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# Analysis of Rocker Arm Failure on Diesel Engines Using Finite Element Method

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**Abstract**. Rocker arm is a reciprocating lever that is used as a tool for internal combustion of the engine to transfer the pushrod movement to the valve stem. Finite Element Method (FEM) uses ANSYS Workbench software to predict stress, deformation and fracture that occurs in the rocker arm hole with two loading models. Rocker arm design using Autodesk Inventor Software and the material used is gray iron cast. The force inputted to the simulation is 550 lbs equal to 2446.52 N. The simulation results show that the equivalent stress, main stress, and maximum shear stress on the loading model 1 are higher than the load model 2. For deformation the value is very low because of the brittle material properties, including the crack simulation test cannot produce J-Integral values and stress intensity factors (K1).

## 1. Introduction

The rocker arm shaft is the part that supports the input and drain valve of the engine that passes through the rocker arm. Rocker arm is a reciprocating lever that is used in internal combustion engines to transfer the movement of the cam or pushrod to the valve stem. The results of the questionnaire about problematic parts of vehicles revealed that the rocker arm failure accounted for 30% of engine errors and was the main cause of fatal traffic accidents. Rocker arm is also reported to have experienced fracture during sports vehicle inspection routines with a four-cylinder diesel engine. Fractures that often occur in rocker arms are fractures in the rocker arm hole and on the rocker arm neck [1, 2]. The location of the fracture on the rocker arm is shown in Figure 1.


(a) fracture in the rocker arm hole (b) fracture on the rocker arm neck

**Figure 1.** Rocker arm fracture position [3]

Material damage (crack) usually starts from the flaw on the surface of the material due to the influence of environmental factors such as corrosion or wear due to the interaction with other components [4]. Based on the explanation above, in order to the rocker arm contained in a diesel engine has a long life, it is necessary to plan an effective and efficient design. Along with the purpose of knowing the damage effects caused by the dynamic load acting on the rocker arm, a rocker arm simulation analysis is needed to determine the distribution of stresses, deformations, and fractures that occur.

## 2. Method

The approach used in this analysis is Finite Element Method (FEM) through the ANSYS Workbench software. Finite element method is a numerical method that can be used as the accurate solutions towards the complex technical problems. This method is widely used to cope with the engineering and mathematical problems from a physical phenomenon [5], [6]. Types of technical and mathematical physical problems that can be solved by elemental methods such as stress / stress analysis, Buckling and Vibration Analysis [7]. FEM is used to predict stress, deformation and fractures that occur in rocker arm holes, with steps such as designing, determining mesh, support, loading until executing and getting simulation results. This type of analysis provides a way to conduct easy and efficient research on various parameters used with design and manufacturing conditions which are easily evaluated [8].

### *2.1 Contruction model*

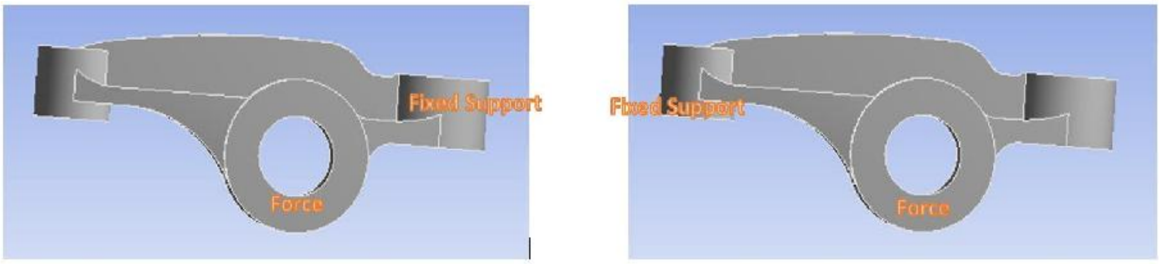
Rocker arm is designed using Autodesk Inventor Software with dimensions that follow the rocker arm on a diesel engine. This rocker arm uses gray iron cast material. Cast iron comes to be the most used material in manufacturing industry [9]. The selection of this material is based on the rocker arm YQL brand which is widely circulated on the market [10]. Where the material properties consist of density = 7200 kg / m3, young's modulus = 110000 MPa, poisson's ratio = 0.28, yield strength = 124 MPa, and ultimate tensile strength = 240 MPa.

| | | | |
|---|---|---|---|
| Brand Name: | YQL | Model Number: | ZS1130 |
| Type: | Rocker Arm | material: | casting iron |
| delivery: | in time | market: | more than 20 countries |

**Figure 2.** Details of the YQL brand rocker arm [10]

### 2.2 *Simulation*

Simulation of material strength uses ANSYS Workbench software. The rocker arm simulation process starts by giving 2 types of loading conditions. For the type of loading force shown by Figure 3. The force input is 550 lbs equal to 2446.52 N. This force is the maximum force of a load from a diesel engine [11]. In simulation using 2 mm meshing. The results of the simulation analysis performed, obtained stress and deformation on the rocker arm due to loading for maximum conditions. The results of the analysis are the basis for analyzing the fracture of the rocker arm, as the rocker arm has fracture (see Figure 1). The fracture location is based on the maximum principal stress results, with dimensions of 1 mm (major radius), 0.2 mm (minor radius), and meshing size 2 mm.

