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# RELIABILITY AND FATIGUE LIFE PREDICTION OF CYLINDRICAL ROLLER BEARINGS BASED ON FINITE ELEMENTS METHODS

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***Abstract:*** *This paper presents a case study of the reliability and of the lifetime of cylindrical roller bearings, using experimental information and finite elements methods. The main objective of this paper is to estimate the fatigue life and the reliability parameters of a cylindrical roller bearing subjected to accelerated experiments using the analysis with finite elements. Taking into account the aspects regarding the statistical processing of experimental data, we determined the main reliability parameters, which in turn determine the main characteristics regarding the performance and the warranty period of the cylindrical roller bearings. In this paper, the analysis with finite elements was used to validate and to compare the data resulted from the accelerated reliability tests of the cylindrical roller bearing.*
***Keywords:*** *reliability, FEA, roller bearings, life*

## 1. INTRODUCTION

When moving an object, friction force often comes into play, and must be surpassed to move the object. Various types of bearings are used to lessen this friction force for moving mechanisms such as machines. The bearing gets its name from the fact that it bears a turning axle or shaft, but those parts used for sliding surfaces are also called bearings. Bearings include rolling bearings, which use balls, or rollers called "rolling elements." Most rolling bearings (figure 1) consist of rings with raceway (inner ring and outer ring), rolling elements (either balls or rollers) and cage. The cage separates the rolling elements at regular intervals, holds them in place within the inner and outer raceways, and allows them to rotate freely. Rolling elements classify in two types: balls and rollers. Rollers come in four types: cylindrical, needle, tapered, and spherical. Theoretically, rolling bearings are so constructed as to allow the rolling elements to rotate orbital while also rotating on their own axes at the same time [2].

**Figure 1:** Cylindrical roller bearings

## 2. MATERIALS AND METHODS

### 2.1. Rolling bearings tested

Rolling bearings come in many shapes and varieties, each with its own distinctive features. However, when compared with sliding bearings, rolling bearings all have the following advantages:

- The starting friction coefficient is lower and there is little difference between this and the dynamic friction coefficient.
- They are internationally standardized, interchangeable and readily obtainable.
- They are easy to lubricate and consume less lubricant.
- As a general rule, one bearing can carry both radial and axial loads at the same time.
- May be used in either high or low temperature applications.
- Bearing rigidity can be improved by preloading.

Double-row cylindrical roller bearings have high load-carrying ability and high stiffness. The bearings are especially used as main shaft bearings of machine tools. They are mainly used in machine tools, rolling mill stands, plastic calendars, grinding mills and also large gearboxes. The cylindrical roller bearings type NN3020 is described in figure 2.

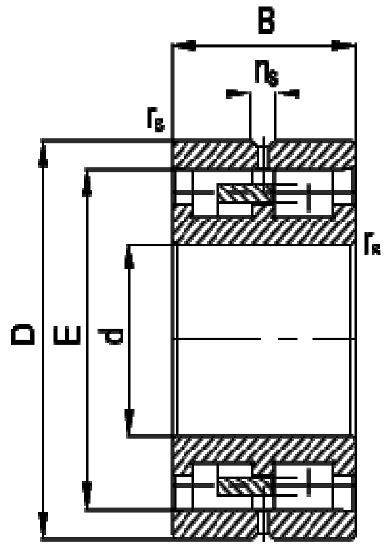


**Figure 2:** Cylindrical roller bearings type NN3020

In the table 1 is described the geometric and constructive aspects of the cylindrical roller bearings type NN3020, used for the accelerated experiments.

**Table 1:** The characteristics of the cylindrical roller bearings type NN3020

| Type | Cylindrical roller bearings type NN3020 |
|---|---|
| d mm | 100 |
| D mm | 150 |
| B mm | 37 |
| $r_{s\,min}$ mm | 1,5 |
| $n_s$ mm | 6,5 |
| F,E mm | 137 |
| Load rating static $C_0$ | 265 |
| Load rating dynamic C kN | 157 |
| Fatigue stress limit $C_u$ kN | 37 |
| Limiting speed rot/min | 4.460 |
| Weight ≈ kg | 2,32 |

## 2.2. Testing procedure

The accelerated experiments realized on cylindrical roller bearings offer a multitude of data concerning the reliability and quality of essential and auxiliary materials, the technological and constructive design, the methods of processing being used, the accuracy of execution and, of course, their durability [2]. Therefore, the methodology of accelerated experiments of the cylindrical roller bearings represents a complex process, which takes place in several stages (figure 3):

