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AFASES 2015
Brasov, 28-30 May 2015

RELIABILITY AND STATISTICAL ANALYSIS OF THE FATIGUE LIFE OF THE TAPERED ROLLER BEARINGS

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Abstract: *This paper presents the results of the reliability analysis and fatigue life on tapered roller bearings. Consider the aspects regarding the statistical analyzing of data we determined the main reliability indicators, which in turn determine the main characteristics regarding the performance and the warranty period of the tapered roller bearing. The obtaining information regarding the reliability of tapered roller bearings is usually done either by following the behavior of the products during operation or during the reliability tests.*

Keywords: *tapered roller bearing, reliability, fatigue life, reliability indicators*

1. INTRODUCTION

The selection of the proper bearings for all mechanical systems is essential to the functional and commercial success of that system. The bearings must not only be of the right type, but also the correct size to assure reliability and cost effectiveness. The bearings must be installed properly, supplied with the correct lubricant, and provided with a compatible environment for the system to be successful. The number of revolutions under load determines the fatigue life of a rolling bearing that bearing experiences prior to the initiation of rolling contact fatigue. Because of the natural scatter of lives in a group of bearings operating under identical conditions, the life of the group is specified at some reliability level, usually 90% [1].

The obtaining information regarding the reliability of industrial products is usually done either by following the behavior of the products during operation or during the reliability tests. A reliability test is represented by an experiment performed to determine the parameters of reliability for a well-defined product. The main reliability parameters during reliability tests is mean time to failure (MTTF), knowing that, based on the existing relations between reliability parameters, they can be easily deduced from one in other [2].

The most used reliability tests are the following [3]:

• Complete tests (type n out of n) - in these tests n products of the same kind, the experiment being considered finished when all of the n products have failed. This kind of tests can't be applied in all the situations, because in the case of expensive products is uneconomical, and in the case of products that have a relatively long life time by nature, the experiment will take too long.

• Censored tests (type r out of n) - are commonly used and they consist of subjection to testing of n products of the same type, the experiment being considered finished after the failure of r<n tested products; obviously, the r number is previously determined, usually by technical, economical and statistical considerations. At this type of experiments, the testing duration is random, because it's unknown when the r-th product will fail; the information here is incomplete, because in the end we will have only r, instead of n experimental data

• Truncated tests (with a fixed testing time) - a n number of products are subjected to testing, but the experiment doesn't stop according to the number of failed elements, but according to a tr time, previously set, a period during which the testing takes place. After this testing time (previously set) has passed, the experiment is considered finished.

The reliability of bearings depends on [4]:

- The design, which can be elementary, for normal requirements of reliability, and optimized, for certain operating conditions;

- The materials being used, this can present changes of the chemical structure, of the micro or macrostructure, in relation to the recommended specifications, with consequences on the product;

- The technology of execution, which, despite all the details and recommendations associated with the modern technologies for ball bearings, the complexity of the systems, machines, devices, tools and testers, because of the difficulties of continuous qualification of the personnel, still leaves room for errors, out of which the majority are eliminated through automatic control, the forced regime of adjustment leading to the reduction of the capacity of resistance at contact fatigue;

- The montage, which often weighs in with multiple factors of disturbance of the reliability;

- The operation conditions (the variations in load, the number of revolutions, the temperature, the contamination or aging of the lubricant, the humidity conditions), which manifest their influence in extremely complex ways.

2. EXPERIMENTAL SETUP

The reliability tests realized on 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. Therefore, the methodology of accelerated testing of the ball bearings represents a complex process, which takes place in several stages (figure 1) [6].

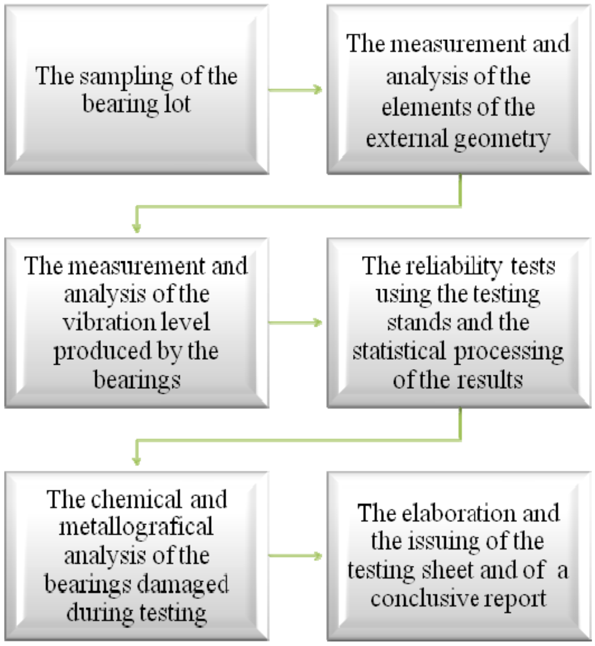

Figure 1. The testing methodology of the bearings

Table 1 describes the geometric and constructive aspects of the tapered roller bearings type, used for the reliability testing [5].

