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RING ROLLING AS A NEAR NET SHAPE FORMING TECHNOLOGY IN BEARING PRODUCTION

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ABSTRACT:

Bearings are products which are usually manufactured in mass production. For a long period of time, metal cutting technologies were dominant in this field of production. However, due to significant material waste, this way of ring production has been abandoned and replaced by more efficient methods. For that reason, several procedures - based on the application of near and net shape forming technologies such as forging, extrusion and rolling - have been developed. The introduction of near net shape forming technologies in bearing industry has led to significant savings in material, time, energy and man power, especially for rings with complex profiles. Accordingly, the efficiency of the process was increased and the cost of manufacturing reduced. Rings obtained by near net shaping technologies have better mechanical properties than their machined counterparts, enabling longer service life.

In this paper, possibilities of application of ring rolling as near net shape forming technologies in bearing production shall be discussed from technical and economical point of view. Details regarding the process of hot ring rolling and the software for automatic calculation of workpiece geometry will be presented.

Key words: near net shape forming, ring rolling, bearings

1. INTRODUCTION

Permanent rise in the cost of energy and raw materials along with limited sources has influenced many industries in the last few years to make a review of their manufacturing methods and consider alternatives to traditional methods, with the aim of finding a more economical way method of material usage. Demands of the market simply expressed by the following words: more, faster and cheaper, together with application of CAD, CAM, CIM and other computer based techniques, led to the significant changes in industry too, which we are every day witnesses. The field of metal forming manufacturing has also been affected by these changes resulting in the development of such technologies and procedures that enable the manufacture of parts which are ready to be ground or directly assembled (NSF-Net Shape Forming) or parts which require finish machining only on some surfaces mostly non-active (NNSF-Near Net Shape Forming) [1]. Reaching the goals of NNSF and NSF, i.e. produce parts with very narrow shape and geometrical tolerances require numerous activities to be undertaken. Usually it involves a long-term approach of continuous process improvement considering the entire manufacturing process, including the) machine and tool system, die life, part design etc. The application of NNSF and especially NSF technologies means an increase in time and money investments for producers in the beginning, but after a short period of time its considerable techno-economical advantages appear, especially in the case of mass production of complex parts.

Bearings are mostly produced in large series. It is estimated as a 30$ billions worth industry worldwide [4]. A variety of different possibilities in the design process of bearing production are available (technologies, production steps, needed equipment etc.). For a long period of time metal cutting technologies were prevailing in this field of production. Because of significant material waste, by time, this way of bearing production has been replaced by some metal forming technologies. Due to this a few different procedures based on application of precision forging and rolling methods have been developed. These methods are always attractive, both for economical and technological reasons (less material and energy consumption, higher product quality, shorter cycle time, better mechanical properties, longer service life). Investigations have shown that up to 40% of the price of the ring are costs of raw material and 20-50% of starting material (mostly still alloyed with Cr) when bearings are produced by machining is directly converted to chips [3]. Distribution of manufacturing cost in case of machining tapered bearing is shown in Fig 1.

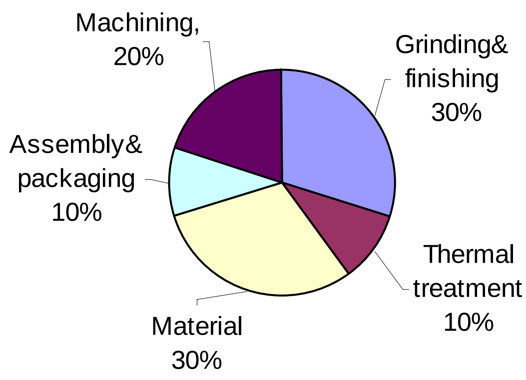

Figure 1. Distribution of manufacturing costs of tapered bearing [4]

