IOP Conf. Series: Materials Science and Engineering **416** (2018) 012074 doi:10.1088/1757-899X/416/1/012074

Determination of Material Characteristics of Bearing Balls Through Static and Dynamical Actuation

T Manescu[1,*], G Balan[2] and R Avram[2]

[1]"Aurel Vlaicu" University of Arad, Bv. Revoluţiei, no. 77, 310130 Arad, România
[2]"Eftimie Murgu" University of Reşiţa, Sq. Traian Vuia, no. 1-4, 320085 Reşiţa, România

[*]Corresponding author: manescu.tiberiu@gmail.com

Abstract. In order to achieve a normal behavior of the bearing during exploitation, it is necessary to study the characteristics of the rolling elements material. The experiments are meant to determine the mechanical characteristics of the material used in ball bearing manufacturing (e.g. tensile strength, fatigue). The trials conducted have been split into two different categories: in a first stage statically tests have been performed, in which the bearing ball has been tested for compression until breakage using a special device developed for this purpose. The second stage has been dedicated to dynamical tests, using a specially designed fatigue test machine for bearing balls. The experimental results have been statistically worked out, acquiring conclusive results for the trials performed.

1. Introduction

Bearing analysis concerns a wide number of specialists from various engineering fields. Several approaches can be identified: vibration analysis [1],[2], fatigue tests, lifetime assessments with different lubricants, etc. Most of the scientific research is related to the bearing assembly, without highlighting the importance of the bearing components (inner ring, outer ring, cage, rolling elements). If the bearing components have defects, a shorter lifetime of the bearing is to be expected. The authors study in the current paper the bearing balls mechanical characteristics in order to evaluate if they can have a significant impact in the bearing

The analysis performed in the current paper is orientated in two directions: the first one is related to mechanical compression trials performed with a specialized device executed for this task and the second one is related to fatigue issues of the bearing balls.

2. Materials and methods

2.1. Mechanical compression device

The trials have been performed on a universal testing machine, [3]. Thus, there have been six sets of bearing balls tested at compression (with five balls each set) with the diameters: D_w = 6,8; 8.8; 12,7; 15,0; 17,8 and 20 mm.

For the mechanical compression trials, a specialised device was designed and executed (figure 1). The bearing balls or semi balls are fixed in the device as shown in figure 2. The devices maneuverability is facile and it can be mounted in the universal testing machine with ease. The force until breakage is recorded by the universal machine. The whole ball can be tested for static trials and the semi ball can be tested for the stress and deformation study with the electric resistive tensiometry method, using the adequate tensiometric stamps with a big measurement base [4]. However, in the current paper only the necessary force until breakage was evaluated by the authors.

Figure 1. Specialised device for bearing balls compression test

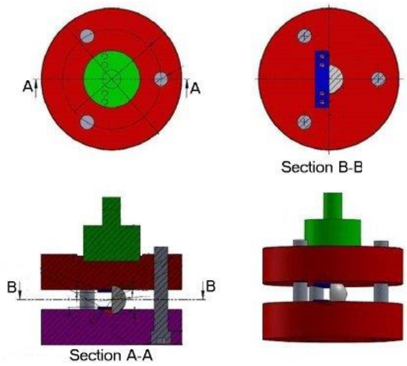

Figure 2. Schematic of the **s**pecialised device for bearing balls compression tests

2.2. Fatigue trial machine

The bearing balls where tested on the machine presented in figure 3. In order to obtain similar results during all the tests performed, several parameters had to be carefully monitored and maintained in a narrow range of values. The tests performed where under constant load (F=3600kN/test chamber) and the test chamber was permanently greased, using Mobil SHC Cibus 68. The oil flow was at around 1500ml/min. In every test chamber there were 6 balls tested in each trial, using the sudden death method (until the failure of one of the balls). The machine stopped the test every time the vibration sensor detected higher vibrations in the assembly, meaning one of the bearing balls had a material pitting.

The balls are located in a cage with 12 holes (figure. 4c), working in a vertical position (figure. 4.b.). The horizontal load F_a is shown in figure 4.a. The test chamber has two cages, allowing up to 24 simultaneous ball trials. The machine, described in detail in [5]-[9], is presented in figure 3.

