Simulation of Grooved Wear on Mass Rapid Transit Train Wheels by Finite Element Method

Ilham Satrio Utomo[1], Dadang Sanjaya Atmaja[1], Akbar Zulkarnain[1], Moh. Dheo Firmansyah[1]

[1] Railway Mechanics Technology, Indonesian Railway Polytechnic Madiun, Indonesia
ilham.satrio@ppi.ac.id

Abstract. The purpose of this study is to obtain stress values and safety factors on wheels with grooved wear. Grooved wear was found on the MRT wheel during the monthly inspection. The method used in this research uses the finite element method, namely ANSYS software. The depth of grooved wear used is 2 mm, 3.5 mm and 4 mm. The simulation results show that Grooved Wear with a depth of 4 mm has the highest stress. In static loading it has a stress of 186.3 MPa with a safety factor of 3.6. Simulation results show that at grooved wear depths of 2 mm, 3.5 mm and 4 mm, the stress value is still below the allowable stress of 514.2 MPa or yield stress of 685.6 MPa so it can be concluded that it is still safe.

Keywords: Grooved wear, fenite element, wheel.

1 Introduction

Bogie is an important component of the train that has the function of supporting the train body. The wheels on the train have a function to deliver passengers from the origin station to the destination station, and also have a function to help move the train at high speed or according to the specifications of the equipment [1], [2].

MRT Jakarta has recently had a problem during monthly maintenance, which is damage to the wheels called Grooved Wear or what can be referred to as grooved wear on the wheels. Grooved Wear is present on all wheels of the MRT facilities[3]. Grooved Wear occurs every day that the trains operate [1], [2], [4]. Each train of wheel material is eroded to a depth of 0.2-0.4 mm per month according to data obtained during monthly maintenance of the MRT Depot. With the existence of the current Grooved Wear condition on the MRT wheels, many things may happen when the train is operating, which can have an impact on passenger safety, such as derailment or train crashes. Therefore, it is necessary to analyse the Grooved Wear stress so that the reliability of the wheels while on the main line can be maintained[5]–[7].

A. Pradipta et al. (eds.), *Proceedings of the 2nd International Conference on Railway and Transportation 2023 (ICORT 2023)*, Advances in Engineering Research 231,
https://doi.org/10.2991/978-94-6463-384-9_34

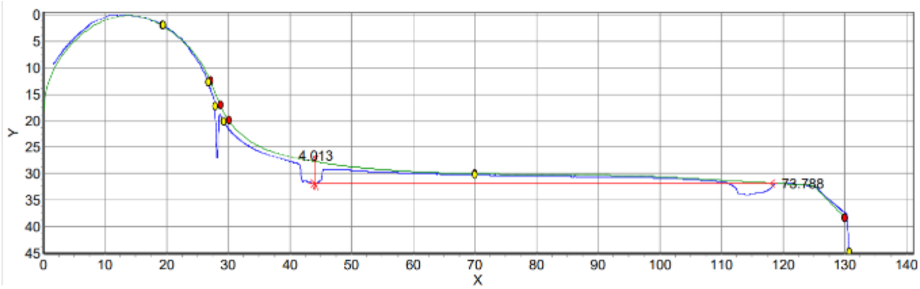

Fig 1. Groove wear

To investigate the stress on the wheels of the Jakarta MRT, stress analyses were carried out on wheels that contained Grooved Wear and were in contact with the rail using ANSYS 2019 software. This simulation test consists of static load stress tests, vertical dynamic loads, and lateral dynamic loads. The loading on the wheels is based on the maximum axle load of the Jakarta MRT rail, which is 14 tons [8].