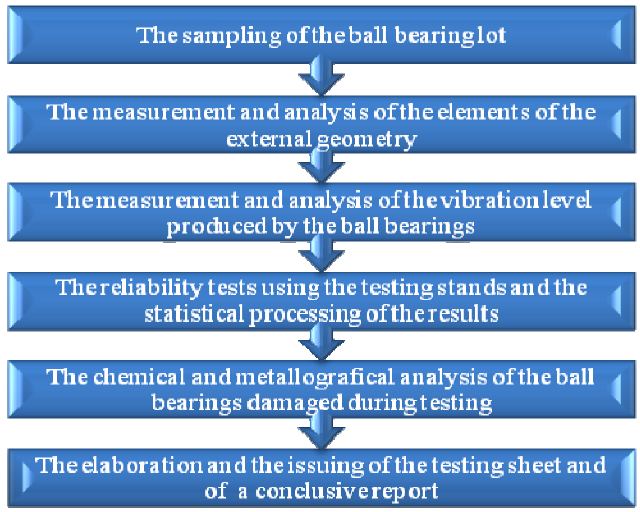


**Figure 3:** The testing methodology of the cylindrical roller bearings

Accelerated experiments is used in electronics (resistors, lasers, liquid crystal displays, electronic bounds, switches, relays, cells) in the study of metals and composite materials, but also for certain components and mechanical assemblies (hydraulic components, tools, bearings). The degree of interdisciplinary of research in the field of accelerated experiments is complex and can include the following industries: manufacturing engineering, the aerospace industry, the nuclear industry, the electronic industry, the dental industry, the pharmaceutical industry and the industry of renewable energy resources [3,5]. In order to determine the reliability parameters, the statistical processing of experimental data is necessary. The results obtained at the accelerated experiments of cylindrical roller bearings - for the two levels of accelerated stress are shown in table 2.

**Table 2:** The number of hours until failure of the cylindrical roller bearings type NN3020

| No. | Time to failure [hrs] | Load bearing [kN] |
|---|---|---|
| 1 | 500 | 50 |
| 2 | 550 | 50 |
| 3 | 578 | 50 |
| 4 | 456 | 80 |
| 5 | 413 | 80 |
| 6 | 408 | 80 |
| 7 | 398 | 80 |
| 8 | 290 | 100 |
| 9 | 281 | 100 |
| 10 | 267 | 100 |
| 11 | 234 | 100 |
| 12 | 200 | 100 |

## 2.3. Fatigue life prediction

Fatigue failures are failures caused in components under the action of fluctuating loads. They are estimated to be responsible for 90% of all metallic failures since loads on the components usually are not constant but instead vary with time. Fatigue failures occur when components are subjected to a large number of cycles of the applied stress. With fatigue, components fail under stress values much below the ultimate strength of the material and often even below the yield strength. What makes fatigue failures even more dangerous is the fact that they occur

suddenly, without warning. One of the most common tests for components susceptible to fatigue failures involves running specimens to failure at constant stress amplitude. Each specimen is loaded in four-point bending and the stress on the specimen is cycled by rotating the specimen. The number of cycles to failure is noted for the stress value.
The main reliability indicators followed during the accelerated experiments of the cylindrical roller bearings are: B10, the mean life, the reliability function, the unreliability function, the failure rate, the probability density function.
The purpose of reliability analysis (figure 4.a) is to indicate the probability of success for a specified time. This probability is called the reliability, and is always associated with a given time. That is, the given percentage representing the probability of success is a function of time, and is essentially paired with an associated time. Life vs. Stress plots is the most important plot type in accelerated life testing analysis. Life vs. Stress (figure 4.b) plots are widely used for estimating the parameters of life-stress relationships [6].