Figure 3. Fatigue testing machine for bearing balls

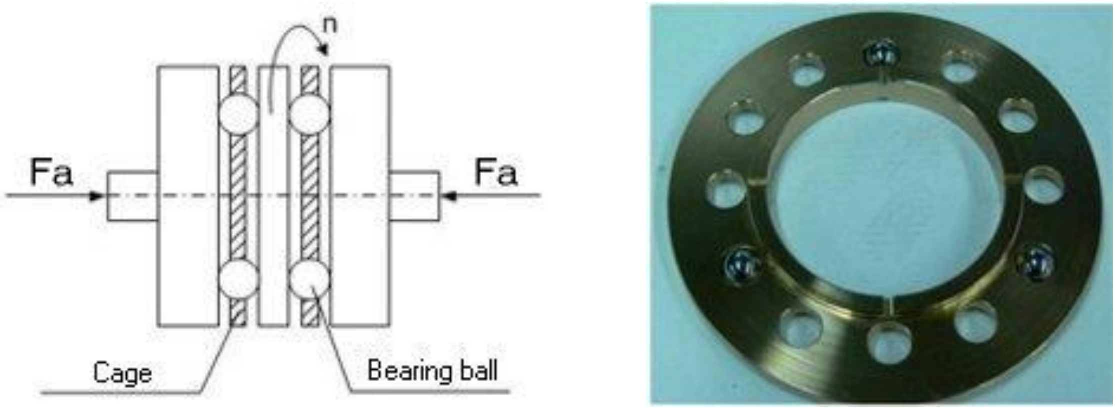

Figure 4. Schematic of the test chamber and the cage

The rolling elements of a bearing are made of chrome alloy steel: 100Cr6 for smaller bearings and 100CrMn6 for large bearings. The material used to conduct the trials is 100Cr6 with $E=2\cdot10^5$ MPa, Poisson coefficient $\mu = 0{,}29$ and admissible stress $\sigma_a = 6000$ MP, also known as the admissible contact pressure p_a.

A total of 120 bearing balls with the diameter $D_w = 12{,}7$ mm, without production defects have been tested for fatigue at $n = 200\cdot10^6$ rotations.

3. Results and discussions

3.1. Mechanical compression trials

The balls have been tested until breakage (figure.5). The balls had no manufacturing defects and no wear. The force at the breaking moment Fr [N] has been validated as the arithmetic mean of the individual values obtained for each ball in the respective set.

Figure 5. Ball tested at compression

It can be observed that the intensity of the necessary force in order to break the ball F_r is dependent to the ball diameter D_w and the value is increasing linear, as shown in figure 6, where the tendency line is correspondent to the ball diameter/breakage force.

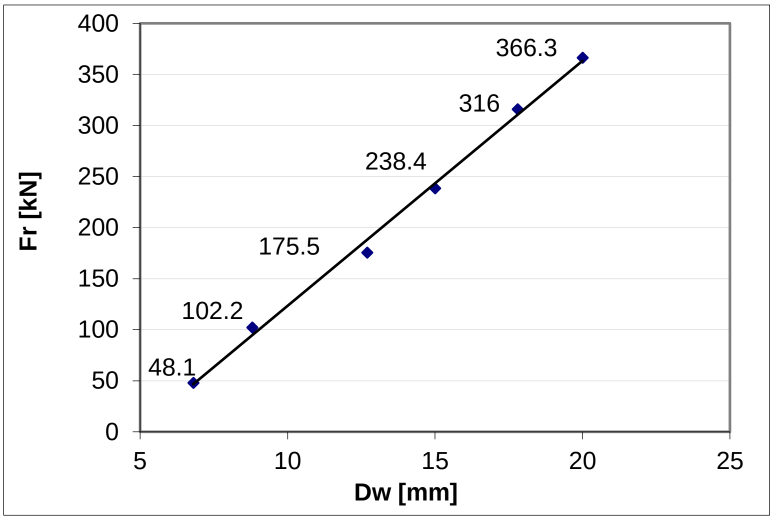

Figure 6. Breakage force variation depending on the ball diameter

3.2. Fatigue trials of bearing balls

After the testing of 120 bearing balls [10]-[12], a total of 60 balls have been randomly selected for the analysis, shown in figure 7.

