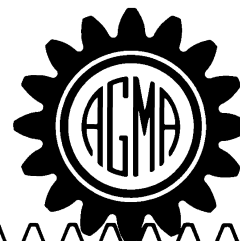


How to Determine the MTBF of Gearboxes

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American Gear Manufacturers Association



TECHNICAL PAPER

How to Determine the MTBF of Gearboxes

Dr. Gerhard G. Antony, Neugart USA LP

[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

Mean Time Between Failures (MTBF) became a very frequently used value describing reliability of components, assemblies, and systems. MTBF was originally introduced and used mainly in conjunction with electronic components, and systems. The definition and application of the MTBF for mechanical components is not broadly available, used, or recognized. There is no clear standard which would describe how to determine for instance the MTBF of a gearbox. On the other hand, more and more customers and consultants are requesting an MTBF number from the manufacturer for mechanical devices, such as a gearbox. Electronic components of modern drive-trains generally consist of an electronic controller and electronic drive, motor and gearbox. The drive / controller manufacturer normally has an MTBF value, so do meanwhile some motor manufacturers supply MTBF values for their product. In the field of gears it is difficult to obtain an MTBF from the manufacturer due to the lack of applicable, generally recognized definitions and standards. The paper shall evaluate, compare and suggest ways in determining a gearbox MTBF based on the already established, proven, design, calculation standards and test methods used in the gear design.

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Introduction

In the past decades, “Mean Time Between Failures” (MTBF) has become a very frequently and broadly used characteristic measure of reliability for components, systems and devices used mainly in conjunction with electrical and electronic equipments.

From the engineering point of view, assessing the life and reliability of products is a vital part of product design, development, and selection. Life and reliability of a product are also important characteristics for the user (customer) in comparing the widgets (gearboxes) to assess their useful value or life for a certain application. The reliability of a product becomes a frequently used marketing and sales feature.

The life characteristics of different products and components depend of a wide range of factors from type and condition of material to type of exposure to loads, magnitude of the loads and other effects such as environment. Products are designed for a certain purpose, function, duty, load etc. The life and reliability is a characteristic statistical value and it can be only approached and assessed by statistical methods.

Today an increasing number of manufacturers combine a mechanical device, such as a gearbox, with an electromechanical, such as an electric motor, and electronic drives, logic controllers sensor into a compact integrated “mechatronics” product. The (Mean Time Between Failures) MTBF value of many electronic components and systems is obtainable from the manufacturer. The design life of mechanical components and systems is mainly based on the endurance characteristics of the components on the statistical life expectancy under a certain load such as the L10 design life. Can the reliability of a mechanical device such as a gearbox be expressed in terms of MTBF? How many hours MTBF equals a known L10 life to? The here presented paper is an attempt to find some answers for these and similar MTBF related questions.

Life and reliability related issues are based on tests, observation of populations of “widgets” applying

mathematical (statistical) evaluations, approximations, using appropriate functions and formulas. It is common practice to define characteristic values, and choose “scientific” statistical methods to analyze and evaluate them. It is fairly easy to define certain characteristics of selected number of test specimens apply statistical methods on an observed population/group and come up with a “scientific statistical conclusion”. However to have realistic, meaningful conclusions the definitions and the evaluation methods must be clear and transparent. This paper is an attempt to express the life and reliability of gearboxes in terms of MTBF without going into an in-depth discussion of statistical methods. As mentioned MTBF is a widely used characteristic value to quantify reliability of electronic components and systems, but it is not commonly used for reliability assessment of mechanical components and systems.

For the correct interpretation of the MTBF value it is necessary to understand some basic concepts of probability of failures and the methods of their evaluation.

Failure rate

The fundamental first step in determining the reliability and life of a widget is to observe a representative set of samples, a “population” of widgets and record the failures over a certain time frame.

The collected data will show a certain number of failures over an observed time period. An absolute number of failures has no real practical meaning; it always has to be related to the observed population size. This is expressed by the failure rate.

Failure rate is the relative frequency at which a component or system fails in a given time i.e., failures/minutes, hours, years or within a certain time related measure such as distance i.e., failures/miles (in automotive field), or per operating cycles such as failures in 1 million revolutions (bearings) etc. As we can see, it is not an absolute number of units failed but rather a relative number, related to the size of the observed tested number of units, population of products, see figure 1.

