

Experimental studies of ultrasonic stabilization of rings of rolling bearings

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Abstract. The article describes the results of experimental studies on ultrasonic stabilization of the bearing rings. The mean and root-mean-square values of non-roundness of the rings after ultrasonic and thermal treatment were compared. Comparative analysis showed that the root-mean-square deviation and the mean value of non-roundness after ultrasonic stabilization was lower than that after thermal stabilization.

1. Introduction

The ability of bearings to retain their geometric accuracy for a long time mainly determines their reliability and service life of the machine as a whole. Therefore, ensuring the stability of the geometric accuracy of the bearing rings is a task of primary importance.

In the process of manufacturing the bearings are subjected to repeated physical, mechanical, chemical and thermal effects. As a result of this the internal stresses are accumulated in the bearing material. Sometime after the production a relaxation of residual stresses occurs that results in deformation of the original shape of the product. Further, some bearings after the manufacturer's quality control are discarded at the input control of the enterprise customer. The major hazard for machine reliability is related to the bearings, which have passed the input control and still have residual stresses.

The operation of these bearings is characterized by repeated dynamic loads when the relaxation of unrelieved residual stresses occurs. During the relaxation of residual stresses, the size of the surfaces, contact area, magnitude of interference, and friction force change. This leads to a deterioration of the operating conditions and further reduction of the service life of bearings. Residual stress relaxation mechanism is described in numerous studies [1-5], according to them the value of relieved stresses is not linearly dependent on the time of operation. The operation can be roughly divided into three periods: the initial, main, and final. Stress relaxation is most intense in the initial and final periods of operation of the product. At the initial stage of operation more intense stress relaxation is caused by the running-in when the system goes into equilibrium-stressed state. During the subsequent period, the main relaxation occurs relatively slowly over a long period of time, which determines the service life of the product. In the final period of operation, the strain magnitude caused by residual stresses



relaxation reaches a critical value and leads to the limit state of rolling bearings and the completion of the service period.

The service life of a rolling bearing can be increased due to the artificially accelerated relaxation of residual stresses of the first period prior to the operation of bearings. The application of the operation of residual stresses relaxation is expected to stabilize the geometric parameters of the bearings over time and substantially increase reliability of the machine as a whole.

2. Comparative analysis of experimental data

Currently, there are many different methods of residual stress relaxation. According to the physical principle of operation these methods can be divided into thermal, chemical and thermal, mechanical, electromagnetic [6-9]. The analysis of the existing methods enabled to choose an ultrasonic method of residual stresses relaxation as it was considered the most economical and productive [10]. To evaluate the effectiveness of this method a process of stress relaxation of bearing rings in a liquid medium was developed. For the implementation of this process an automated equipment that cleans and removes the residual stresses of bearing rings was designed and manufactured. For the treatment of the outer rings of bearings of a combined construction the equipment had special technological means. The cycle of ring treatment using the equipment was divided into four stages. In the first stage the sequential automatic feed of rings from the feeder on the conveyor into the liquid medium with anti-corrosion and detergent additives was performed. In the second stage the rings were exposed to the ultrasonic effect of piezoceramic emitters by transmitting vibrations in the liquid medium. In the third stage the rings were directed to the drying zone. Here the moisture from the rings was removed by a mechanical vibrator and a fan. In the fourth stage the rings were directed from the drying zone to the collector bunk.

In order to confirm the effectiveness of the technology experimental research was performed on the manufactured equipment.

Two groups of bearing rings 2112-1006135-01 containing 30 pieces each were randomly selected as the object of the study. Both groups were subjected to the same process operations. Bearing rings 2112-1006135-01 contained metal final machined parts and their outer surfaces had polyamide flanges melted on them. In the course of flange welding the heating caused the deformation and change in the original geometric parameters of the rings. This lead to changes in operating conditions of the bearings and reduction of their service life.

Non-roundness was selected as a controlled geometrical parameter of the rings. It was measured using the equipment Talyrond R-105 in normal conditions. Non-roundness of each ring was determined prior to the flange casting, immediately after the casting, 3 hours after stabilizing treatment, and 15 days after the treatment.

In order to conduct a comparative analysis, the first group of the rings was subjected to ultrasonic stabilizing treatment on the equipment described above according to the authors' technology. The second group was subjected to the conventional thermal tempering at 150 °C for 3 hours in an oven under production conditions in JSC "EPK Saratov" according to the existing stabilizing technology.

According to the results of statistical processing of the measurement the mean (Figure 1) and root-mean-square (Figure 2) values of non-roundness before and after stabilizing treatment were obtained. The statistical difference between the indices in the two groups of bearing rings was assessed using Student's t-test with a confidence level of 0.95.

