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Research paper

Prediction of Automotive Component Load Configuration Using Best Fit Life Distribution

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Abstract

An extreme event such as strong shock resulting from a violation of the hole or a large object on the road can cause damage to vehicle components. As such, the study needs to be done to address the behavior of failure data using the fatigue life and reliability characteristics of extreme fatigue life failure statistical approach. The study also be done by developing a characterization of life distributions based data and configuration best match load to allow a generalized prediction. The research involves testing the fatigue life and cyclic strain fatigue life data generation using Monte Carlo simulation based on the parameters of probabilistic stress cycle curve. Features for all parametric distributions were analyzed by the method of maximum likelihood estimation (MLE) for the generalized extreme value distributions. Assess the suitability of the life distribution for the reliability of extreme fatigue life can be seen through a probability density function. This study found that the developed method capable of predicting the relationship between the load configuration and shape of the distribution of a component failure studied. This approach can contribute to reduced time of experimental testing which is an emphasis in the production process components. This implication provides a particularly significant impact on the development of the automotive industry and enhance the manufacturing sector.

Keywords: *Extreme fatigue life; Generalized extreme value; Load configuration; Reliability*

1. Introduction

In addition to accepting random forces as a result of driving conditions, roads and environments, the resistance of the vehicle components is also influenced by the load of carrying with him as discussed by Nor Fazlina & Badrul Kamal (2011). This load is always variable depending on the user of the vehicle where at times there is only one driver and at times there are five people who can certainly differentiate their driving controls. Likewise, cargo load carried by heavy vehicles can also affect the performance and life of the vehicle's component. Overloaded vehicles can cause dangers to road users. All vehicles are designed and manufactured to fit certain stress levels and if they exceed the stress level then they may cause sudden failure to the key components such as brakes, wheels, hangers and steering systems (NHTSA Summary Report, 1997). It is therefore important to analyze the performance of the components involved by taking into account the load carried by the vehicle.

According to Tang & Zhao (1995), the reliability of a component, strength or fatigue is as a random variable that can be obtained when the diversity has been determined. In the automotive design process, as with any other design process, diversity and uncertainty in operating conditions and characteristics of the engineering system have led to its performance is erratic. Therefore, engineers and researchers in the automotive industry should seek quality issues from multiple disciplines. All these quality issues have been influenced by uncertainties in the load, materials and manufacturing processes that make quantitative assessments more complicated. There is difficulty in evaluating the reliability because the evaluation is only possible after the product is ready to be molded or assembled, which is then tested for durability either in the laboratory or in the testing field. However, developments in the use of computerized statistical methods as tools for understanding, improving and maintaining, make product reliability evaluation is more accurate. More reliability prediction models are developed using computers which can reduce dependency on expensive physical experiments. In most cases, mechanical component failure resistance depends on the durability test detected at the production stage in the manufacturing industry.

2. Problem Statement

The quality improvement of a product is very important and it is a challenge to ensure the product is always ahead of other competitors. Accordingly, product manufacturers need to look at the entire production system and look for improvements that can be done and enhanced to produce a higher product quality (Escobar & Meeker, 2006). In this study, the components' reliability is related to the failure of fatigue life that is affected by various external elements including extreme loads that can contribute to a failure of the component (Stephen et al., 2001).

Furthermore, a relationship between extreme life failure and load configuration should be developed through the best-fit life distribution. These life distribution parameters need to be studied with the load configuration so components predictability can be performed on different load weights without carrying out physical experiments. As is well known, experiments related to the improvement of the quality of an automotive component involve significant expenditures which include the purchase of equipment and experimental samples (Walpole et al., 2010). In addition, each component's reliability analysis usually taking a longer time to get the results. Therefore, it is important to identify every idea and approach that can solve the problem.

3. Background Components of Study

This study is based on the joints of steering knuckle as in Fig.1 of the McPherson hatch type used in the steering system for wheelchair racing.

Fig.1: Steering knuckle

Referring to the test conducted with the Proton Berhad, the finite element analysis of FEM be found in a test report entitled P211A Knuckle Vertical Fatigue SN Curve. This FEM analysis using bending sets of bending sine worms in the 6377 N range to 7848 N indicates the location of critical components as in Fig.2 (Proton Berhad 2010). In the same test report, the location of the critical stress encountered is closely related to the configuration of the knuckle steering joint system in which this component is attached to some other component. In this case, external forces act to the component as well as the factor of small surface area caused the stress to rely on the location of the corresponding item.