The purpose of this loading simulation is to obtain the maximum stress value and safety factor. From the results of the analysis, it can determine the safety conditions on the wheels that have Grooved Wear on the MRT. In addition, it also gets an overview of the stress distribution and shape changes that occur due to the application of loads on wheels that have Grooved Wear. The results of the analysis will determine the resulting safety level of the MRT wheels containing Grooved Wear

2 Method

This research was conducted by testing using ANSYS 2019 software[9], [10]. The first thing to do is to make modelling by designing the part first, after the part is finished in the new design, combine the wheels with the rails with the assembly process. After the wheel is in contact with the rail from the assembly process, then import geometry from solidwork 2020 software to ANSYS software with the STEP (.stp) file type. The purpose of this modelling is to analyse the stresses resulting from static and dynamic loading simulations.

Figures 2 and 3 above are an outline of the Jakarta MRT wheels (Mono-bloc corrugated) and MRT rails (UIC 54) and Dimension Grooved Wear British Standard, (2010), which will be recreated into three dimensions with a depth of 0 mm, 2 mm, 3.5 mm, 4 mm (MRTJ Depot Laboratory, 2021).

After modelling, in this simulation, material input is given in the form of mechanical properties of wheel and rail materials, which are also used in the simulation. Can be seen in tables 1 and 2.

Table 1 MRT Wheel Material Specifications

Item	Specification

Young modulus	148000 MPa
Poisson ratio	0,3
Density	7850 kg/m^3
Ultimate strength	857 MPa
Yield stress (σ_y)	685,6 MPa
Gravitational acceleration	9,8 m/s^2

Table 2 MRT Rail Material Specifications

Parameter	**Satuan**
Modulus Young (E)	210000 MPa
Yield stress (σ_y)	1130 MPa
Density	7859,8 kg/m^3
Poisson Ratio	0,3
Tensile Strength	1190 MPa
Gravitational acceleration	9,8 m/s^2

After inputting the material, the next step is to determine the mesh size. Mesh itself is dividing several elements into several nodes or points. Mesh uses element size 15 mm and resolution 2 in ANSYS software.

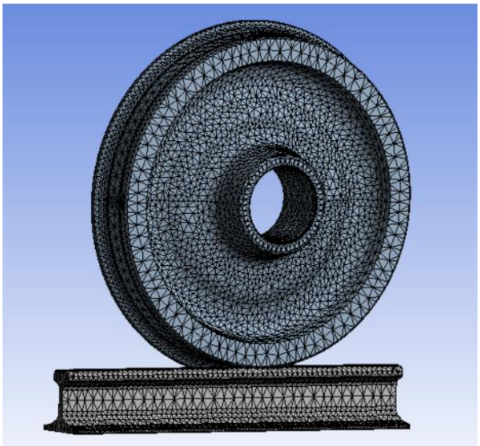

Fig 2. Meshing

The quality of meshing during analysis can be seen from the skewness table, where the smaller the skewness number the better and more acceptable. After the meshing process can be continued by giving restrictions and loading. Providing support is done at the axle place on the wheel. Based on the Jakarta MRT rail maximum axle load standard of 14 tonnes Ramadhani, (2020).

After inputting materials, loading, constraints and meshing, then perform the solve process. The more and more complex the number of geometries and elements produced, so the longer the solve process in static and dynamic analysis in ANSYS 2019 software, the output produced in the test is stress, safety factor.

3 Result

3.1 Static Load on Normal Wheels

The results of the maximum stress of the normal wheel with the wheel in Figure 3, it is found that the von mises point has a stress at a certain point shown in the figure, namely with a maximum stress of 46.383 MPa on the normal wheel and a safety factor of 14.7.

