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**OPTIMISATION PROCEDURE OF INNER GEOMETRY IN SPHERICAL ROLLER BEARINGS WITH REGARD TO THEIR DURABILITY**

**Summary.** This article deals with an optimisation procedure of inner geometry of rolling elements designed for spherical roller bearings. A process of selection of the most appropriate solution to increase spherical roller bearing durability is understood under the term optimisation in this case. The aim of this article is to examine the impact of a change of inner geometry on the durability and reliability of spherical roller bearings regarding production technology and competitiveness. Contact strain along with a spherical roller by means of Finite Element Method (FEM) in contact points of components of a spherical roller bearing by means of designed 3D parametric models. The most appropriate shape of inner geometry of a bearing from the standpoint of calculated durability will be determined based on the results of analyses.

**Keywords:** spherical roller bearing, rolling element, optimisation, contact strain

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## 1. INTRODUCTION

Rolling bearings are an inseparable part of most machines and devices, in which takes place rotational movement or linear motion. There are different requirements on rolling bearings. Production machines need bearings, which are able to work in high revolution, in power engineering, bearings have to carry heavy loads, trains require bearings with high-speed performance, etc.

Development or rather rolling bearing optimisation is conditioned by an increase of technical parameters in machines and devices. This fact refers especially to an increase of input parameters such as power and revolution, weight and volume reduction, noise level reduction, etc. However, the most important parameters requiring optimisation are bearing lifetime and reliability.

The development of new technologies introduces also new construction materials, new production techniques of semi-finished products and bearing components or new installation methods. It is important not to overlook the bearing construction. Here, it is possible to perform geometry adjustment optimisation. This adjustment applies especially to geometry adjustment of runways and rolling elements in the spherical roller bearings.

## 2. SPHERICAL ROLLER BEARINGS DURABILITY

The double-row angular spherical roller bearing has a runway spherically ground on the outer ring. The bearing is able to accommodate very high radial loads, as well as heavy axial loads in both directions. High radial load capacity is caused by the great number of rolling elements, so-called spherical rollers and their close contact on the inner ring runways [2].

Rolling bearings durability depends on a revolution number which the bearing can perform until fatigue of any of their components takes place. A peeled material is a sign of component fatigue. Fatigue is a basic and natural way of bearing damage. It is demonstrated by the presence of small cracks under the bearing runway surface. The depth of these cracks is usually about 0.05 - 0.3 mm depending on the surface curve radiuses of rolling elements and the bearing rings runways. The crack depth allows the material changes which are caused by slide pulsing strain. This process leads to a gradual crack formation under the surface. It can take quite a long time before it is visible on the surface in the form of a peeled-off material, so-called pitting [1,6,7].

## 3. CONTACT STRAIN ALONG SPHERICAL ROLLER IN SPHERICAL ROLLER BEARING

It is possible to calculate the intensity of the contact pressure and the size of the contact surface - effective length  $l_{ef}$  and width  $2b$  from the contact pressure distribution on the most strained point in the bearing inner ring. The picture (Fig. 1) shows the course projection (the curve) of the contact pressure along the contact surface  $l_{ef}$  of the contact ellipse on the bearing inner ring. The contact strain curve was calculated using the finite element method [5].

