Proceedings of MUCET2008
Malaysian Technical Universities Conference on Engineering and Technology
March 8-10, 2008, Putra Palace, Perlis, Malaysia

ISBN 978-983-42358-4-0

ANALYSIS OF CONNECTING ROD BASED ON FINITE ELIMENT APPROACH

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Abstract: The connecting rod is one of the most important pats of an automotive engine. The connecting rod is subjected to a complex state of loading. High compressive and tensile loads are due to the combustion and connecting rod's mass of inertia respectively. The connecting rod fails during the operation of the engine is the critical situation. Therefore the connecting rod should be able to withstand tremendous load and transmit a great deal of power smoothly. The objective of this paper is to investigate the failure analysis of the connecting rod of the automotive engine. The materials including carbon steel, mild steel, bass and aluminum are considered in this study. The linear static analysis was carried out utilizing the finite element analysis codes. The numerical results were verified with the experimental results. It can be seen from the acquired results that the carbon steel gives good results in terms of hardness and endurance limit compared with the other materials.

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***Keywords*:** connecting rod, finite element, stress, hardness, endurance limit.

I. INTRODUCTION

A connecting rod, driving shaft, or also known as Cardan shaft is a mechanical device for transferring power from the engine or motor to the point where useful work is applied. Most engines or motors deliver power as torque through rotary motion: this is extracted from the linear motion of pistons in a reciprocating engine; water driving a water wheel; or forced gas or water in a turbine. From the point of delivery, the components of power transmission form the drive train [1]. In automobiles, axle shafts are used to connect wheel and differential at their ends for the purpose of transmitting power and rotational motion. In operation, axle shafts are generally subjected to torsional stress and bending stress due to self-weight or weights of components or possible misalignment between journal bearings. Thus, these rotating components are susceptible to fatigue by the nature of their operation and the fatigue failures are generally of the torsional, rotating-bending, and reversed (two-way) bending type [1].

Reference [2] studied the common failure types in automobiles and revealed that the failures in the transmission system elements cover 1/4 of all the automobile failures. Some common reasons for the failures may be manufacturing and design faults, maintenance faults, raw material faults as well as the user originated faults. Several researchers studied on the failures of the elements of power transmission system as there are many cases of the failures [3–6]. Bayrakceken analyzed the failure of a pinion shaft of a differential in a previous study [7]. Kepceler et al. studied the stress and life calculation of the elements of power transmission system of a four wheel drive vehicle [8]. Some researchers studied on the drive shafts. Among these Reference [9] carried out a study on a failed axle and obtained the stresses on the axle by numerical analysis technique. Reference [10], investigated the fatigue cracks on the rear axle of a tractor. The main reason for the observed cracks on the axes was the cyclic stresses occurred on the axle. Heat treatment errors were observed on 80–85% of failed axles. The axles were generally fractured at keyway locations.

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II. EXPERIMENTS SET-UP

2.1 Cutting processes (disc cutter)

The connecting rod, it must be cutting into small specimen for used in hardness test. The connecting rod was cuted into four pieces of specimens. Disc cutter was employed in this process.

2.2 Cutting process (lathe machine)

To make fatigue test, the connecting rod must be cut into the standard fatigue specimen that has shown in figure 1. Conventional lathe machine as shown in figure 2 was used to reduce the diameter of the connecting rod to the size of specimen.

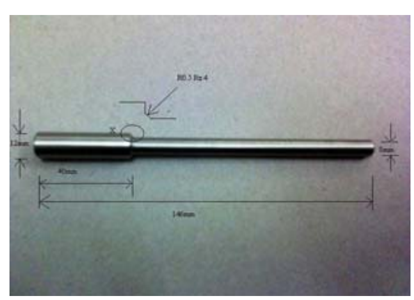

Figure 1: Standard size of fatigue specimen.

Figure 2: Conventional lathe machine

2.3 Rockwell Test

HRA and HRB scale was used in the testing as shown in figure 3. The indenter that been use is 1/16” steel ball. The total load give is 100 kg for HRB and 60 kg for HRA. The testing time is 12 second and dwell time is 3 second.

Figure 3: With digital display for Rockwell A, B, C and superficial hardness testing.

Figure 4: Fatigue test machine

The other method to analysis drive shaft failure is by fatigue test method. Fatigue test is a method for determining the behavior of materials under fluctuating loads. A specified mean load (which may be zero) and an alternating load are applied to a specimen and the number of cycles required to produce failure (fatigue life) is recorded. Generally, the test is repeated with identical specimens and various fluctuating loads. Any misalignment of a specimen will produce bending, causing premature failure and giving erroneous results. Strain gauge as shown in figure 4 is recommended to measure and thus eliminate bending strains which could be induced in the specimen during a test.

III. Stress Analysis by Finite Element Analysis

In the new technology, before the manufacturing produce their product there must test their product first whether in good condition or not. ALGOR software is one of the software that can analyze the component for example do the stress testing for the component.

IV. Result and Discussion

4.1 Result of Hardness Test

The testing is performed on the four specimens that had been cut by disc cutter from the original connecting rod. Each specimen had been tested for 24 point where 6+ point at each crosses section area. The Rockwell Hardness testing machine been used in this experiments. table 1 shows the first testing results. figure 5 shows the hardness number conversion to HRA (ASTM).

Table 1: Hardness number of specimen for first crosses line.

