Numerical Simulation Research on Mandrel reaming of Ring Steel Ingot

Zhiyuan WAN*, Minghui ZHENG
The Academy of Mechanical Engineering, Shandong Hua Yu University of Engineering, Dezhou 253034, China
wxy@huayu.edu.cn

Abstract. The mandrel reaming forging is of great significance to the billeting of the ring ingot. Through the analysis of the reaming deformation of the ring steel ingot mandrel, it is concluded that the ring steel ingot reaming deformation exists in the radial, axial and tangential directions, which are similar to the rigid zone, active plastic deformation zone and passive plastic deformation zone in the upsetting theory. Numerical simulation methods are used to analyze the reaming of the ring steel ingot mandrel, and it is verified that the ring steel ingot reaming deformation has a rigid zone, an active plastic deformation zone and a passive plastic deformation zone in the radial, axial and tangential directions. At the same time, the reduction rate is found has a greater impact on the three regions.

1. Introduction
Since the advent of core shaft reaming forging technology, countries all over the world have been trying to apply it to the production of various large cylinder forgings due to its incomparable advantages in material and energy consumption [1-2]. The purpose of mandrel shaft opening forging is to break the coarse grain, forge the defect, press the solid part and reduce the influence of inclusion [3]. At present, based on the casting characteristics of core shaft reaming, drawing or reaming should be taken as the forging step in the process of core shaft reaming, and the casting metallurgical defects of core shaft reaming should be eliminated by large forging ratio deformation [4]. In this paper, the drawing length of core shaft is studied by theoretical and numerical simulation to explore the deformation law of core shaft reaming.

2. Analysis of Core Shaft Reaming for Annular Ingot
According to the analysis of the law of least resistance of metal flow, the essence of mandrel shaft reaming is that the forging metal flows along the circumferential direction, but the metal flows less in the axial direction, which can be approximately equal to the drawing length along the circumferential direction. The arc length of the contact surface between the forging and the mandrel is the length of the forging deformation zone, and the height of the forging is the width of the deformation zone [5].

The drawing length of mandrel is a forging process which decreases the outer diameter of mandrel reaming and then increases its length. It can be regarded as radial upsetting deformation. The core shaft reaming can be regarded as a special process of the core shaft drawing process, but the drawing process can be similar to the combination of upsetting process, so the core shaft reaming horse bar reaming can be similar to the radial upsetting process. In this paper, the core reaming deformation is studied from the Angle of upsetting deformation. As a common plastic forming method, many experts at home and abroad have conducted a lot of scientific research on the deformation characteristics and
mechanism of cylinder upsetting [6]. Professor Liu Zhubai et al. from Yanshan University established the hydrostatic stress mechanical model of interplate cylinder compression [7].

The reaming deformation of the core shaft is equivalent to the deformation between the anvil and the core shaft. Because of the friction between the chopping board, the mandrel and the forgings, the reaming deformation is similar to the upsetting downward deformation, that is, there are rigid zones, active plastic zones and passive plastic zones. The difference with upsetting is that it is different in the radial, axial and tangential directions of the forgings, as shown in Figure 1.

3. Numerical simulation of reaming of ring ingot core shaft
Selection of ring ingot size: Φ800×350×350mm; Material: 2.25Cr1Mo0.25V, initial forging temperature: 1200 °C, pressing rate: 4mm/s, anvil and core shaft material: AISI-H-13 rigid material, initial temperature: 400 °C, the spindle diameter is Φ250, the anvil width ratio is 1.5, the friction coefficient between the forgings and tools is 0.3, and the external load is static pressure.

With the continuous increase of the reaming pressure reduction rate, the deformation in the forgings becomes more and more intense, and the deformation area will change accordingly. The rationality of the above theoretical region division is verified by the following three-way simulation results.

Radial cutting was carried out along the reaming of a large mandrel shaft, and half of which was selected for analysis. The equivalent strain distribution of different reduction rates in the radial direction was shown in Fig. 2.
The variation trend of radial deformation can be seen from the equivalent strain sub-diagram of the radial cutting diagram. With the increase of the reduction rate, the rigid zone decreases gradually. When the reduction rate reaches a certain rating, the rigid zone generated by the interaction between the core shaft and the core shaft reams completely disappears. The passive plastic deformation zone increases with the increase of the reduction rate, and the active deformation is mainly concentrated in the inner wall, and the regional variation is not obvious.

Axial cutting was carried out along the large core shaft reaming, and then half of it was selected for analysis. The equivalent strain distribution of different axial reduction rates was shown in Fig. 3.

Variation rule of axial deformation distribution can be seen from the equivalent strain distribution of axial tangent graph. When the reduction rate is too small, the rigid zone mainly concentrates on the outer wall. With the increase of the reduction rate, the rigid zone decreases gradually. When the reduction rate reaches a certain rating, the rigid zone completely disappears. The passive plastic deformation zone increases with the increase of the reduction rate, while the active deformation mainly concentrates on the inner wall, showing a "V" shape. With the increase of the reduction rate, the zone tends to shift toward the outer wall.

Cut the hole along the tangential direction of the large core shaft at half the thickness. The equivalent strain distribution of tangential reduction rates is shown in Fig. 4.
The distribution of tangential deformation can be preliminarily seen from the equivalent strain distribution of tangential tangential graph. With the increase of the reduction rate, the rigid zone decreases gradually but does not disappear completely, and the rigid line can move to both sides. The passive plastic deformation zone increases with the increase of the reduction rate, while the active deformation mainly concentrates on the upper and lower end faces, which presents a "V" and an inverted "V" shape distribution and is basically symmetrical. With the increase of the reduction rate, the two zones tend to approach the center line.

4. Conclusions
In radial, axial and tangential directions, the core shaft reaming deformation of a large annular ingot exists a rigid zone, an active plastic zone and a passive plastic zone similar to the upsetting theory, and the simulation results are verified. The numerical simulation results show that the reduction rate has a great influence on the three regions.

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