# The Current and Future Developments in the Simulation Technology of Manufacturing Processes

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## ABSTRACT

Development of finite element techniques in the simulation of manufacturing processes is presented focused on historical background, current capability and recent research trend. Several topics related to remarkable improvement in this research area during last decade are discussed including incompressible finite element, a technique of element consolidation, a specialized iterative solver. Finally, some recent research efforts are briefly introduced.

## I. INTRODUCTION

The finite element method(FEM) associated with the flow formulation of a rigid-plastic material model has been used successfully for the analysis of large plastic deformation problems in material forming since 1980s. Pioneering works in US have been done at the UC-Berkeley and the Battelle Memorial Institute in Columbus, Ohio, and a few Korean-native scholars have made key contribution to technical development. As a successor of these pioneering works, the DEFORM™ system from SFTC in Columbus, Ohio, has served as one of worldwide leading simulation software in various manufacturing industries including aerospace, automobile, ship building, tooling and machinery, and so on since 1991.

## II. FINITE ELEMENT FORMULATION

In order to apply rigid-plastic problems to FEM, several intrinsic difficulties need to be resolved first such as two sources of discontinuity: material law and friction law, and two sources of constraint: volume incompressibility and non-penetration (contact). Topics related to these issues are discussed. A new incompressible finite element based on the mixed formulation has been proved computationally very efficient for metal forming applications.

## III. SOLUTION METHOD

There is always a continuous demand to increase the size of FEM model in order to predict any possible defect in a real process more accurately and in detail. On the other hand, the simulation time increases drastically as the number of elements in a given FEM model increases. Because the implicit method of solution for a quasi-static analysis of manufacturing processes requires to solve a set of equations in a form of matrix equations repeatedly and the solution time increases much faster than the size of matrix increases. Thanks to not only the advances in the computer resources and the parallel computation but also the development of innovative solution methods, the size of FEM model used in industrial applications has increased almost five times during last decade. It means that a several-weeks task is now reduced to a day or hours task for the same size of FEM model. Several topics related to such improvement are discussed including the technique of element consolidation(Rigid Super Element) and a specialized iterative solver with a hybrid type of pre-conditioner.

## IV. RECENT RESEARCH TREND

As the simulation software becomes robust and fast enough to model conventional manufacturing processes, more realistic material representation by including and coupling residual stress and micro-structure evolution during the manufacturing processes is being investigated. Using this Integrated Computational Materials Engineering (ICME) approach, process modeling of the entire manufacturing processes, from ingot break-down, forging, heat treatment, to final machining, becomes feasible. These recent research efforts are also discussed briefly.