Jurnal Asiimetrik: Jurnal Ilmiah Rekayasa Dan Inovasi
Terakreditasi "**Peringkat 3**" berdasarkan SK Dirjendiktiristek, Nomor: 225/E/KPT/2022
Volume 6 Nomor 1 Tahun 2024, Januari 2024, Halaman 1-10
Website : http://journal.univpancasila.ac.id/index.php/asiimetrik/

p-ISSN 2655-1861
e-ISSN 2716-2923

Finite Element Analysis of Aluminum Based R22 Car Wheel Design Modification

Analisis Elemen Hingga pada Modifikasi Desain Velg Mobil R22 Berbahan Aluminium

Salman Alfarisi, Riyan Ariyansah*, Dan Mugisidi
Universitas Muhammadiyah Prof. Dr. Hamka, Jl. Tanah Merdeka No. 6, RT. 10/RW. 5, Rambutan, Kec. Ciracas, kota Jakarta Timur, Daerah Khusus Ibukota Jakarta 13830, Indonesia

Article information:

Received:
21/06/2023
Revised:
16/07/2023
Accepted:
29/07/2023

Abstract

The wheels are one of the main parts of the vehicle. To make car wheels, manufacturers must complete several stages. Especially in the design of the wheels. This study aims to determine the comparative value of three different types of wheels with the same material using aluminum type 6061-T6 (SS). We will test the three-wheel models, namely model 1, model 2, and model 3, with a force of 3000 N and a pressure of 800 N to compare their performance. This test uses Solidworks 2019 software with the finite electronic analysis (FEA) method. The results obtained are the value of von Mises stress, resulting displacement, equivalent strain and its deformation, and factor of safety. The dimensions of the wheels are 22 inches. The results of the best Model 3 alloy wheel research indicate that the design process is easier. These wheels have a von Mises stress value of 11.02 MPa with a resulting displacement value of 0.021 mm, an equivalent strain of 0.000096, a safety factor of 25, and a deformation value of 1. Based on these results, model 3 alloy wheels are safe.

Keywords: velg, von Mises stress, equivalent strain, safety factor, displacement.

***SDGs*:**

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Abstrak

Roda merupakan salah satu bagian utama dari kendaraan. Pembuatan velg mobil terdiri dari beberapa tahapan yang harus dilakukan. Terutama dalam desain roda. Penelitian ini bertujuan untuk mengetahui nilai perbandingan 3 *type* velg yang berbeda dengan bahan yang sama menggunakan aluminium *type* 6061-T6 (SS). Hasil perbandingan dari tiga model velg, yaitu velg model 1, model 2 dan model 3 yang akan diberikan pengujian dengan *force* sebesar 3000N dan *pressure* sebesar 800N.Pengujian ini menggunakan software Solidworks 2019 dengan metode *finite elemnent analysis* (FEA). Hasil yang didapatkan yaitu nilai *von Mises stress, resultant displacement, equivalent strain* serta deformasinya dan nilai *factor of safety*. dimensi velg yaitu 22 *Inch*. Dapat disimpulkan hasil penelitian velg Model 3 yang terbaik dan lebih mudah dalam proses perancangannya. Velg ini memiliki nilai *von Mises stress* sebesar 11,02 MPa dengan nilai *resultant displacement* 0,021 mm, *equivalent strain* yaitu 0,000096 dan faktor keamanan sebesar 25 serta nilai deformationnya yaitu 1. Berdasarkan hasil ini Velg model 3 aman.

Kata Kunci: *velg, von Mises stress, equivalent strain, safety factor, displacement.*

*Correspondence Author
email : riyan_ariyansah@hamka.ac.id

This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License

1. INTRODUCTION

One automotive part that always experiences design developments and is more prioritized for appearance is alloy wheels. Therefore, a new rim design must be created to meet the wishes of customers. However, we must note that the design must meet the test criteria. A rim, which after passing the testing stage becomes fit for production. Both rim modifications and the need for standard parts for certain vehicle brands continue to increase, resulting in an increase in rim demand in Indonesia. A very diverse variety of modified rims is a problem, and of course, in order to increase rider comfort and safety, rims must be standardized. One very important part in the transmission of power between the vehicle and its wheels is the rim (Rizki, Anwar and Heryadi, 2021). The type of loading can be either static load or dynamic load (Pris, Suyitno and Suhadi, 2019).

