Stress and Crack Simulation on Axle Housing Mitsubishi L300 Pickup Car using Finite Element Method

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Abstract. Axle housing in pickup cars receives the main load that is direct or indirect. The direct load referred to is the weight of the load and the weight of the vehicle itself, while indirect loading can be in the form of twisting and bending moments. Due to the load experienced by the axle housing will result in deformation, cracking, and even fractured. Based on the case of failure, an analysis of the axle housing was performed which covers two things, namely stress analysis and crack analysis. Axle housing analysis uses the Finite Element Method (FEM) approach, through the Ansys software. The result of stress analysis shows the maximum value of Equivalent (von-mises) Stress is 14,356 MPa, the Maximum Principal Stress is 14,977 MPa, and the Maximum Shear Stress value is 7,5471 MPa. The result of crack analysis shows the maximum value of J-Integral is 0.00051126 mJ / mm² and the maximum value of SIFS (K1) is 10.823 MPa.mm⁰.5.

1. Introduction

One type of transportation that is widely used in Indonesia is the pickup type L300 produced by Mitsubishi. This type of vehicle is in great demand because it is more flexible to transport goods, has a large engine power and has the ability to break through various road conditions, and has a greater payload capacity compared to other types of pickup cars[1]. Due to high cruising range, there are several cases of failure on some vehicle components. One of the failures in the engine component is the axle housing, which is bent, cracked, even fractured.

![Cracks on Axle Housing](image)

Figure 1. Cracks on Axle Housing
One of the causes of failure due to loading experienced as in Figure 1 and 2 occurs resulting in cracks and fractures. This is due to the limit of the ability to withstand the load exceeded, besides that there is also a stress concentration on the cross section changes. Based on the description, a failure analysis is done on two things, namely stress analysis and crack analysis.

2. Axle Housing on Car
Axle housing accepts various loads when the vehicle is moving, including bending loads due to weight, twisting loads due to driving torque, cornering loads, and braking loads[2], inertia loads [3], and vertical loads due to rough road conditions[4]. The frame on the Leaf Spring car provides a vertical load down on the axle housing due to the load load from the vehicle, while the wheel of the vehicle will provide an upward reaction force due to the load, especially when passing through uneven road surfaces, holes or bumps.

Axle housing consists of three types, namely Spilt Type, Banjo Type [4], and Salisbury or Integral Carrier Type[5]. The type of axle housing on the Mitsubishi L300 pickup is a banjo type.

![Figure 2. Fracture on Axle Housing](image)

3. Method

3.1. Axle Housing Material
Axle housing material must be strong and have high stiffness, mostly made of steel , cast steel, soft iron, cast aluminum/forged steel[5]. This analysis uses Steel S460N type material with modulus of elasticity = 208.5 Gpa, poisson's ratio = 0.3, yield limit strength = 467.5 MPa, tensional strength = 629.9 MPa, and density = 7850 Kg.m-3 [6][7].

3.2. Loading Model on Axle Housing
Axle housing analysis uses the Finite Element Method (FEM) approach, through the Ansys software. Finite Element Method (FEM) is one of the most widely used numerical methods in the world of engineering and widely applied to start from stress and deformation analysis[8]. 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 [9].

![Figure 3. Axle Housing Banjo Type](image)
There are three force models on the axle housing for preliminary analysis, namely.

![Axle Housing Forces](image)

**Figure 4.** Axle Housing Forces (a) First Model [10][11], (b) Second Model[3][4][12][13][14][15][5][16], (c) Third Model [2].

Based on the preliminary analysis in accordance with Figure 4, shows that the third model (c) produces stress concentration in accordance with the crack position in the axle housing. Based on this, the third model is used as a basis for further analysis. The force value in the analysis process is determined based on the maximum load of the pickup car of 23,000 N.

