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Reliability Assesment of Mechanical Component under Loads of Extreme Fatigue Life Load

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Abstract: Failure of a component that due to extreme load events such as strong shock can affect the overall quality and reliability of the mechanical component groups. As such, the study needs to be done to draw the behavior of failure data using the fatigue life and reliability characteristics of extreme fatigue life failure statistical approach. This research involves in testing the fatigue life and cyclic strain fatigue life data generation using Monte Carlo simulation based on the parameters of probabilistic stress cycle curve and assesses the suitability of the life distribution for the reliability. An extreme fatigue life can be seen through a probability density function, cumulative distribution function and through reliabilities obtained. The contribution of this study is to introduce generalized extreme value distribution applications in the mechanical domain where overall comparisons found that the method using the Generalized Extreme Value (GEV) distribution is more flexible and satisfied the given failure of extreme life curve. This methodology is also expected able to predict the reliability and performance of mechanical components such as turbines in hydro power plant.

Key words: Reliability, generalized extreme value, hydro power plant, statistical, density

INTRODUCTION

The prediction of mechanical component reliability is among the important task that must be carried out to make sure the product is robust. In automotive industries that experienced a rapid development in terms of their design and innovation. By the way, vehicles manufacture with more persistent attempted forced to issue a high-quality vehicle and attractive compared with their nearest competitor (Shende, 2014). Good product quality is a prerequisite for high reliability products. Such as where the product quality, product reliability also is a major focus on customer satisfaction (Escobar and Meeker 2006). Products reliability is defined as components or systems perform the functions required for a particular period of time and operate under circumstances that have been established (Ebeling, 2004).

The reliability of a component is associated with a failure to function normally. The failure of a mechanical component is always associated with failure caused by fatigue life. The fatigue life of a component is influenced by many factors, including material specifications, operating environment and testing, manufacturing methods and component geometry (Bedkowski, 2014). Failure mechanisms that cause component failure is extreme stress, fatigue fracture and others. Since fatigue is the most important parameter to be controlled in relation to the life so the relationship between fatigue life and reliability under specific operating conditions must be established to assess the reliability of components. Generally extreme shock load or unusual power can cause severe damage to vehicle components and provides a huge impact on the determination of the fatigue damage (Wannenburg, 2007).

The extreme loads should be taken into account in any process simulation. Events like this are rare in comparison of regular tremor or random forces that arise during driving of a vehicle but it cannot be ignored altogether because it can also contribute to the failure of a component. There are studies that have been done on mechanical components which showed that the scattered component fatigue life caused by factors inherent physics of materials conform to distributions normal, lognormal and Weibull (Han *et al*., 2015; Safdar and Ahmed, 2014; Schijve, 2015; Bedkowski, 2014).

Monte Carlo simulation has been used to generate large amounts of data that have the same criteria with the original data. According to Zaretsky *et al.* (2007) Monte Carlo simulation can result in the estimated useful life similar to real life as has done to study the reliability of the fatigue life of sixty four unit turbo-prop box and refers to (Liu and Mahadevan, 2015) life fatigue life generated by

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Monte Carlo simulations can be plotted and matched by a probability distribution. After the distribution of the best fit is obtained, then it is easy to calculate the probability of the number of cycles of different loads. A complete set of rules was necessary in the early stages of design to assess the fatigue life of components using the data reproduction at Monte Carlo and diversify the suitability of fatigue life data to see patterns of component failure through a different distribution. There are several life distributions that is used to analyze the fatigue life of a component failure such as a lognormal distribution and the Weibull distribution. However, in this study the distribution of life possible matches will be introduced to analyze and address issues related to random failure include extreme value events that happened on the vehicle components that occur during its operation life.

MATERIALS AND METHODS

Referring to the experiments performed with the Proton Holding Berhad as shows in Fig. 1, the result of finite element analysis (finite element analysis) FEM can be found in the report entitled experiment results P211A Knuckle Vertical Fatigue SN Curve (Liu and Mahadevan, 2015). The materials used for the components of the steering knuckles are spheroidal graphite cast iron FCD500-7 of resilient material with high abrasion features and low thermal shock (Kim and Ji, 2006). The aim of cyclic loading in fatigue life test is to get the characteristics of the fatigue life of a component failure. For this purpose a sample of nine units of the steering knuckle have gone through five different stress levels.