There are 2 types of alloy wheels, namely steel wheels and aluminum alloy wheels (Alloy wheel). However, many people choose aluminum alloy wheels because of their modern design variations. Another advantage of using aluminum alloy wheels is their lighter mass, which means they are better for fuel and more corrosion resistant. Therefore, the most suitable material for this study is aluminum alloy wheels type 6061-T6 (Naufal, 2019). Three types of tests are used to test the design of an alloy wheel, namely the rotary flexure test, radial fatigue test, and impact test (Wang, Zhang and Xu, 2019; Trimulya, Cholis and Wahyuni, 2020). This test determines the degree of fatigue and durability of the wheels (Wiley and Elsaleiby, 2011).Testing vehicle wheels with fatigue and flexure test methods ensures wheel safety levels with low maintenance costs (Chai *et al.*, 2019).

One method that has been widely used to assess alloy wheel characteristics is the finite element analysis (FEA). The FEA method can solve complex structural problems in solid body mechanics and produce solutions in the form of stress, strain, deflection to fatigue life (Bagherzadeh, Murugesan and Deka, 2020). The advantage of the FEA method is the use of time and low costs, even this method can be used before the actual prototype is made, besides that this method is also supported by CAE-based software such as the Solidworks program and the Pro Engineering program.

Formulating finite element models for alloy wheels and comparing the results with Pro Engineering for displacement, strain, and stress parameters, the results show that modeling with Pro Engineering can be a very useful tool for analyzing simple structures such as car wheels (Sumiyanto and Abdunnaser, 2018).

This study has a problem formulation, namely, what are the results of von Mises stress, resultant displacement, equivalent strain and its deformation as well as the value of the factor of safety of the three existing wheel models and which wheel model is theoretically best and analyzed. This study aims to determine the comparative value of analysis of 3 different types of wheels with the same material and using the same type 6061-T6 (SS) aluminum because Aluminum 6061-T6 has advantages such as relatively high tensile strength, good formability, corrosion resistance and is a lightweight metal. The analysis conducted in this study uses Solidworks 2019 software with a customizable computing base to achieve high precision. Analyze the shape of the wheel, where there are three shapes, shapes 1, 2, and 3. The results of the three models will be searched for Von Mises stress, displacement resultant, equivalent strain value, and deformation value and safety factor.

2. METHODOLOGY

Technological developments in the automotive industry have brought significant progress in ensuring safety and driving comfort. One of these advances is the use of lightweight wheels that are able to carry heavy loads and beautify the appearance of the vehicle.

System simulation software is used as a design tool to build rims quickly, precisely and efficiently. The use of manual wheel designs is no longer common, so software is a continuation of an effective and efficient design process. One of the two-wheeled vehicle wheel construction simulation programs is Solidworks. With this software, designers can make various types of rims, determine the strength of the materials used, test static and dynamic loads, and determine design safety factors (Wibawa, Akbar and Pramesti, 2021).

Before conducting research, a flowchart of the research process is made, this allows to find out how the research will be carried out (Jiang *et al.*, 2018). The following is the flow diagram of the research conducted as shown in Figure 1.

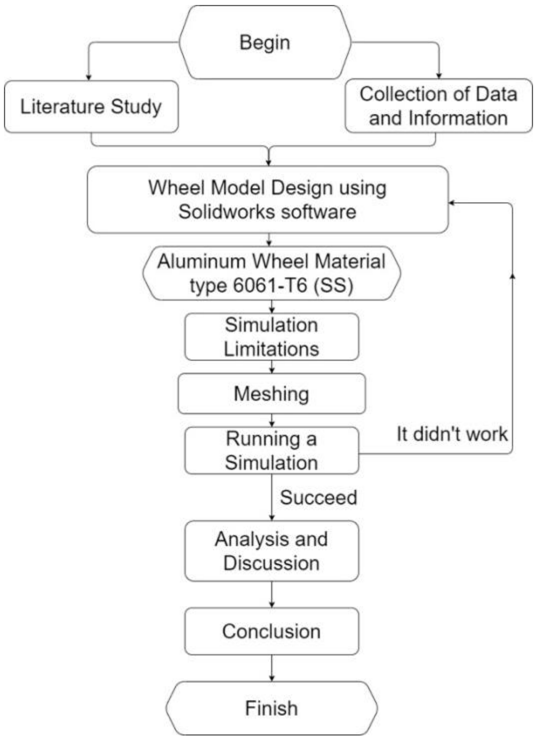

Figure 1. Research flow chart.

2.1. The Equipment and Materials Spesifications for the Research

2.1.1. Hardware

The laptop to be used in this study must have specifications that are able to run Solidworks software. The laptop used has specifications, Intel Core i5-7200U CPU 2.50GHz processor, 12 GB RAM, 64-bit System, Windows 10.

2.1.2. Software

Solidworks on this simulation is used to create designs as well as analysis. Here is an initial picture of the Solidworks software research conducted as in Figure 2.

