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Review

Incorporation of material behavior in modeling of metal forming and machining processes: A review

U.S. Dixit [a,*], S.N. Joshi [a], J.P. Davim [b]

[a] Department of Mechanical Engineering, Indian Institute of Technology Guwahati 781 039, India
[b] Department of Mechanical Engineering, University of Aveiro, 3810-193, Portugal

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ABSTRACT

Manufacturing process modeling is gaining importance in view of stiff global competition to produce the goods of specified design in an optimal way. In particular, metal forming and machining (both traditional and non-traditional) have been extensively modeled using numerical techniques. Three basic steps of modeling of manufacturing processes are analytical representation of working principle of the process, modeling of material behavior and method of solution. In this paper, a comprehensive review of various approaches of material behavior modeling has been presented. The material behavior modeling has great influence on the design of process, tools and the final product. This aspect is highlighted in the present review. Metal forming processes, traditional machining processes and non-traditional machining processes are considered for the study. Different material models are compared with respect to their suitability for the design of process, tooling and product. Finally, the paper suggests the directions for further research in this area.

1. Introduction

With the advent of globalization, manufacturing industry is facing a challenge to produce a variety of high quality products at reduced price and reduced cycle time. Metal forming and machining are two major secondary manufacturing processes. Metal forming processes are also used as primary shaping processes [1]. The production of almost all finished metallic products needs at least one of these processes. Almost all metal forming processes consists of plastically deforming the metal by applying the forces. A recently developed manufacturing process, laser forming, plastically deforms the material with the help of thermal gradient [2] and can also be called metal forming process. In metal forming, the shape change is accomplished by plastic deformation only and consequently there is no wastage of material. This is in sharp contrast to machining processes, in which the shape change is accomplished by removing the material.

The metal forming processes can be broadly classified into bulk metal forming and sheet metal forming processes [3]. In bulk metal forming processes, usually the workpiece has a high volume to surface area ratio. As a result of plastic deformation, this ratio changes considerably in the finished product. Some examples of bulk metal forming processes are rolling, wire drawing, extrusion and forging. In sheet metal forming processes, usually the workpiece has a low volume to surface area ratio and is in the form of a sheet with thickness less than 6 mm. In most of the sheet metal forming processes, the change in thickness is undesirable; hence the surface area does not change considerably during the process. Some examples of sheet metal forming processes are deep drawing, stretch forming, bending and spinning. Metal forming processes can be performed at hot, cold or warm states.

Machining is a metal removing process, in which the desired shape is produced by removing the material from the workpiece [3]. Thus, it is a subtractive manufacturing process. In traditional machining processes, a cutting tool or suitably controlled abrasive particles removes the material in the form of the chip. In so-called non-traditional machining processes, the mechanism of material removal may be thermal, electrical, chemical, electrochemical or mechanical [4].

Metal forming and machining processes have become more of science than art. The mathematical modeling of the process can predict the product quality as well as the forces required. The information from modeling can be helpful in the design of product, tool, machine and process. Incorporation of material behavior is crucial in modeling. The process and information needed by modeling is a deciding factor for choosing a suitable material model. For example, in metal forming, if only the forces required are to be calculated and residual stresses in the product are not important, a rigid-plastic material model is sufficient. If the information about residual stresses is needed, then an elastic–plastic material model is needed. Similarly, in several non-traditional machining processes, the melting and boiling points of the material and latent

* Corresponding author.
E-mail addresses: uday@iitg.ernet.in, usd1008@yahoo.com (U.S. Dixit).

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