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LabTecta Life Expectancy

Predicting Product Life Expectancy of the LabTecta Bearing Protector

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This article examines the statistical life expectancy of the LabTecta bearing protector, supplied by AESSEAL over a seven year period. The LabTecta is an IEEE 841-2001 and API-610 Ed10 certified non-contacting labyrinth bearing seal containing an integral self-adjusting shut-off valve. This shut-off valve prevents moisture contamination of rotating equipment in both operational and stand-still (idle) conditions. The statistical assessment was conducted using Weibull-based WeiBayes techniques. The results demonstrate that the LabTecta life expectancy is in excess of 100,000 hours, which far exceeds typical bearing L10 life expectancy. The analysis is based on methods used to predict failure/product reliability by examining product design and, more specifically, product wear parameters. However, since the only failures ever experienced were due to installation errors (i.e. not design or wear related) the results must be viewed as conservative. The work demonstrates how it is possible to verify that the expected product life predicted during testing is in close agreement with statistical product life predictions based upon actual performance of devices in field service. It further demonstrates that a properly installed and operated non-contacting LabTecta bearing protector can have an infinite life expectancy.

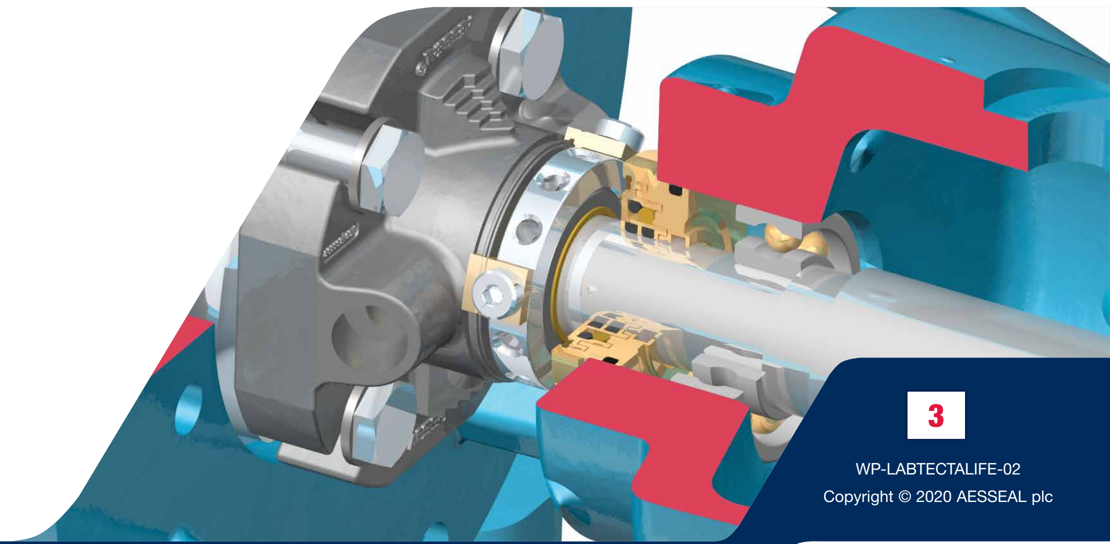
Objective

The objective of this analysis is to statistically determine the life expectancy, hence product reliability, of the LabTecta bearing protector based upon field service performance data. To that effect, the co-authors used widely accepted probability techniques.

1.0 Introduction

Mechanical reliability can be defined as the probability that a component, device or system will perform its prescribed duty without failure for a given time when operated correctly in a specified environment. One of the most efficient reliability prediction tools used for failure analysis is the Weibull analysis. This tool statistically models component failures, even with small samples of failure data. It is primarily used for failure analysis of mechanical components for which good age-to-failure data are available. The quality of its evaluation largely depends on the quality of the failure data that are used. It requires data tracking (e.g., monitoring the time to failure) for a specific component.

Another probabilistic model for failure analysis is the WeiBayes analysis (described by Nelson, 1985). This is often used for preliminary design when there is little or no failure data on the new design. This method may be used to estimate the Weibulls for the new design. When the number of failures is extremely small and there is good prior knowledge of either the slope (known from prior experience), or component average life (known from accelerated life test), the WeiBayes is more accurate than the Weibull.



