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Numerical simulation of different types of voids closure in large continuous casting billet during multi-pass stretching process

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Abstract

Large continuous casting billet always contain void defects which may adversely affect the mechanical properties and safe performance of final products. The void must be completely eliminated during hot forging process. In this paper, different types of void defects in large billet are showed and analyzed. It is found that the voids have different geometry, orientations and positions. Using finite element (FE) software DEFORM 3D, a FE model was developed to investigate the void closure in large continuous casting billet during multi-pass stretching process. The wide die heavy blow forging (WHF) method which has been proved to be an effective method to eliminate void defects was adapted during the stretching process. Then, the stretching processes of various sizes of billets which contained different kinds of void defects were simulated. The closure processes of different kinds of void defects were obtained. The critical forging ratio for large billets from Φ500mm to Φ1000mm was obtained as 2.40. In addition, the void closure evaluation index is analyzed, and the critical value for the closure of all voids is 0.87. The work in this paper is verified by actual production, which illustrates that the simulation results and the proposed criterion in this research are reliable.

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Keywords: Void closure; Large continuous casting billet; Multi-pass stretching; Numerical simulation

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1. Introduction

In recent years, there is an increasing need to produce large forgings for aerospace, naval, energy, and other applications [1]. Large forgings generally obtained from casting ingot or continuous billets. And with the technology of continuous billet development, more and more large forgings begin to select continuous billet as raw material. But continuous billets usually have void type defects caused by shrinkage and gas evolution during solidification [2]. If void defects are not eliminated completely during hot forging process, the mechanic quantity of large forgings will be influenced seriously. So, to eliminate the voids inside large billet is one of the important tasks of hot forging [3].

Much research has been done to understand the effects of some important process parameters on void closure during forging process. Ståhlberg et al. [4] analyzed the closure of artificial voids by plastic deformation and found that the rate of void closure increases with reduction. Tanaka et al. [5] investigated the void closure in a cylinder during upsetting process using finite element (FE) method. They concluded that the effective strain and the integration of hydrostatic stress around the void are the main factors for void closure. Cui et al. [6-7] studied the void evolution on the axial line during the upsetting process by FE method and found that void evolution has a strong relationship with void location, void size and height to diameter ratio of ingot. Feng [8] established a 3-D model for void evolution in viscous materials under large compressive deformation. Banaszek and Stefanik [9] investigated the influence of the anvil shape and the main forging process parameters on the elimination of metallurgical defects. Lee et al. [10] investigated pore closing during the cylinder upsetting process. They found that effective strain has a strong relationship with the pore closing phenomena. The ratio of pore-to-cylinder diameter has a great influence on the finishing time of pore closing. Zhang et al. [11-12] developed a cell model to study the void closure. A criterion for void closure in large ingots during the hot forging process was proposed. Kakimoto et al. [13] studied voids closure in steel ingots during the upsetting process. They found the reduction ratio of 75% or over is required to close voids during the compression process. Saby [14] proposed a geometry-dependent model to predict void closure in hot metal forming.

As described above, much research has been done to investigate the void closure at the central axis of workpiece during upsetting process or single-pass stretching process. However, different kinds of voids defects located at different positions of cross section of large billet are not invested clearly, especially during the multi-pass stretching. In fact, multi-pass stretching is the most important procedure in large forgings production. In this paper, various void defects in large continuous casting billets are observed. An FE model of large billet for multi-pass stretching is developed to investigate the closure of different kinds of void. Void closure evaluation index and critical forging ratio for different types of void is obtained.

2. Void defects in large continuous casting billet

According to the description in YB/T153-2015 and YB/T4149-2006 [15-16], various kinds of void defects are contained in the large continuous casting billets. Typical void defects in the billet are spherical shaped voids at the center of billet, ellipsoidal voids at the middle of billet and ellipsoidal voids under surface of billet, as shown in Fig.1. Generally, the billet only contains one spherical shaped void at the center, but there may be several ellipsoidal voids with different orientations.

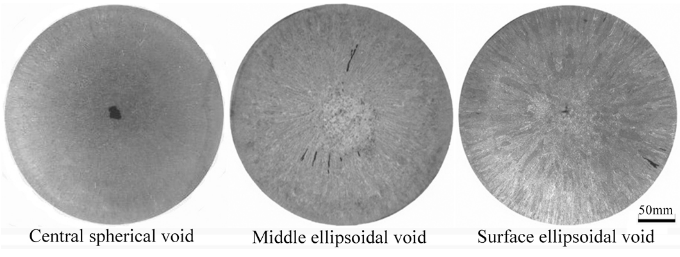

Fig. 1. Typical void defects in the billet.