Table 1. The characteristics of the tapered roller bearings type 30205

Type	Tapered
Cage Material	Steel
Dynamic Load Rating	33.5kN
End Type	Open
Fatigue Limit Load	3.45kN
Inside Diameter	25mm
Limiting Speed	13000rpm
Material	Metal
Number of Rows	1
Outside Diameter	52mm
Race Width	16.25mm
Reference Speed	11000rpm
Roller Bearing Type	Taper
Static Load Rating	33.5kN

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The tapered roller bearings type 6205 2RS are described in figure 2.

Figure 2. Tapered roller bearings type 30205

3. RELIABILITY AND STATISTICAL ANALYSIS

For the results obtained from the reliability testing of the tapered roller bearings for the use level stress (30 bars) we verified the hypothesis that the distribution law of the hours is Weibull (the Kolmogorov - Smirnov test was used). For this verification, we measured the spacing between empirical distribution function of the sample and the cumulative distribution function of the reference distribution. We compared these results with a level of confidence of the Kolmogorov – Smirnov test. Following the statistical processing of the experimental data for levels of stress the Weibull distribution was accepted (figure 3).

Goodness of Fit - Details [hide]

Weibull [#59]

Kolmogorov-Smirnov

Sample Size Statistic P-Value Rank	15 0.12328 0.95523 27				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	0.26588	0.30397	0.3376	0.37713	0.4042
Reject?	No	No	No	No	No

Figure 3. Kolmogorov-Smirnov Goodness-of-Fit Test

After the introduction of data into the Weibull 9 software program (figure 4), we calculated the parameters corresponding to the Weibull distribution by using the maximum likelihood estimation method. For the data resulted from the reliability testing of the tapered roller bearings, the two determined parameters have the following values: shape parameter β=2,679; scale parameter or characteristic life η= 1569.

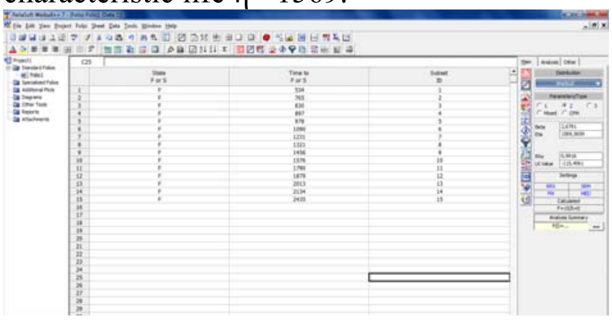

Figure 4. Introduction dates in Weibull 9 software

The basic reliability indicators followed during the reliability tests of the ball bearings are: B10 line, the mean operating time, the reliability function, the unreliability function, the failure rate, the probability density function [6]. Reliability/unreliability function is described in figure 5 and figure 6.