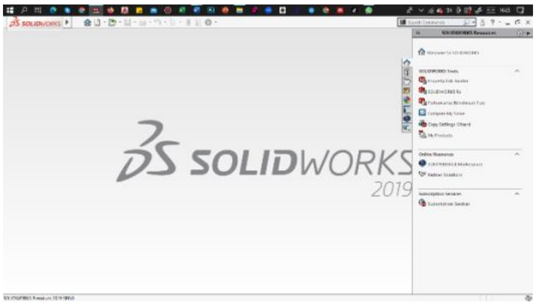

Figure 2. Software Solidworks 2019.

2.2. Wheel modeling and design

This study examines 3 different types of wheel models in the center bore. With these 3 types, it was designed using Solidworks 2019 software using aluminum type 6061-T6 (SS) material. The following are specifications for aluminum material type 6061-T6 (SS) research conducted as in Table 1 (HandWiki, 2023).

Table 1. Load research material parameter (HandWiki, 2023).

Aluminum 6061-T6 (SS)		
Parameter	**Value**	**Unit**
Mass Density	2700	kg/m^3
Yield Strength	275.0000009	N/mm^2
Tensile Strength	310.0000021	N/mm^2
Elastic Modulus	69000.00067	N/mm^2
Poisson's Ratio	0.33	N/A
Shear Modulus	26000.00013	N/mm^2

The estimated size of the wheels to be used is 22 inches. The model on the wheels will use three models, namely 1, 2 and 3 where the difference in model 1 has a center bore with an angle of R160, model 2 with an angle of R0 and model 3 with an angle of R60 will vary in the position of the center bore. There are the dimensional drawings for this study as shown in Figure 3, Figure 4, and Figure 5 (Jadhav and Mali, 2021).

2.2.1. Load Data Input

This stage includes data on the materials needed in accordance with the research. Material data entry can be set up in the Solidworks 2019 software in the materials tool. Regional boundaries need to be determined to facilitate calculation; a loading group is needed that must be adjusted to the desired loading point. Analysis wheels are given a load with a force of 3000 N and a pressure of 800 N. The loading on the wheels to be analyzed is as in Table 2 (Zapata, González-Estrada and Pertuz, 2018).

Table 2. Load research (Zapata, González-Estrada and Pertuz, 2018).

No	Load Details		
	Load name	Value	Units
1.	Force	3000	N
2.	Gravity	-9,81	m/s²
3.	Pressure	800	N/m²

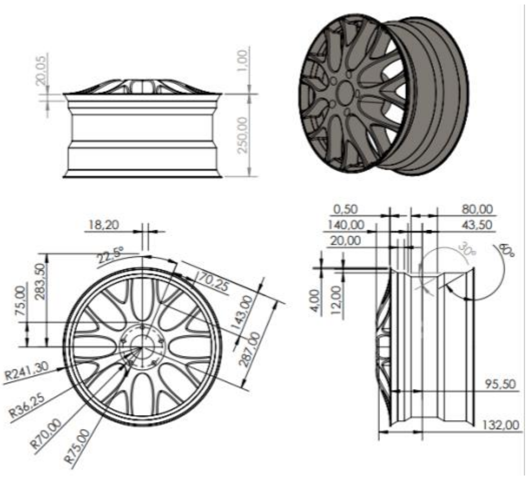

Figure 3. Model 1 design and dimensions.

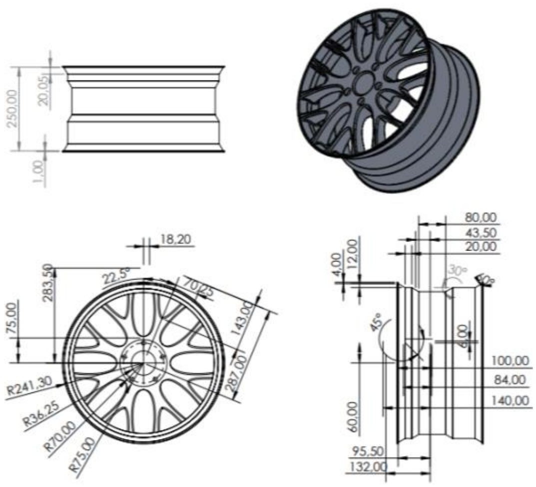

Figure 4. Model 2 design and dimensions.