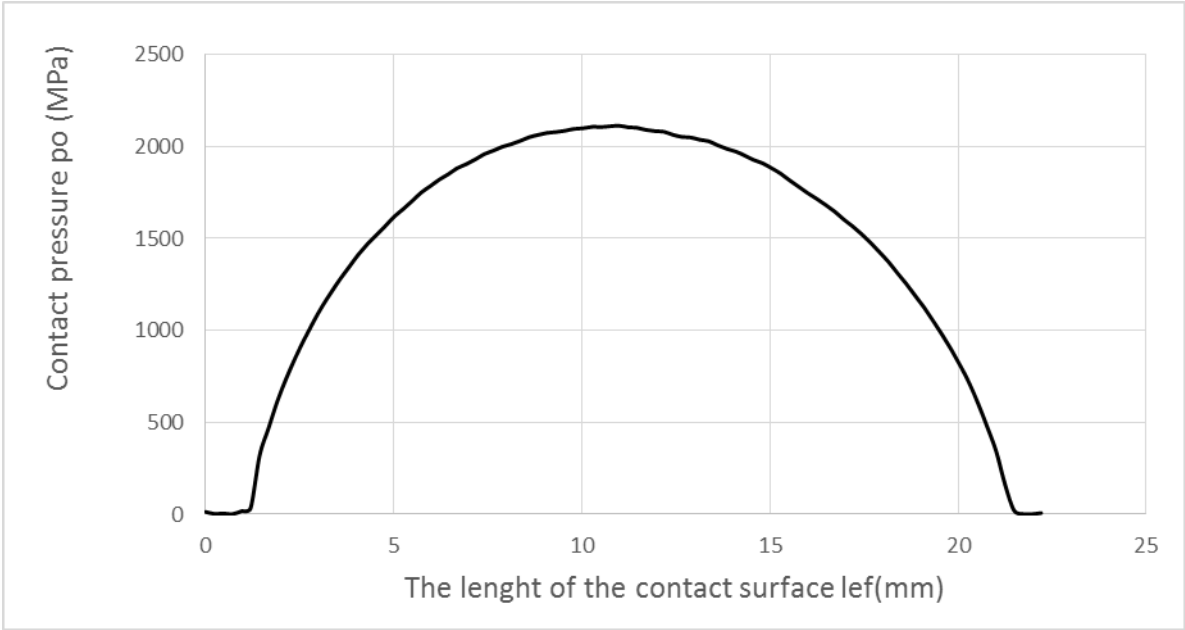


Fig. 1. The contact pressure course on the inner bearing ring runway

**4. PREPARATION OF PARAMETRIC 3D MODEL AND CONTACT ANALYSIS**

The double-row spherical roller bearing model (Fig. 2) has been simplified to the maximum extent due to the even load distribution on both rows and individual rolling elements. The model consists of the rolling element, the outer ring, the inner ring, and the contact surfaces. These surfaces are important for more precise model meshing in FEM system ANSYS. The contact pressure was measured in the above-mentioned parts [12].

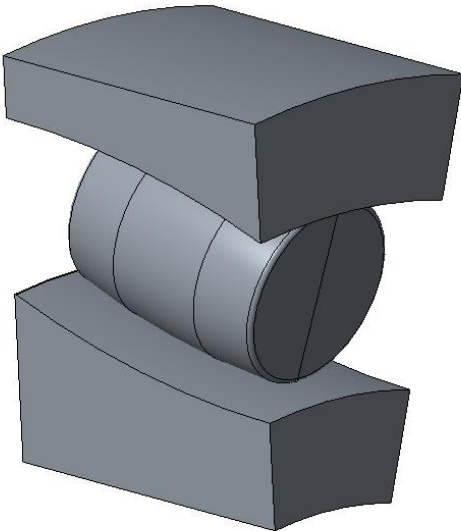


Fig. 2. The simplified model of the double row spherical roller bearing

## 5. OPTIMISATION OF GEOMETRY OF SPHERICAL ROLLER BEARING

The aim of optimisation is a decrease of contact pressure that acts in the point of contact of the rolling element with the outer and inner ring. The profile of a rolling element will be optimised, and we also calculated the contact strain between rolling elements and bearing rings [10].

We designed three new geometries of the rolling element for spherical roller bearings that were consequently compared with the reference profile. A selection of the most appropriate design of the new geometry of the rolling element was based on a comparison of volumes of contact pressures of bearing runways of the inner and outer bearing rings.

The comparison of curves of contact pressures of rolling elements depends on the length of the contact surface  $l_{ef}$ . The pictures Fig. 3 (inner ring) and Fig. 4 (outer ring) show the curve shape. We reached a decrease of contact pressure on bearing runways of bearing rings in all designs of a new geometry of the rolling element [11].

As shown in Figs. 3 and 4, the lowest contact pressure acts between two bearing rings and the rolling element with new geometry 4. At the same time, contact pressure that acts between bearing rings and the rolling element does not produce maximum strain values that negatively affect bearing durability. The new geometry of the spherical roller bearing formed by the logarithmic curve is the most appropriate for optimisation of the spherical roller bearing regarding its durability and lifespan [9].

The evaluation and selection of the most appropriate design of the new geometry are shown in Tables 1 and 2.