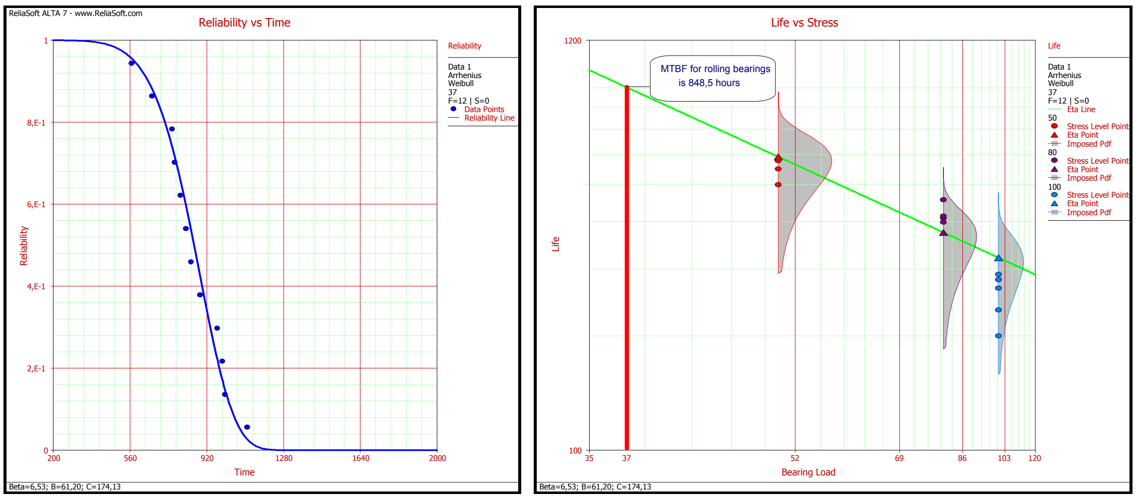


**Figure 4:** Reliability indicators of roller bearings type NN3020
a) Reliability function plot b) Fatigue life plot

Using the QCP, the mean life at normal load bearing (37 KN) is estimated to be 848,5as shown in figure 5,a. The term BX is derived from the terminology used by bearing manufacturers, specifically the B10 life. B10 life refers to the time by which 10% of the bearings would fail (figure 5.b).

