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LOADING ANALYSIS ON ALLOY WHEELS TYPE-253 SIZE 6.5 X 15JJ BASED ON SNI 1896:2008 WITH FINITE ELEMENT METHOD

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ABSTRACT

This study analyzes the loading on the model wheel-253 size 6.5 x 15JJ based on SNI 1896: 2008 with finite element method. This load analysis tested the resistance to dynamic radial fatigue on alloy wheels by using load simulation with quasi-static failure mode approach ie failure mode which is independent of time, and its resistance to failure is expressed with strength. Test wheels are said to fail if there is crack (crack) by giving the liquid penetrant. Crack conditions in the simulation can be seen from the stress and elastic strain. The equivalent elastic stress and elastic strain values that occur on the rim must be less than the Ultimate Tensile Stress (UTS) and the elastic strain at break. The properties values for Aluminum A356-T6 material for UTS of 228 N/mm^2 and strain elastic fracture values obtained from a plastic material strain of 0.059 m/m.

Keywords: Alloy Wheels, Dynamic Radial Fatigue, Finite Element Method.

INTRODUCTION

Automotive industry four-wheel vehicle is very rapidly growing in Indonesia. Automatically also, the need for spare parts continues to increase, one of which is alloy wheels. The number of rims demand continues to increase so that many rims industries are trying to meet market needs. BSA is one of the manufacturing industries that produce alloy wheels. Various models of wheels have been produced to meet various vehicle variants that are produced by the automotive principal. The wheels produced must meet the passenger safety standards in driving in Indonesia.

To meet passenger safety standards, BSA always performs testing on each model wheels produced. The purpose of testing is to determine the cracks that occur on each part of the component wheels. A slight crack that arises has an effect on the stress distribution of the wheel material. Alloy wheels is a very important vehicle component. Alloy wheels serves as an energy distributor and vehicle load buffer. The load on the wheel can be differentiated into the static load and dynamic load.

Indonesian National Standard (SNI) is a standard that regulates all aspects of national standardization. One of them is standardization of four-wheel wheels. This standard is regulated in SNI 1896: 2008. This standard specifies the quality requirements of alloy wheels for motor vehicles made of metal that is steel alloy wheels and alloy wheels lightweight metal wheel four.

The quality requirements of alloy wheels shall meet the criteria of SNI 1896: 2008, such as visible properties, resistance to tiredness due to turn curves, resistance to dynamic radial fatigue, impact resistance to light alloy wheels, the durability of the air circumference of alloy wheels for light alloy wheels.

One of the quality requirements on the visible properties is the surface of the wheels should not be cracked due to production defects and sharp surfaces and must pass the loading test. One of the testing loads on the alloy wheels is the testing of resistance to dynamic radial fatigue is a test on the wheels are done to determine the strength of the fatigue on the structure of alloy wheels against the radial load. The wheels often experience repeated loading so that it can cause cracks. Cracks greatly affect the stress distribution of wheel material which can cause fractures to a much lower degree than the maximum voltage of static loading.

The purpose of this study is to provide an alternative load analysis on rims model-253 size 6.5 x 15 JJ based on SNI 1896: 2008 by visualizing rims in dynamic radial fatigue testing using Solid works Simulation, and analyze the stresses and strain that occur by simulating the wheels that have been made on the software finite element method.

THEORETICAL BASIS

Wheel Rim

Wheel Rim is an important component for every vehicle that works on the vehicle suspension system that provides static load and dynamic load on a vehicle. Vehicles such as cars that run, rims components are very important for the safety and comfort of passengers. Safety factor and economical cost are the things that need to be considered to do mechanical structure design on a wheel. The burden, the style, the level of manufacturing process capability, and the performance of the wheels are the cornerstone of the new design optimization of alloy wheels. Rims are made of steel or aluminum alloy depending on needs. Aluminum alloys are often chosen because they are corrosion resistant, very lightweight and easy to shape

SNI 1896: 2008

SNI 1896: 2008 is the standard of motor vehicles of category M, N and O. This standard specifies the quality requirements and testing procedures of alloy wheels for motor vehicles made of metal that is steel alloy wheels and lightweight alloy wheels alloy wheels. This standard does not apply to wheeled wheels, industrial vehicles, and agricultural vehicles.