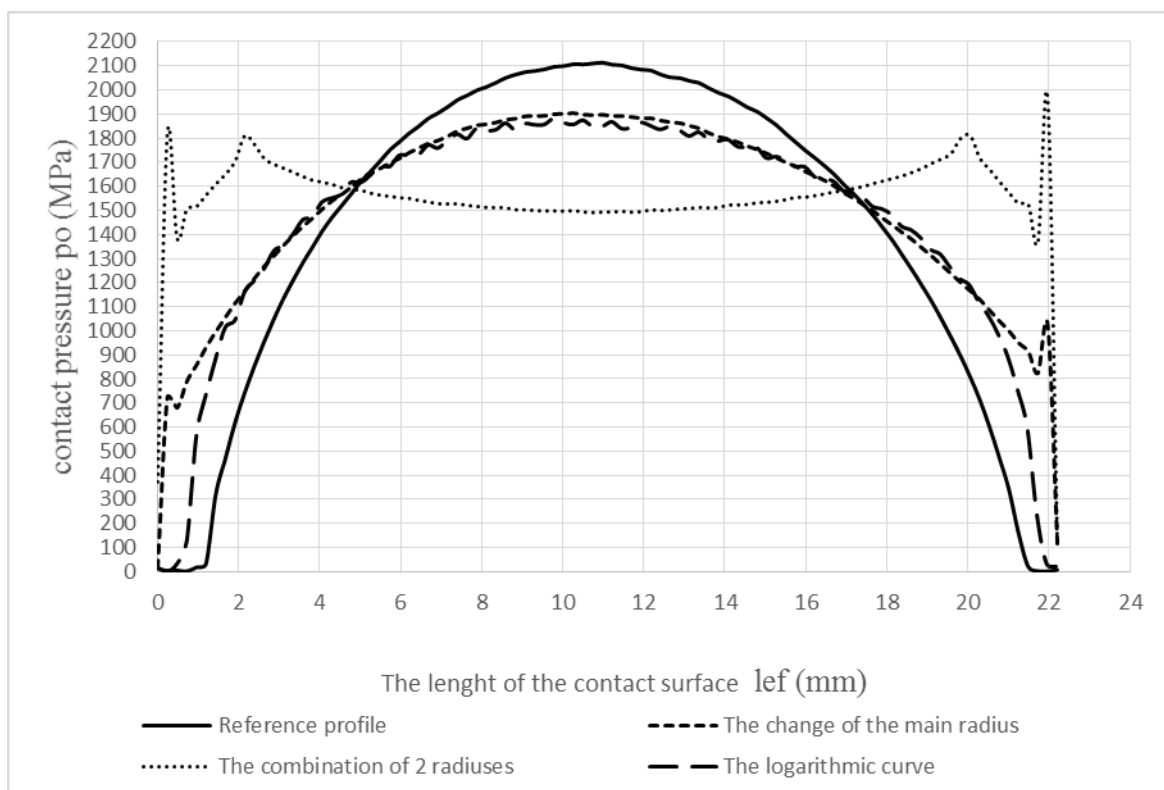


Fig. 3. The comparison of contact pressure courses in the bearing runway of the inner ring of the spherical roller bearing of analysed geometries of the rolling element

Tab. 1

The evaluation of results of analyses in the inner ring of the spherical roller bearing

| Design nr.        | Title                         | $l_{ef}$ [mm] | $b_{ef}$ [mm] | $p_o$ [MPa]   | $\sigma_{max}$ [MPa] |
|-------------------|-------------------------------|---------------|---------------|---------------|----------------------|
| Reference bearing | Profile                       | 21            | 0.96          | 2106.1        | 1426                 |
| 1                 | The change of the main radius | 22.13         | 0.96          | 1921.5        | 1319.9               |
| 3                 | The combination of 2 radiuses | 22.14         | 0.64          | 2106.1        | 1315.3               |
| <b>4</b>          | <b>Logarithmic curve</b>      | <b>21.9</b>   | <b>0.63</b>   | <b>1948.3</b> | <b>1302.6</b>        |