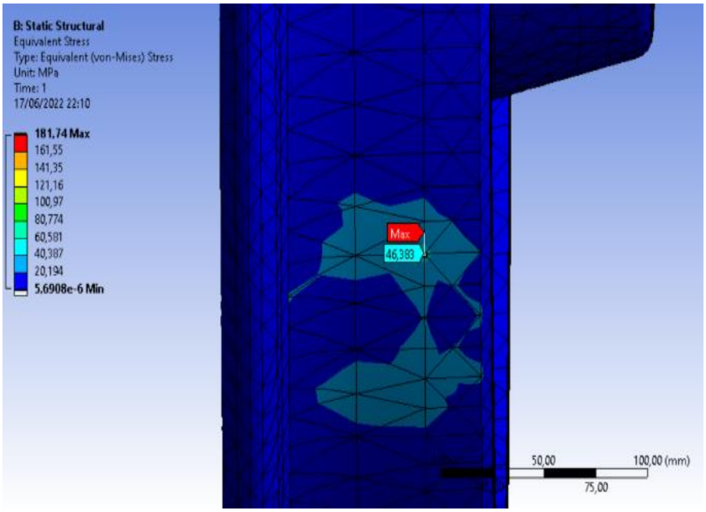

Fig 3 Maximum Stress on Normal Wheel

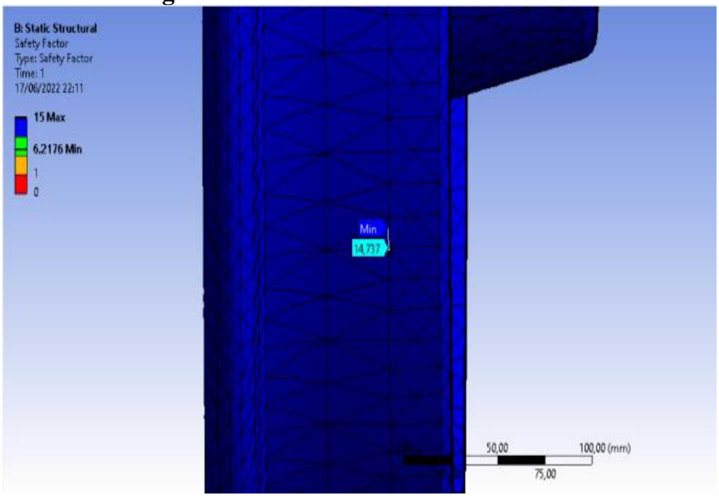

Fig 4. Safety Factor on Normal Wheel

3.2 2 mm Grooved Wear Stress Static Condition

The results of the maximum stress of the Grooved Wear wheel with a depth of 2 mm in Figure 5, it is found that the von mises point has a stress at a certain point shown in the figure, namely with a maximum stress of 117.75 MPa on the wheel with a Grooved Wear depth of 2 mm and a safety factor of 5.8.

