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Experiment study on warm ring rolling of 52100 bearing steel coupling microstructure spheroidisation

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Abstract

As an advanced rotary forming technology, ring rolling is an important application in bearing ring manufacturing. Spheroidising annealing is necessary for ring rolling of 52100 bearing ring because of the cold working requirement, but its long processing period results in high energy consumption, low productivity and poor surface quality. In this work, based on the favourable effects of divorced eutectoid transformation and plastic deformation on microstructure spheroidisation, a warm ring rolling method for 52100 bearing steel was proposed and expected to directly realize the spheroidisation by ring rolling, and experimental studies were carried out to testify its feasibility. Firstly, warm comprehension experiment of 52100 steel was performed on Gleeble-3500 thermo-simulation system to pre-evaluate the spheroidisation effect in warm deformation. Then, warm ring rolling experiment of 52100 bearing steel was conducted on ring rolling mill. The experimental results show that the effective spheroidisation with finer carbide particles and acceptable microhardness compared to regular spheroidizing annealing were obtained under both of warm comprehension and warm ring rolling with suitable deformation conditions. The experimental study verified that warm ring rolling of 52100 bearing steel coupling microstructure spheroidisation is feasible, it can be potentially as a new ring rolling method for 52100 bearing ring with the advantageous of energy saving, efficiency increasing and procedure shortening.

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Keywords: warm ring rolling; 52100 bearing steel; spheroidisation; carbide particles

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1. Introduction

Ring rolling has extensive application in manufacturing of various seamless rings, especially for bearing ring. As an advanced rotary forming technique, ring rolling plays an important role on improving the technical and economic indicators and product quality with its outstanding superiorities, such as energy and material saving, productivity increasing and performance improving [1].

As a typical and popular bearing steel, 52100 steel is largely used as the raw material of bearing ring and be processed with ring rolling. The lamellar pearlite microstructure of 52100 steel under conventional hot-rolled conditions has high hardness, low plasticity and poor cold workability, thus the spheroidizing annealing is needed to obtain the globular pearlite microstructure, so that the annealed steel can supply the improved mechanical property for cold working requirement and the appropriate preparative microstructure for final heat treatment[2]. Besides, spheroidal pearlite is conducive to reduce the tool wear while lamellar carbides of the type associated with incomplete spheroidisation lead to enhanced tool-degradation [3]. Hence, in ring rolling technology of 52100 bearing ring, spheroidizing annealing is a requisite process both in cold ring rolling and hot ring rolling.

It is usually applied before cold ring rolling process to meet the cold deformation and after hot ring rolling process to satisfy the machining. However, the regular spheroidizing annealing usually consumes long time with more than 10 hours[4], which leads to low productivity, high energy consumption, and also causes the obvious decarburization and oxidation to go against the following working. Because of the material feature and the technological character, the manufacturing efficiency and cost of 52100 bearing ring rolling is apparently restricted by spheroidizing annealing.

Facing this problem, some studies have been performed and can be classed as two directions in general. One focuses on shortening spheroidizing annealing period. A new transformation mode called the divorced eutectoid transformation (DET) is reported Sherby et al[5] and receives attention since it's faster than conventional annealing process. When the austenite contains cementite particles or nuclei with a spacing on the order of a few microns or less, the transformation product consists of spheroidal cementite particles in a ferrite matrix, rather than lamellar pearlite. Verhoeven et al[6] investigated the mechanism and role of divorced eutectoid transformation (DET) on rapid spheroidisation and evaluated the favourable conditions for DET in 52100 steel; Shepelyakovskii[7] reported an inducting annealing method to promote DET and produce the divorced pearlite. Another concerns omitting the spheroidizing annealing process, for example, Zhu et al[8] explored the possibility of direct spheroidising during hot deformation in 52100 steel, and studied its advantageous conditions. From these studies, two conclusions can be summarized: (1) DET is an effective method to accelerate spheroidisation; (2) hot plastic deformation promotes the spheroidizing of lamellar carbide[9]. Meanwhile, they also rely on some certain conditions, DET needs the dual-phase microstructure consisted of austenite and undissolved cementite, and the deformation role on spheroidizing depends on suitable deformation temperature and cooling rate.

Based on above conclusions, an imagination can be made that the ring rolling process of 51000 bearing ring coupling spheroidization is probably realizable by integrated utilizing the roles of DET and hot deformation on rapid spheroidisation. As lower heating temperature and deformation temperature are more suitable for DET and hot deformation actions on rapid spheroidisation, a warm ring rolling method of 52100 steel was proposed and expected to direct realize the spheroidisation by rolling, thus the spheroidizing annealing can be omitted to create significant economic effects. So, in this paper, experiment study was carried out to evaluate the feasibility of spheroidisation of 52100 steel during warm ring rolling and investigate its required conditions.

2. Warm compression experiment

2.1. Experimental procedure of warm compression

Warm compression experiment of 52100 steel was conducted to pre-evaluate the spheroidisation effect during warm deformation and possibly reduce the cost of direct warm ring rolling experiment. The compression specimens with diameter of 8 mm and height of 12 mm were processed from the hot-rolled 52100 steel bar. The warm compression experiment was performed on Gleeble-3500 thermo-simulation system to accurately control the compression process.