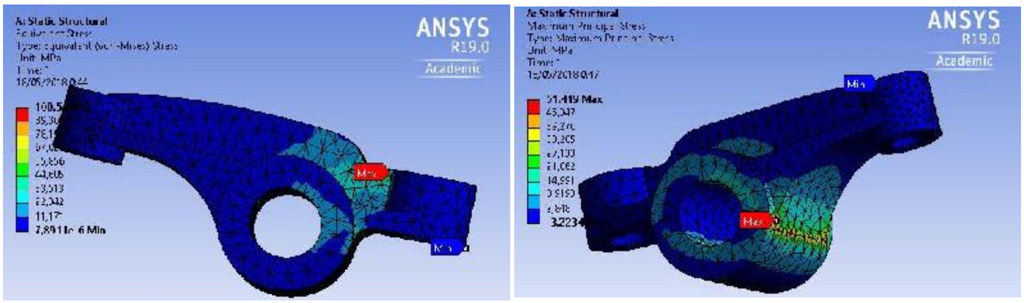



(a) Type of loading 1 (b) Type of loading 2

**Figure 3.** Type of loading position

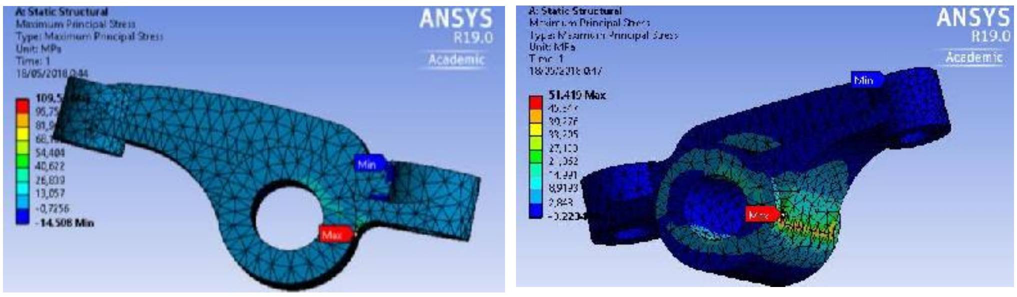
## 3. Result and discussion

### *3.1 Stress and deformation*



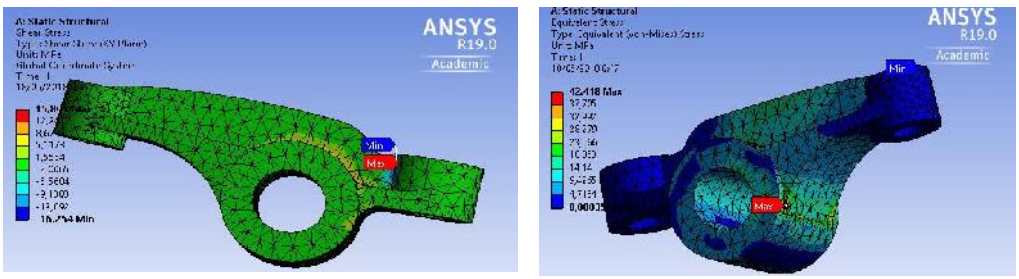

(a) Type 1 loading (b) Type 2 loading

**Figure 4.** Equivalent stress (von-Mises)



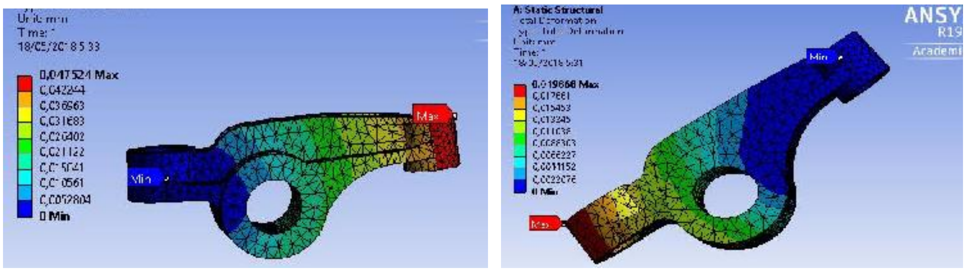

(a) Type 1 loading (b) Type 2 loading

**Figure 5.** Maximum principal stress




a) Type 1 loading (b) Type 2 loading

**Figure 6.** Maximum shear stress



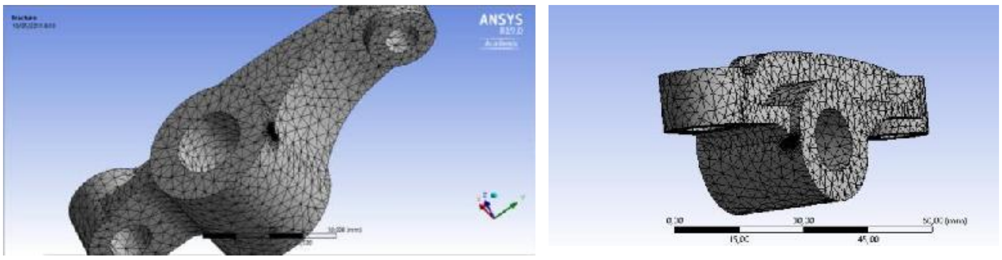
a) Type 1 loading (b) Type 2 loading

**Figure 7.** Total deformation

The simulation results of equivalent stress (von-mises) using type 1 loading indicate a maximum value of 100.5 MPa and a minimum value of 7.8911e-6 MPa. While the loading type 2 maximum value is 51.419 MPa and the minimum value is -3.23434 MPa as shown in Figure 4. Then to simulate maximum stress principal stress shows a maximum value of 109.5 MPa and a minimum value of -14.5 MPa on loading type 1, for loading type 2 the result is lower than the loading type 1 which is a maximum value of 51.419 MPa and a minimum value of -3.2234 MPa which can be seen in Figure 5. Furthermore, Figure 6 shows the simulation results of maximum shear stress conditioned on loading types 1 and 2. In Figure 6 (a) it can be seen that the maximum shear stress value is 15.8 MPa and the minimum value is -16.254 MPa, while in Figure 6 (b) shows a maximum value of 42.418 MPa and a minimum value of 0.00032 MPa. If further scrutiny then the stress results (all) of the loading type 1 get a higher maximum value compared to the stress output (all) of the loading type 2. This is due to the fix supported location of the loading type 1 shorter than the loading type 2. So the stress received by the loading type one will be higher due to the shorter distance and vice versa.

Figure 7 shows the total deformation changes experienced by the rocker arm. Deformation can be interpreted as a condition of material resistance to tensile or compressive energy if the energy does not exceed the material's physical characteristics. Deformation itself is divided into two, namely plastic deformation (cannot return to its original form) and elastic deformation (can return to its original shape) [12]. In the loading type 1 maximum total deformation is 0.047524 mm and the minimum value is 0 mm, while in the loading type 2 the maximum value is 0.019868 mm and the minimum value is 0 mm. Low deformation values indicate that the rocker arm with gray cast iron material does not experience significant deformation, this is due to the material properties of brittle cast iron. The intensity of the material is contrary to tenacity, while the height of deformation is influenced by the tenacity of a material. The higher the tenacity of a material, the higher the deformation value.