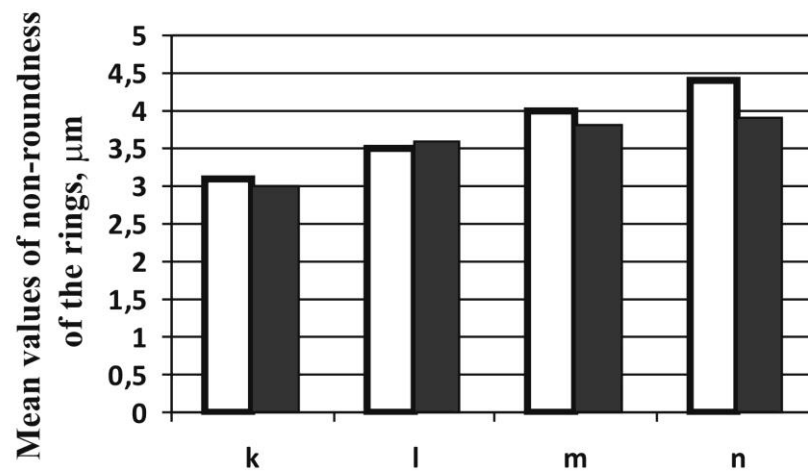


Figure 1. Mean values of non-roundness of the rings after thermal stabilization (white) and after ultrasonic stabilization (black): k - before the flange casting; l - after the flange casting; m - after stabilizing treatment; n - 15 days after stabilizing treatment

Figures 1 and 2 show that the difference between the mean and root-mean-square deviations of non-roundness of the rings before and after pouring of flanges in both groups was insignificant. Immediately after the flange casting mean non-roundness in both groups increased by 14-15% (Figure 1) and the root-mean-square deviations of non-roundness increased by 12-14% (Figure 2). 3 hours after thermal tempering the mean value of non-roundness increased by 13% (Figure 1) and the root-mean-square value of non-roundness by 29% (Figure 2). After the ultrasonic stabilization the mean roundness value increased by 5% only (Figure 1) and the root-mean-square value of non-roundness by 3% (Figure 2). After 15 days the value of the root-mean-square deviation of roundness after thermal and ultrasonic treatment did not change significantly, i.e. within 3%. 15 days after thermal treatment the mean non-roundness increased by 10%, whereas after the ultrasonic treatment it increased by 3% only.

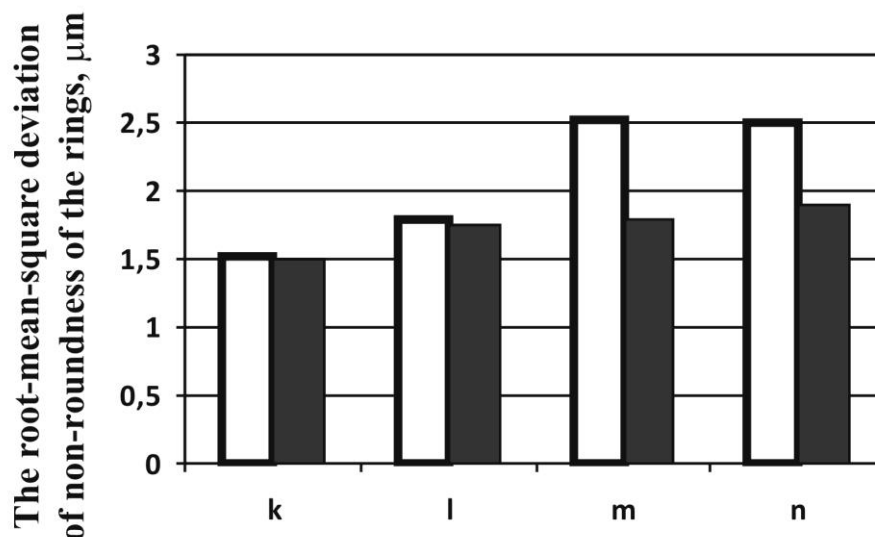


Figure 2. The root-mean-square deviation of non-roundness of the rings after thermal stabilization (white) and ultrasonic stabilization (black): k - before the flange casting; l - after the flange casting; m - after stabilizing treatment; n - 15 days after stabilizing treatment

Comparison of the measurement results after two kinds of treatment showed that the ultrasonic treatment allowed to achieve lower and more stable changes of the geometrical parameters of rings compared to thermal treatment. Additionally, it should be noted that the full cycle of the ultrasonic treatment of one part at a continuous conveyor feed equals 0.6 seconds. The full cycle of thermal stabilization together with the auxiliary time, loading and unloading from the furnace of maximum amount of 10000 parts is 7.6 hours. The mean thermal treatment cycle for one part is 2.74 seconds. Thus the ultrasonic stabilization is 4.5 times more productive than thermal tempering.

3. Conclusion

After the comparative analysis of the experimental results it was found that the ultrasonic stabilization method can significantly reduce the effect of residual stresses on the geometric parameters of rings compared to the thermal tempering. Taking into consideration the higher performance and lower power consumption the ultrasonic method can be regarded as a rational replacement for thermal tempering.

Acknowledgments

This paper has been developed under the state order of the Ministry of Education and Science of the Russian Federation (No. 9.896.2014/K).

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