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Flow characteristics of continuous shear drawing of high carbon steel

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ABSTRACT

Equal channel angular drawing (ECAD) is a method to obtain the material with large plastic deformation in a continuous way. While flow instability tends to occur at the exit channel during the ECAD, the shear drawing (SD) process might be an alternative technique that secures stable flow and continuous process at the same time. The aim of the present work is to develop the SD process, which prevents flow instability of the ECAD and imposes a high plastic deformation on the material. For this purpose, the multi-pass SD process consisting of the die intersection angle of 150° was designed by the finite element analysis. For verification of the designed process, experiments were carried out with commercially available high carbon steel. Experimental results showed that the newly designed SD process improved flow stability and roundness of the specimens compared to the conventional ECAD. Compression and hardness tests were made to investigate mechanical property of the specimen. Scanning electron microscopy was employed to check changes of the microstructure. The results of SEM indicated that the original cementite lamellae were fragmented into short and distorted segments. Additional numerical study was carried out to investigate flow characteristics and distribution of the effective strain with varied die intersecting angles. According to the present investigation it was found out that the effective strain value and flow instability increased by decreasing the intersecting angle.

1. Introduction

Severe plastic deformation (SPD) processes are used to produce the ultra-fine-grained materials by imposing large plastic deformation on the materials. The main aim of the SPD process is to produce high strength and lightweight parts with environmentally friendliness. Among various procedures, an equal channel angular pressing (ECAP) originally introduced by Segal [1] is the most widely used technique to produce bulk nanostructured materials by imposing simple shear deformation on the material. However, the ECAP is not suitable for a continuous industrial process of manufacturing bars or wires because of its discontinuous characteristics.

Chakkingal et al. [2,3] investigated an equal channel angular drawing (ECAD) as a continuous process for grain refinement. The ECAD process draws a material in the form of a bar or wire through a die consisting of two channels of equal cross-section intersecting at an angle, usually between 90° and 135°. The ECAD process with the dies of an intersecting angle of 90° was numerically investigated to determine the strain and stress distributions and compare the strain level of the ECAD process with one of the conventional drawing by León and Luis [4]. They reported that the plastic strain accumulated with the ECAD process was higher than that obtained by the conventional drawing process for the same area reduction. A device for applying the ECAD process to sheet metals was designed and tested on thin strips of commercially pure aluminum by Zisman et al. [5]. According to their work, the ECAD process was an efficient method to strengthen aluminum sheets by controlling textural evolution during the process.

In addition, Pérez et al. [6] studied the effect of different processing routes and heat treatment on the deformation behavior and the microstructure. It was found out in their study that the imparted deformation through the dies with an intersecting angle of 90° was not enough for achieving grain size within submicrometer range owing to insufficient simple shear compared to the drawing stress. They also found that it is of essential importance that the specimen fills the dies to prevent the flow instability of the specimen during the process. Semiatin and Jonas [7] pointed out that formability and workability of metals are limited owing to flow instability, which was attributed to the destabilizing influence of area reduction during deformation. Since the ECAD process is mainly driven by the tension, flow instability should be carefully controlled for the process design as pointed by Pérez et al. [6]. According to the work by Alkorta et al.

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