Simulation of Initial Cracks in Truck Wheel Drive Axle Flange Fillets Using the Finite Element Method

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ABSTRACT

Langsa residents rely on trucks as the main means of transporting palm oil from plantations. In mechanical systems, component failures often occur, often characterized by the breakdown of a particular part. Cracks are a key factor contributing to failure in machine structures. Early detection of cracks in shafts is critical to reducing damage, requiring the use of appropriate methods in the early stages of crack formation. This research aims to analyze the effect of crack initiation in truck drive axle flange fillets on stress and strain distribution using the finite element method. The simulation results show that the maximum shear stress in the area without cracks ranges from 0.0032 to 61.282 MPa, while after crack initiation, the shear stress value increases to 70.036 to 78.79 MPa. Likewise, the Von Mises stress increased from 0.006 to 106.74 MPa to 121.99 to 137.23 MPa after the crack was modeled. In addition, the maximum shear strain increased from 7.506×10^{-8} - 5.389×10^{-4} to 6.159×10^{-4} - 6.929×10^{-4} in the cracked area. These increases in stress and strain values indicate that the initial crack increases the stress concentration and local deformation, which accelerates the accumulation of structural damage in the shaft. This research emphasizes the importance of early crack detection and design strengthening to prevent structural failure in truck drive axle components.

Keywords: Maximum shear stress; von mises shear stress; shear strain; initial crack; driveshaft; finite element method.

INTRODUCTION

The truck driveshaft is a vital component in the heavy vehicle transmission system, functioning to transfer power from the engine to the wheels. In heavy vehicle applications such as trucks, especially in oil palm plantation areas in Langsa, the drive shaft operates under significant cyclic loads. This condition increases the risk of stress concentrations appearing, especially in the flange fillet area, which is susceptible to crack initiation and propagation.

Initial cracks in the shaft are often ignored in the routine inspection process, even though their presence can be a weak point that accelerates structural failure [1-3]. The high stresses that accumulate around these critical areas cause small cracks to develop into larger damages, thereby impacting vehicle performance and causing the potential for significant economic losses[4-7]. Therefore, early detection and in-depth understanding of the effects of crack initiation are critical to improving component safety and service life.

The finite element method (FEM) has been proven to be an effective analytical tool for studying stress and strain distribution in mechanical components. With the ability to simulate complex conditions in detail, this method allows identification of critical areas and analysis of the influence of crack initiation on the mechanical behavior of components.

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This research aims to analyze the effect of crack initiation on truck wheel drive axle flange fillets using the finite element method. It is hoped that the research results can contribute to the development of component designs that are more resistant to damage, while supporting increased operational efficiency and safety of heavy vehicles.

RESEARCH OBJECT

This research uses a truck wheel drive axle with an initial crack condition in which the axle is manually made into a semicircle with a radius of 0.25 mm and a width of 0.25 mm and the CAD design results are given in Figure 1.

