IN SITU STUDY OF THE DAMAGE EVOLUTION OF A ROLLING LINE CONTACT UNDER HEAVY LOAD

B.D. Onofrei, I. Muscă

Faculty of Mechanical, Mechatronic and Management,
University "Stefan cel Mare", Suceava, Romania

e-mail:b.onofrey@yahoo.com
e-mail:iliem@fim.usv.ro

Abstract: *Heavy load contacts are less presented in the literature because of small area of industry utilization. Large dimensions of the bodies in contact is an additional limit of the study presented furthermore. The paper presents a particular case of an example in wood industry and subjects like loads, materials, defects or contact conditions will be touched. Observations regarding insufficient lubrication and change of contact conditions in use were made.*

Keywords: *load, line contact, cast iron, stress, crack, fatigue, failure*

1. Introduction

Mechanic contacts are studied by a lot of industry branches in special by mechanic designers to ensure a reliable equipment. Point contacts covers more than 70% of studies or applications and regarding line contacts it can be said that is used at specific applications in industry associated with heavy loads.

Usually heavy loads occur at industrial equipments that have large dimensions.

Lubrication is an essential aspect of contact design and study because of his roles as generator of a thin permanent film, take over or absorb speed and load modification and avoid direct friction between bodies.

Most of the equipments with high dimensions are designed based on theoretical methods and less physical tested because of high costs.

Furthermore, in this paper work will be presented an in situ investigation of a damaged large ring-roller contact and some observations and conclusions related to the subject.

2. Description of the problem

The studied situations is related to a chip dryer from wood industry. This dryer has a length of more than 30 meters with a mass of about 200 tones (fully loaded) which is supported at the ends by 2 sets of rolling contacts ring type (in diameter d_1=7720 mm and cast iron as material) on cylindrical roller with a diameter of d_2=1500 mm and cast iron as material, Fig. 1. The damage occurred on the rolling contact surface of the ring is the subject of this study.

After 4 years in use at a routine maintenance check on the contact surface of the ring could be observed some wear defects, especially fretting and fatigue. After an additional time some material loss and small cracks could be seen which finally led to a total failure of the big ring by crack on the entire section. All stages of damage and defects development occurred in a short period of time of about 8 weeks.

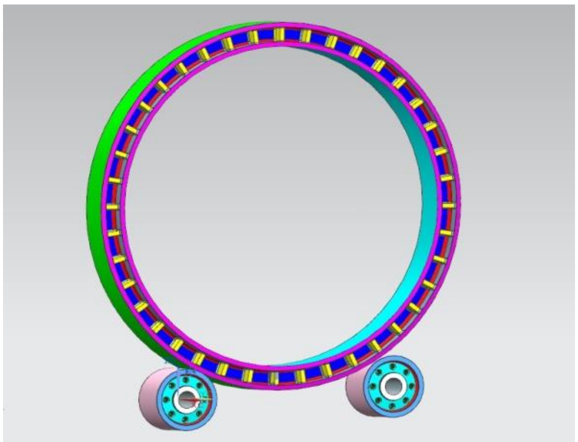

Figure 1 *Assembly drawing of contact bodies*

3. Spot investigation

First observation made in situ was regarding the material loss from the ring surface cracks and crushed areas, Fig. 2 which lead to possible explanation about contact fatigue.

Hardness tests were carried out on the surface of the ring according with SR EN ISO 6506-1 and the result revealed some unusual values compared with base material EN-GJS-600-3 of the ring that have a hardness value between 190 and 270 HB.

The surface of the ring was split in 7 vertical sections parallel with the race way to perform the tests (5 on surface and 2 on sideways). Results can be see in the table.

Measurements	1	2	3
Right side	248	248	245
Section 1	223	223	241
Section 2	215	223	267
Section 3	241	223	268
Section 4	235	244	294
Section 5	**273**	**285**	**280**
Left side	248	239	248

Table 1. *Hardness measurements*

High values of the hardness in section 5 could be explained by the plastic deformations present around area were material was lost.

Figure 2 *Damage of the ring*

A test with a penetrant liquid was conducted on the surface of the ring to highlight the cracks according with SR EN ISO 3452-1.