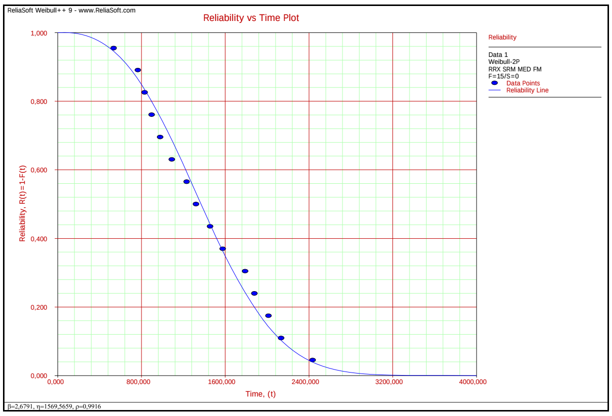

Figure 5. Reliability function

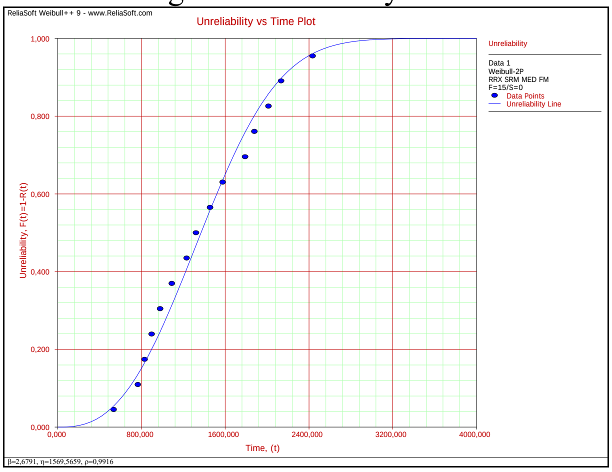

Figure 6. Unreliability function

Following is a plot of the probability density function - pdf 2D (figure 7) and 3D (figure 8) for our data, using the Weibull distribution.

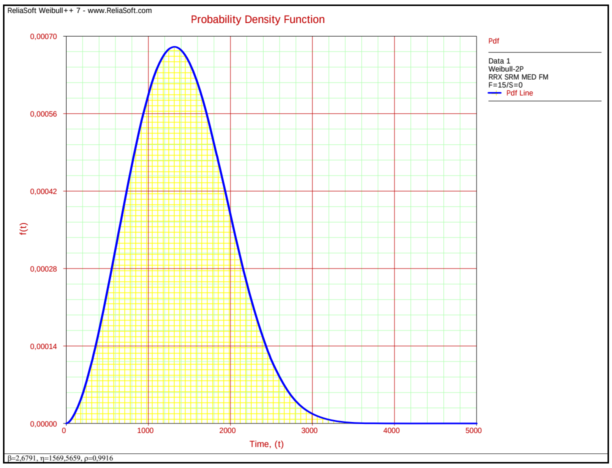

Figure 7. Probability density function

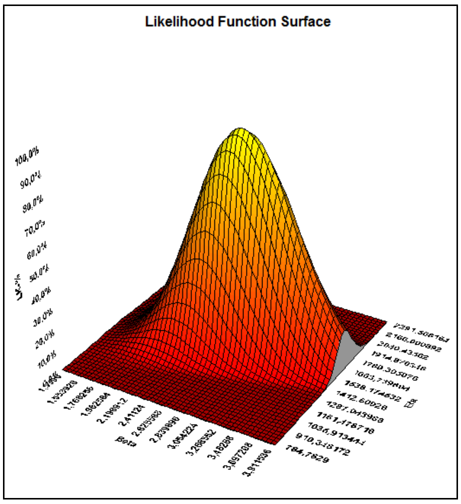

Figure 8. Probability density function – 3D

The number of failures per unit time that can be expected to occur for the tapered roller bearings is failure rate (figure 9).

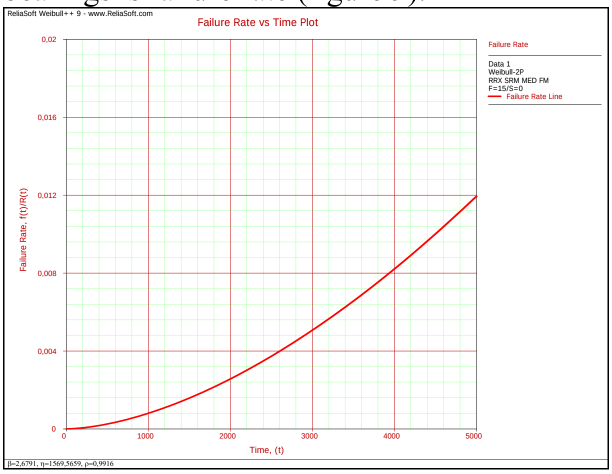

Figure 9. Failure rate plot

MeanLife (figure 10) is the average time that the tapered roller bearings in the data are expected to operate before failure.