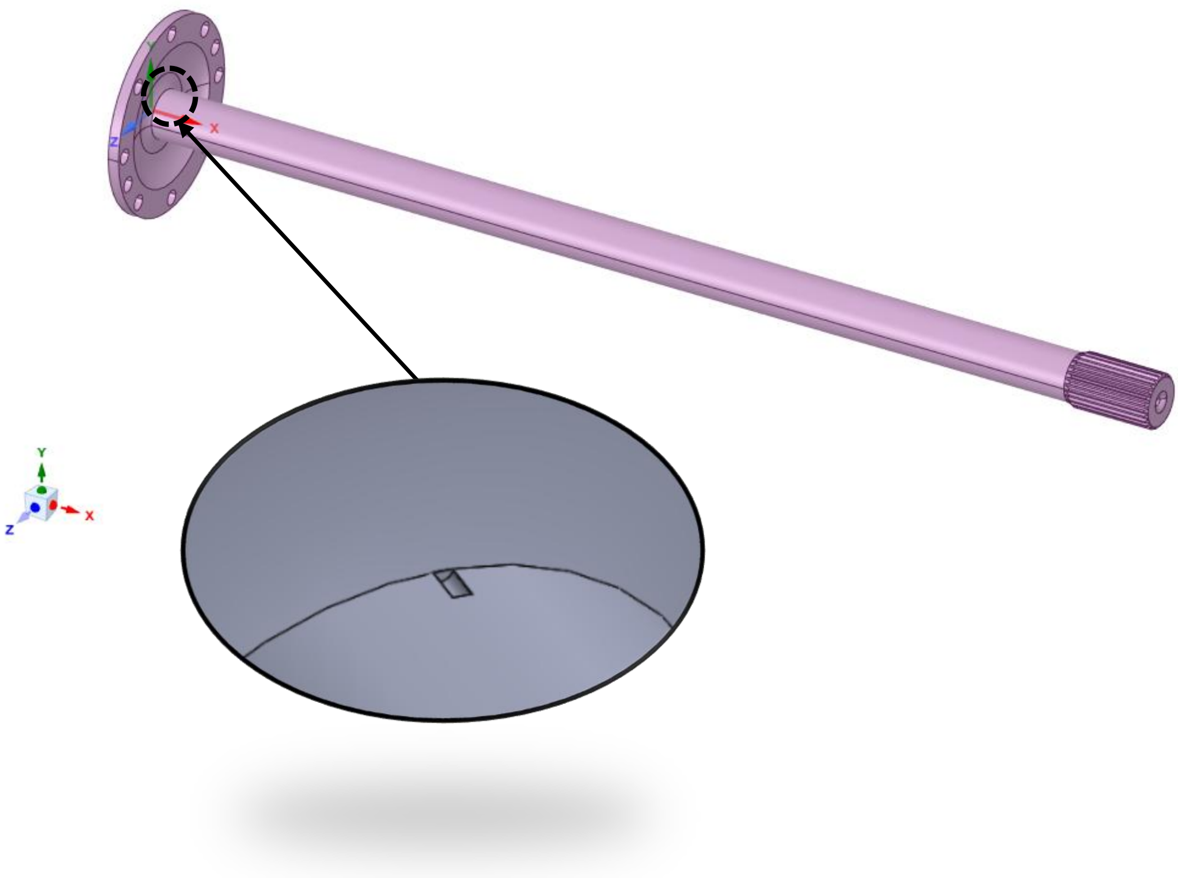

Figure 1. CAD shaft.

RESEARCH METHOD

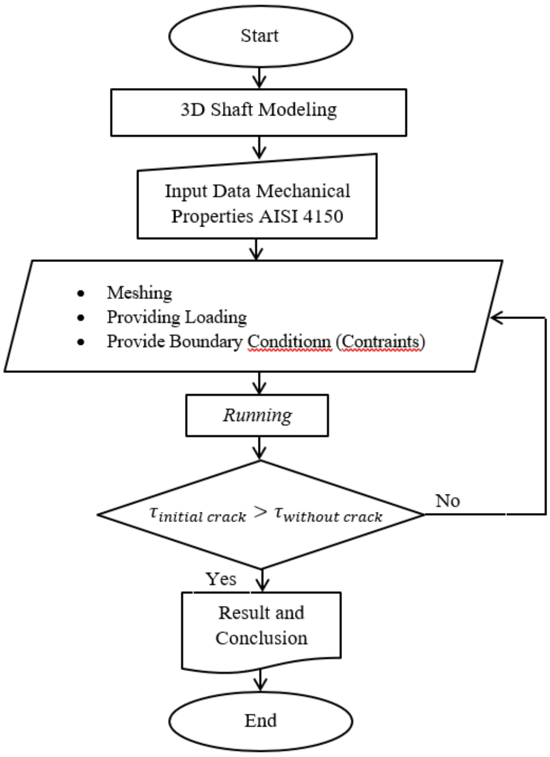

Figure 2. Research flow diagram

Meshing

Meshing is a crucial stage in finite element analysis (FEM), where the model geometry is broken down into small elements to simplify numerical calculations [1-7]. In this research, a truck drive axle model was created using CAD software, which was then imported into ANSYS software for the analysis process.

Tetrahedral meshing with a size of 0.005 which produces a total number of meshings on the shaft of 66568 drops. The results of the CAD analysis of the shaft using ANSYS software which has been given a mesh and a maximum torque load of 372.4 Nm are shown in Figure 3.