In every group of steering knuckle that has been set in accordance with the stair-case method, three specimens were tested for each stress level for a lifetime probability of 10, 50 and 90%. Assessment of fatigue life of the steering knuckles was performed using nCode Glyphworks™ software. In this process the stress SN-life approach is used to assess the fatigue life of components in which the results of a test cyclic loading and fatigue life of the reaction components to service the load is its main characteristic. Fatigue life component assessment using SN approach is based on the results of fatigue life test in which the load of cyclic stress values versus the number of cycles to failure plot into a curve which is also known as the SN curve. It was found that the relationship between the load and cycle-to-failure of the steering knuckle is very important to look of its performance. This relationship plotted on a curve PSN using a Power Law. Some random variables available from the PSN curve is a random variable for the material components such as the location of the gradient changes that represent the fatigue ductility coefficient and stress level of random variables intercept representing the fatigue strength stress. Reliability software, Weibull ++ is used to generate the data generated using Monte Carlo simulation to the slope and the intercept of PSN curve obtained from the SN curve.

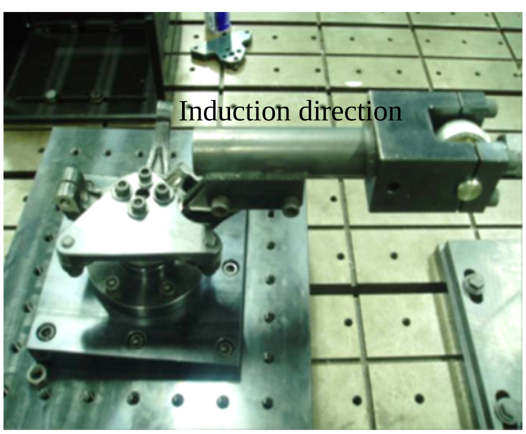

Fig. 1: Cyclic loading fatigue life test configuration

There are a total of five hundred random variable data was generated. These variables represent different SN curve which shows the diversity in the mechanical characteristics of the component concerned. For each value of the slope and the intercept of the curve of fatigue life of the PSN was derived using the Glyphworks software. In this study, cyclic loading fatigue life test conducted on the steering knuckle for data failures fatigue life. Cyclic loading fatigue life test was carried out according to JSME standard method which refers to stair-case method. Selection of distribution in fatigue life reliability assessment was intended to determine the most appropriate distribution to address the problem of estimating the reliability of a component failure caused by extreme fatigue life. Normal distribution, lognormal and Weibull distributions are three commonly used to analyze the fatigue life. Apart from the selected distribution, the other distribution which is characterized by extreme values which is Generalized Extreme Value (GEV) distribution was also identified to be analyzed together and was compared to determine the best distribution life.

RESULTS AND DISCUSSION

Probability Density Function (PDF) curve is obtained by distribution parameter values in which parameters are the shape and scale parameters for Weibull distribution and the location and scale parameter for lognormal distribution. The PDF curves are plotted against cycle to failure for each method of Rank Regression on X (RRX),

