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Review of Processing Maps and Development of Qualitative Processing Maps

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Abstract

Significant investigations in the area of theory of processing maps for hot working of different materials are reviewed. Special attention is focused on Dynamic Material Model, Power Dissipation Maps, Instability Maps, Hot Deformation Mechanisms, which are generally believed to be the dominant factors for determining processing maps at different temperatures and strain rates. The basic constitutive equation describing the process in which power is converted at any instant into different forms is presented along with a general survey of the numerous papers, investigating specific linear and nonlinear effects on these models. Estimates of the associated temperature ranges and strain rates are discussed, and a summary of relevant experimental results is given. Studies of the Hot Deformation Mechanisms like Dynamic Recrystallization (DRX), Super plastic Deformation, Dynamic recovery (DRY) are also surveyed. Methodology for development of qualitative processing maps for warm forming of different materials is discussed.

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Keywords:Dynamic Material Model, Power Dissipation Maps, Instability Maps, Dynamic Recrystallization (DRX), super plastic Deformation, Dynamic recovery (DRY)

1. Introduction:

Mechanical processing is an essential step in shaping materials into engineering components which require not only dimensional accuracy but also specified microstructures and mechanical properties. The techniques of mechanical processing involve bulk metal working using rolling, forging, extrusion generally conducted at elevated temperatures in order that large strains may be imposed in asingle step of the operation without the onset of the fracture. The secondary metal working process generally use cold working which ensures good surface finish, high dimensional tolerance and better strength.

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However processes like sheet metal working, cold forging, impact extrusion, coining, wire tube drawing involve smaller strains and require large number of steps with intermediate annealing to restore the ductility. In recent years, with the advent of rapid solidification processes and atomization techniques for producing powders of desired shape and size, powder metallurgy has assumed a significant role in shape making. Using this technique it is now possible to make complicated shapes with exotic alloys for critical applications like gas turbine components.Among all the mechanical processing methods, the bulk metal working stage is considered to be of primary importance. Firstly, in this stage major micro structural changes occur and have profound influence on the subsequent processing steps in view of the large tonnage of materials being processed by bulk metal working processes. The ultimate objective is to manufacture components with controlled micro structure and properties without macro or microstructural defects, on a repeatable basis in a manufacturing environment. Manufacturers are forever striving to reduce the cost of production and raw materials. Price slashing is becoming so dominant that quality is often sacrificed for other considerations. In order to deal with quality issues, industries need to use more effective design practices and adopt upstream design processes that enable them to deliver customized services and products at relatively lower cost. Historically, the design of metal-forming processes is based on expensive trial and error techniques. The geometry of the piece and the capability of the machine are the main considerations, while behavior of the materials is often ignored. This trial and error method is unsuitable for the production of small batches and newer materials, which has restricted work involving forming. It is to be emphasized that our Indian industries often handle small batches and newer materials. Hence, any scientific methodology explored and employed to optimize processing parameters to produce quality products at low cost is a significant research contribution to the area of manufacturing engineering.

In recent years, however, the trial and error techniques are replaced by modelling techniques which are developed on the basis of science based principles. These techniques address the following design and manufacturing issues involved.

The design requirements are:

1.Arriving at optimum processing conditions

2. Controlling the microstructure of the component

3.Designing optimum die shapes or performing geometry without restoring to shop floor trails

4.Obtaining the process limits for the design of control systems

An optimization procedure has been proposed by Venugopal[1] for the selection of safe temperature zone for processing based on various technical parameters as given in figure 1(a). This procedure involves establishing the relationships between various process variables and properties of billet and tool materials.

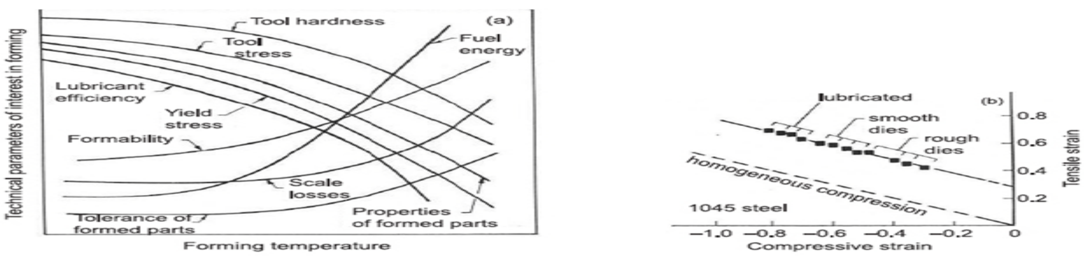

Figure 1. (a) Consolidated concepts involved in selecting optimal temperature in metal forming [1] (b) Optimization of cold workability using locus of surface strains at fracture [2].

The process variables are optimized based on correlation, empirical criteria and fracture models are proposed for the optimization of workability, in particularly cold workability. In this approach, compression tests are performed for establishing experimental fracture criteria for bulk forming processes. Compression test specimens are provided with small grid markings at the mid-height of the cylindrical surface. Measurements of the grid displacements at various stages of the test permit calculation of principal strains and stress histories. The test is performed by compressing a series of