Failure data used for Weibull and WeiBayes analysis are always known as life data. These life data are special in the sense that the "ages" of the parts that are failing must be known. The "age" may be operating time, starts and stops, landings, takeoffs, low cycle fatigue cycles, mileage, shelf or storage time, cycles or time at high stress or temperature or many other parameters. The appropriate aging parameter is usually seen easily from the physics of the failure mode, but sometimes there may be confusion. Without engineering knowledge to tell which aging parameter is best, the choice is determined from Weibull plots of the alternatives. The best aging parameter is the one with the best fit compared to a straight line.

Sometimes the life data for the best aging parameter are not available. However, when the best aging parameters are not available, the calendar time between production acceptance and return due to warranty claim may be the only data available (Abernethy, 2006). These data are called "dirty data" because they have deficiencies. The Weibull plot against calendar time will be a poorer fit and have more uncertainty than the (unobtainable) plot against the best aging parameter. A measure of goodness of fit will determine if the calendar time Weibull plot may be useful. As Weibull analysis becomes more widely accepted, the quality of the data usually improves because management recognizes the cost effectiveness of good data. Failure data are acquired in two ways. These data are acquired from either the customers using the products or carrying out accelerated life tests (Nelson, 2004). These accelerated tests are usually conducted on the components beyond their design life in order to uncover the unknown failure modes as well as estimating the components average life.

A report was first published approximately two years after the LabTecta product launch and it was based upon the data available at that time. Since the original report there has been a significant increase in the number of LabTectas sold and hence this revision takes into account all of the latest data available. To further add to the quantities supplied is the fact that there have been no reported wear or design type failures for the product, thereby endorsing and supporting the assumptions made in the original report.

The operational performance (time before failure in most cases) of nearly all components can be described by either the log-normal or Weibull probability density functions (pdf). The pdf describes how the percentage of failures is distributed as a function of operating time. The traditional way of plotting probability of life data can be described as follows:

1. Acquiring good failure data

2. Ranking the data - rearranging the data so that the earliest failure is listed first and the latest failure is last.

3. The plotting position is then calculated with the equation below:

$$P = 100\left(\frac{i-0.5}{n}\right)$$

(Eq. 1)

where n is total number of failures at a specific failure mode and i is the median rank.

4. Plotting P versus the failure time (age) for a specific failure mode on an appropriately scaled graph paper (either logarithmic or Weibull). The time scale is always logarithmic while the vertical scale, which is the proportion of the units that will fail up to age (t), is always in percent.

From the Weibull plot, three parameters are identified. These are the slope or shape parameter (β), the characteristic life or scale parameter (η) and the threshold parameter (λ). Each of the parameters has a specific function. The slope shows which class of failures is present. The slope values that classified the failures into different failure classes are:

$\beta < 1.0$ indicates infant mortality

$\beta = 1.0$ indicates random failures (independent of age)

$\beta > 1.0$ indicates wear-out failures

The characteristic life is defined as the age at which 63.2% of the units will have failed and it scales the age variable. The threshold parameter is used to define a suitable zero point.

The Weibull cumulative distribution function (CDF), is shown in equation below.

$$F(t) = 1 - e^{-\left(\frac{t-\lambda}{\eta}\right)^{\beta}}$$

(Eq. 2)

Here, F(t) is the fraction failing and t is the failure time. When the threshold parameter is set to zero, equation 2 reduces to the 2-parameter Weibull equation popularly known as the standard Weibull equation. When β is greater than one, the rate increases with t and the mean-time-to-failure (MTTF) and characteristic life are approximately equal. The MTTF is an estimate of the average, or mean time until a design's or component first failure. It can be regarded as component average life. When β is less than one, the rate decreases with t. When β is equal to one, the rate is constant in which case the Weibull distribution equals the exponential distribution as well as the mean-time-to-failure (MTTF) being equal to the characteristic life.