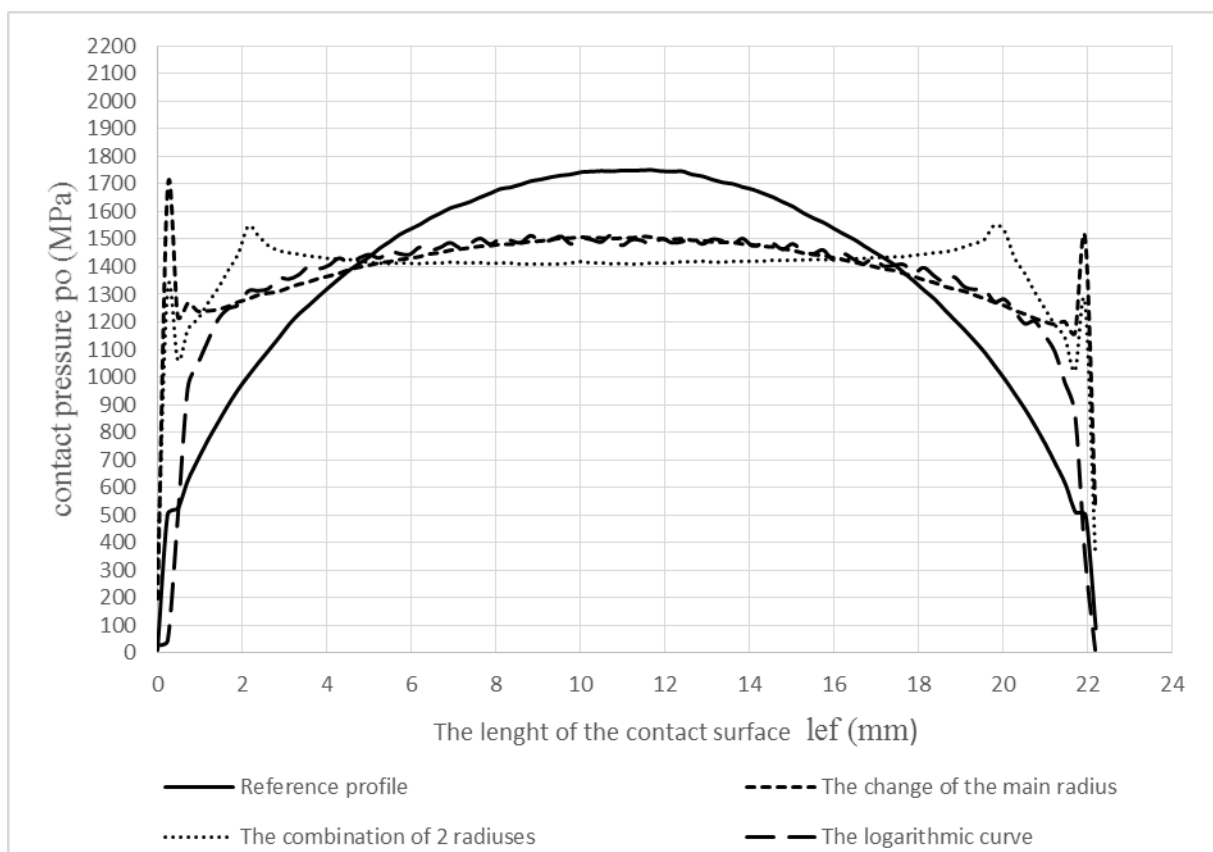


Fig. 4. The comparison of contact pressure courses in the bearing runway of the outer ring of the spherical roller bearing of analysed geometries of the rolling element

Tab. 2

The evaluation of results of analyses in the outer ring of the spherical roller bearing

| Design nr.        | Title                         | $l_{ef}$ [mm] | $b_{ef}$ [mm] | $p_o$ [MPa]   | $\sigma_{max}$ [MPa] |
|-------------------|-------------------------------|---------------|---------------|---------------|----------------------|
| Reference bearing | Profile                       | 21.8          | 0.8           | 1758.4        | 1426                 |
| 2                 | The change of the main radius | 22.14         | 1.21          | 2048.7        | 1319.9               |
| 3                 | The combination of 2 radiuses | 22.14         | 1.18          | 1719.7        | 1315.3               |
| <b>4</b>          | <b>Logarithmic curve</b>      | <b>22</b>     | <b>0.64</b>   | <b>1576.9</b> | <b>1302.6</b>        |

For a better evaluation of analysed geometries, we calculated the durability of individually analysed geometries according to the Lundberg-Palmgren theory:

$$\ln \frac{1}{S} \approx A \cdot \frac{N^e \cdot \tau_0^c \cdot V}{z_0^h} \quad (1)$$

$$\tau_0 \approx 0,256 \cdot p_o \quad (2)$$

$$z_0 \approx 0,25 \cdot 2b \quad (3)$$

where  $S$  is the probability of survival,  $N$ - the number of load cycles,  $V$ - stressed volume,  $e$ ,  $c$ ,  $h$ ,  $A$ - material constants defined by experiments,  $p_o$ - pressure present in the contact point,  $2b$ - the minor axis of the ellipse [12].