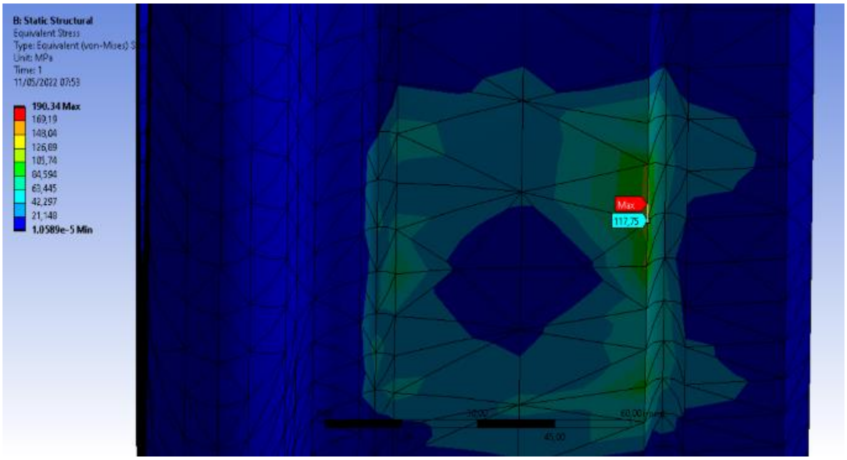

Fig. 5 2 mm Grooved Wear Stress Static Condition

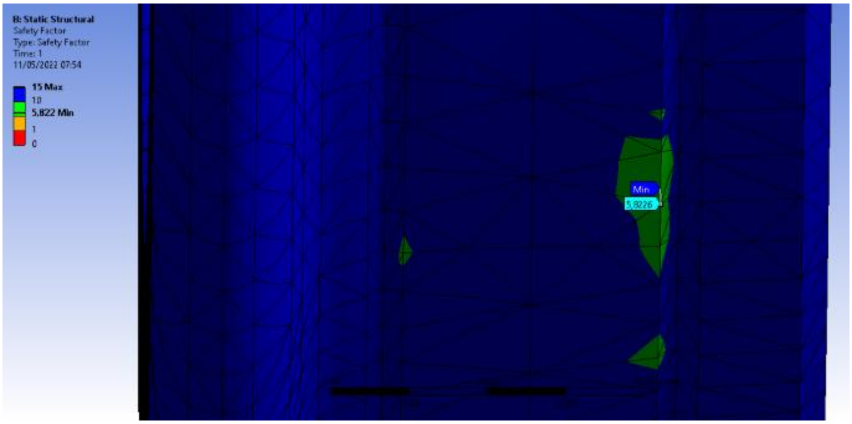

Fig. 6 Safety Factor

3.3 3 mm Grooved Wear Stress Static Condition

The results of the maximum stress of the Grooved Wear wheel with a depth of 3.5 mm in Figure 7, it is found that the von mises point has a stress at a certain point shown in the figure, namely with a maximum stress of 116.55 MPa on the Grooved wear wheel and a safety factor of 5.8.

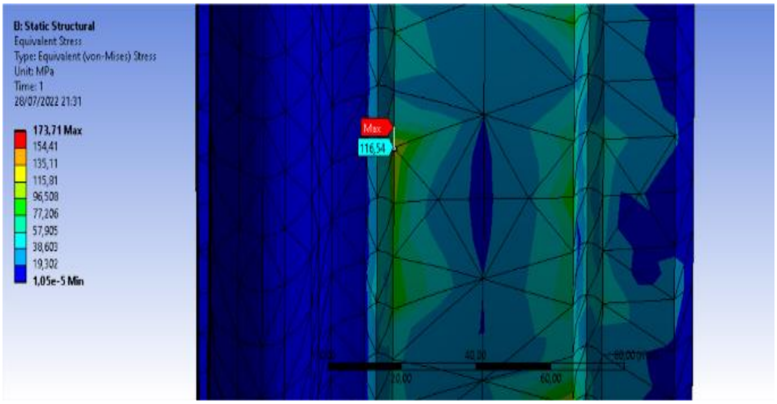

Fig 7 3.5 mm Grooved Wear Stress Static Condition

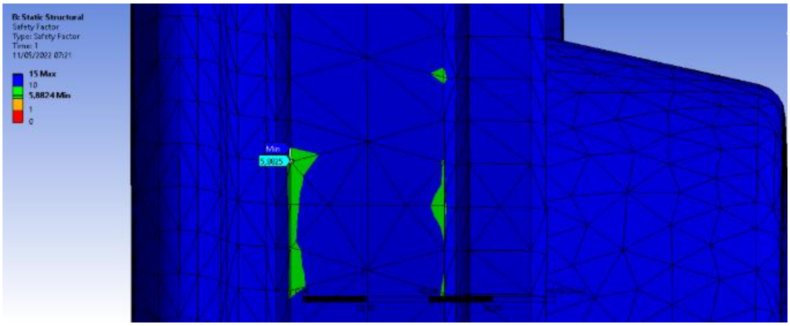

Fig 8 Safety Factor

3.4 4 mm Grooved Wear Stress Static Condition

The results of the maximum stress of the Grooved Wear wheel with a depth of 4 mm in Figure 9, it is found that the von mises point has a stress at a certain point shown in the figure, namely with a maximum stress of 184.14 MPa on the Grooved wear wheel and a safety factor of 3.7.

