JOURNAL OF MATERIALS PROCESSING TECHNOLOGY 209 (2009) 2794–2802

journal homepage: www.elsevier.com/locate/jmatprotec

Research on gripping conditions in profile ring rolling of raceway groove

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ARTICLE INFO

Article history:
Received 15 February 2008
Received in revised form 9 June 2008
Accepted 14 June 2008

Keywords:
Ring rolling
Profile ring rolling of raceway groove
Gripping
FE simulation

ABSTRACT

Ring gripping means that under the pressure of roll and friction, ring grips the rolling gap and produces rotating rolling motion, thus ring thickness receives equal rolling and the outer diameter expands equally, and this is a sufficient condition for ring rolling forming. In this paper, gripping course in profile ring rolling of raceway groove is analyzed based on ring rolling principle and static theory. The gripping mechanical model for profile ring rolling of raceway groove is established, and gripping conditions are researched according to the geometrical relationship in rolling. The results indicate that ring could be ensured to continuously grip the gap in rolling by controlling feed per revolution and preventing it from exceeding the maximum feed per revolution allowed by ring gripping. Furthermore, influencing factors of gripping conditions are analyzed. At last, the experiments and the FE simulation for profile ring rolling of raceway groove are performed to testify the validity of gripping conditions. Both the experimental and simulation results show that when feed satisfies gripping conditions, ring can continuously grip the gap and be formed by rolling. Otherwise, ring cannot grip the gap and is squashed between the rolls. The results of this research provide a theoretical basis for design of technological parameters of profile ring rolling of raceway groove.

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1. Introduction

Ring rolling is a materials processing technique which reduces ring thickness, enlarges the diameter and forms the section by ring rolling mill (Hua et al., 2001). Profiled rings are widely used in machinery, automotive, aerospace and other industrial fields. A typical example are bearing rings with a raceway groove profile. Profile ring rolling of raceway groove is the main manufacturing method of raceway groove ring at present. The principle of it is shown in Fig. 1. Driving roll and mandrel profiles both have shoulders to limit the spread of the ring and flatness of ring faces. Forming roll takes active rotation. Mandrel is the pressure roll, and takes linear feed motion and passive rotation. Guide roll takes translational motions and is always in contact with outer surface of ring to keep the stability of process.

As seen in Fig. 1, although the blank for profile ring rolling of raceway groove is a rectangular section, but the shape of rolling gap is different from rectangular section ring rolling. Taking profile ring rolling of inner raceway groove as an example, working surface of forming roll is a flat surface and that of mandrel consists of a flat surface and a groove ball surface. It can be seen that in profile ring rolling of raceway groove, shapes of rolling gap and the contact conditions different from rectangular section ring rolling. Therefore, the ring stress and deformation conditions in the rolling gap also different, and more complex. At present, there are many research have reported on ring rolling: Hua and Zhao (1997) has researched

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doi:10.1016/j.jmatprotec.2008.06.033

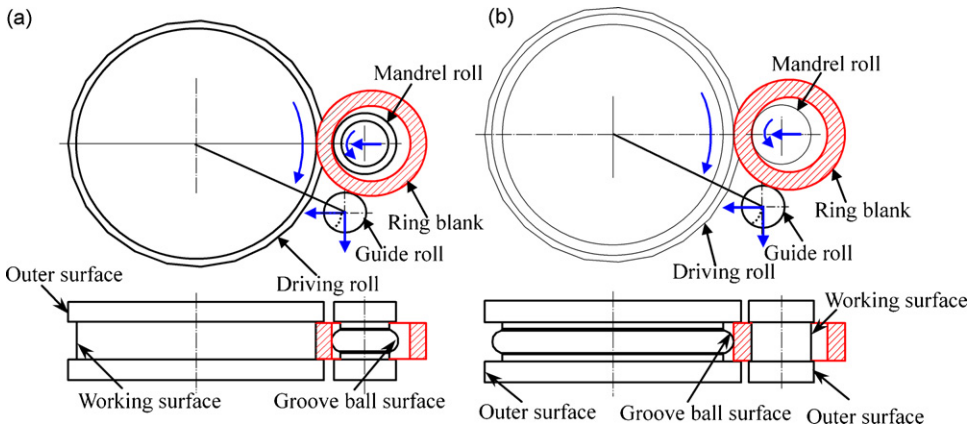

Fig. 1 – Elementary diagram of profile ring rolling of raceway groove: (a) profile ring rolling of inner raceway groove; (b) profile ring rolling of outer raceway groove.

