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Effect of Temperature and Strain Rate of The Hot Deformation of V Microalloyed Steel on Flow Stress

Md Israr Equbal, Associate Professor, Department of Mechanical Engineering, JB Institute of Engineering & Technology, Moinabad, Hyderabad, India

Azhar Equbal, Assistant Professor, Department of Mechanical Engineering, RTC Institute of Technology, Anandi, Ormanjhi, Ranchi, India

Md. Asif Equbal, Assistant Professor, Department of Mechanical Engineering, Cambridge Institute of Technology, Tatisilwai, Ranchi, India

R. K. Ohdar, Professor, Department of Forge Technology, National Institute of Foundry and Forge Technology, Hatia, Ranchi, India

ABSTRACT

Medium carbon micro-alloyed forging steels are employed in various automotive components. The impetus for the use of micro alloyed (MA) steels is cost reduction due to elimination of post-forging heat treatment. Compared to conventional quenched and tempered steels micro-alloyed steels can achieve similar or more superior properties simply by properly controlling the process parameters. Forging temperature, strain, strain rate and cooling rate are some of the important process parameters that influence the flow stress and final forging product quality. In the present study, hot compression test on a micro-alloyed steel grade 38MnSiVS5 were conducted on thermo-mechanical simulator (Gleeble-3500) to study the effect of temperature and strain rate on flow stress. The results indicate that the flow stress of 38MnSiVS5 steel is greatly affected by both deformation temperature and strain rate. Obtained true stress-true strain curves showed that the flow stress of the alloy increased by increasing the strain rate and decreasing the temperature, which can be represented in terms of an exponent type Zener-Hollomon equation. Finally, the constitutive equations for the flow behavior of 38MnSiVS5 microalloyed steel were determined.

KEYWORDS

Microalloyed, Strain Rate, Thermo-Mechanical Simulator, Zener-Hollomon

1. INTRODUCTION

Medium carbon micro-alloyed steels are considered for a wide array of engineering applications. Automobile components such as crank shafts, connecting rods, and wheel hubs are manufactured from these steels. The service performances and soundness of the components manufactured by these steels are largely depends on the applied thermo-mechanical processes and involved process parameters. A great amount of attention needs to be paid to the design of the thermo-mechanical

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processes by optimizing process variables to achieve a component that is defect free (Park, Yeom & Na, 2002). In metal forming processes such as rolling, forging, extrusion, wire drawing and sheet metal forming, the flow stress of the metal is a key factor for successful operation. Flow stress is defined as the stress required to sustain a certain plastic strain on the material. The forming pressure and the load are directly related to the flow stress, and therefore a lower flow stress is desirable in most of the forming operations. Factors such as strain, strain rate and temperature affect the flow stress of materials. The temperature plays an important role in forging of metals to attain optimum flow stress which in turn decreases the forging load and increases the die life. Alongside temperature strain rate also plays an essential role in the selection of forging process, as strain rate directly has an effect on the grain size and mechanical properties which ultimately affect the durability and fatigue life of the component. Because of the finite element method being extensively use, so as to characterize the true behaviour of work piece under various stages of metal forging, knowledge of the constitutive relationships relating process variables viz. strain rate and temperature to the flow stress of the deforming material is imperative, and hence it becomes important to evaluate the flow stress. Uni-axial hot compression test is the most common method employed for generating data and to study the flow behavior and workability of the materials (Goetz, Semiatin & Mater Eng, 2001). The generated data through uni-axial compression testing of cylindrical specimens are used to evaluate the constitutive flow behavior of materials (Lin & Liu, 2010) as well as to identify the optimum process parameter for thermo-mechanical processing (Lin, Chen & Zhong, 2008; Shi, McLaren, Selaars, Shahani & Bolingbroke, 1997; Takuda & Fujimoto, 1998). The present work involves uni-axial hot compression test of medium carbon vanadium micro-alloyed steel grade 38MnSiVS5 on Gleeble-Thermo Mechanical Simulator (TMS) to study the influence of forging temperature and strain rate on flow stress. The tests were carried out to analyze the effect of forging temperatures ranging from 900°C to 1100°C, with a 100°C interval. The strain rates were also varied in multiples of 10 from $0.2s^{-1}$ to $20\ s^{-1}$ covering the appropriate processing range.

2. METHODOLOGY

The chemical composition of the material is given in Table 1. All compression tests were conducted on cylindrical specimens of dimensions 10 mm in diameter and 15 mm in length. A size ratio (i.e. L/D) of 1.5 was selected to prevent buckling during the deformation. Both ends of the specimen were kept parallel to ensure uniform deformation during testing. In order to prepare the sample for testing first step is welding of thermocouple. All specimens had a 0.254 mm (0.010 in) diameter type K control thermocouple spot welded on the surface at the centre of the specimen as given in Figure 1. Thermocouple wire has PFA (a fluorocarbon polymer) coated to prevent shorting between the wires away from the specimen. After which specimens are fixed between the anvils exactly at the centre without any deviation such that deformation axis is straight and doesn't result in formation irregular shape as shown in Figure 2. MoS_2 was used as the lubricant and between the anvil and specimen, graphite (up to 1000 °C)/ tantalum foil (>1000°C) of thickness 0.1 mm was used in order to avoid sticking of the anvil to the surface of the specimen specimen. Gleeble 3500 (A thermo-mechanical simulator, Dynamic Systems, Inc) was utilized for uni-axial hot compression testing as shown in Figure 3. Hot deformation software (HDS) was used to carry out the tests in Gleeble 3500. The specimens were deformed to 66% and the flow stress data was recorded. All the tests were carried out under isothermal conditions. The Gleeble system incorporates a closed-loop thermal system and a closed-loop hydraulic servo system under synchronous digital computer control, providing the performance that is needed to perform accurate testing and physical simulations. Gleeble systems are unique in that they are the only systems capable of maintaining uniform temperature cross sections - isothermal planes at the midspan of the specimen, even while heating or cooling rapidly. Figure 4 shows the samples during and after deformation in Gleeble 3500.

Polymer/Clay Nanocomposites Produced by Dispersing Layered Silicates in Thermoplastic Melts