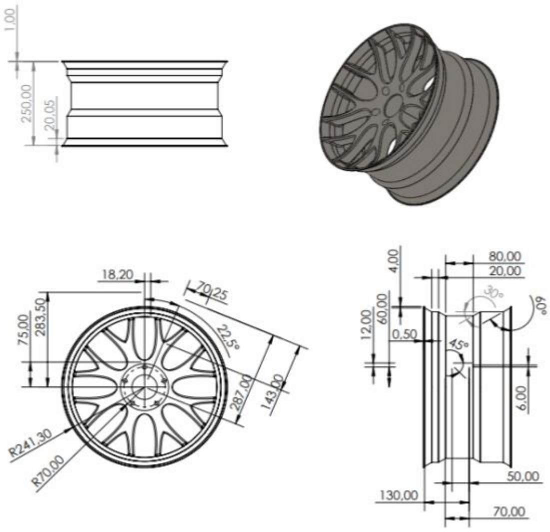

Figure 5. Model 3 design and dimensions.

2.2.2. Loading Points on wheels

Loading point is an attempt to group the load so that it can be assumed well to get maximum results from the results of the testing process. This loading must be adjusted to its position, each wheel model is given the same loading value, which only calculates the load weight in an effort to obtain static wheel simulation results. Loading is given the same value so that the best alloy wheels can be specified for the same loading variable. The following is a picture of the loading position applicable to aluminum wheels type 6061-T6 (SS). Figure 6 is the fixed geometry position, Figure 7 is the force load point position, Figure 8 is the gravity point position, and Figure 9 is the pressure load point position and messing in Figure 10.

Figure 6. Fixed geometry load point.

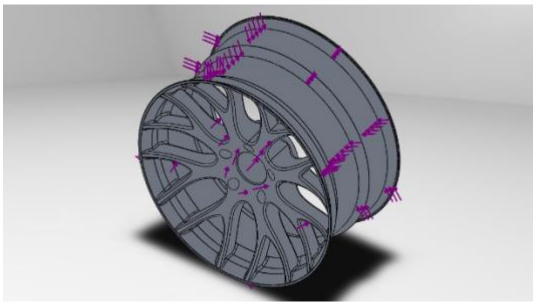

Figure 7. Force load point.

Figure 8. Gravity load point.

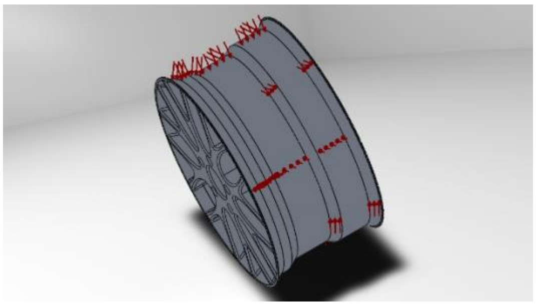

Figure 9. Pressure load point.

Figure 10. Messing.

2.2.3. Static Analysis Simulation

After completing 3-dimensional modeling of wheels with aluminum type 6061-T6 (SS) material usingn Solidworks Software. This simulation produces maximum and minimum voltage values for loading performed at predetermined points todetermine stress loads and strain loads. It can be seen in the simulation that there is a dark blue to red color that affects the concentration of stress (Ali, Sawadi and Tilefih, 2021).

Deflection on wheels is influenced by predetermined forces on each specific part of the wheels that have been determined. Then the results of the safety factor for the wheels will be obtained from a safety perspective. Static analysis on the chassis with three Models 1, 2 and 3 can see which pattern is the best according to the calculation of Von Mises Stress, Resultant Displacement, Equivalent Strain along with its deformation and the value of Factor of Safety that has been obtained.

3. RESULTS AND DISCUSSION

The design results obtained are based on the results of research by simulating static analysis of the chassis designed in the center bore with different models, namely model 1 shown in Figure 11, then model 2 shown in Figure 12, and model 3 results shown in Figure 13. The design of the center bore wheels uses aluminum type 6061-T6 (SS).

Figure 11. Model 1 wheel results.

Figure 12. Model 2 wheel results.

Figure 13. Model 3 wheel results.

The following are the results of testing the car prototype wheels on the center bore section with the help of the 2019 Solidworks software:

a. Model 1

The following are the results of the analysis of model 1 wheels. Analysis in the form of von Mises stress, resultant displacement, equivalent strain values along with their deformation and Factor of Safety values obtained from static analysis simulations using Solidworks 2019 software.

The value obtained from the simulation results shows that the von Mises voltage value has a minimum value of 0 MPa and a maximum value of 11.62 MPa. The following is shown in Figure 14.

