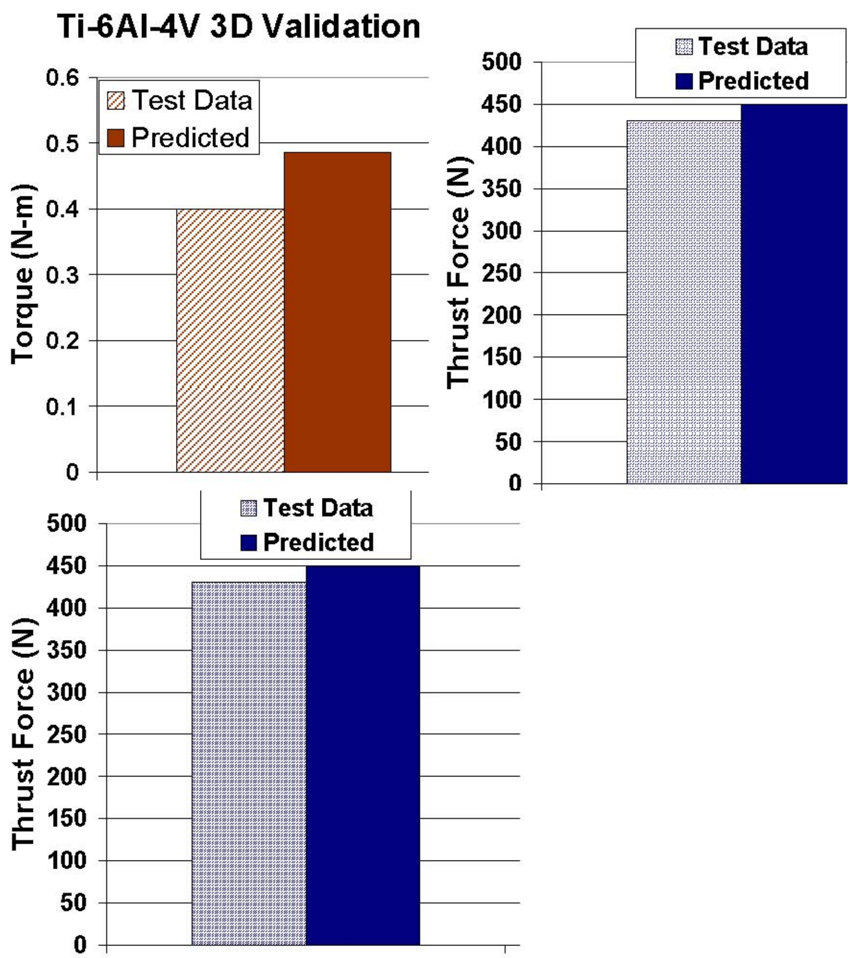


Figure 9. Validation data for drilling with 3.97-mm diameter drill, 734 rev/min, and 0.05-mm/rev feed.

diameter and tests were performed at 0.05 mm/rev feed, and 734 rev/min and 1468 rev/min spindle speeds. AdvantEdge simulations were performed by Third Wave Systems. Simulation results were analyzed and compared with the experimental test data, F. It was observed that the model prediction for thrust force was within 15% of experimental thrust force at 734 rev/min speed and within 25% at 1468 rev/min, F. Third Wave Systems continues to concentrate its efforts on significant improvements in the computational times and accuracy of the predictions.

Future Work

Third Wave Systems continues to work with University of Michigan and ORNL for completion of remaining tasks per milestone.