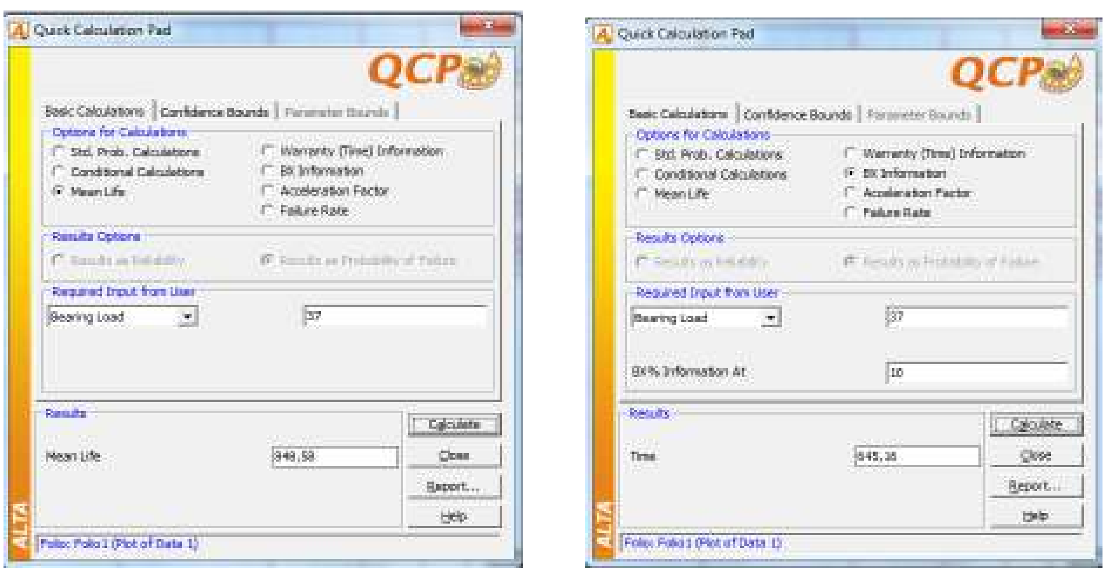


**Figure 5:** Reliability indicators of roller bearings type NN3020
a) Mean life b) B10 life

## 3. FINITE ELEMENT METHOD

FEM consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction [4]. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEM may be used to help determine the design modifications to meet the new condition. A variety of specializations under the umbrella of the mechanical engineering discipline (such as aeronautical, biomechanical, and automotive industries) commonly use integrated FEM in design and development of their products. Several modern FEM packages include specific components such as thermal, electromagnetic, fluid, and structural working environments. In a structural simulation, FEM helps tremendously in producing stiffness and strength visualizations and also in minimizing weight, materials, and costs. FEM allows detailed visualization of where structures bend or twist, and indicates the distribution of stresses and displacements. FEM software provides a wide range of simulation options for controlling the complexity of both modeling and analysis of a system [1].
This paper presents finite element analyses that are being used to analyze and estimate the structural performance of cylindrical roller bearings used Ansys 14 software. The focus of fatigue in ANSYS is to provide useful information to the design engineer when fatigue failure may be a concern. Fatigue results can have a convergence attached. In figure 6.a, safety factor of the cylindrical roller bearings is described. Several options such as accounting for mean stress and loading conditions are available. In figure 6.b, the total deformations of the cylindrical roller bearings are described.

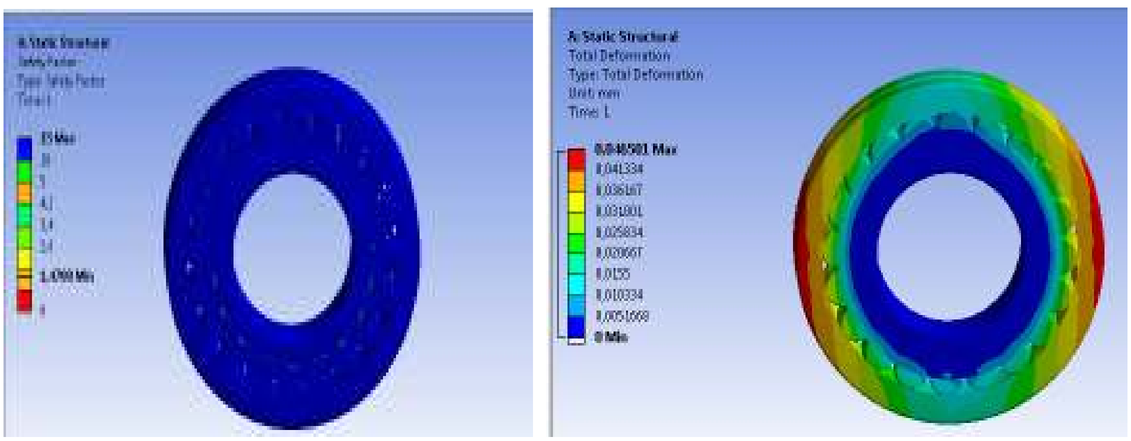


**Figure 6:** Finite Element Analysis of the roller bearings type NN3020
a) Stress Life b) Total deformation

Equivalent Strains (figure 7.a) and Equivalent (von -Mises) stress (figure 7.b) is described in the following picture. The equivalent stress is often called the "Von Mises Stress" as a shorthand description. It is not really a stress, but a number that is used as an index. If the "Von Mises Stress" exceeds the yield stress, then the material is considered to be at the failure condition.

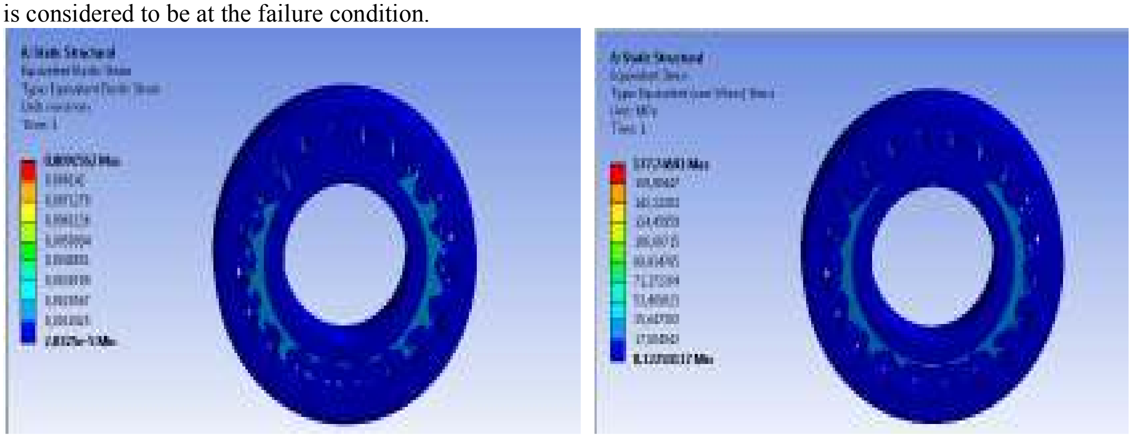

**Figure 7:** Finite Element Analysis of the roller bearings type NN3020
a) Equivalent elastic strain b) Equivalent Stress