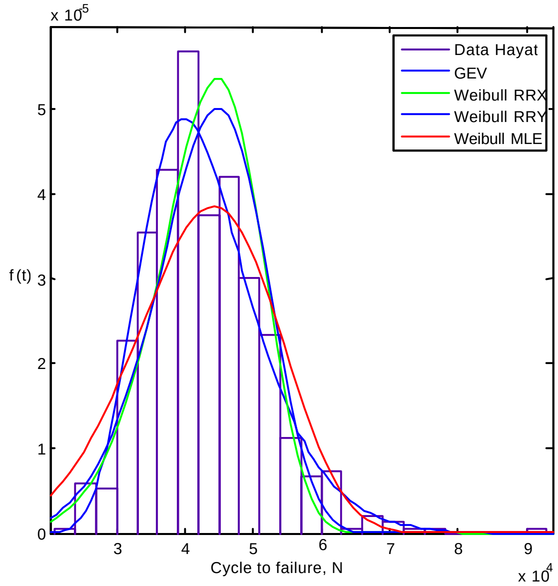

Fig. 2: Comparison PDF GEV with Weibull RRX, RRY, MLE

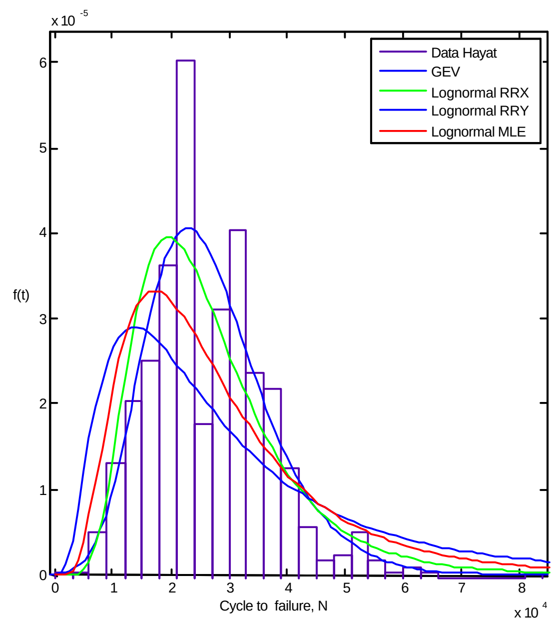

Fig. 3: Comparison PDF GEV with lognormal RRX, RRY, MLE

Rank Regression on Y (RRY) and Maximum Likelihood Estimation (MLE) for Weibull and lognormal distribution. Each of PDF plotted curve is paired with the scattered fatigue life extreme load range to see the best fit and also view the location as well as the distribution range of fatigue life at every cycle of his life. Distinction that in the overall analysis of the arches of this PDF is caused by the influence of parameters pertaining distribution.

The Generalize Extreme Value (GEV) distribution is influenced by the shape parameter, parameter scale and location parameters. Suitability of these methods to assess the fatigue life so it can be seen through the plot of PDF. From the PDF curve generated in Fig. 2 shows that the distribution is bell-shaped and there are positive slant.

The same figure can also be noted that on the left side of the PDF curve begin in the life cycle of a zero followed by the central region found that the PDF plot for GEV distribution is more balanced and commensurate with scattered fatigue life range as expressed by Alentorn Markose (2008) that GEV distribution is very flexible. PDF curves for the Weibull RRX distribution and MLE did not match with the scattered fatigue life range. In contrast, for the Weibull RRY distribution PDF curve is unbalanced and skewed to the right side. With this it is clear that the GEV distribution is more suitable to be used to estimate the reliability of components suffer from extreme fatigue life compared to the method of using the Weibull distribution RRX, RRY and MLE.

Figure 3 shows that is noted that at left side of the graph all PDF curve starts at zero but ended the life cycle of a different life cycle in which the GEV distribution of 7.4×10^4, the lognormal RRX at 8.5×10^4 while Lognormal RRY and MLE method had come off of the X-axis. The center also found that the PDF curve of GEV distribution is more balanced and commensurate with fatigue life scattered range while the PDF curves of RRX, RRY and MLE of the Lognormal distribution is unbalanced and skewed to the right side.

This means that the GEV distribution is more suitable to be used to estimate the reliability of components that experience extreme fatigue life load when compared with the use of the lognormal distribution RRX, RRY and MLE. Referring to Fig. 2, PDF curves of the Weibull distribution for all three methods of entering a negative part of the cycle of life plot probability density function is not perfect and cannot fully reflect the characteristics of the Weibull distribution and are among the factors that indicate the Weibull distribution is not suitable for analyzing component reliability that has extreme load.

Referring to Fig. 3, PDF curves of the lognormal distribution produced by the three methods were not much range and are distinguished by the scale parameter. Overall PDF curves of the GEV distribution shows a better match to the respect scattered life. In this case, a new application in the field of mechanical GEV distribution is attempting to address weaknesses of Weibull and lognormal distributions for matching failure fatigue life scattered data. PDF curves for Weibull distribution for all three methods are entering the negative life cycle and make a plot probability density function is not perfect and cannot be fully reflect the characteristics of the Weibull distribution and are among the factors which shows the Weibull distribution is not suitable for analyzing component reliability with extreme load.

PDF curve for lognormal distribution generated by the three methods are not many range and only distinguished by the value of parameter scale. Overall PDF curves for GEV distribution shows a better match to the life distribution. In this case, a new application of GEV distribution can address weaknesses of Weibull and lognormal distribution for analyzing fatigue life failure.

CONCLUSION

The evaluation of extreme value reliability was conducted using statistical functions such as Probability Density Function (PDF). A comparison between the Weibull, lognormal and GEV distributions through function is able to determine the best fit life distribution to analyze the data loading failures extreme fatigue life by looking at the shapes of the resulting curve function. Overall comparison showed that GEV distribution method is more elastic in conformity with the failure curve extreme life given. Accuracy is indirectly putting the GEV distribution as the most appropriate distribution in evaluating the reliability of the load of extreme fatigue life of the steering knuckle. With this evidently that the greatest contribution of this study is to introduce the GEV distribution applications in the mechanical domain such as turbines in hydro power plant.

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