Glossary and definition of wheels based on SNI 1896: 2008: (1). *Wheel Rim*: place of vehicle tires attached; (2) Light alloy wheels: The rims and discs are made of lightweight alloy materials; (3) Round wheel: Belt section of the round wheel where the tire is attached; (4) Disc: the center of the wheel where the bolts and nuts are mounted to other parts of the vehicle; (5) Geometric eccentricity (Run Out): Geometric deviation or axis inequality; (6) Radial geometric eccentricity (Radial Run Out): Deviation of geometric or axis shape in radial direction; (7) Lateral Run Out: Deviation of geometric shape or axis in the lateral direction; (8) *Offset*: The distance between the placement of alloy wheels attached to other parts of the vehicle with the middle radial area of the rim wheel; (9) Axis diameter of the nut holder (Pitch circle diameter/PCD): Axis diameter of the nut stand on the dish;(10) Flange: The lips of the outer part of the rim that hold the tire in place; (11) Bead seat: The circumference of the wheel rim where the tire lip rests; (12) Well: The curve around the rim of the wheel which strengthens and strengthens the wheel; (13) Type: The type of alloy construction represented by each different design. What is meant by design is the form, size of diameter wheel, wheel width, *offset*, *PCD* and the number of bolt holes.

Terms of quality alloy wheels. Resistance to dynamic radial fatigue *(Dynamic Radial Test/ Drum Test)* ie wheels should be free from cracks that are checked with a penetrant liquid, free of cracks, visible deformations and no restriction of nuts or bolts of abnormal wheels.

Material Fatigue

Fatigue is one type of failure (broken) on a component due to dynamic load (repetitive or variable loading). It is estimated that 50% - 90% (Figure 1) mechanical failure is caused by fatigue.

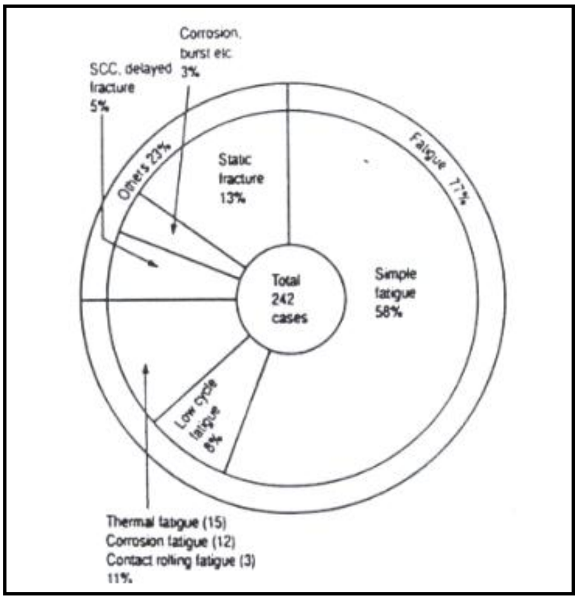


Figure 1. Distribution Mode Failure

Component or structure failure modes can be divided into 2 main categories, namely: (1) Quasi-static failure mode (failure mode that is not time-dependent, and resistance to failure is expressed by force); (2) Failure mode that depends on time (resistance to failure is expressed by age or lifetime).

Types of quasi-static failure modes: (1) Failure due to tensile load; (2) Failure due to compressive load; (3) Failure due to sliding load. Fractures that include this type of failure mode are broken ductile and brittle fractures.

Finite Element Method **(FEM)**

Finite Element Method is a numerical method to solve various mathematical problems from a physics phenomenon, such as structural mechanics. The basis of the finite element method is to divide the work piece into finite small elements so that it can calculate the reaction due to the load on the given boundary condition. From these elements can be arranged matrix equations that can be resolved numerically and the result becomes the answer of the load conditions given to the work piece. From mathematical completion by calculating inverse matrix, the equation will be obtained in the form of a matrix for one element and the shape of the total matrix which is an assemblage of the element matrix (figure 2).