Application of metal forming technologies in bearing production today is widespread. The optimal technique of ring production depends on the following factors: quantity, size, tolerances, complexity of the ring race etc. Diagram shown in Fig. 2 presents recommendations for choosing the optimal method of ring production technology depending on the ring diameter. According to this criterion rings are divided into following five groups:

a) Small rings (diameter to 60mm) – machining (from tube billet) or high speed hot forging
b) Rings from 50mm to 200mm – cold forging or cold ring rolling
c) Rings up to 800mm – cold ring rolling or hot ring rolling
d) Rings from 100mm to 7000 mm – hot ring rolling
e) Heavy rings (up to 35 000kg) –free forging and hot ring rolling

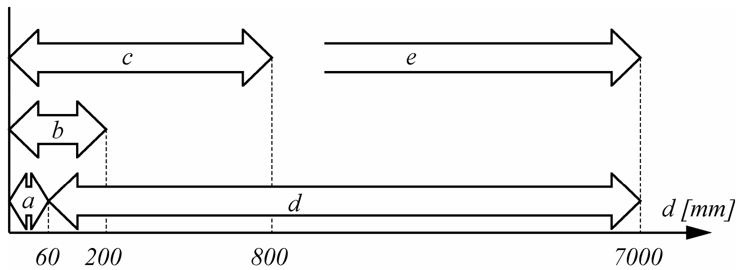

Figure 2. The review of the optimal ring production procedure

2. RING ROLLING

Ring rolling is a metal forming process which is used in the production of sizes and shapes different types of seamless rings such as rings for ball bearing, rings for railroad wheels, pipe flanges, rings for turbines etc., ranging from several centimeters to over 8 meters in diameter. Ring rolling can be performed with cold and hot ring shaped workpieces from any forgeable materials. It is a very cost effective and property efficient process and rings obtained by this method are mostly classified as NNSF parts which require some machining or grinding, but some new procedures (based on cold rolling) enable manufacturing of NSF rings.
Main advantages of the ring rolling process are uniform quality, smooth surface with favorable grain orientation, high dimensional precision, short production time, relatively small material loss

especially for rings of complex profiles (up to 95% of the starting billet is utilized and the continuous attempts to minimize the loss due to slug in the piercing of ring as well as machining allowance are present), short set-up time, low total cost, low labour and energy input.
Depending of the way material flows during the process ring rolling can be classified as:

- Radial ring rolling
- Radial-axial ring rolling

Classical radial-axial ring rolling process is performed by rolling machine equipped with two sets of rolls. Radial sets consist of drive and mandrel rolls, which are used to reduce the thickness of the walls of the annular billet, while conical pair of axial rolls controls the width of the ring. During the process the gap between the two radials rolls decreases continuously and accordingly that causing the ring wall to decrease as the diameter of the ring progressively grows due to the incompressibility of the material. Radial ring rolling is performed only by radial rolls so in this case there are no deformations in axial direction (initial width of the ring stays approximately constant during the process). In both processes the geometry of radial rolls is determined by the ring profile. Due to great diversity of the rings (geometrical and dimensional), the application of classical ring rolling processes require large number of roll sets, which increase set up time and manufacturing cost. To improve those lacks a few more efficient processes including the new concepts of rolling machines have been introduced recently. Such a new concept of the ring rolling process is presented in [3], where mandrel, which could have any profile, is used to shape the ring cross-section. The mandrel is controlled to move both radially and axially during the forming process. It enables many ring profiles to be made with the same tooling, without set-up times between products. This procedure could be performed in both hot and cold ring-rolling, and either radial or axial faces of the mandrel can be used.
It can be said in spite of the fact, that the radial-axial ring rolling process patented by Krupp more than 150 years ago [5] is substantially the same to the one used commercially today, there is a great potential for process innovation and improvement. The concept of modern ring rolling procedure development is not only to eliminate chips from production, but also to increase and establish new standards of quality.