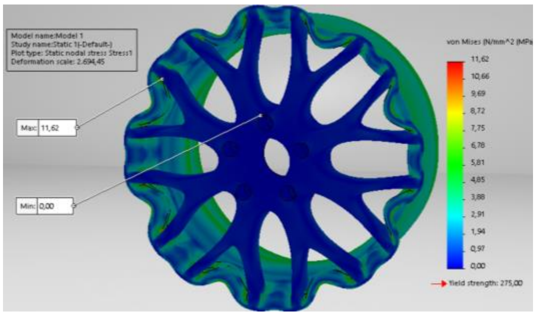

Figure 14. Results of von Mises stress and deformation for model 1.

The value obtained from the simulation results shows that the minimum resultant displacement value is 0 mm and the maximum value is 0.024 mm as shown in Figure 15.

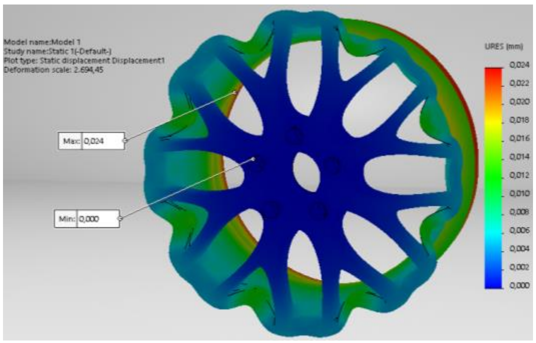

Figure 15. Results of resultant displacement and deformation for model 1.

The value obtained from the simulation results shows a minimum equivalent strain value of 0 and a maximum value of 0.000099 as shown in **Figure 16.**

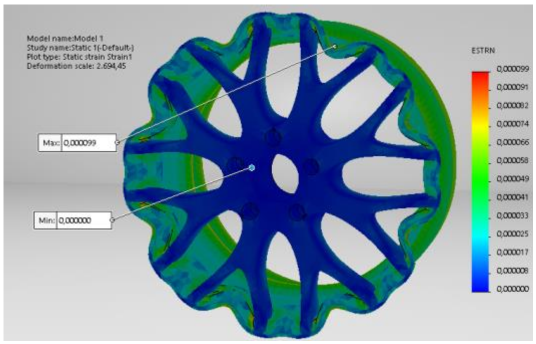

Figure 16. Results of equivalent strain and deformation for model 1.

The value obtained from the simulation results shows a minimum safety factor value of 24 and a maximum value of 95.098 as shown in Figure 17.

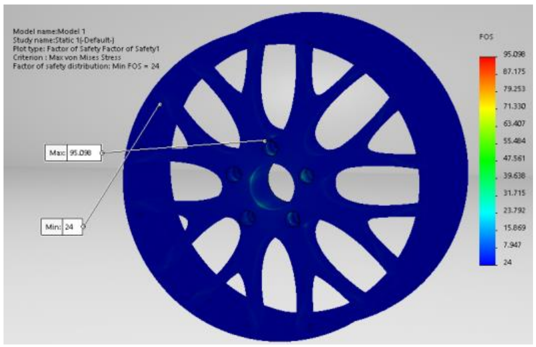

Figure 17. Results factor of safety for model 1.

b. Model 2

The following are the results of the analysis of model 2 wheels. Analysis in the form of von Mises stress, resultant displacement, equivalent strain values along with their deformation and Factor of Safety values obtained from static analysis simulations using Solidworks 2019 software.

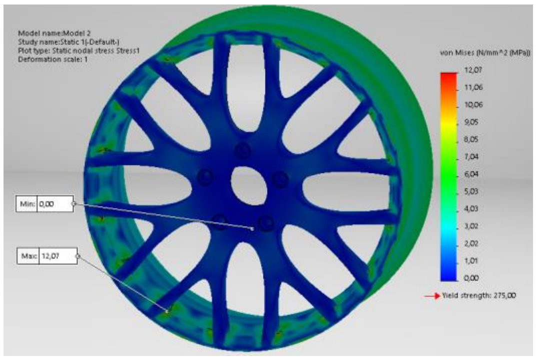

Figure 18. Results of von Mises stress and deformation for model 2.

The value obtained from the simulation results shows that the von Mises voltage value has a minimum value of 0 MPa and a maximum value of 12.07 MPa. The following is shown in Figure 18.

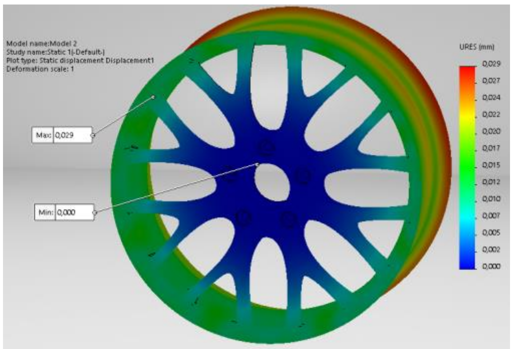

Figure 19. Results of resultant displacement and deformation for model 2.