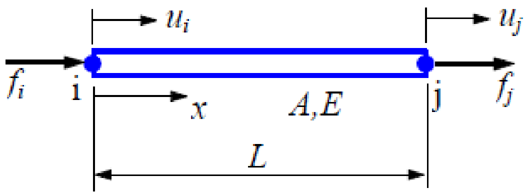


Figure 2. Free body bar diagram

RESEARCH METHODS

Overall in the use of the finite element method consists of 3 main steps: (1) *preprocessing,* (2) *analysis,* and (3) *post processing.* Following is the flow of the testing process using the finite element method:

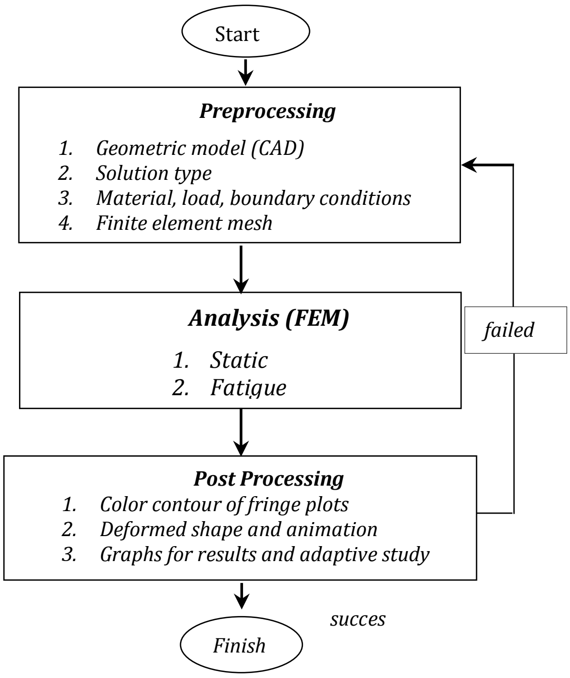


Figure 3. SolidWork simulation flowchart

RESULTS AND DISCUSSION

Preprocessing stage

This stage the author re-modeling the alloy wheels based on the actual image, Next, do the meshing process by using 4 node tetrahedron element.

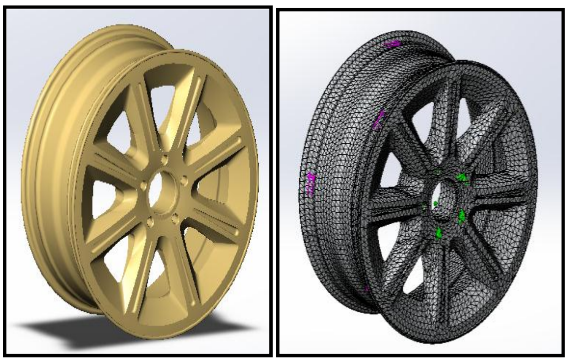


Figure 4. Geometry and meshing models remodeling results

In the simulation process required certain parameters used for modeling. In the modeling process, generally, only a few parameters are used. This is because the modeling only uses modeling to the extent of elasticity only. Modeling until the elastic area actually meets various forms of simulation. However, if the research requires data from the region after the elastic region then the parameters used must be completed. Modeling using only elastic area parameters is called elastic material modeling and modeling using plastic area parameters is called plastic material modeling.

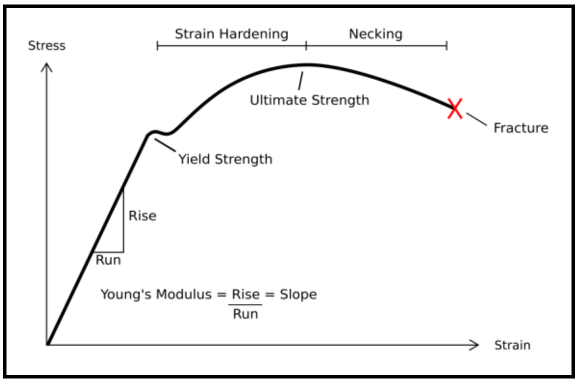


Figure 5. Stress Curve - Strain Diagram

Table 1. Parameter A356-T6 on elastic modeling

Parameter	Symbol	Value	Unit
Elastic Modulus	E	72400	N/mm^2
Mass Density	ρ	2680	kg/m^3
Poisson's Ratio	Y	0,33	
Shear Modulus		27200	N/mm^2

Table 2. Parameter A356-T6 on plastic modeling

Parameter	Symbol	Value	Unit
Yield Strength		152	N/mm^2
Tangent Modulus		1330	N/mm^2
Elongation at break		0,059	m/m
Shear Modulus		27200	N/mm^2
Tensile Strength		228	N/mm^2

In the actual test, the specimen will be tested under pressurized tire conditions. This pressure results in the distribution of loading on the seat and flange beat. Therefore, in the simulation of fatigue dynamic radial loading analysis, the force distribution due to the effect of tire pressure is divided into two, namely on the beat seat and flange according to the limits of the actual test conditions.