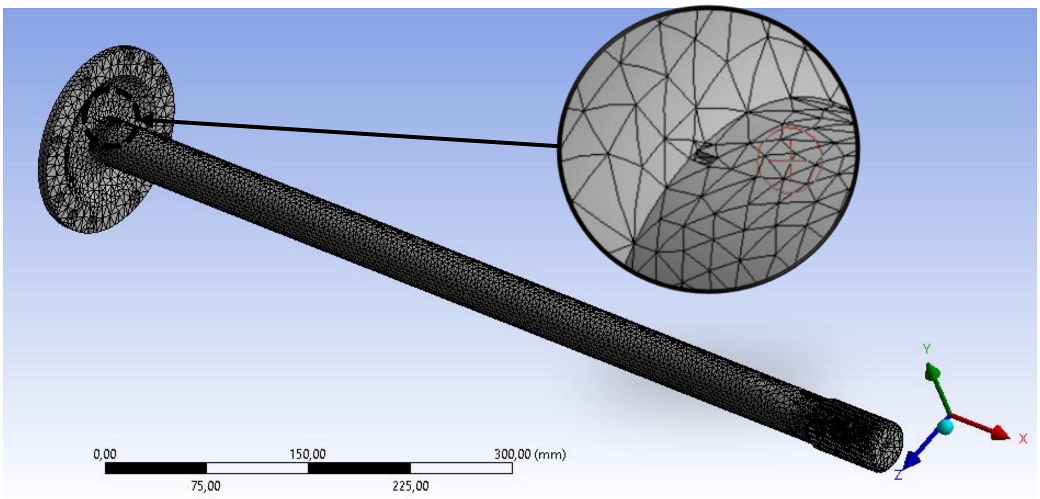

Figure 3. Meshing

The simulation results using ANSYS software will be presented in the form of color contours, which depict the magnitude of the shear stress values on the shaft. The red color on the contour shows the maximum shear stress, while the blue color shows the minimum shear stress.

Loads and Constraints

Loads and constraints have a significant influence on simulation results. The load is applied to the spline area with a torque value of 372.4 Nm, while the constraints are provided in two types, namely bolts and bearings [3].

RESULT AND DISCUSSION

Previous research [1-2] revealed that the shaft material used was AISI 4150, as listed in Table 1.

Table 1. Mechanical properties of AISI 4150.

Parameters	Metric
Tensile Strenght, σ	731 MPa
Yield Strenght, S_y	380 MPa
Shear Modulus,G	80 GPa
Poisson's ratio, v	0.27-0.30

Maximum Shear Stress Analysis

The results of the shaft simulation with maximum shear stress analysis are shown in Figure 4 in MPa units.

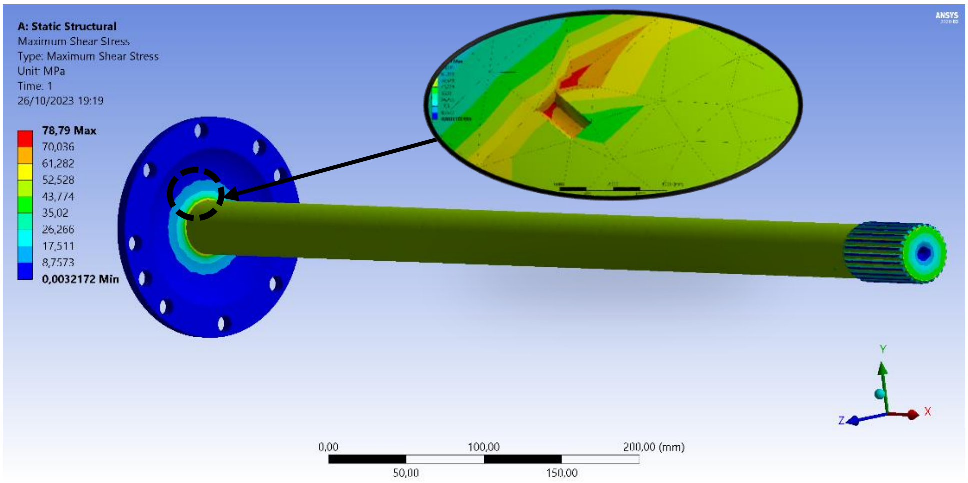

Figure 4. Maximum shear stress in the shaft

The simulation results show that the maximum shear stress that occurs on the truck wheel drive axle experiences a significant increase in the shear stress value. Where in areas without cracks, the maximum shear stress value ranges from 0.0032 to 61.282 MPa. However, at crack initiation modeled in the flange fillet area, the maximum shear stress increased to 70.036-78.79 MPa.

Von Misses Shear Stress Analysis

The results of the shaft simulation with Vonmisses shear stress analysis are shown in Figure 5 in MPa units.