WeiBayes is a one-parameter (η) Weibull. It has smaller uncertainties than the 2-parameter Weibull. Similarly, the 2-parameter (η and β) has smaller uncertainties than the 3-parameter (η, β and ג) Weibull. WeiBayes uncertainties are reduced by the prior knowledge of either the slope or component average life. It can be defined as shown in equation 3, below.

$$\eta = \left[\sum_{i=1}^{N} \left(\frac{t_i^{\beta}}{r} \right) \right]^{\frac{1}{\beta}}$$

(Eq. 3)

In equation 3, η is the maximum likelihood estimate of characteristic life, β is the slope, N is the total number of failures and suspension, ti is the time/cycles on unit ti and r is the number of failed units. WeiBayes offers significant improvements in accuracy compared to small sample Weibulls. It is helpful in treating situations with failures as well as without failures. When a situation without failures is considered, it is always assumed that the first failure is imminent, hence r is set to a value of one to avoid the denominator of the last equation being zero.

The LabTecta bearing protector is a non-contacting bearing seal, supplied by AESSEAL since 2005.

The LabTecta prevents: - the egress of oil / bearing lubricant, and

- the ingress of water/moisture vapour

in both equipment operational and idle (stand-still) conditions in accordance with the widely used and respected centrifugal pump specification API610, 10th Edition.

The LabTecta design is IP66 compliant to IEEE Std 841-2001 and BS EN 60034-5:2001 (IEC 60034-5:2000) and hence has been widely employed throughout the world to specify protected Electric Motors.

LabTectas have also been employed on all types of equipment including pumps, mixers, fans, blowers, pillow blocks, rolls and gearboxes in all industry sectors.

In order to provide an indication of LabTecta product life expectancy, the recorded product failures and issues data must be reviewed.

Over 120,000 LabTecta's were supplied during the period of this study. In that time fifty two have been removed from service and examined. These reports span a 92 month period between Jan 2006 and September 2013. The outcome of these detailed examinations was that any abnormality was found to be operator based including mis-installation and lubricant overfilling and therefore these failures are not attributable to the design of the product.

Table 1 details the recorded LabTecta returns between January 2006 and September 2013 (note that the first occurrence was in June 2006).

Year	Quantity Supplied	Number of Returns
2006	5182	5
2007	11721	1
2008	17714	5
2009	14245	10
2010	16925	8
2011	20993	7
2012	20132	6
2013 (Aug)	13785	10
Note: All reported failures were attributed to installation errors. None of the instances were design or wear failures.		

Table 1 - LabTecta Product Returns

The total quantities supplied and corresponding dates of the LabTecta seals supplied during this period are shown in Table 2.

From Table 2, it is known that 120,697 LabTectas have been supplied in the period from January 2006 to August 2013.

Date Supplied	Quantity Supplied							
Year / Month	2006	2007	2008	2009	2010	2011	2012	2013
January	193	923	1471	1400	1394	1797	1317	1909
February	164	646	1597	1223	1330	1870	1804	1848
March	580	859	1220	1075	1437	1591	2001	1718
April	345	878	1292	1003	1355	1573	1597	1436
May	314	134	1378	1131	1379	1601	1916	1820
June	594	952	2024	1261	1445	1911	1782	1712
July	436	1228	1969	960	1321	1585	1870	1780
August	454	1267	1544	1052	1374	1421	1604	1562
September	588	786	1365	1741	1389	2041	1197	
October	678	939	1637	1366	1190	1996	1914	
November	110	1937	1296	1166	1908	1991	1840	
December	726	1172	921	867	1403	1616	1290	
Total	**5182**	**11721**	**17714**	**14245**	**16925**	**20993**	**20132**	**13785**

Table 2 – Labtecta Seals Supplied from Jan 2006 to August 2013

Further supporting information that is deemed appropriate to project a life expectancy of the LabTecta product is the manufacturer's product test data.

From Test ref. PT00791, an accelerated life test was carried out which provided an estimate of the average life of the component. The average life estimated was 3865 days (92,760 hours, approximately 10.582 years). This was based on an equipment stop-start cycle of four times per day.

Using the above data, the objective of this article is to determine the LabTecta characteristic life and the slope.

With the available data, the Weibull analysis method is not applicable. The best applicable method is the WeiBayes analysis method. This method is applicable since an idea of the average life, number of failures, the supplied dates and quantities of the LabTecta seals produced during this period are known.