3.3. Crack Simulation
Crack simulation in this analysis was created with reference to the position of the maximum stress concentration point as in the results of stress analysis in the preliminary test. This type of crack is a "semi elliptical crack" type to see cracks in mode 1 (K1), which is cracks due to tensile force. The crack position is shown in Figure 5.

![Position of Cracks](image)

**Figure 5.** Position of cracks

4. Result

4.1. Stress

![Results of Equivalent (von-mises) Stress Analysis](image)

**Figure 6.** Results of Equivalent (von-mises) Stress Analysis
Figure 7. Results of Maximum Principal Stress Analysis

Figure 8. Results of Maximum Shear Stress Analysis.

Based on Figures 6, 7, and 8 shows the maximum value of Equivalent (von-mises) Stress is 14,356 MPa, the Maximum Principal Stress value is 14,977 Mpa, and the Maximum Shear Stress value is 7,5471 MPa.

4.2. Crack
Crack simulation is done with crack specifications of 25 mm long and 0.5 mm wide. Position of the crack point is at the point of stress concentration.

Figure 9. Fracture Crack in Crack Analysis

Based on Figure 9, the results of crack analysis of the maximum J-Integral value is 0.00051126 mJ/mm², while the maximum value of SIFS (K1) is 10.823 MPa.mm⁰.5. J-Integral value shows that the strain energy release rate of every 1 mm² cracks is equal to 0.00051126 mJ. The SIFS value (K1) shows the fracture intensity in terms of the material tensile stress every 1 mm² is 10.823 MPa.
5. Discussion
Cracks in the axle housing result from continuous stress concentration resulting in fatigue on the surface. The strength of the real fracture of the material is always lower than the theoretical value because most materials contain small cracks that focus stress. If the load is above a certain threshold, microscopic cracks will begin to form on the surface, eventually the crack will reach a critical size, and the structure will suddenly crack [7]. Cracks always start from stress raisers, so to eliminate cracking defects can be performed by increasing fatigue strength.

In addition, the factors that affect the failure of axle housing include the uneven loading effect, housing slope, and eccentricity [14]. This condition will result in excessive load on the ability of the vehicle, especially at the axle housing. As explained [3] when the vehicle is running on the road, the axle housing is the part of the engine that receives the load dynamically. One of the weaknesses of cast iron on axle housing is related to its brittleness, thus being liable to break easily particularly in accepting a dynamic loading, impact loading (sudden attack) or flexure loading [17]. These conditions will cause stress (stress) on the axle housing, repeatedly there will be a concentration of tension on the axle housing which risks resulting in fatigue and cracks [18][19].

Based on the failure analysis above there can be several solutions that can be done in order to reduce the failure of the L300 axle housing pickup including (1) thickening the axle housing material will reduce the concentration of the attachment on the workpiece so as to minimize the occurrence of failure [3]. One modification of the axle housing to reduce stress concentration is to provide a ring in the stress concentration area to increase the thickness of the axle housing material, this can increase fatigue life. (2) Giving a radius to the stress concentration will increase the fatigue strength of the axle housing [7], (3) using a composite material can increase the axle housing safety factor. Composite material has a higher safety factor for maximum loading when the load is applied statically [4], and hardening of material to improve the properties of hardness and performance of components or materials [19].

6. Conclusion
The simulation results show that the cracks occur in the L300 pickup axle housing come from the vertical force of the vehicle's wheels as the reaction force of pickup load, the uneven road surface effect and so on. Cracks occur due to a continuous stress concentration on the axle housing resulting in fatigue at the concentration point, and eventually small cracks occur at the point of stress concentration. Alternatives in overcoming the risk of cracks in the axle housing pick include (1) thicker axle housing material by providing installments at the point of stress concentration, (2) providing a radius at the point of stress concentration, and (3) using material that has a high safety factor such as composite material. J-Integral value shows that the strain energy release rate of every 1 mm² cracks is equal to 0.00051126 mJ. The SIFS value (K1) shows the fracture intensity in terms of the material tensile stress every 1 mm² is 10.823 MPa.

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