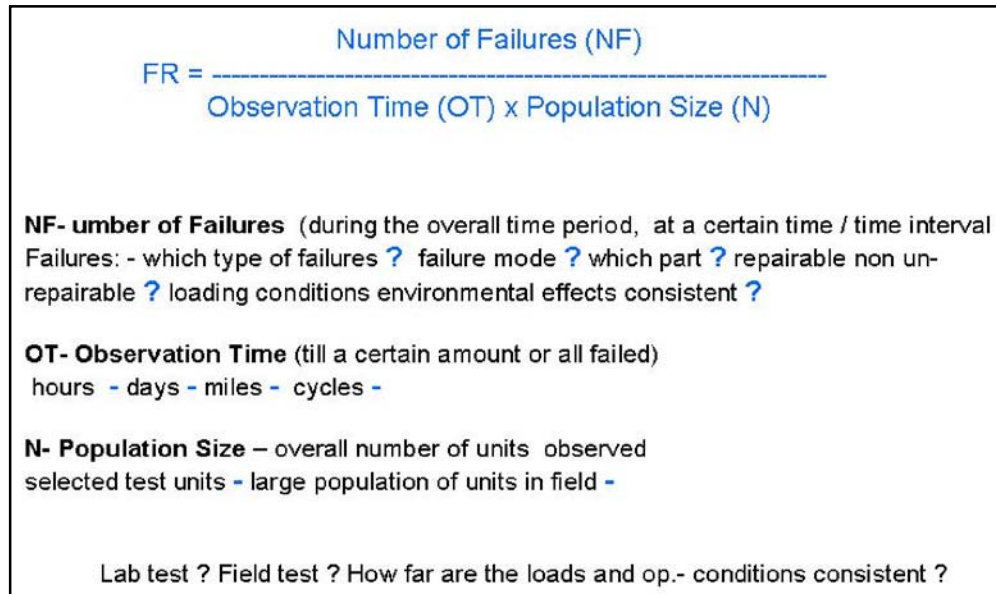


Figure 1. Failure rate, FR

It would be more exact to call it the “relative failure rate”; because the value is related to the overall observed population, it assumes a value between 0 (0% failures) and 1 (100% failures per hour). This relative failure rate can be recorded at regular time intervals (important in where we want find out if and how the failure rate is changing over the life time) or just record it for a predefined period such as the “design life” the widget, – this would mean, we assume that the failure rate is constant during this period.

Example iPod:

(– source: “AppleInside” July 27 2006 reporting, under headline “iPods built to last 4 years”)

“Apple spokeswoman Natalie Kerris recently told the *Chicago Tribune* that iPods have a failure rate of less then 5%, which she said is “fairly low” compared with other consumer electronics.

However, a survey conducted by “*Macintouch*” last year found that out of nearly 9,000 iPods owned by more than 4,000 respondents, more than 1,400 of the players had failed. The survey concluded that the failure rate was 13.7 %, stemming from an equal mix of hard drive and battery related issues”

Remark:

Based on the numbers, the actual failure rate should yield to $FR = 1400/9000 = 0.155$ or 15.5% for the ob-

served time interval, which can be interpreted that $15.55\% - 13.7\% = 1.8\%$ failed for some other reason than the listed. Other explanations are also possible however the survey does not list any reasons.

Is Mrs. Kerris from Apple correct with the 5% value over the design life or are the conclusions of the survey with 13.7% correct?

Here are some important questions before we take sides:

Are both talking about the same type of failures? Does Apple consider the necessity to replace the battery a failure? How many units were surveyed by Apple? Is the population of 9000 samples in the survey representative? (Apple ships in excess of 10 million units a quarter.) What was the real usage time or reference time of both observations? Does the statement “built to last 4 years” means 4 years 24/7 usage, or for instance only 4 hours a day usage say 6 days a week (duty cycle)?

None of the above two failure rates gives any specific information about these important basic factors, neither about the conditions under which the data were collected. Let us assume that the survey was based on a 12 hour daily usage over a 2 year period, the failure rate, should be calculated as: