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Topology Optimization of Motorbike Footsteps Using Finite Element Method

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Abstract. Footsteps are a foothold for motorbike riders and passengers; they also play a role in maintaining stability when driving. Footsteps must have a solid and lightweight material to support the load from the feet and body of the rider and passengers. In this study, the footstep with the material made from the waste drum brake shoe varied by reducing mass through the static structural simulation process and topology optimization process using Ansys Workbench to get optimal mass, total deformation, equivalent stress, maximum principal stress, and safety factor from each variation. The footstep geometry will be subjected to a load of 1000 N and provided with the necessary support. Based on the data obtained during this study, the initial footstep geometry produces data in the form of total deformation (1.383 mm), equivalent stress (21.013 MPa), and safety factor (1.227). The 10% variation produces data in the form of total deformation (1.4368 mm), equivalent stress (20,564 MPa), and safety factor (1.2538). The 20% variation yields data in the form of total deformation (0.98037 mm), equivalent stress (18.111 MPa), maximum principal stress (18.41 MPa), and safety factor (yield strength: 1.4236. At the same time, the 25% variation produces data in the form of total deformation (1.3058 mm), equivalent stress (22.27 MPa), and safety factor (1.1577).

Introduction

Motorbikes are a vehicle that many Indonesian people choose as a mode of transportation because of their affordable price, as well as because public transportation in Indonesia does not provide good service. Based on data from the Association of Indonesia Motorcycle Industry, there will be an increase in the distribution of motorbikes, dominated by scooters, in 2023 as shown in Fig. 1 [1].

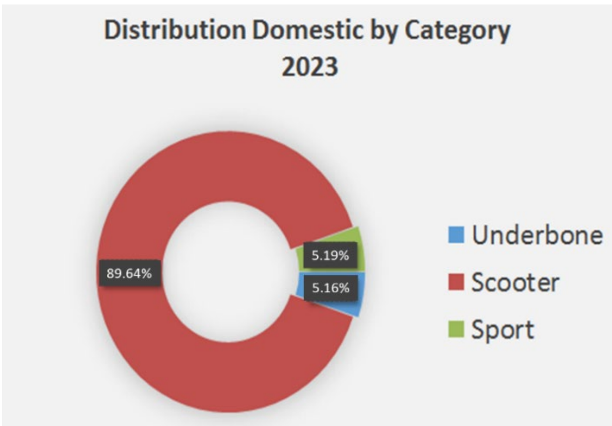


Fig. 1. Distribution domestic of motorbikes [1]

Footsteps are a motorbike component that uses aluminum as the main material. Footsteps play a role as a foothold for motorbike riders and passengers, apart from that, footsteps also play a role in maintaining stability when driving. For this reason, this component is one of the components that is always present on motorbikes. Footsteps are required to have strong and light material so that they can support the weight of the feet and body of the rider and passenger. However, OEM footsteps on the market tend to have quite high prices.

Alternative materials need to be developed to reduce footfall prices, one way is by recycling metal waste. In Indonesia, metal waste accounts for 3.04% of various types of waste [2]. The use of metal waste to be recycled back into new products has been carried out by several researchers, such as the use of waste motorbike brake shoes which are cast into brake handles [3], and as a footrest holder [4].

The simulation process using engineering software has been widely carried out by researchers and manufacturers to analyze the quality of a product or component [5]–[17]. Analysis using engineering software has advantages in terms of cost, time, and resources because there is no need to create a product to carry out the necessary analysis. Likewise with the optimization process [18], [19].

Based on the problems above, this research will analyze the strength of aluminum-based footsteps from brake shoe waste using the finite element method using the ANSYS Workbench R2 2021 application. This research aims to determine the strength of the product, in this case, the stress, strain, and safety factors. Furthermore, based on the simulation results of the product, topology optimization will be carried out to get a product that is lighter but does not reduce the strength of the product.