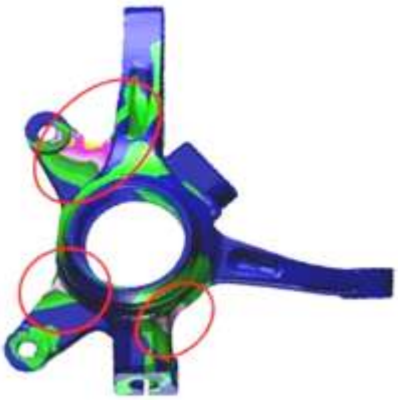

Fig.2: The finite element model and the location of the critical area
Source: National Automobile Company Bhd. 2010

4. Methodology

The actual operation of the vehicle is actually affected by its weight. Total carrying load has a significant impact on the performance of the vehicle and its components. Therefore, the appropriate test should be made to look at its component fatigue failure. The selected components are analysed to know the critical stage either at the maximum load condition or vice versa. For these purposes two types of cyclical load fatigue tests are carried out on a GVW called gross vehicle weight where data is called Gpave data while another group uses a load from a vehicle carries half loaded HW/Midladen halfway where data is called Hpave data.
According to the Dictionary of Military and associated terms. (2018), GVW is actual weight for vehicles that include weight without load, weight load and weight of passengers. Weight without load here is the weight that includes the weight of the vehicle with standard equipment, full tank fuel weight, full tank water weight and weight of equipment fluid. In this study, two heavy conditions are the weight of the fully-loaded GVW vehicles and the weight of vehicles carrying half HW/Midladen load used for fatigue life tests of cyclic load.
An analysis of service load configurations is also taken into account in this experiment to see whether this load configuration can affect the deflation of component fatigue failure. The actual service loads are obtained from the field test SWIFT (spinning wheel integrated force transducer). Vehicles equipped with this SWIFT system must first load with reasonable load according to the test carried out. Load for this test are known as service loads. Configuration of service load for a test against this vehicle uses a fully loaded vehicle called weight with GVW charge. Items that are weighted to this weight are replaced with an equivalent weight by using plastic bags contains sand made specifically for this test. Sandbags as shown in Fig.3 and Fig.4, are easier and faster to operate during testing than when compared with other weights.

Fig. 3: The sandbag (yellow) represents the weight of the passenger
Source: National Automobile Company Bhd.

Fig. 4: The sandbag (yellow colored) represents the load weight on the rear of the vehicle
Source: National Automobile Company Bhd.

The weight difference between GVW and HW is 200 kg, which equals the average weight of three adults, the weight of passengers in rear seats (Proton Berhad, 2010). The purpose of these two types of service loads is to see the configuration effects of component fatigue life cycle and to analyse any relationship that exists between the two.

5. Results and Discussion

Based on the fatigue life data generated by the curve parameter and gradient of the PSN curve the shape parameter value ξ, the

scale parameter, σ and the location parameter, μ of GEV distributions can also be obtained via MLE methods. The suitability of these methods for evaluating the subsequent fatigue life can be seen through the PDFs probability density functions. From the PDF curve generated in Fig.5 and Fig.6 it is found that the shape of the distribution is bell-shaped and there is a positive slanting. The distribution PDF scale characterized by the mean value is influenced by the stress value. Here the relationship between stress and life-long values characterized by the PDF curve is available from the GEV distribution scale parameter.
The suitability of these methods to evaluate the subsequent fatigue life can be seen through PDF plots. In Fig.5, it is found that the shape of the PDF curve of the Hpave load is almost identical to the PDF curve of the Gpave load in Fig.6 where there is a slight positive opening on the shape of the two curves. However, the right end of the plot for both loads ends on different cycle-to-failure.