3. HOT RING ROLLING OF BEARING

In order to achieve optimal design, the process of ring rolling has to be regarded as a complex system consisting of the following parameters: machine, tools, process and material. The manufacturing process of hot ring rolling in the bearing production mainly consists of two phases:

1. Forging of a bulk in order to get annular blank
2. Rolling of the annular blank into the finished ring

Forging of annular blanks consists of three subsequence processes: free upsetting, backward extrusion (piercing in the die) and piercing. After forging, annular blanks are transported to the ring-rolling machine. The profile (cross-section) of annular blank for most rings is rectangular. In case of rings with more complex profile, annular blank can have a different cross-section which should be technologically compatible with the final ring shape.
One of the most important things in developing the bearing process is to determine the initial billet. Failure in perform design may lead to surface defects and under-filling in the cross-section. When designing a billet for forging process, there are two scopes of consideration:

a) geometrical aspects of the finished ring
b) the limitations of the individual processing operations utilized in the total process sequence.

Starting with the geometry of the formed ring, development work proceeds to determine the volume and the geometry of workpiece from previous stages, working backwards towards the starting billet. The calculation of total volume must take into account slug and volume increasing due to scaling as well as machining allowances. Dimensions of the annular blank are determined by the dimensions of the ring after rolling, the mandrel diameter and the value of the limit strain degree expressed by the coefficient of reduction. This coefficient is given by the ratio of the ring cross section areas before and after rolling and its value depends on material properties and bearing race complexity. After that, following the forging procedure, geometry and dimensions of workpiece in each stage, are calculated including the diameter of starting cylindrical billet.

In the Laboratory for metal forming-University of Novi Sad software for automatic dimensioning of workpiece and choosing initial cylindrical bar has been developed. Also this software enables the calculation of load of the forging process stages. The software is created by Access (part of Microsoft Office 2000 program package). It is tabular based computation program and user only needs to enter data of the final ring dimension, material properties and to choose the type of the forging press (Fig.3). After that software automatically does all the necessary calculations and results are displayed in the next program windows.

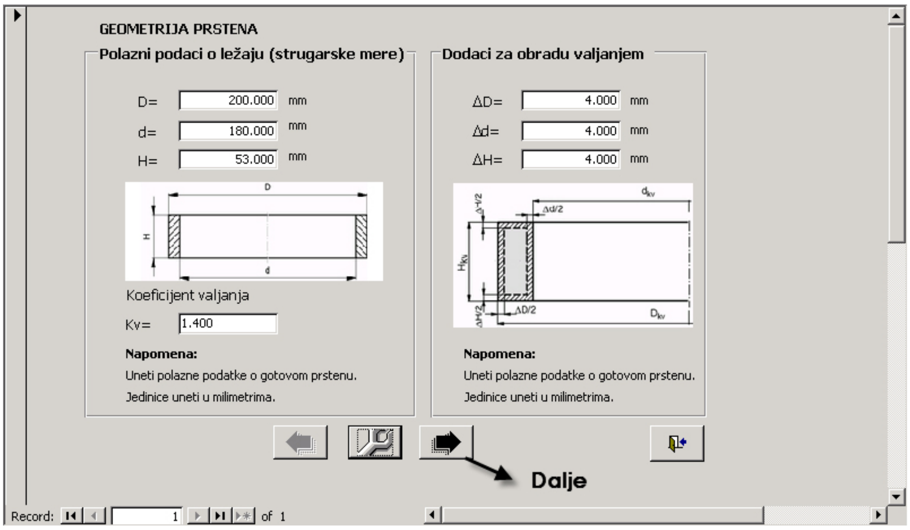

Figure 3 – Starting window for enter ring data

4. CONCLUSION

Due to the technical and economical advantages manufactory of bearing is based mainly on metal forming technologies. Main advantages of the ring rolling process are:

1. The process is highly material efficient. Perform typically utilizes up to 95% of the starting billet.
2. Better physical properties of workpiece. It is attained by mechanical fibering and hardening due to the plastic deformation.
3. The process is continuous and most suitable for mass production.
4. Tooling cost is low, set-up time is fast, rolled sections require little or no machining

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