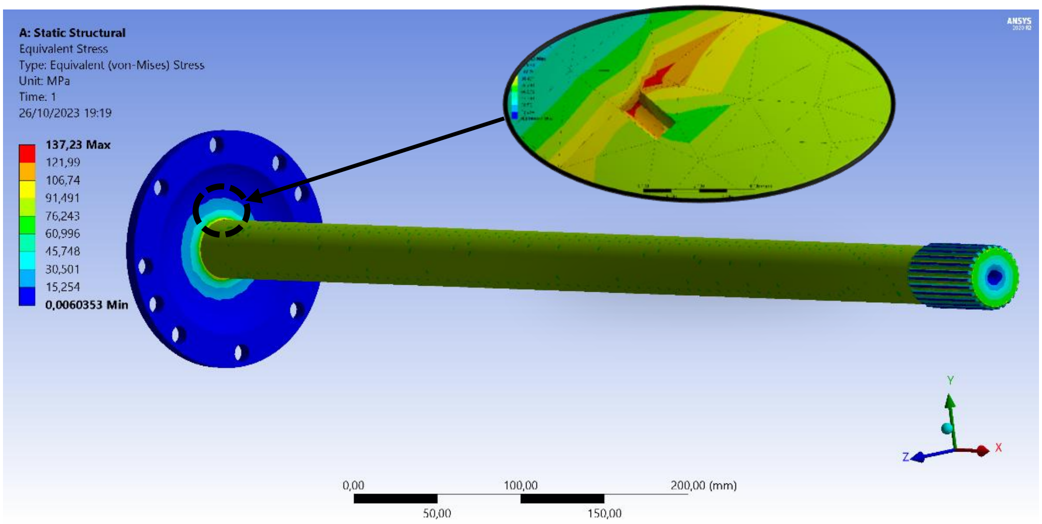

Figure 5. Vonmisses shear stress in the shaft.

The simulation results show that the Vonmisses shear stress that occurs on the truck wheel drive axle also experiences a significant increase in the shear stress value. Where in areas without cracks, the maximum shear stress value ranges from 0.006 to 106.74 MPa. However, at crack initiation modeled in the flange fillet area, the Vonmisses shear stress increases to 121.99-137.23 MPa.

Shear Strain

The results of the shaft simulation with shear strain analysis are shown in Figure 6.

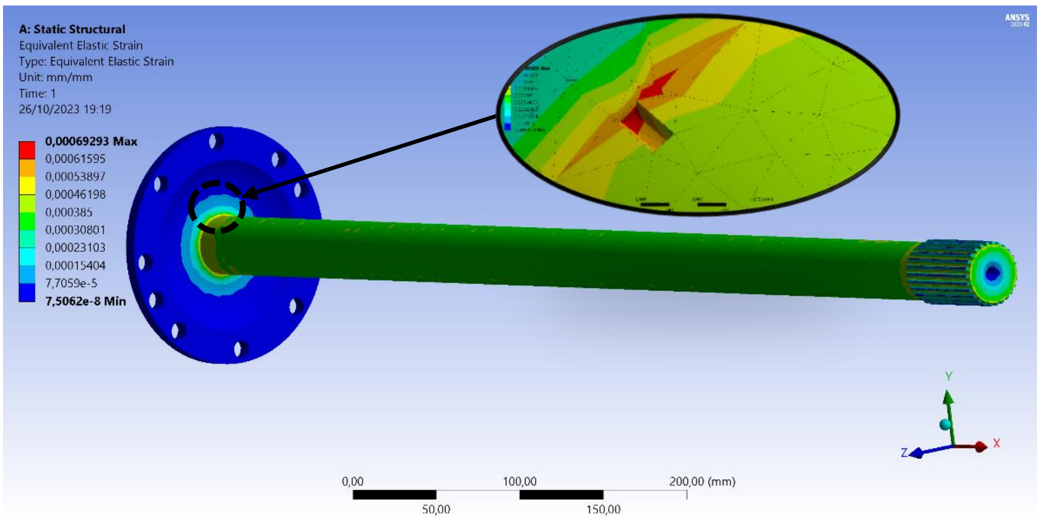

Figure 6. Shear strain in the shaft

The simulation results show that the shear strain that occurs in the truck wheel drive axle also experiences a significant increase in the shear strain value. Where in areas without cracks, the maximum shear strain value ranges from 7.506×10^{-8} -5.389×10^{-4}. However, at crack initiation modeled in the flange fillet area, the Vonmisses shear stress increases to 6.159×10^{-4} - 6.929×10^{-4}.

CONCLUSION

The research results show the influence of the initial crack in the flange fillet of the truck driveshaft on the stress and strain distribution using the finite element method. Based on the simulation results, the following conclusions are obtained:

1. The maximum shear stress increases significantly in the flange fillet area after crack initiation. The shear stress value increases from 0.0032-61.282 MPa MPa (in the area without cracks) to 70.036-78.79 MPa (in the initial crack area), indicating that the initial crack acts as a stress concentration center.
2. Von Mises stress also shows a significant increase, from 0.006-106.74 MPa (in the area without cracks) to 121.99-137.23 MPa (in the initial crack area). This indicates that the presence of initial cracks increases the risk of material failure due to stresses focused around the crack tip.
3. The maximum shear strain increases from 7.506×10-8 -5.389×10-4 in the area without cracks to 6.159×10-4 -6.929×10-4 in the initial crack area. This increase indicates significant local deformation around the crack, which accelerates the accumulation of structural damage.
4. The presence of initial cracks in the flange fillets significantly affects the stress and strain distribution, increasing the risk of mechanical failure of the shaft. Therefore, mitigation measures are needed such as early crack detection, material strengthening, or modification of the flange fillet design to increase resistance to crack propagation.

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