Material and Method

The material used in this research is waste motorbike brake shoes which are cast using the sand casting method to obtain their mechanical characteristics. Based on the tensile test results, Young's modulus value was 1.4 GPa, the yield stress was 25.78 MPa, and the ultimate stress value was 101.94 MPa. This data is entered into the ANSYS Workbench software's Engineering Data section's table. Fig. 2 shows the waste brake shoe used.

Fig. 2. Waste brake shoes on the motorcycle

The next stage is to model the footstep with geometry and size as shown in Fig. 3 and Ansys Space Claim Geometry in Fig. 4.

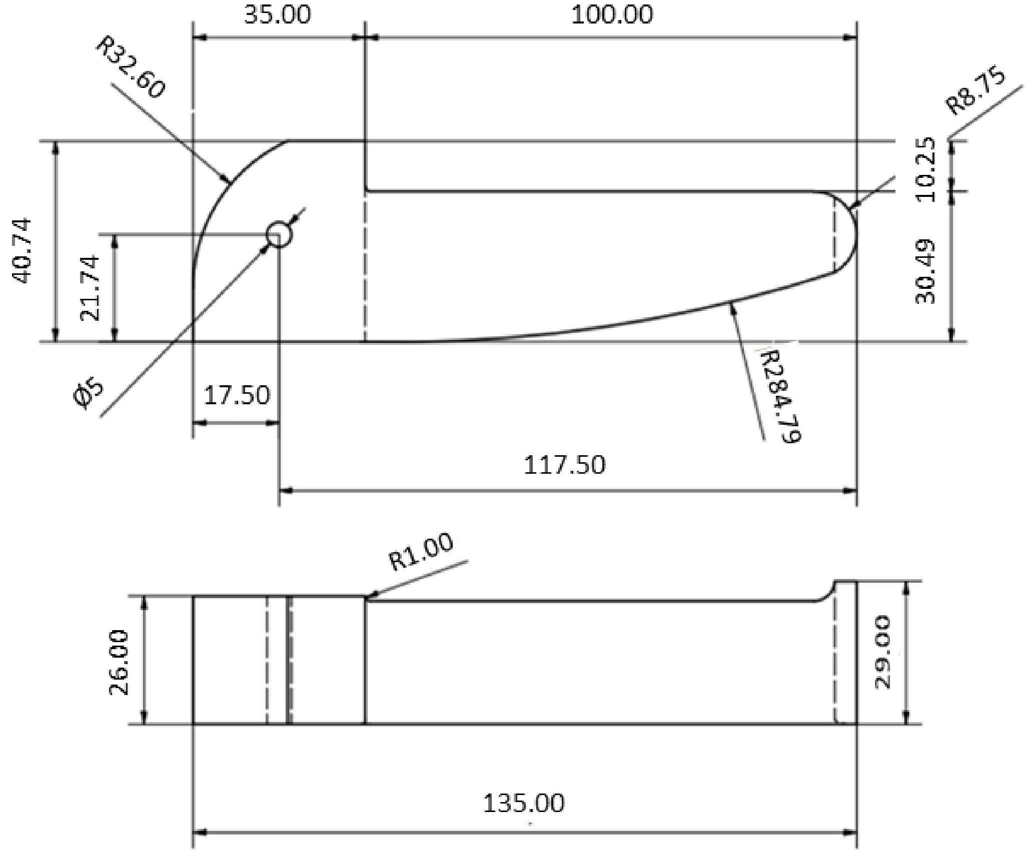


Fig. 3. Footstep drawing

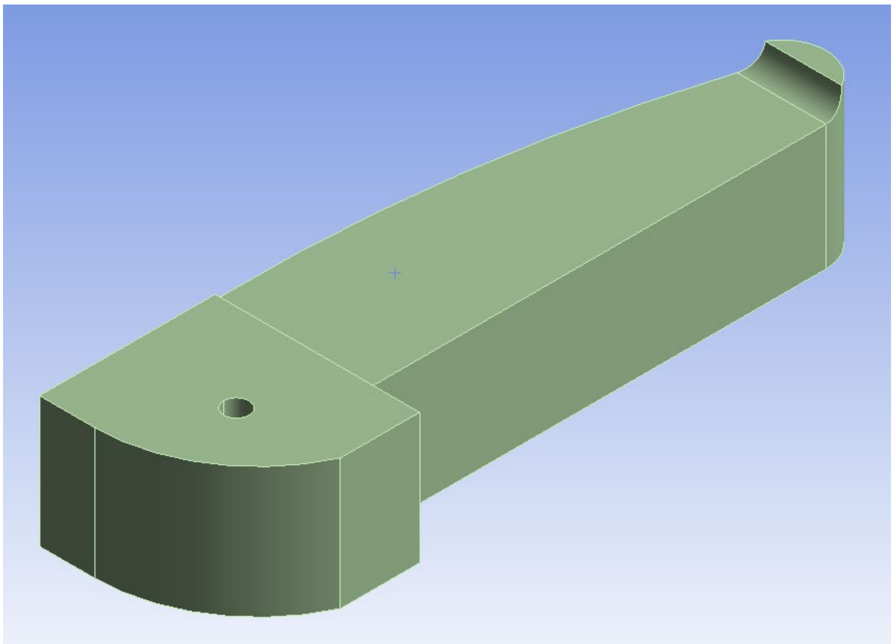


Fig. 4. Footstep model

The load given to the footstep section is the full load of the weight of one passenger with a mass of 100 kg. Assuming the acceleration due to gravity is 10 m/s^2, the passenger load will be 1000 N.

The element used is Tet10 with a mesh size that will be used initially of 1 mm which is then smoothed to a fine resolution at level 7. The mesh shape and mesh settings can be seen in Fig. 5 and Fig. 6. This mesh size was chosen because it produces very good skewness values, the skewness of the mesh matrix spectrum can be seen in Figure 7.

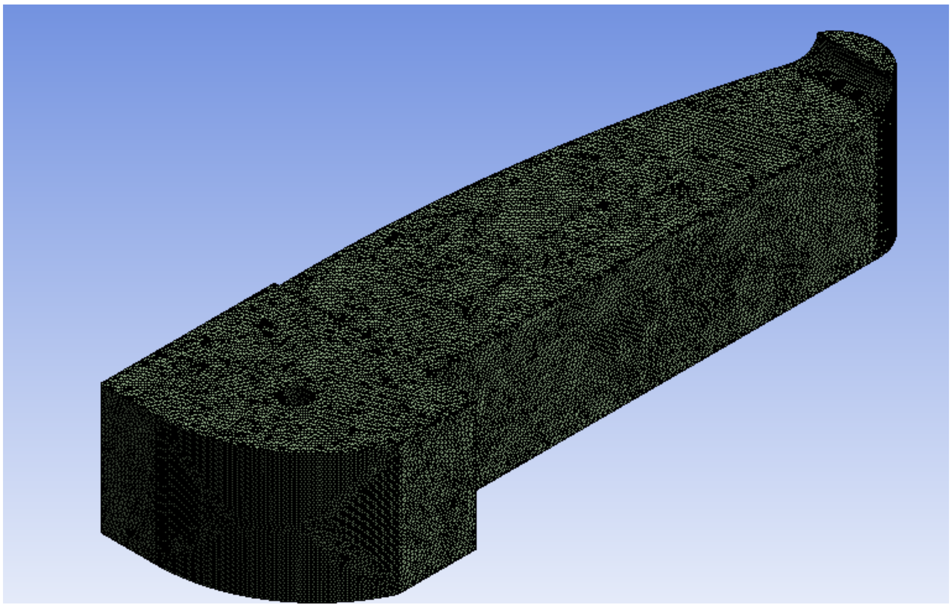


Fig. 5 Mesh on footstep

Details of "Mesh"

Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	1.0 mm
Sizing	
Use Adaptive Sizing	Yes
Resolution	7
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Fast
Span Angle Center	Fine
Initial Size Seed	Assembly
Bounding Box Diagonal	287.98 mm
Average Surface Area	3597.2 mm²
Minimum Edge Length	1.4719e-002 mm
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Aggressive Mechanical
Target Quality	Default (0.050000)
Smoothing	Medium
Mesh Metric	Skewness
Min	3.376e-007
Max	0.99992
Average	0.30968
Standard Deviation	0.16171

Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	No
Rigid Body Behavior	Dimensionally Reduced
Triangle Surface Mesher	Program Controlled
Use Asymmetric Mapped Mesh (Beta)	No
Topology Checking	Yes
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Statistics	
Nodes	809956
Elements	537676

Fig. 6 Mesh setting

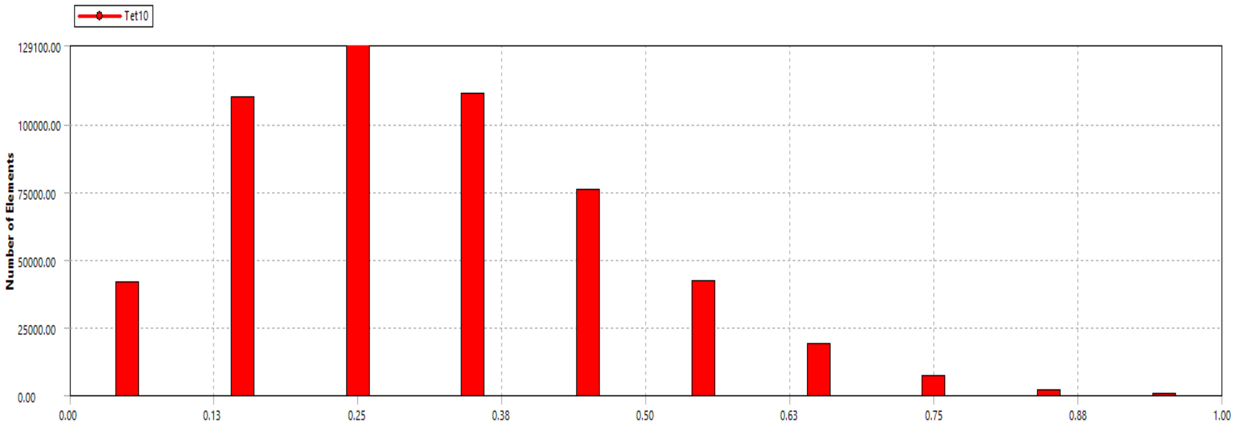


Fig. 7 Skewness mesh metric spectrum

After the meshing process continues with the setup process where the load and support points are placed on the geometry which can be seen in the Fig. 8.

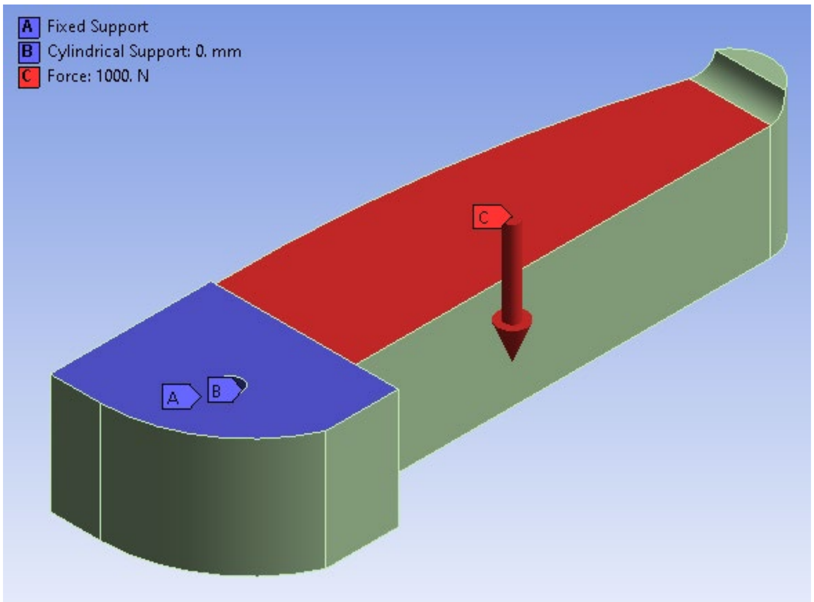


Fig. 8 Footstep setup

The process continues by entering the solution settings, this process inputs the desired final result. Where the desired final results are von Mises stress, deformation, and safety factor.
After getting the desired results, continue with topology optimization by setting up the optimization region and response constraints according to the variations made.

Result

Table 1 shows the initial design and design after the topology optimization process at a mass reduction of 10%, 20%, and 25%.

Table 1 Initial design and after mass reduction

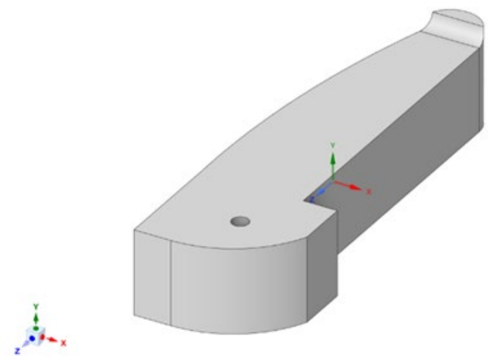
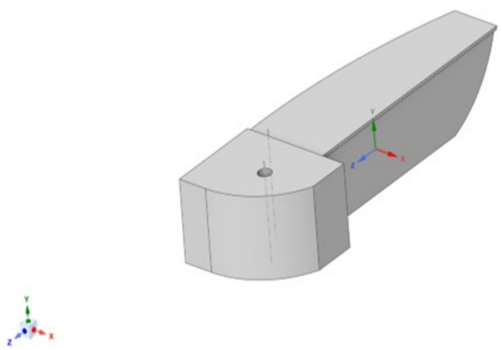
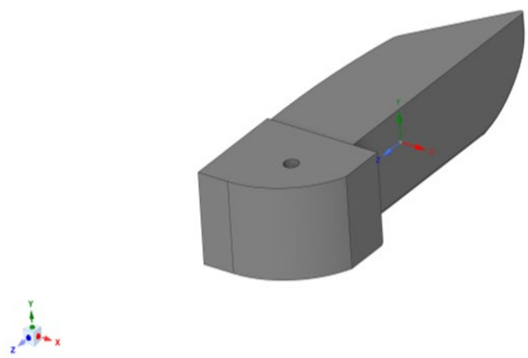
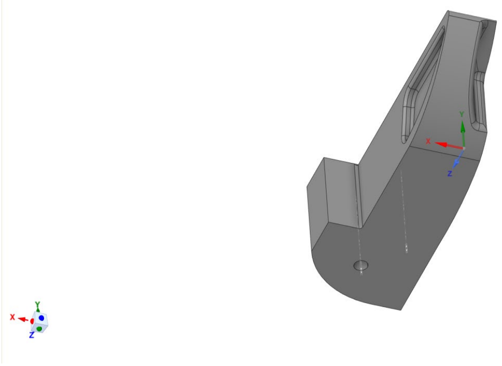
Condition	Shape
Initial	
10% mass reduction	
20% mass reduction	
25% mass reduction	

Table 2 shows the simulation results in the form of total deformation and von Mises stress for initial conditions and after undergoing topology optimization

Table 2 The stress and total deformation for each model.

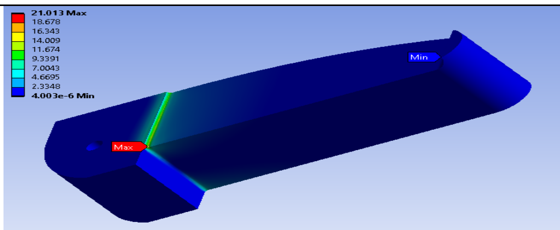
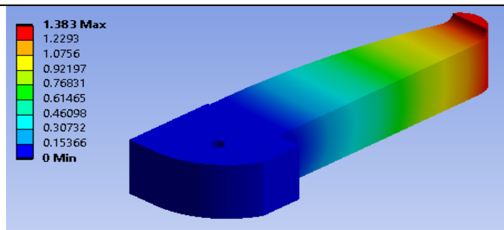
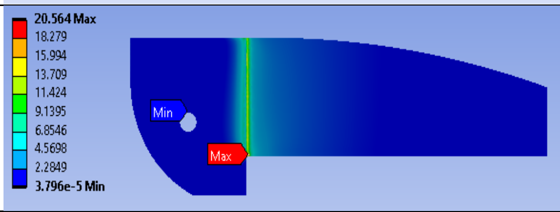
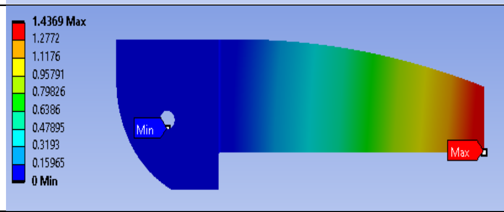
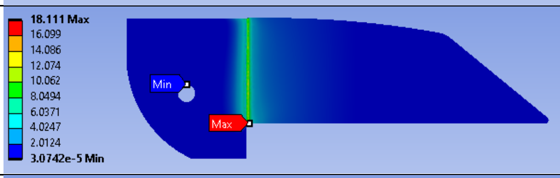
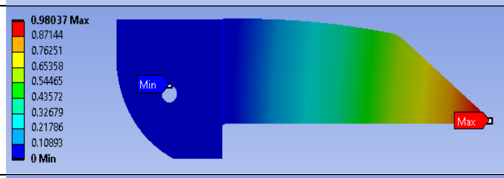
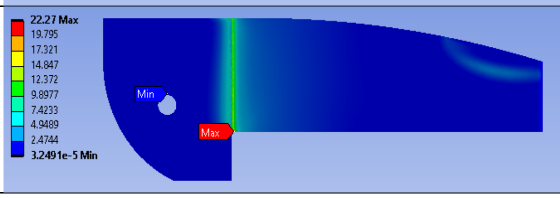
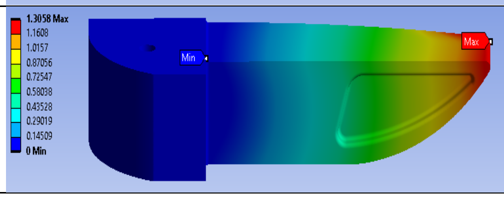
Mass	Von Mises Stress	Total Deformation
Initial		
10% mass reduction		
20% mass reduction		
25% mass reduction		

Table 3 The result of topology optimization of the footstep

Mass Reduction	Mass (kg)	Von Mises Stress (MPa)	Total Deformation (mm)	Safety Factor
Initial	2.048	21.013	1.383	1.227
10%	1.903	20.564	1.4369	1.2538
20%	1.783	18.111	0.98037	1.4236
25%	1.553	22.27	1.3058	1.1577

Table 3 shows details of the initial conditions and after the topology optimization process. Based on these data, the best footstep design is a design with a mass reduction of 20% because when compared with other conditions it produces von Mises stress results, the smallest total deformation, while the safety factor is the largest. Even though a 25% mass reduction provides the smallest mass reduction, there is an increase in total deformation and von Mises stress, resulting in the safety factor decreasing again.

Conclusion

From the results of topology optimization, there was a reduction in mass from the initial 2.048 kg to 1.553 kg (25%). The results show the best design is footstep with a mass reduction of 20% from the initial shape.

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