Specimen	1	2	3	4	5	6	
A	58.9	58.8	57.1	56.5	58	58.8	HRA
B	55.3	54.5	54.4	54.4	54.8	54.9	HRA
C	63.2	50.3	49.7	49.2	51.1	62.1	HRA
D	57.5	55.1	54.9	51.7	53.9	59	HRA

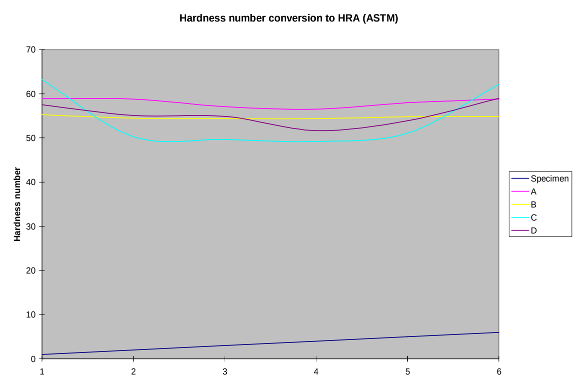

Figure 5: Hardness number conversion to HRA

From the graph above we can see that for each specimen, the first and last point that is measure is higher than the other point. The trend of the graph is like a ‘U” shape. It because the hardness is lower when near to the center point of the connecting rod. It is due to outer side of connecting rod, there are coated by the other material such as chromium, black oxide, ceramic or other materials.

The results of the experiments are been compared with the "Machinery's Handbook" 24th Edition. From the Engineer to Win book, the hardness number (HRB) is 79 to 100.2 and has an ultimate tensile strength between 70,000 and 112,000 psi. Refer to Machinery’s Handbook, medium carbon steel (AISI 1045) has ultimate tensile strength (80 - 182,000 psi). Carbon steel is dividing by four types that is low carbon steel, medium carbon steel, high carbon steel and ultra-high carbon steel. The big different between the type of carbon steel is the percentages of carbon. For low carbon steel (approximately 0.05–0.29%), medium carbon steel (approximately 0.30–0.59%), high carbon steel (approximately 0.6–0.99%) and ultra-high carbon steel (approximately 1.0–2.0%) content of carbon.

4.2 Result for fatigue test

The objective of this experiment is to look for Endurance limit of each specimen and compare it. Endurance limit also known as fatigue limit, a limiting stress, below which metal will withstand without fracture an indefinitely large number of cycles of stress. If the term is used without qualification, the cycles of stress are usually such as to produce complete reversal of flexural stress. Above this limit failure occurs by the generation and growth of cracks until fracture results in the remaining section. The results of the experiments are listed at table 2.

Table2: Endurance limit on different materials.

Specimen	Load (N)	Stress σ_a (N/mm^2)	Endurance (N)	Duration (n=2800/min)
Medium carbon steel	150	300	29650	635s
Mild steel	150	300	8626	188s
Aluminum	150	300	1319	47s
Brass	150	300	6088	137s

Compare to four materials that had been done for the endurance limit test, medium carbon steel has high endurance limit (29650 N) then follow by mild steel (low carbon steel), brass and aluminum. That why medium carbon steel is suitable to make a connecting rod because it has high endurance limit besides high strength. From previous study, mild steel and aluminum also been use to make connecting rod of automotive vehicle. For mild steel, manufacturer design two-pieces to increase the strength but it also increase the weight. From the experiment, aluminum that been use is pure aluminum as a result it has lowest endurance limit compare to other specimens that been tested. To improve the strength of aluminum, manufacturer was design hybrid aluminum/composite drive shaft. As a result, the hybrid connecting rod can improve static torque capability and fundamental natural frequency compare to mild steel. It also can reduce weight 25% compare to mild steel connecting rod but it highly in cost.

4.3 Stress analysis on connecting rod

By use SolidWork software, the connecting rod has been draw and been analyze by use ALGOR software. The main objective of this analysis is to determine the minimum and maximum stress that applies to the drive shaft. The result is performed in figure 6:

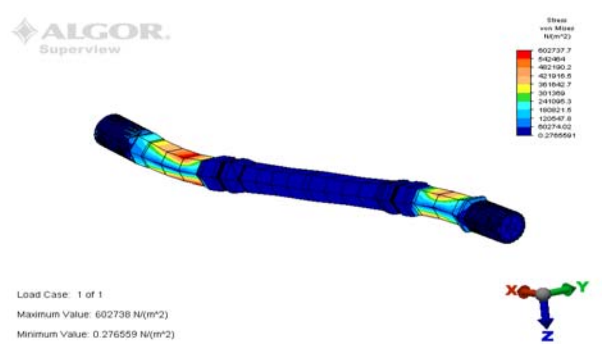

Figure 6: Stress analysis by using finite element analysis

Refer to figure 6, the maximum stress is 0.6 MPa and the minimum stress is 0.2 MPa. The load (2500N) was given at the both end of the drive and the middle of the shaft was constrained. The maximum stress occurs at the both end of connecting rod. As we know, medium carbon steel has low strength compare to the low alloy boron steel.

V. Conclusion

The purpose of this project is to analyses the failure of connecting rod. To analyze the failure, there are few type of experiments need to be run and software been used. The comparison of harness number (HRB) and the type of material used, connecting rod that made from medium carbon steel shows good balances ductility, strength and has good wear resistance. The endurance limit of the medium carbon steel is higher than materials like mild steel, brass and aluminum (pure). That show, it can make more cycle before it rapture. From the analysis, the maximum and the minimum stress also determined.

Acknowledgment

The authors would like to thank the faculty of Mechanical Engineering, Universiti Malaysia Pahang for provides laboratory facilities.

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