As stated the Weibayes method requires that there are a given number of failures where this figure is required in the method to calculation the characteristic life. In the case of the LabTecta there were no actual failure incidents and hence it was necessary to use the returns data as the basis for the calculation.

In order to solve this problem, an assumed initial guess of slope (say 0.0001), tolerance error of 5 (about 0.0002695%) with a minimum of 26 (half of the assumed 'failures') and maximum number of 130 failures (2.5 times) were taken. While it could be argued that adopting only one value is really necessary (i.e. the actual number of 'failures'), the approach adopted makes the assessment far more thorough and can be used to assess the stability of the verification process.

Number of Failures	Characteristic Life (Hours)	Slope
130	92765	10.88
104	92765	11.39
78	92765	12.06
52	92765	13.01
26	92765	14.69

Table 3-Characteristic Life & Slope Results For Failure Number Variations

Table 3 shows the results of the characteristic life and the slope as the number of failures varies. It can be deduced that the beta values are higher when the numbers of failures are small. There is not much difference in the characteristic life since beta values are greater than one; the characteristic life is approximately equal to the component average life as discussed in section two.

From the Weibull plot shown in Figure 4, the data resulted in a reasonably straight-line fit; hence it can be assumed that the data fit the Weibull distribution well.

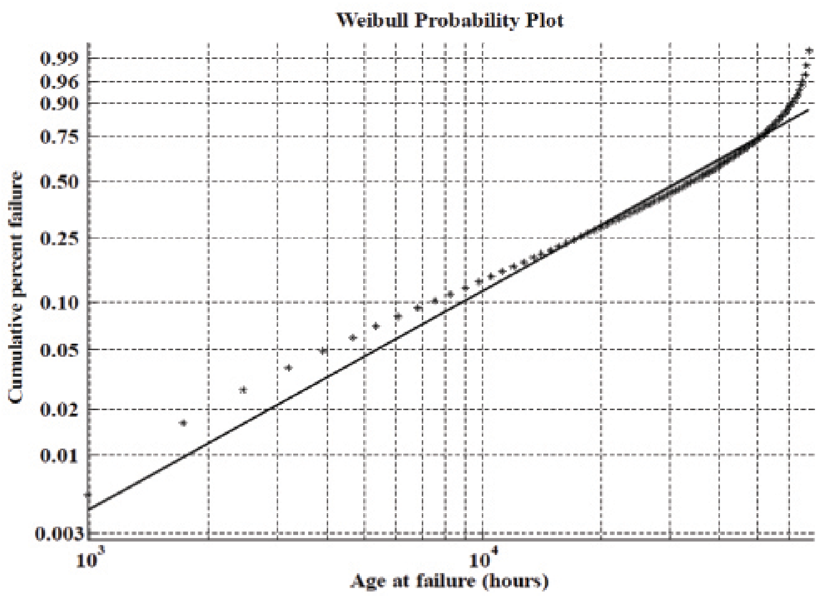


Figure 4 - Weibull Plot when WeiBayes method was used

From the statistical analysis, the ETA (point where 63.2%) of the items in service will have) = 92765 hours (10.6 years). This was in close agreement with the life predictions from the accelerated wear tests conducted during development.

The β slope (also known as the shape parameter) from the statistical analysis was 13.01 for 52 failures (occurrences). Its value represents which class of failures is applicable (see section 2) to the data. There are three classes of failures; infant mortality failures (slope less than one), random failures (slope equal to one) and wear out failures (slope greater than one). The slope obtained from the analysis of the 120,697 LabTecta seals supplied from 2006 to 2013 is 13.01. This value indicates that the reliability of the device in service is high and the trends indicate that this value would be expected to increase over time.

As stated, these results are deemed to be conservative because none of the failures (occurrences) received and examined had exhibited any seal design failure characteristics. This life prediction thus estimates the “installed failure probability”, which is actually representative of the probability of operator and equipment errors.