A calculation of a total lifetime of the bearing was based on partial lifetimes of bearing rings. As far as a logical comparison is concerned, 100 per cent lifetime is assigned to the reference geometry. A comparison of the calculated lifetimes of analysed geometries is shown in Fig. 5 [8].

## 5. CONCLUSIONS

Spherical roller bearings can be optimised by a modification of the geometry of the rolling element, that is, the spherical roller. The most appropriate geometry seems to be the one formed by the logarithmic curve after a comparison of lifetimes of the bearing with the new geometry of the rolling element (Fig. 5). The logarithmic curve is described by equations while in this case, a parameter of a loss of the logarithmic curve profile, that is, a modified surface of the spherical roller. The optimal value of the parameter is 0.00035 mm which is similar to the case of the rolling bearing with the logarithmic profile [5,12,14].

The new geometry of the rolling bearing composed by the logarithmic curve increases total carrying capacity, and thus, bearing durability by more than 25 per cent. This new geometry does not form strain peaks that negatively affect total bearing durability.

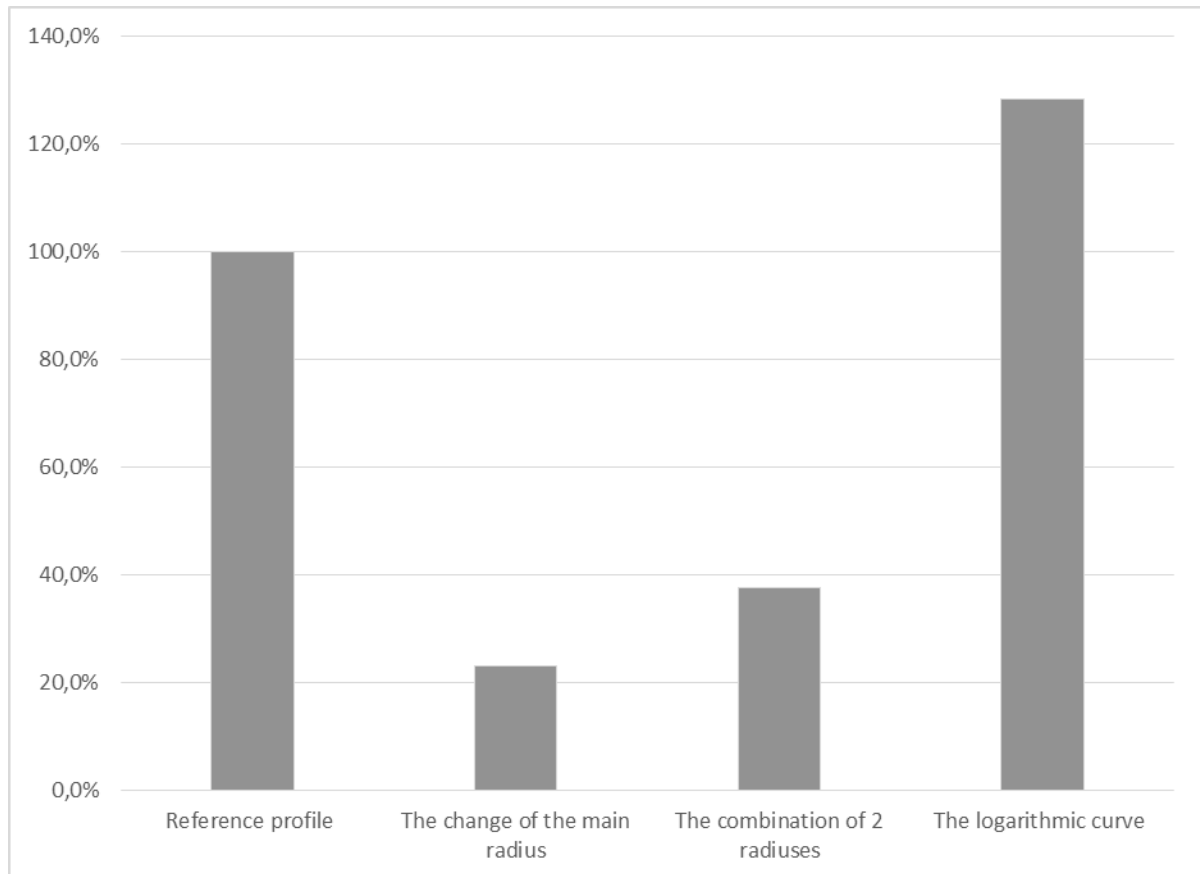


Fig. 5. The comparison of calculated lifetimes of analysed geometries

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