The value obtained from the simulation results shows that the minimum resultant displacement value is 0 mm and the maximum value is 0.029 mm as shown in Figure 19. The value obtained from the simulation results shows a minimum equivalent strain value of 0 and a maximum value of 0.000098 as shown in Figure 20.

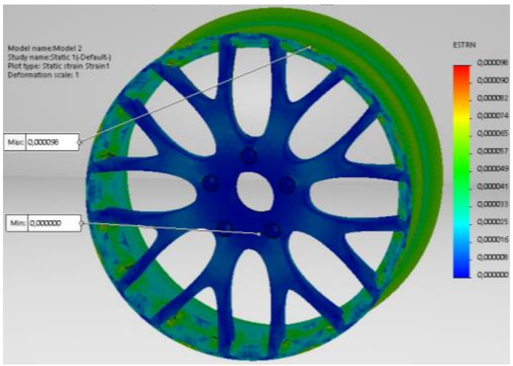

Figure 20. Results of equivalent strain and deformation for model 2.

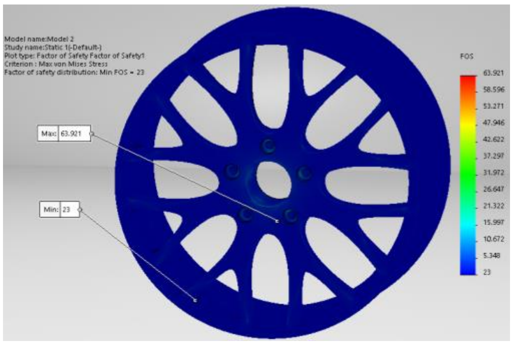

Figure 21. Results factor of safety for model 2.

The value obtained from the simulation results shows a minimum safety factor value of 23 and a maximum value of 63.921 as shown in Figure 21.

c. Model 3

The following are the results of the analysis of model 3 wheels. Analysis in the form of von Mises stress, resultant displacement, equivalent strain values along with their deformation and Factor of Safety values obtained from static analysis simulations using Solidworks 2019 software.

The value obtained from the simulation results shows that the von misses voltage value has a minimum value of 0 MPa and a maximum value of 11.02 MPa. The following is shown in Figure 22.

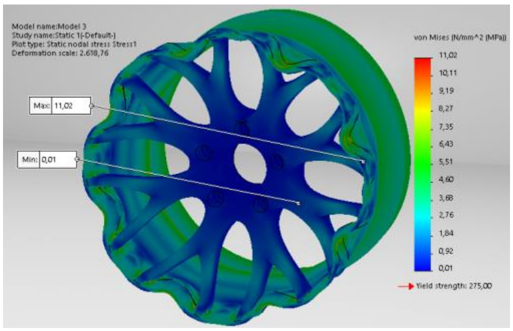

Figure 22. Results of von Mises stress and deformation for model 3.

The value obtained from the simulation results shows that the minimum resultant displacement value is 0 mm and the maximum value is 0.021 mm as shown in Figure 23.

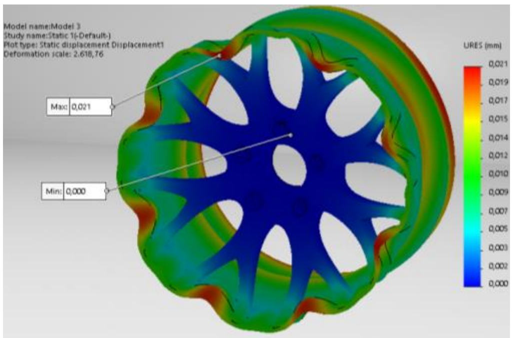

Figure 23. Results of resultant displacement and deformation for model 3.

The value obtained from the simulation results shows a minimum equivalent strain value of 0 and a maximum value of 0.000096 as shown in Figure 24.

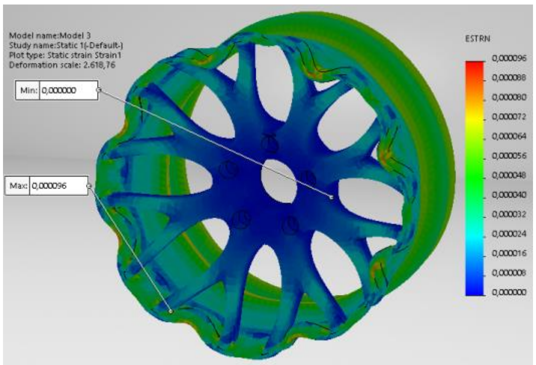

Figure 24. Results of equivalent strain and deformation for model 3.