Assessing fatigue damage is critical in almost all industries. Various sources have estimated that as much as 90% of all structural failures have a fatigue mechanism. In addition, fatigue damage is cumulative and difficult to detect, so fatigue failures can be catastrophic. Design Life uses finite element results along with a loading history to predict fatigue damage. ANSYS Design Life has a state-of-the-art complement of CAE durability tools, including stress-life fatigue, strain-life fatigue and crack-life analysis engines. Fatigue analysis (figure 8.a and 8.b) helps designers to predict the life of a material or structure by showing the effects of cyclic loading on the specimen. Such analysis can show the areas where crack propagation is most likely to occur. Failure due to fatigue may also show the damage tolerance of the material.

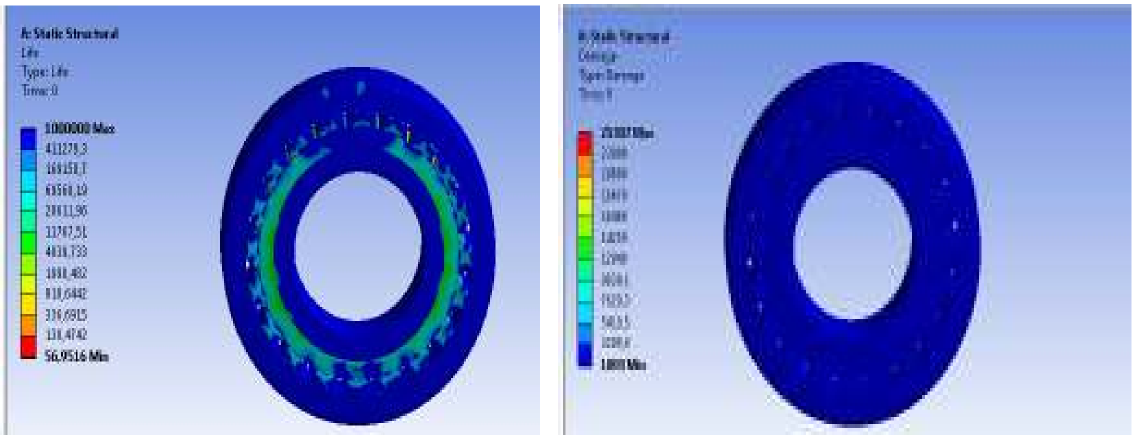


**Figure 8:** Finite Element Analysis of the roller bearings type NN3020
a) Fatigue life b) Damage

## 3. CONCLUSION

To meet increasing competition, get products to market in the shortest possible time, and satisfy demanding customer expectations, industry is turning to sophisticated methods and techniques of testing. Many of today's products are capable of operating under extremes of environmental stress and for thousands of hours without failure. Traditional test methods are no longer sufficient to identify design weaknesses or validate life predictions. Accelerated experiments is an approach for obtaining more information from a given test time than would normally be possible. It does this by using a test environment that is more severe than that experienced during normal equipment use. Since higher stresses are used, accelerated testing must be approached with caution to avoid introducing failure modes that will not be encountered in normal use. By using the accelerated experiments and the FEA analysis on the roller bearings type NN3020, the failure times were reduced by 10 times, this result entails also significant reductions of material costs. For this reason we opted for the accelerated experiments and finite element simulations. FEA is now a convenient and speedy tool for approximation of the solution to a wide variety of complicated engineering problems across a wide range of industries.

## REFERENCES

[1] Alawadhi E. M., Finite Element Simulations Using ANSYS, CRC Press, New Jersey, 2009.
[2] Changsen W., Analysis of Rolling Element Bearings, Wiley, New York, 2005.
[3] Klyatis L. M., Accelerated Reliability and Durability Testing Technology, Wiley, ISBN 978-0470454657, New Jersey, 2012
[4] Nelson W.B., Accelerated Testing: Statistical Models, Test Plans, and Data Analysis, Wiley, New Jersey, 2004.
[5] Rao S. S**.,** The Finite Element Method in Engineering, Elsevier, New York, 2005.
[6] Zaharia S.M., Martinescu I., Reliability Tests, Transylvania University Press, Brașov, 2012.
[7] http://www.weibull.com/