Figure 7. Bearing balls D_w =12,7 mm after n = $200 \cdot 10^6$ rotations

Initial parametrical data for the bearing balls:
- Initial diameter: $D_w = D_o = 12{,}7$ mm
- Maximum section area: $A_0 = 506{,}7074791$ mm^2
- Volume: $V_0 = 1072{,}530831$ mm^3
- Material density: $\rho = 7{,}80$ g/mm^3
- Initial weight: $m_0 = 8{,}36570$ g

The data has been measured individually for each ball tested after n = $200 \cdot 10^6$ rotations. The results have been obtained by calculating the mean of the measured parameters:
- Final diameter $D_{med} = 12{,}686567$ mm
- Final weight $m_{med} = 8{,}35238$ g

The results after the weight measuring sequence of the balls highlight the loss of weight due to fatigue:

$D_{med} = D_o - D_{med} = 0{,}013433$ mm

$m_{med} = m_0 - m_{med} = 0{,}01332$ g

The fatigue becomes relevant only after a certain number of rotations (n> 100.000.000 rotations)[13]

4. Conclusions

The current paper presents a study regarding the static and dynamic behavior of the bearing balls of different sizes. The results obtained through the two test methods (mechanical and fatigue) emphasise that the bearing balls have a high liftetime expectance, exceeding the lifetime calculated for the bearing assembly according to ISO 281:2007 norm. [14] Thus, the breakdown of a bearing is not caused by the rolling elements as long as they do not have production defects.

5. References

[1] Ntakpe J L, Gillich G R , Mituletu I C, Praisach Z I and Gillich N, 2016 An Accurate Frequency Estimation Algorithm with Application in Modal Analysis, *Romanian Journal Of Acoustics And Vibration*, **13**(2), pp. 98-103

[2] Nitescu C, Gillich G R, Wahab M A, Manescu T and Korka Z I, 2017 Damage severity estimation from the global stiffness decrease, 12th International Conference On Damage Assessment Of Structures, in: *ROM J PHYS*, Vol. **842**

[3] Gafiţanu M, Năstase D, Cretu S and Olaru D, 1985 *Rulmenţi, Proiectare şi Tehnologie*, vol.1 şi 2, Editura Tehnică Bucureşti

[4] Mgharbel A, Delanoë-Ayari H and Rieu J-P, 2009 Measuring accurately liquid and tissue surface tension with a compression plate tensiometer, *HFSP J.* (3) 213–221

[5] Manescu T Jr, 2014 Analiza duratei de viaţă a bilelor de rulment de dimensiuni mici, Ştiinţă şi Inginerie, Sebeş, vol. **25**, pag. 575-580, ISSN 2067-7138

[6] Manescu T Jr, 2014 Analiza dimensională și calitativă a suprafețelor bilelor de rulment încercate la oboseală, *Ştiinţă şi Inginerie*, Sebeş, vol. **25**, pag. 581-588, ISSN 2067-7138.

[7] Manescu T Jr, 2014 Uzura bilelor de rulment încercate la oboseală, *Ştiinţă şi Inginerie*, Sebeş, vol. **25**, pag. 589-598.

[8] Manescu T jr, 2014 Contribuţii privind analiza stării de tensiuni şi deformaţii în bilele rulmenţilor radiali, de mici dimensiuni. cu si fara defecte de fabricatie, Phd. Thesis, UEM Resita

[9] Mănescu T Jr, Iancu V and Pomoja F, 2015 Incercarea de compresiune a bilelor de rulment, *Ştiinţă şi Inginerie*, Sebeş, vol. **27**, pag. 575-580

[10] Gillich G R, Bratu P, Frunzaverde D, Amariei D and Iancu V, 2010 Identifying Mechanical Characteristics of Materials with Non-linear Behavior using Statistical Methods, *4th WSEAS International Conference on Computer Engineering and Applications*, Harvard Univ, Cambridge, MA, USA, pp. 96-103

[11] Sadeghi F, Jalalahmadi B, Trevor S.S., Raje N and Nagaraj K A, 2009 A Review of Rolling Contact Fatigue, J. Tribol **131**(4)

[12] SKF General Catalogue 6000 EN, 2008

[13] SKF, Catalogue 5000E, 2003

[14] ISO 281:2007 Rolling bearings - Dynamic load ratings and rating life