

Comparative Visualization of FEM-Based Cutting Simulations in a Virtual Environment

Fritz Klocke, Andreas M. Straube

Department of Process Technology, Fraunhofer Institute of Production Technology IPT, Aachen, Germany

Abstract

As one of the final steps in the industrial manufacturing chain, machining operations require significant economic consideration. At this stage, design components have already passed through several steps of this value-added manufacturing process. Industrial companies today are using Finite Element Simulations to optimize manufacturing processes, such as mechanical cutting. In order to obtain an increased understanding of the cutting process, several simulations with different input parameters are performed. A new method for comparing these results has been developed and has many potential benefits. In this poster abstract, the comparative visualization of cutting chip formation and distribution of data values, such as tool and work piece temperatures, is investigated using a Virtual Environment.

Keywords:

Comparative Visualization, Cutting Simulation, FEM, Virtual Environment

Categories and Subject Descriptors (according to ACM CSS): I.6.6 [Simulation and Modeling]: Simulation Output Analysis; I.3.7 [Computer Graphics]: Virtual Reality

1. Introduction

In order to reduce costs and increase efficiency in mechanical cutting operations, our understanding of the metal cutting process must be improved. Predictive models of cutting processes are used to forecast evaluate cutting performance indicators such as chip formation, cutting force, cutting temperature, tool wear, and surface finish. Currently, three-dimensional numerical cutting simulations allow elastic-plastic computation deformation of the work piece and linear-elastic treatment of the cutting tool. These simulations calculate model behavior over several time increments and show the development of cutting chip formation [1].

Changing a cutting input parameter and examining its effects on the final solution allow engineers to isolate regions and physical quantities most affected by the change and provide multiple solution data sets for comparison. Two major software packages for cutting simulation are AdvantEdge™ and Deform3D™. These simulation systems offer little or no simultaneous comparative analysis support. Instead, each data set can only be viewed individually. The user must remember the properties of interest or initiate multiple visualization sessions and

display the windows side-by-side. For both AdvantEdge™ and Deform3D™, it is not possible to superimpose multiple data sets or synchronized animated visualizations of several time increments on the same model.

In our approach, the scientific visualization and Virtual Reality software known as COVISE™ is used as a post-processor for cutting simulations. Converters to translate data from AdvantEdge™ and Deform3D™ to COVISE™ were developed, and cutting simulations were performed. Two parameters are examined: formation of the cutting chip and data distribution over and within the work piece, chip, and tool. This study investigates the use of a Virtual Reality system for comparative analysis of numerical cutting simulations.

2. Comparative Visualization

For comparison of cutting chip formation, we found the superimposed visualization of results from different data sets to be the most effective method. In the 3-D visualization environment, the domain surfaces of all data sets are computed and superimposed. Because the chip formation is compared over several time increments, all simulations must have the same time interval and number

of increments. The user views the process from the perspective of the cutting tool. It is easier to observe the cutting process in this manner, because the cutting zone and chip are always in the users field of view during the animation. For a detailed comparison of chip formation differences, the animation speed should be lower than one frame per second. To obtain a good impression of the chip formation process, we recommend a speed of at least 15 frames per second. The total number of visible data sets should not exceed four to avoid difficulties in identifying each data set. To clearly observe the chip formation of each data set, good color contrast between the chip and work piece and between the different chips must be used. This can be done by mapping the computed plastic strain values onto the domain surfaces of each simulation. In addition, the color map boundaries must also be adjusted. The cutting chip endures the highest effective plastic strain and therefore provides an ideal data point to achieve good color separation of the chip and the work piece. For determination of different chip colors, the boundaries of each data set color map can be adjusted.

The comparison of data value distributions on the work piece, chip, and cutting tool is done most effectively in a side-by-side visualization. Each data set is aligned along the same z-axis and offset by a certain amount. It is also imperative that all data sets are visualized with the same color maps and color map boundaries. The time increments of all data sets are shown in a synchronized fashion that allows the user to see the differences in the distribution of data values. We found that the data distribution of two data sets can be conveniently compared at a time. For this analysis the animation speed should be less than one frame per second. Additional insights can be obtained by visualizing the boundary lines of the mesh instead of the domain surface and placing cutting planes inside the objects. The cutting planes can be introduced interactively in the Virtual Environment during the animation. Critical stress values, for example, can be visualized using iso-surfaces.

3. User Study

We found that in our method for comparative visualization of a cutting simulation, user productivity increased when compared to the conventional desktop solution. Analysis in the post-processors provided with AdvantEdge™ and Deform3D™ requires more time because the user must rotate the data set several times before the formation of the cutting chip in space is clearly depicted. Using the Virtual Environment of COVISE™, the cutting chip formation is understood more quickly with the aid of stereo visualization. It is also possible to superimpose data sets,

which is most effective for comparison of the chip formation. The possibility to compare two data sets side-by-side synchronized over several time increments is another advantage that reduces evaluation time. Here tracking plays an important role because the user can quickly alternate views between both data sets. Large projection screens allow specific regions of interest to be analyzed in detail with minimal scaling. On a desktop monitor, the user must zoom into regions of interest more frequently and can only examine a small portion of the object at a time. The user may consequently lose the context of that part relative to the rest of the data set.

On the other hand, a Virtual Reality system is an expensive investment. Other factors may offset this cost, such as in the automotive industry, where thousands of parts are produced from cutting processes. In this situation, stable manufacturing processes with long tool life must be conceived. Normally this is achieved by performing experiments that use machine and personnel time, materials, and tools. The investment in computational cutting simulations and Virtual Reality can lower overall costs by reducing the need for these experiments. It then depends on the costs of experiments to determine when the use of a Virtual Reality system would be justified.

4. Future Work

Further development will include the creation of reader modules that allow data sets to be loaded directly from the simulation without conversion. Furthermore, a data comparison technique will be devised whereby a differenced data set is created from two different simulations. This differenced data set will be mapped onto one mesh. A similar procedure for comparison of identical computational grids for single time steps is described in [2]. For cutting simulations, the grids differ from one simulation to another.

References

1. Klocke, F.; Straube, A. M.: "Virtual Process Engineering - Approach to Integrate VR, FEM and Simulation Tools in the Manufacturing Chain", Proceedings of Virtual Concept 2002, October 9.-10. 2002, Biarritz, France, ISBN 2-9514772-2-8, pp. 66-71.
2. Freitag, L.; Urness, T.: "Analyzing Industrial Furnace Efficiency Using Comparative Visualization in a Virtual Reality Environment", Journal of Manufacturing Science and Engineering, May 2002, Volume 124, Issue 2, pp. 456-461.