The value obtained from the simulation results shows a minimum safety factor value of 24 and a maximum value of 50.400 as shown in Figure 25.

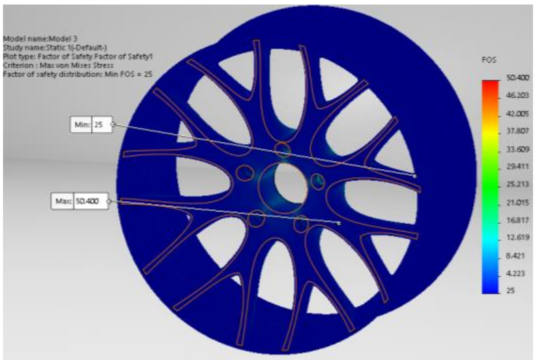

Figure 25. Results factor of safety for model 3.

The results of the analysis of the images above are the purpose of this study, these results will be compared in Table 3 to make it easier to identify the values of the three-wheel models.

The discussion is based on the results of a simulated analysis of car wheels using aluminum type 6061-T6 (SS) material with the help of Solidworks 2019 software, namely to find the value of von Mises stress, resultant displacement, equivalent strain along with its deformation and the value of factor of safety on the three wheel models 1, 2 and 3. The results of Model 1 analysis are von Mises stress value of 11.62 mpa with resultant displacement value of 0.024 mm, equivalent strain of 0.000099 and safety factor of 24 and deformation value of 2,694.45. Then obtained the von Mises stress value for model 2 of 12.07 MPa with a resultant displacement value of 0.029 mm, equivalent strain of 0.000098 and a safety factor of 23 and a deformation value of 1. This analysis resulted in von Mises stress on model 3 wheels of 11.02 MPa with a resultant displacement value of 0.021 mm, equivalent strain of 0.000096 and a safety factor of 25 and a deformation value of 2,618.76.

Table 3. The results of the analysis of 3 wheel models.

Model	Classification	Result
Model 1	Von mises stress	11,62 MPa
	Resultant Displacement	0,024 mm
	Equivalent Strain	0,000099
	Factor of Safety	24
	Deformation Scale	2.694,45
Model 2	Von mises stress	12,07 MPa
	Resultant Displacement	0,029 mm
	Equivalent Strain	0,000098
	Factor of Safety	23
	Deformation Scale	1
Model 3	Von mises stress	11,02 MPa
	Resultant Displacement	0,021 mm
	Equivalent Strain	0,000096
	Factor of Safety	25
	Deformation Scale	2.618,76

This analysis also obtained the results of the wheel mass, namely the 1 Wheel model has a chassis mass of 15.29 kg, 2 wheels have a mass of 11.65 kg, and 3 wheels have a mass of 11.05 kg. The difference in the shape of the wheels in this analysis results in different results in static analysis simulation results. The value of von Misses stress with safety factors is inversely proportional. In the previous study, it discussed the natural frequency analysis of 16-inch alloy wheels using the finite element method. Its purpose is to identify wheel deformation in case of failure and facilitate design analysis. The modeling material used is aluminum alloy, and ANSYS Workbench software is used to analyze vibration modes.

The results show the natural frequency and measurement of the maximum deformation of the wheel. The study emphasizes the importance of knowledge in designing wheels to avoid failures and the use of numerical simulation to minimize failures in automotive components (Prasetiyo *et al.*, 2022). While this study discusses the analysis of three types of car wheel designs made from aluminum R22 using the finite element analysis method (FEA). The purpose of this study was to determine the comparative value of three wheel models based on von Mises stress, resultant displacement, equivalent strain, deformation, and factor of safety.

4. CONCLUSION

Based on the results of research conducted using Solidworks 2019 software, with the aim of analyzing three models of alloy wheels made of aluminum type 6061-T6 (SS) material that have different models with loading at the same fulcrum. Force of 3000 N and pressure of 800N on three Wheel models can be well received according to the results of the analysis.

The results of the static analysis simulation stated that the three Wheel models obtained close and best analysis results were model 3 wheels because they had a Von Misses Stress value of 11.02 MPa with a Resultant Displacement value of 0.021 mm, Equivalent Strain of 0.000096 and a safety factor of 25 and a deformation value of 2.618,76. The von Mises voltage value is still relatively safe because it is still far below the yield voltage value, which is 275 MPa. The value of the safety factor is above 1, so it is classified as safe in terms of safety and the displacement value is below 1. This value is actually not much different from the 1 Wheel pattern but seen from another aspect, that is, modeling is easier to design, then the best category of the three Wheel models is model 3 wheels.