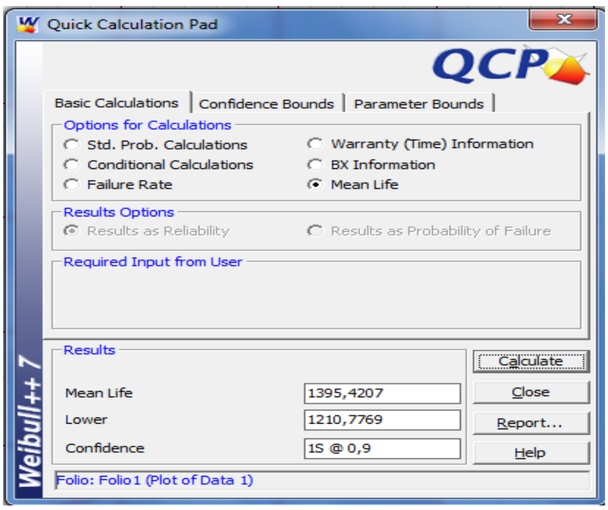

Figure 10. Fatigue life of tapered roller bearings

The BX (figure 11) 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.

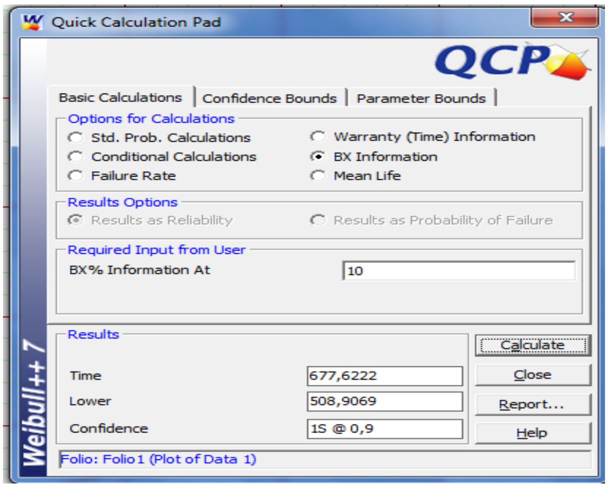

Figure 11. B10 life of tapered roller bearings

F/S Timeline plot (figure 12) displays the values for each failure and suspension of tapered roller bearings.

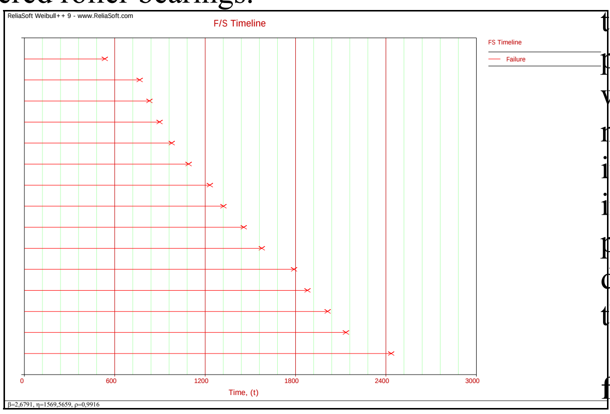

Figure 12. B10 life of tapered roller bearings

Histogram plot (figure 13) shows the number of failures/suspensions at a given time interval. Users can set the time interval at the control panel.

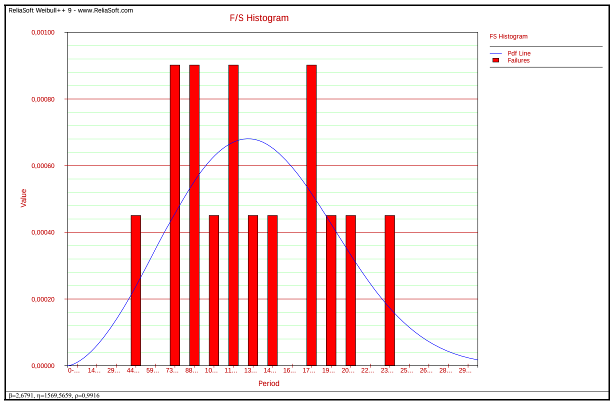

Figure 13. B10 life of tapered roller bearings

4. CONCLUSIONS & ACKNOWLEDGMENT

Many of the industrial products produced today for complex technical systems have very high reliability under normal use conditions. The main purpose of the reliability tests is to determine the reliability indicators for use level. The reliability tests have a great importance, aiming either to determine, either to check the reliability characteristic of a product, if this is established in a predictive way. The reliability tests are extremely necessary and they have a decisive role in improving the technical solutions and in increasing the performances. The essential problem of reliability tests is the testing duration, which is generally comparable with the product's useful lifetime.

We hereby aknowledge the structural founds project PRO-DD (POS-CCE, O.2.2.1., ID 123, SMIS 2637, ctr. No 11/2009) for providing the infrastructure used in this work.

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