Table 3. Limitations of actual testing conditions

Condition Testing	Test 1	Test 2	Test 3
Rotation Speed	19,42 rps	19,27 rps	19,15 rps
Moment of Bending	2775.28 N.m	2667.41 N.m	2667.41 N.m
Cycles	5000	75000	150000

Analysis and Post-Processing Phase

In static loading analysis, processor (analysis) process is used to enter parameters, meshing and boundary to get a result in process post-processor. The following figure shows the boundary condition for the loading position to be given on the wheel.

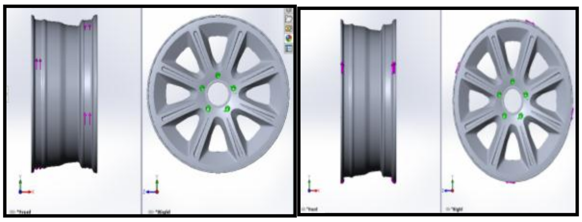


Figure 6. Boundary condition by giving fixed support and giving equivalent force to the seat and flange beat

The provision of boundary conditions is giving constraints to the wheel simulation. This construct provides fixed support on wheels. The provision of equivalent force is given to the wheel according to the extent of the area affected by the striker. After the processor process is complete, then proceed with the post-processor process to analyze the simulation result.

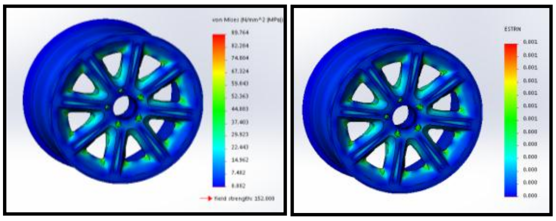


Figure 7. (a) tension and (b) strain that occurs on the seat beat and wheel flange due to bending moment

Crack on the simulation can be seen from the value of stress and elastic strain. The value in the simulation, the equivalent voltage on the wheels that occur should be smaller than the Ultimate Tensile Stress (UTS). Meanwhile, the elastic strain value equivalent to the wheel that occurs must have a value smaller than the elastic strain value when the fracture (elongation at break).

The ultimate tensile stress on alloy wheels with Aluminum material A356-T6 is 228 N/ mm^2 and elastic fracture strain value is obtained from the plastic strain of material of 0.059 m/ m (59 mm/ mm)

The simulation results are obtained, the equivalent tensile that occurs 77.985 N/ mm^2 at the angle of the rim radius (marked in green) and the equivalent elastic strain shows the number 0.001 mm/ mm (marked in red) at the corner of the alloy radius. Based on the simulation results, the equivalent tensile and strain values of the simulation results are still below the material properties value. This shows that the wheels simulated with static structural loading analysis are safe

Table 4. Stress of test load simulation results in 1

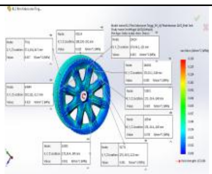
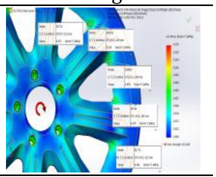
Condition	Centrifugal: 19,42 rad/ sec	
Test 1	Load Position	
	Beat Seat	Flange
Stress Equivalence		

Table 5. Tensile of test load simulation results in 2

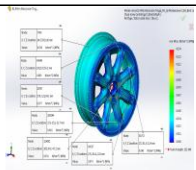
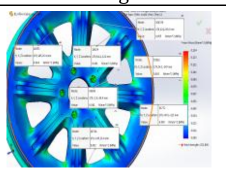
Condition	Centrifugal: 19,27 rad/ sec	
Test 2	Load Position	
	Beat Seat	Flange
Stress Equivalence		

Table 6. Tensile of test load simulation results in 3

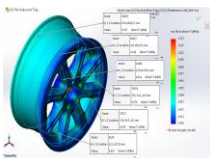
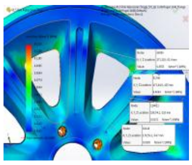
Condition	Centrifugal: 19,15 rad/ sec	
Test 3	Load Position	
	Beat Seat	Flange
Stress Equivalence		