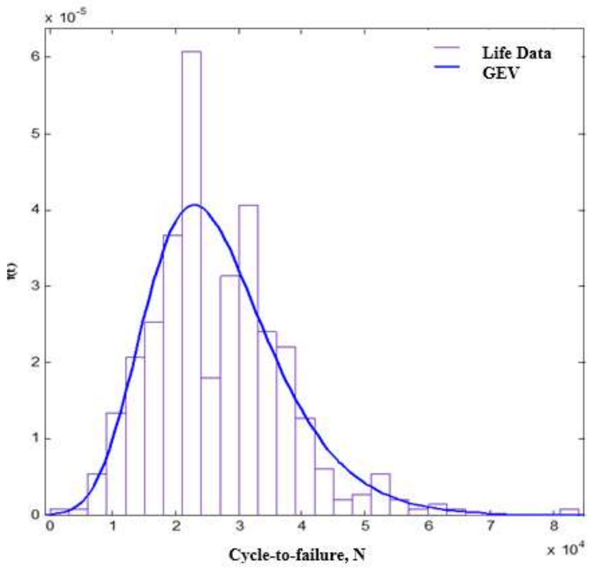

Fig. 5: Graph PDF for Hpave load

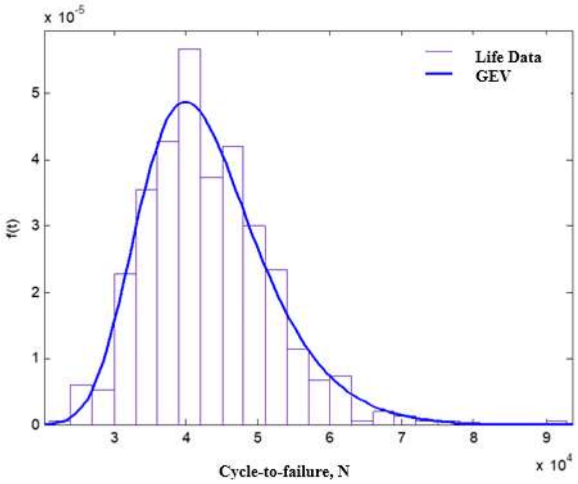

Fig. 6: Graph PDF for Gpave load

5.1. Determination of life parameters

Determination of life parameters of best fit distribution which is generalize extreme value (GEV) distribution using Hpave load and compared with distribution life parameters using Gpave. The relationship between GEV distribution parameters and load configurations is also evaluated. The value of the MLE method for GEV distribution using the result of a cyclic load failure test is shown in Table 1. These parameters are then used in finding the relationship between the fatigue life cycle failure and the load configuration.

Table 1: GEV Distribution Parameters and MLE Values for Hpave and Gpave Loads

Parameter	Hpave(half weight)	Gpave(full weight)	deviation (%)
ξ (shape)	-0.077753	-0.08123	4.2
σ (scale)	9080.12	7573.02	16.60
μ (location)	22154	39288.9	43.61

The characteristic life of the GEV distribution for Hpave loads are published and listed in Table 2 and likewise with Gpave's characteristic life.

Table 2: GEV Distribution Characteristic Life of Hpave and Gpave Loads

characteristic life	GEV Hpave	GEV Gpave
Min or MTTF	26742.80	43093.40
Median	25435.00	42023.60
Mod	22886.66	39928.26
Standard deviation	10629.67	8833.65

For both these loads, the life features obtained for the GEV distribution have the same flow pattern, the maximum value of the lifetime value is min, followed by median, mod and standard deviation.

5.2. A relationship between GEV distribution parameters and load configuration

For the purpose of analysing the relationship between GEV distribution parameters and load configurations, shape parameter values, scale parameters and location parameters as in Table 1 are used to see the deviation of values for Hpave loads and Gpave loads. Referring to the same table it is found that the location parameter most affected the GEV distribution of different loads with a deviation of 43.61%. This means that any changes to the carried load can change the value of this distribution location parameter. If observed in Table 1, clearly shows that the heavier the load, the greater the value of the location parameter.
According to the National Automobile Company, the weight difference between Gpave and Hpave loads was 200 kg while the difference in location parameter values for the same weight change was 17134.9 with each weight gain of one kg could increase the value of the location parameter by 85.67. With reference to Fig.5 it is found that the cycle-to-failure of Hpave loading ends at a cycle of 7.3×10^4 and in Fig. 6 it is found that the cycle-to-failure of the Gpave load ends at a cycle of 8.3×10^4 which results in a cycle-to-failure different of 10,000 cycles. This means that the increase of 200 kg in weight of the vehicle will lead to the decreasing of component life by 10,000 cycles, with each weight gain of one kg can reduce the component life by 50 cycles from the actual failure.
This relationship is inversely proportional to the load configuration and the form of its failure distribution which is basically obtained through the value of the GEV distribution location parameter. Therefore, the relationship between the location parameter and the load configuration can be used to predict the distribution of life failure for other loads without having to conduct the relevant experiments and thus reduce the experimental time. This relationship can help the industry to save time in performing fatigue failure tests on mechanical components especially at product development stages.

6. Conclusion

This study has successfully examined the extreme load of fatigue life failure data, distribution life characteristic, and reliability functions by using parameter estimation method such as MLE method. For the best-fit life distribution, the characterization of the data can be developed using the GEV distribution that is best suited to be used to analyse the extreme load data. The method developed in this study is able to predict the relationship between load configuration and the shape of failure distribution of the components studied. This relationship is inversely proportional to the load configuration and the shape of its failure distribution which is basically obtained through the value of the GEV distribution location parameter. This allows the forecasting of the distribution of the failures in different load configurations to be determined without requiring the physical experiment to be performed repeatedly. This approach can contribute to the reduction of experimental time which is very important in a process component production and it has a huge impact especially on the development of the country's automotive industry.

Acknowledgement

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