### *3.2 Crack testing*



a) Type 1 loading (b) Type 2 loading

**Figure 8.** Fracture / Crack

The simulation analysis results of the crack test on the rocker arm experience an error and cannot display the J-Integral value and stress intensity factor (SIF) K1. J-Integral value is the strain energy release rate of a crack body per unit increasing the crack length that occurs in the body. While the SIFS value (K1) functions to determine the stress intensity factor (K) of a material with a certain geometric shape under elastic loading conditions [13]. Error experienced when crack testing occurs after meshing crack, can be said to be successful mesh crack test but failed to display the value of fracture propagation. This occurs as a result of the total deformation which is too low. The low deformation value is influenced by the softness of a material. That is because the metallurgical test results show that addition magnesium for cast iron can produce rounded graphite. Regarding its mechanical properties, the tensile strength of the graphite can double and its ductility is comparable to carbon steel. The magnesium reacts first with sulfur to form a graphite sphere. Spherical graphite flakes cause the working force not to be concentrated; instead, it spreads to the arc of the graphite sphere so that it can withstand heavier loads [14]. So that brittle material will experience very fast crack propagation. That is why in the crack test simulation can not bring J-Integral and SIFS (K1) values.

## 4. Conclusions

The results of the analysis of the rocker arm simulation above are in accordance with the maximum load that has been determined using 2 types of loading conditions. Simulation results of equivalent stress, maximum principal stress, and maximum shear stress on type 1 loading are higher in value compared to type 2 loading. This is influenced by the distance between fix supported positions on loading 1 closer to force. For deformation, the value is very low, this is influenced by the agility of the rocker arm material which is gray iron cast. Because the deformation value that is too low in the simulation test fracture / crack cannot bring up the J-Integral and SIFS (K1) values.

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