Table 7. Tension value of the simulation results

Test	Simulation Result (MPa)		Value UTS	Conclusion
	Beat Seat	Flange		
	0,091	0,081	228	Secure
	0,077	0,084	228	Secure
	0,079	0,069	228	Secure

Conclusions based on the simulation results, the equivalent voltage obtained is smaller than the ultimate tensile strength [UTS] value, where the simulation results show that the model-253 6.5 x 15JJ alloy wheels with centrifugal loading are still **secure.**

Table 8. The strain of the test loading simulation results in 1

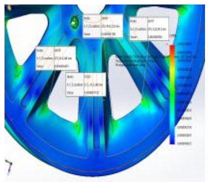
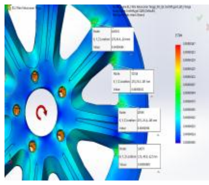
Condition	Centrifugal: 19,42 rad/ sec	
Test 1	Load Position	
	Beat Seat	Flange
Strain Equivalence		

Table 9. The strain of the test loading simulation results in 2

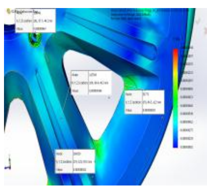
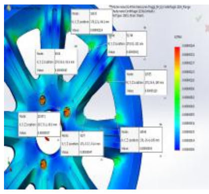
Condition	Centrifugal: 19,27 rad/ sec	
Test 2	Load Position	
	Beat Seat	*Flange*
Strain Equivalence		

Table 10. The strain of the test loading simulation results in 3

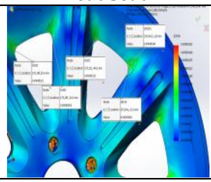
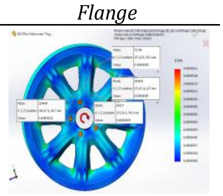
Condition	Centrifugal: 19,15 rad/ sec	
Test 3	Load Position	
	Beat Seat	*Flange*
Strain Equivalence		

Table 11. Strain value of simulation results

ji	Simulation Result (mm/mm)		Fracture Value	Conclusion
	Beat Seat	Flange		
	0,000000956	0,00000102	59	Secure
	0,000000983	0,00000114	59	Secure
	0,000000980	0,00000085	59	Secure

The conclusion based on the simulation results obtained the equivalent maximum strain value is smaller than the elastic strain when fracture. This shows that the model-253 alloy wheels size 6.5 x 15JJ with the provision of centrifugal loading is still secure.

Table 12. The Factor of safety simulation results

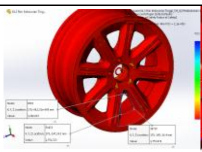
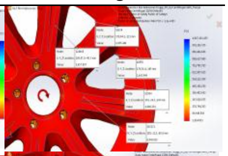
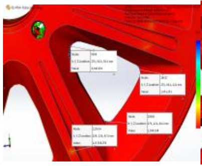
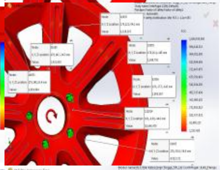
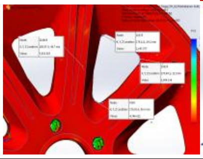
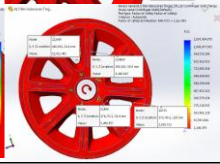
Condition	*Factor of Safety*	
Centrifugal	*Beat Seat*	*Flange*
Test 1 *19,42* rad/ sec		
Test 2 *19,27* rad/ sec		
Test 3 *Ee 19,15* rad/ sec		

Table 13. The value of factor of safety simulated results

Test	Simlation Result		*FoS*	Conclusion
	Beat Seat	Flange		
	1.751	1.663		Secure
	1.996	1.629	> 2	Secure
	1.647	5.450		Secure

Conclusion based on the results of the testing simulation, loading the model-253 wheel size 6.5 x 15JJ obtained a factor of safety greater than two (SF>2). This shows that the wheels simulated with static structural loading analysis have a secure design.

CONCLUSION

From the analysis that has been done using simulation testing, conclusions are obtained: The tensile value is equivalent due to the moment of bending and the rotational speed obtained is smaller than the value of the ultimate tensile strength. The strain value is equivalent due to the bending moment and the rotational speed obtained is smaller than the elastic strain of the fracture. The factor of safety obtained value of FS> 2, so the design of the model-253 size 6.5 x 15JJ alloy wheels has a secure design**.**

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