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Technical Report

Densification behaviour in forming of sintered iron–0.35% carbon powder metallurgy preform during cold upsetting

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ABSTRACT

Plastic deformation is an important process to improve and obtain final product for sintered powder materials to compete with solid metal formed parts. The densification behaviour and forming limits of sintered iron–0.35% carbon steel preforms with different aspect ratios, during cold upsetting with two different lubricating constraints namely nil/no and graphite lubricant were investigated experimentally and is presented in this work. Powder preforms having initial theoretical density value of 84%, with two different aspect ratios were prepared using a suitable die-set assembly on a 1 MN capacity hydraulic press. Sintering operation was carried in an electric muffle furnace at the temperature of 1200 °C for a holding period of 1.5 h. Each sintered compact was subjected to incremental compressive loading of 0.05 MN under two different lubricant conditions till a visible crack appeared at the free surface. The densification mechanism is developed by studying the behaviour of densification against induced strain and Poisson's ratio. Further, attained density is considered to establish flow stress and formability stress index behaviour. Increased frictional constraints produces high circumferential stress on the free surface due to barreling effect and hence inhibits forming limits. The present work provides a guideline for producing P/M components free from open surface pores.

1. Introduction

Powder forging have been studied extensively and raising much interest in many parts of the industry as economic method of producing high strength, high ductility parts from metal powders [1] as powder metallurgy (P/M) method competes with other methods on the basis of cost which can be lower for high volume production of complicated components. The P/M technology is conducive nearly any material that can be processed in powder form. This technology is sometimes the only manufacturing method used to produce parts using materials such as porous materials, composite materials, refractory materials and special high duty alloys [2]. The vast application of ferrous powder metallurgy material in automotive and aerospace industry provides reasons for researchers to analyze powder metallurgy materials behaviour under metal forming processes [3]. Sintered P/M compacts are made by the process of compacting and sintering ferrous powder and non-metal powder. A known limitation of this route is the large number of small voids left in components after sintering. Plastic deformation is a main way to improve the performance of sintered ferrous material and obtain the final product. In general the preform produced by the conventional process will undergo so large degree of plastic deformation with enhanced level of densification [4,5]. Though plastic deformations of powder preforms is similar to that of conventional fully dense material, the additional complications are because of substantial amount of void fractions. Because there is a large number of residual porosity in the sintered powder materials, plastic volume change of sintered compacts will result from the void reducing and closing during plastic deformation. During the elastic deformation of fully dense material, Poisson's ratio remains constant and it is a property of the material; this ratio being 0.5 for all materials that conform to volume constancy. However, in the plastic deformation of sintered P/M preforms, density changes occur, resulting in Poisson's ratio remaining less than 0.5 and tending to approach 0.5 only in the near vicinity of the theoretical density. Since the primary cause of fracture in upsetting is the circumferential tensile stresses, it is therefore essential to investigate fracture during cold upsetting of sintered powder materials [5–7].

It has been reported [8,9] that powder metallurgy route processing involves one die and one deformation stroke hence proper die design, processes and external constraints so as to produce components free from open surface pores must be determined. Sintered P/M preforms are particularly prone to fracture during forging because the presence of high amounts of pores in the preform act as stress risers hence lubrication also influences metal flow in a generally beneficial manner with respect to crack formation. Lubrication is important in most metal forming processes

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