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Process optimization method for cold orbital forging of component with deep and narrow groove

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ABSTRACT

During cold orbital forging of component with deep and narrow groove, the metal flow is complex and it may lead to some defects of underfilling and folding. Moreover, the stress state of the tool, which has a long and thin boss corresponded to the deep and narrow groove of component, is poor and thus the life span of the tool is low. Aimed at these issues, this paper presents a process optimization method for cold orbital forging of component with deep and narrow groove. Firstly, three kinds of metal flow modes are presented according to the preform and tool geometries. Then, the cold orbital forging processes under three kinds of metal flow modes are analyzed by FE simulations and the mechanisms for forging defects of underfilling, folding and poor stress state of the tool are revealed. It is found that the horizontal stress imbalance of the long and thin boss of the tool is the main reason for its poor stress state. To improve the stress state of the tool, a new idea is motivated, i.e., it is through controlling the metal flow to balance the horizontal stress of the long and thin boss of the tool. Finally, the optimization method for the preform and tool is presented to eliminate the forging defects. The experiments are also carried out to verify the presented process optimization method.

1. Introduction

Owing to its conical geometry, the rocking tool keeps local contacting with the component in the entire cold orbital forging period, which results in that smaller forging force is needed compared with overall forging. Cold orbital forging also owns other strengths of fabricating components with high geometrical accuracy, high surface quality and excellent microstructure properties.

The important research development on cold orbital forging has been achieved since it emerged. On cold orbital forging equipment, Marciniak [1] invented the classic cold orbital forging press which can obtain four rocking tool trajectories. Standring [2] invented a novel cold orbital forging press based on Euler angle. On deformation mechanism, Appleton and Slater [3] revealed the influence of rocking tool on the workpiece deformation in cold orbital forging. Standring et al. [4] researched the microstructure evolutions in cold orbital forging of a cylinder. Zhou et al. [5] revealed the mechanism of defects and Oh and Choi [6] revealed center thinning in cold orbital forging of a plate. Liu et al. [7] explained the mushroom characteristic in cold orbital forging of a cylinder. Wang and Zhao [8] and Han and Hua [9] revealed the deformation laws in cold orbital forging of a ring. Nowak et al. [10] compared cold orbital forging with overall forging of a cylinder. Pérez [11] revealed the texture and microstructure evolutions in cold orbital forging of a flange. Loyda et al. [12] revealed the microstructure evolutions and Zheng et al. [13] revealed the metal flow line evolutions in orbital forging of a cylinder. On process design and optimization methods, Yuan et al. [14] presented the compound forming methods of pin part using cold drawing and orbital forging. Sheu and Yu [15] presented cold orbital forging of a gear ring and optimized tool profiles and preform design to prevent tool failure and component defect by FE simulations. Deng et al. [16] optimized the preform based on the tool filling and forging load and Samołyk [17] optimized the rocking tool trajectory based on the tool filling, deformation degree and forging load in cold orbital forging of a bevel gear. Calmano et al. [18] optimized the cold orbital forging process of a flange through mapping the signal from sensor and processing controlling to geometrical target value. Lots of new cold orbital forging processes have also been presented. Merklein et al. [19,20] presented bulk forming of sheet metal to manufacture tailored blank by cold orbital forging and Han et al. [21] optimized cold orbital forging of thin mobile phone shell through analyzing the tool filling and non-uniform deformation mechanisms. Nam et al. [22] and Qu and Zhang [23] presented riveting assembly by cold orbital forging. Grosman et al. [24] presented a novel orbital forging process to form components with complicated upper profiles through adding some