REFERENCES

Ali, H.A., Sawadi, A.S. and Tilefih, R.J. (2021) 'Design and Analysis of Wheel Rims with Various Materials', *Journal of Mechanical Engineering Research and Developments*, 44(11), pp. 96-107.

Bagherzadeh, F., Murugesan, S. and Deka, P. (2020) 'Material Comparison of Dynamic Cornering Fatigue Test (Iso3006) for Automotive Wheel Rim', *International Journal of Engineering & Technology*, 9(4), pp. 881-886.

Chai, W. *et al.* (2019) 'Finite Element Analysis of The Residual Stress of Automotive Wheel Made of Long Glass Fiber-Reinforced Thermoplastic Composite', *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, 233(10), pp. 3592-3602.

HandWiki, H. (2023) *6061 Aluminium Alloy*, *Scholarly Community Encyclopedia*. Available at: https://encyclopedia.pub/entry/35635#:~:text=6061%20Aluminium%20Alloy%20%7C%20Encyclopedia%20MDPI&text=6061%20(Unified%20Numbering%20System%20(UNS,it%20was%20developed%20in%201935. (Accessed: 3 March 2023).

Jadhav, M.V. and Mali, C.V. (2021) 'Design of Wheel Rim by Using Design of Experiments', *International Journal of Advance Research, Ideas and Innovations in Technology*, 7(4), pp. 890-896.

Jiang, X. *et al.* (2018) 'Lightweight Design and Analysis of Automobile Wheel Based on Bending and Radial Loads', in *IOP Conference Series: Materials Science and Engineering. 2018 International Conference on Material Strength and Applied Mechanics*, Japan: Kyushu Institute of Technology, p. 012048.

Naufal, H. (2019) 'Studi Numerik Pengaruh Variasi Jumlah dan Ketebalan Spoke pada Velg Paduan Aluminium untuk Mobil MPV', *Jurnal Teknik Mesin*, 8(1), pp. 39-47.

Prasetiyo, A.B. *et al.* (2022) 'Analisis Frekuensi Natural Velg Ring 16 Menggunakan Finite Element Method', in *Prosiding Nasional Rekayasa Teknologi Industri dan Informasi XVII Tahun 2022 (ReTII). Seminar Nasional ReTII ke 17*, Yogyakarta: Institut Teknologi Nasional Yogyakarta, pp. 354-359.

Pris, F.R., Suyitno, B.M. and Suhadi, A. (2019) 'Analisis Kekuatan Velg Aluminium Alloy 17 Inc dari Berbagai Desain Menggunakan Metode Finite Element Analysis (FEA)', *Teknobiz : Jurnal Ilmiah Program Studi Magister Teknik Mesin*, 9(2), pp. 33-39.

Rizki, M.Z.R.M., Anwar, C. and Heryadi, Y. (2021) 'Analisis Kekuatan Velg Casting Wheel Sepeda Motor Berdasarkan Beban Penumpang dan Kondisi Jalanan Berlubang', *Jurnal Teknologika*, 11(2), pp. 44–56.

Sumiyanto, S. and Abdunnaser, A. (2018) 'Analisis Kekuatan Velg Alumunium Model D30D pada Perusahaan "A"', *Bina Teknika*, 14(2), pp. 225–235.

Trimulya, C.T., Cholis, N. and Wahyuni, F. (2020) 'Analisis Produk Pelek Motor Tipe Cast Wheel Berbahan Paduan Alumunium', *Bina Teknika*, 16(2), pp. 79–84.

Wang, D., Zhang, S. and Xu, W. (2019) 'Multi-Objective Optimization Design of Wheel Based on The Performance of 13° and 90° Impact Tests', *International Journal of Crashworthiness*, 24(3), pp. 336–361.

Wibawa, D., Akbar, A. and Pramesti, Y. (2021) 'Analisis Rangka Jayabaya Prototype 2.0 Menggunakan Aluminium Tipe AA356', *Prosiding SEMNAS INOTEK (Seminar Nasional Inovasi Teknologi)*, 5(3), pp. 188–193.

Wiley, R. and Elsaleiby, A. (2011) 'A Review of Wheel Impact Measurement Variation', in *Technology Digest*. March 2011. USA: Transportation Technology Center, Inc., p. TD-11-007.

Zapata, A., González-Estrada, O.A. and Pertuz, A. (2018) 'Damage Model for The Impact Test of An Automotive Aluminum Wheel', *Journal of Physics: Conference Series*, 1126(1), p. 012002.