Table 1 provided failure details, all of which were installation issues. Given that some were radially misaligned and others had excessive axial movement, none of these can be classified as design issues. Similarly, inspection of the returned parts showed that there were no signs of wear (despite the misalignment). This both endorses the non-contacting design principle of operation and also means that the failure mechanism is not wear related.

The classical Weibull analysis attempts to predict failure/product reliability based on “product design”, more specifically “product wear”. For a product to fail due to wear reasons, it must have wearing parts within its construction. This dictated that a suitable modified statistical approach was adopted.

The LabTecta is a non-contacting bearing seal design. While operating in a correctly installed application, the LabTecta parts are designed so as not to contact each other. If the parts do not contact each other, they cannot wear. Therefore, life expectancy exceeds 20 years, which is often regarded as infinite on equipment parts. In any event, it most certainly exceeds that of wear-prone parts of rotating equipment, such as the rolling element bearings selected using customary L10 life ratings.

The static shut-off valve of the LabTecta is the only part designed to engage the rotor and stator when the equipment is idle. It is designed to disengage the stator when the equipment is operational. One could theorize that in the split second, before said part disengages, wear could take place.

As with all “wearing” parts and in the case of the LabTecta, correctly designed sealing surfaces and materials of construction will influence the wear rate. Furthermore, is it widely accepted that wear rates are not linear. It is the authors' experience in a conventional wearing assembly, such as a mechanical seal face, the wear rates reduce over time.

This article demonstrates how it is possible to verify a conservative life expectancy for a product using different methods. Firstly an average life of over 10.5 years was predicted from the results of an accelerated life test. After a reasonable period after product release had elapsed this data was then combined with field performance and units supplied over this period so that a LabTecta average could be devised using an established statistical (WeiBayes) technique. In this study the data points were a good fit with the characteristic curve thereby indicating good correlation with the statistical approach adopted. The two approaches (experimental and statistical) were in good agreement.

The reliability of most rotating equipment is almost inevitably linked directly to bearing life. One of the primary factors that influence bearing life is the quality of the lubricant or how it deteriorates over time. Clearly contamination has a direct bearing on lubricant quality and hence the life of the bearing protector must be at least equal to that of the bearing.

Certain approaches (ISO 281) allow for 'like adjustment factors' to be adopted that account for lubricant integrity. These factors tend to reduce bearing life as conditions deviate from ideal conditions. One such factor is the contamination level where the amount of debris contained within the lubricant is assessed and assigned a value which is then equated to the calculation and the bearing life is reduced. The significance of this being that the integrity and reliability of the bearing protection device will strongly influence the lubricant contamination and hence provide justification for using a non contacting device that cannot deposit wear debris into the lubricant.

Contamination of lubricants can reduce bearing life just as certain additives can extend bearing life (through reduced metal fatigue, scoring and galling). Since the LabTecta is non-contacting it has no wear and hence no debris can enter into the lubricant from the device. In contrast other types of bearing protectors with contacting elements suffer wear and degrade (i.e. lose material) during operation this contaminating the lubricant.

A further advantage when using proven bearing protection technology is that the periods between scheduled maintenance can be increased due to the improved operating condition of the bearings.

Given that so many reliability studies focus on Mean Time Between Failure (MTBF) one feature of improved bearing protection integrity and prolonged bearing life may mean that MTBF actually develops into Mean Time Between Maintenance (MTBM) and the terms "confidence" and "reliability" start to be used together.

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Dr. Chris Carmody PhD, MSc BEng (Honors) started his career as a maintenance engineer in the chemical and process industry and joined AESSEAL as the companies first full time seal designer and development engineer. Chris went on to academia for a bachelors degree, a master of science in structural integrity and doctoral degree on the fluid structure interaction of bioprosthetic heart valves. He re-joined industry as a Consulting engineer and worked on many prestigious projects such as the A380 Airbus, the award winning Falkirk wheel and the new Wembley stadium. Chris returned to AESSEAL and took up the position of special products manager where he is responsible for development of high integrity sealing projects including dry gas seals. He now has 25 years of experience in the design of mechanical seals and is a named inventor on many of AESSEAL product designs. In addition to his responsibilities at AESSEAL he also sits on several different bodies including the API692 Compressor Dry Gas Seal Committee.

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