Figure 3 *PT test*

Geometrical measurement of the race ring revealed that the thickness of the wall was different, 2 mm less on the right side than the left side. Prominent one side wear phenomena mean a non-uniform load of the race ring was concluded.

Due to a high level cost of the ring replacement, firstly, a ring repair action was done by milling a 8 mm thickness from the external ring diameter of the active contact surface. Adjustments for the rollers supports also were made to ensure a correct dryer position and an uniform contact between bodies. Finally the crack propagation thru entire section occurred after an additional time of 5 weeks of using.

4. Contact condition verification

Starting from the general formula of Hertz theory for line contact maximal pressure calculation were made:

$$p_{\max} = \frac{2}{\pi}\frac{F}{bl} \quad (1)$$

where the width of contact is given by

$$b = \sqrt{\frac{4}{\pi}\frac{\eta F}{l\sum k}},$$

$$\eta = \frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2},$$

Poisson's ratio

ν_1 =0,275

ν_2 =0,275

modulus of elasticity

E_1 =174 GPa

E_2 =174 GPa,

$$\sum k = \frac{2}{d_1} + \frac{2}{d_2},$$

$$p_{\max} = \sqrt{\frac{FE}{\pi l\left(1-\upsilon^2\right)}\left(\frac{1}{d_1}+\frac{1}{d_2}\right)} \quad . \quad (2)$$

d_1 - ring diameter

d_2 - support roller diameter

l - contact length

The material used for the rings is ductile cast iron grade EN-GJS-600-3 (ISO 1083 600-3) and specific values for all formula terms were specified in the material data sheet provided by the constructor.

Maximal load on contact is a value provided by the user of the machine and has the value of *F*=570154 N.

Results of the calculation showed that maximum of the contact pressure is $p_{\max} = 247 N/mm^2$ with the width of contact $b = 6.525$ mm. Maximum stress $\sigma_{\max} = 74,2$ N/mm^2 is reached at a depth of $z = 2,565 mm$ as a maximal shear stress.

According with material quality certificate the elastic limit of the ring material is 370 N/mm^2.

Contact calculations is changing when we consider the inclination of the ring occurred in operation. Deduction made when geometrical measurements were taken is about a very small angle that is changing the contact conditions by introducing a non-uniform load along the contact. Study revealed that even a angular modification by 0.4 degrees could change the load in some area of the line contact with more than $100 N/mm^2$ which lead to a pressure near to elastic limit of the material.

If we add the operational data history, about 21 millions of loading cycles (5 rot/min for 4 years multiplied by 2 support rollers) can be said that the fatigue could occur very quickly.

Scenario above is taking in consider maximum load on the dryer but in reality not all the time the equipment is used fully loaded.

Tests lab base material characteristic is showing that for fatigue stage the elastic limit has a lower value around $260 N/mm^2$. So even if in the operation life of the ring is not used at maximum load after some years just one overload can damage the ring material.
Contact lubrication is an another aspect that was analyzed. Because these contacts are free air exposed contacts, dust or other residuals can get into the contact. Insufficient lubrication of bodies makes this case a mixed regime and contaminated oil is reused.

5. Conclusions and discussions

First conclusion made was about the lubrication system that need an upgrade to avoid contamination and dry regime.

Additional filter system was mounted and a spray system to spread the lubricant was

adopted and visual check of the surface revealed a cleaner contact surface.

Thickness measurement of the race ring can prevent load modification of the line contact by keeping the big ring parallel with the support rollers.

Hardness measurements of the ring material needs to be taken at least 4 times / year to check if the material deformed plastic and this can keep under control the wear process or to have a uniform wear.

Furthermore, an investigation about end effect can be made or a combination between

fatigue, compression and bending of the ring material in the area around the contact.

References

[1] T.A. Stolarski and S. Tobe, Rolling contacts, London, UK, 2000, ISSN 1470-9147.
[2] K.L. Johnson, Contact mechanics, Cambridge, UK , 1987, ISBN 0 521 25576 7.
[3] D.N. Olaru, Fundamente de lubrificatie, Iasi, Romania, 2002, ISBN 973 8292 02 6
[4] M. Harald, Schaeffler technical pocket guide, Nuremberg, Germany, 2014