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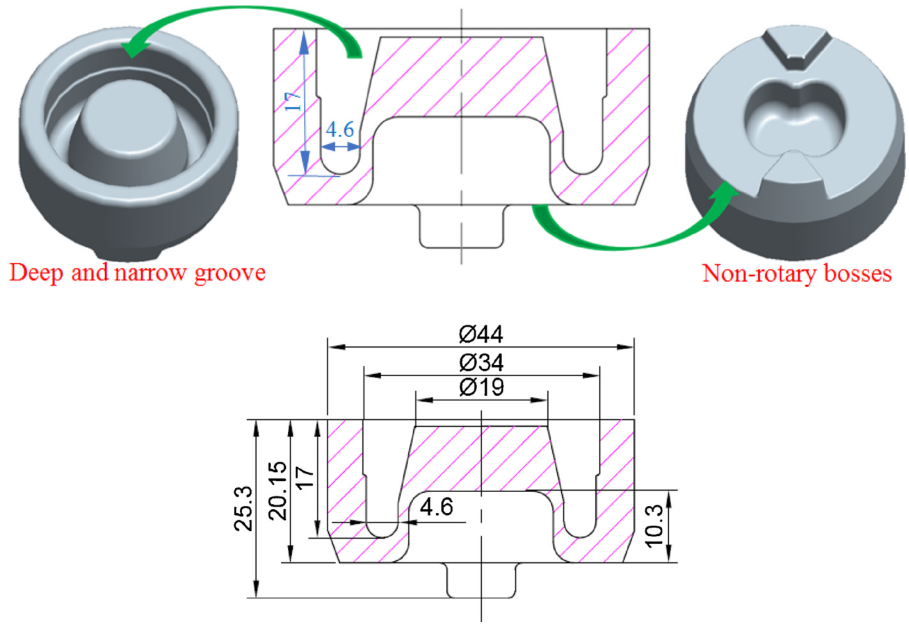

Fig. 1. Diagram of a typical component with deep and narrow groove.

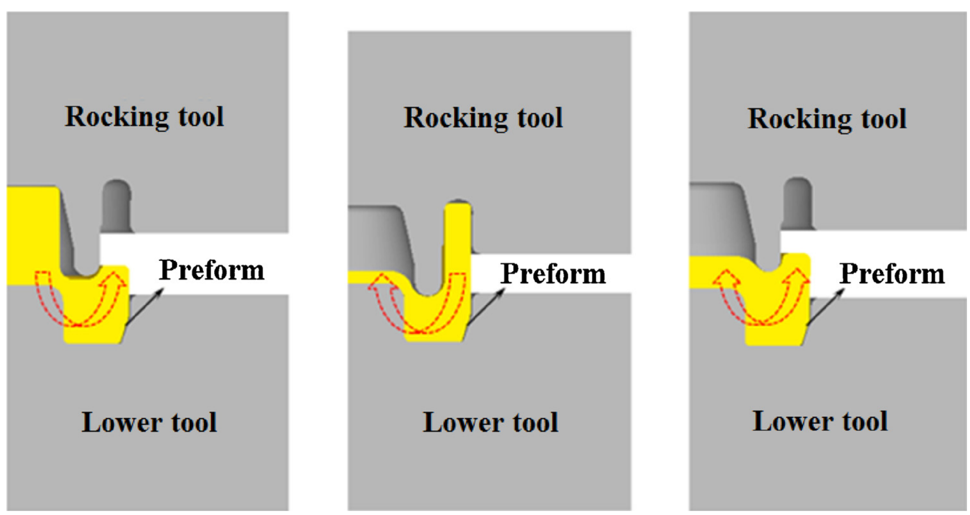

Fig. 2. Three kinds of metal flow modes according to the preform and tool geometries.

anvils between rocking tool and components. Han et al. [25,26] and Milutinović et al. [27] achieved the cold orbital forging process of non-rotary components through analyzing the geometric and kinematic relations between the rocking tool and components. Han et al. [28] presented the process design methods of cold orbital forging of racks using straight line trajectory of the rocking tool through analyzing the contacting modes between the rocking tool and racks. Although achieving the important research development mentioned above, the researches on cold orbital forging of component with deep and narrow groove have been scarce. During cold orbital forging of component with deep and narrow groove, the metal flow is complex and it may lead to some defects of underfilling and folding. Moreover, the stress state of the tool, which has a long and thin boss corresponded to the deep and narrow groove of component, is poor and thus the life span of the tool is low. At present, this kind of component with deep and narrow groove is mainly fabricated by machining.

Therefore, this paper presents a process optimization method for cold orbital forging of component with deep and narrow groove. Firstly, three kinds of metal flow modes are presented according to the preform and tool geometries. Then, the cold rotary forging processes under three kinds of metal flow modes are analyzed by FE simulations and the mechanisms for forging defects of underfilling, folding and poor stress state of the tool are revealed. It is found that the horizontal stress imbalance of the long and thin boss of the tool is the main reason for its poor stress state. To improve the stress state of the tool, a new idea is motivated, i.e., it is through controlling the metal flow to balance the horizontal stress of the long and thin boss of the tool. Finally, the optimization method for the preform and tool is presented to eliminate the forging defects. The experiments are also carried out to verify the presented process optimization method.