on the extremum parameters in ring rolling; Utsunomiya et al. (2002) has researched on the elastic–plastic finite element analysis of ring rolling; Guo et al. (2005) has researched on the plastic deformation behavior in ring rolling; Yang et al. (2006) has researched the influence of material properties on cold ring rolling; Yan et al. (2007) has researched on the planning feed speed in ring rolling; Qian et al. (2007) has researched on the plastic zone distribution in the process of plastic penetration in ring rolling, etc. All these researches provide important theoretical basis for ring rolling. However, most of these researches have been focused on ring rolling of rectangular sections but rarely on profile ring rolling of raceway groove. And lack of research on profile ring rolling technique and deformation rules leads to design and product development of groove ball section ring in actual production being performed through a large number of experiments, which requires a large amount of labor, time and material resources.

Ring gripping means that ring continuously grips rolling gap under the pressure of roll and friction, and then forms rotating rolling motions, thus the ring thickness is rolled equally and the diameter grows. It is an important condition to realize steady rolling and guarantee rolling precision, and is the sufficient condition for ring rolling forming. In this paper, research is developed aiming at profile ring rolling of raceway groove, in order to obtained the gripping condition in profile ring rolling of raceway groove and provided theoretical basis for technical design of profile ring rolling of raceway groove.

2. Ring gripping course in profile ring rolling of raceway groove

2.1. *Mechanical model and conditions of ring gripping*

The gripping condition in rectangular section ring rolling was researched with the static analysis method (Hua and Zhao, 1997). Furthermore, basic principles of profile ring rolling of raceway groove are similar to rectangular section ring rolling. So, static analysis method is also used in this research, mechanical model for gripping of profile ring rolling of inner raceway groove is established firstly based on static analysis method and stress conditions in profile ring rolling of inner raceway groove, as shown in Fig. 2.

Compared to the rolling force, the force of guide roll acting to ring is much smaller, so that it can be ignored. P_d and T_d are pressure and friction force of forming roll acting to ring, respectively, P_m is the pressure of mandrel acting to ring (mandrel is idler roll, it cannot bear moment, thus resultant friction force of mandrel acting to ring is zero) and α_1 and α_2 are contact angles of forming roll and mandrel with ring, respectively, R_{dw} is working surface radius of forming roll, R_{mb} and R_{mw} are groove ball surface radius of mandrel and working surface radius of mandrel, respectively, R and r are outer and inner radius of ring blank, h_0 and h are ring blank thickness at the entry and the exit of the gap, respectively, n_d is rotation speed of forming roll, L is project length of contact arc along the feed direction.

In the model, assuming that the resultant forming roll force acting on the ring acts at angle $\xi_1\alpha_1$ of contact arc of ring outer surface, resultant force of mandrel acting on the ring is situated at angle $\xi_2\alpha_2$ of contact arc of ring inner surface, where ξ_1 and ξ_2 are coefficients with values between 0 and 1. So, in rolling, in order to make ring grip gap, drawing force must

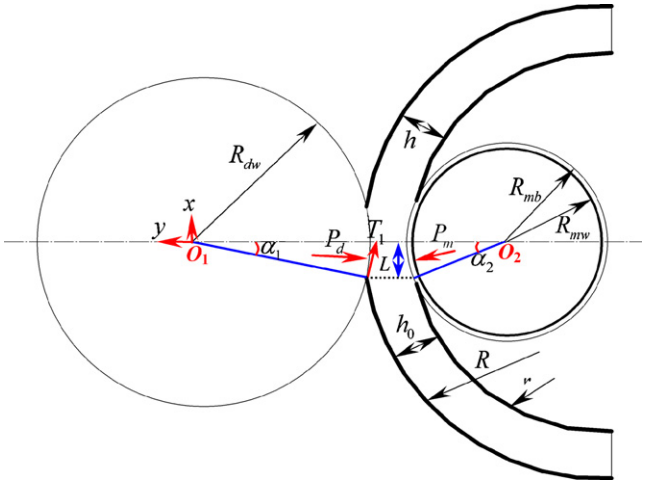

Fig. 2 – Mechanical model for gripping of profile ring rolling of inner raceway groove.

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