DEFORM™ Application #350

Cutting Force Prediction

Background:

Through the past 30 years, computer technology, from CAD and solid modeling, to tool path generation, to CNC machine control has proven its value to industry. While these factors are important productivity aides, the fundamental value added process in any machine shop is the actual material removal process. With ongoing improvements in computer technology, it is now possible to study the interaction between the insert and the chip.

Chip shape and behavior, cutting zone temperature, tool wear, and the influence of coatings on tools can all be studied in computer simulation, but all of these rely on the ability to accurately predict material behavior under the extreme conditions seen at the tip of the tool.

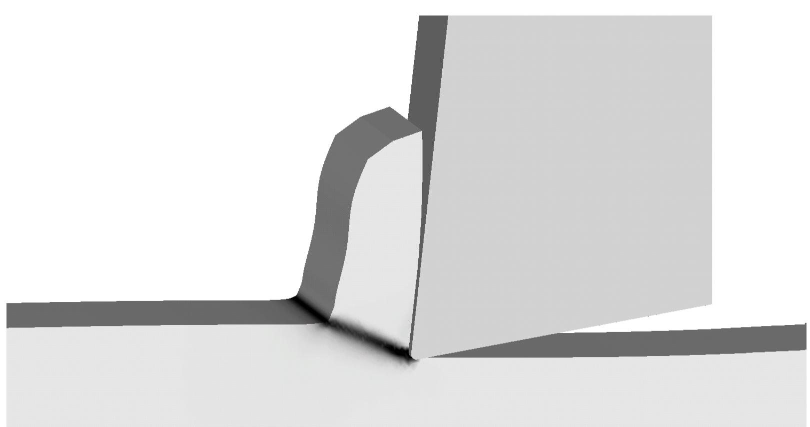
The Problem:

By allowing the study of the chip forming process, computer simulation of the machining process holds the promise of improved productivity and reduced process cost. However, accurate prediction of any behavior in the chip forming zone depends on the ability to accurately simulate the behavior of the workpiece material, and the interaction between this material and the tool or insert. Metal cutting can be considered as a deformation process where deformation is highly concentrated in a small zone[1]. Material data is strongly dependent on the rate of deformation, and data obtained through conventional testing methods is not applicable to the high rates seen in high speed machining.

New Testing Methods:

A material testing method cannot simply provide data for a single metal cutting process (ie turning), but rather should provide information applicable to the full range of operations. Researchers[2] developed a method of using experimental force measurements from a turning operation to determine material properties for the workpiece material. The data from those experiments is general enough to be used in other processes. This was sucessfully demonstrated by accurately predict cutting forces, tool stresses, and temperatures in high speed end milling.[3]

To determine high deformation rate material properties, turning experiments are conducted at a series of speeds and feeds. During the experiment, cutting and thrust forces are measured. The conditions of the experiment are then simulated using DEFORM™-2D, with material data obtained at low deformation rates. An initial assumption of friction conditions is also made. In the initial simulation, there is substantial error between the experimental force measurements and those predicted by the simulation. The material and friction data are then modified, and the simulation is performed again. Modifications in data are continued, and the simulations are repeated until the simulation results are within 10% of the experimental values for all experimental cases.



The simulation of chip formation shows an intense deformation zone (dark area) near the tip of the insert.

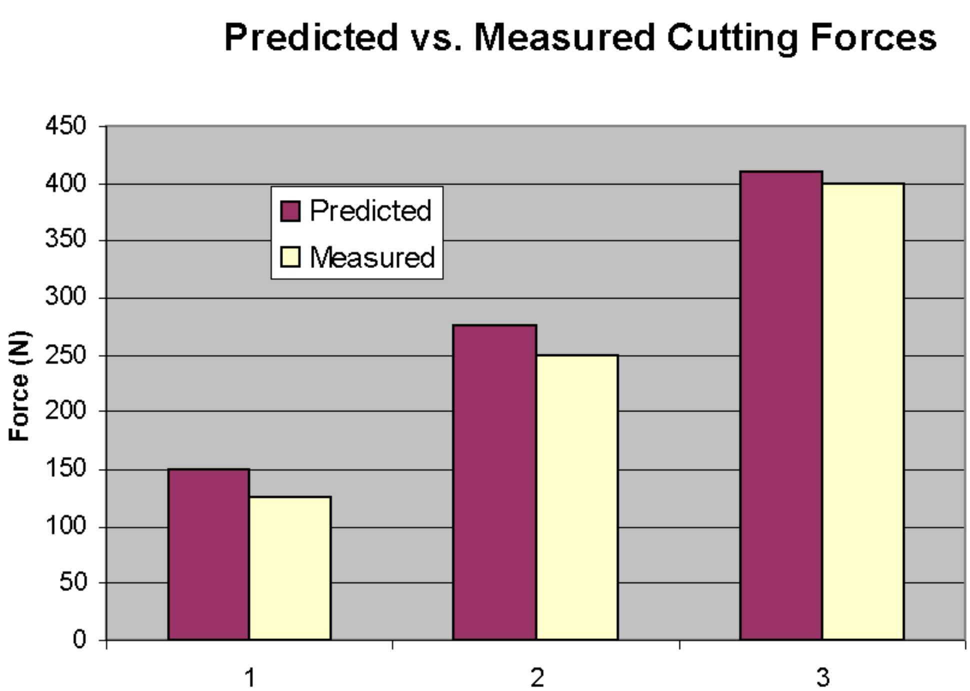
DEFORM™
Design Environment for FORMing

Validation:

By allowing the study of the chip forTo demonstrate that the material data is valid for a general case, and not just the turning experiments, experiments were also performed using an end mill. For experimental convenience, a single insert flat end mill with a null helix angle was used. The workpiece was mounted on a special, force sensitive table. The cutting forces in the x and y direction on the table were recorded during the cutting process. A simulation of the process was also conducted using material data from the turning experiments. The force predictions from the simulation were well within 30% of the experimental values, and in many cases were substantially better.

Conclusion:

Computer Simulation of metal cutting processes holds the promise of improved productivity and reduced tool cost through better selection of cutting paramters, insert design, and materials. Accurate prediction of tool stress and temperature are strongly dependent on proper cutting force predictions. Thus, having accurate data is the first step in successfully predicting the phenomenon which hold the most influence over productivity.



References:

(1) P.L.B. Oxley, Mechanics of Machining, an Analytical Approach to Assessing Machinability, Halsted Press, John Wiley & Sons Limited, New York, 1989.

(2) T. Ozel, T. Altan, "Determinationof Workpiecd Flow Stress and Friction at the Chip-Tool Contact for High-Speed Cutting", International Journal of Machine Tools & Manufacture, V40, 2000, pp. 133-152.

(3) T. Ozel, T. Altan, "Process Simulation Using Finite Element Method – Prediciton of Cutting Forces, Tool Stresses, and Temperatures in High Speed Flat End Milling", International Journal of Machine Tools & Manufacture, V40, 2000, pp. 713-738.

Scientific Forming Technologies Corporation

5038 Reed Road
Columbus, Ohio
43220-2514
Tel: (614)451-8330
Fax: (614)451-8325

www.deform.com
email: sales@deform.com