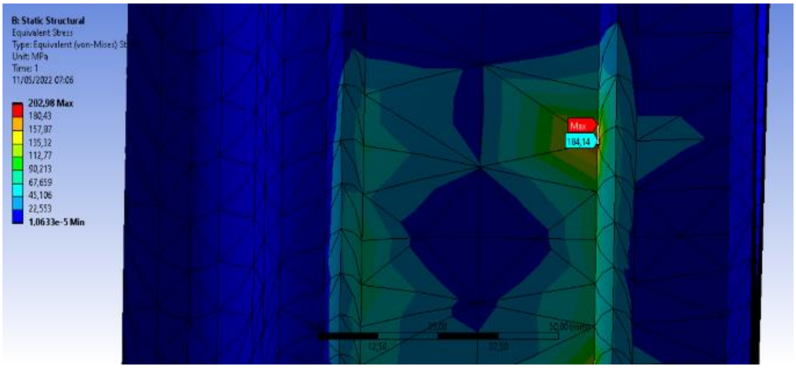

Fig 9 4 mm Grooved Wear Stress Static Condition

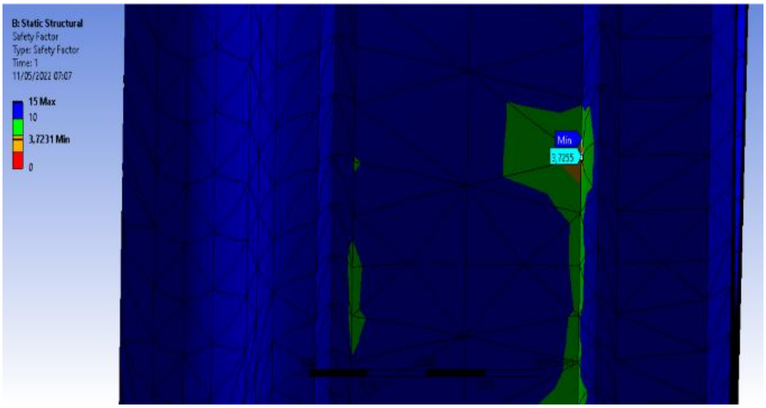

Fig 10 Safety Factor

3.5 **Analysis**

. Figure 11 shows that the presence of grooved wear on the wheel causes an increase in stress in the grooved wear area of the wheel. In addition to the increase in stress, with grooved wear that is too deep when running on the main line, many events may occur, such as endangering the train when passing through the wessel, and when the train runs through the curve.

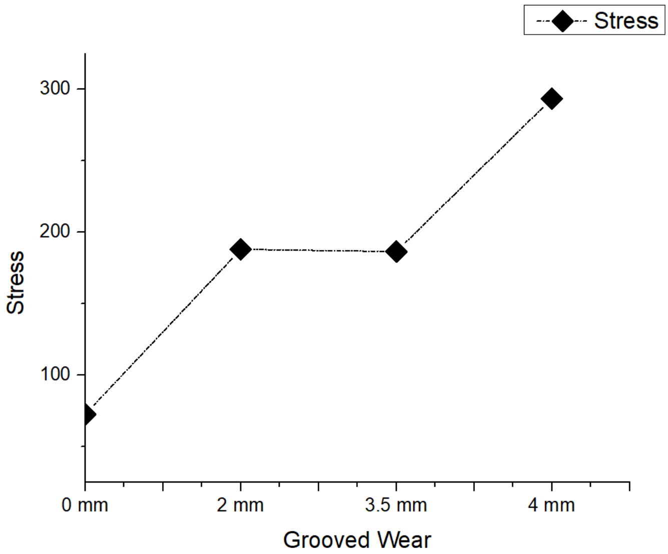

Fig. 11 The relationship of grooved wear depth vs Stress

4 Conclusion

Of the four variations in the depth of Grooved Wear using static and dynamic loading in Ansys Workbench software, it was found that the maximum stress distribution result value occurred at 186.3 MPa at static load against yield stress of 685.6 MPa and allowable stress of 514.2 MPa. These results show that it is still declared safe because the results of the stress value are still below the yield stress.

References

[1] S. M. Mousavi zadeh Noughabi, K. Dehghani, and M. Pouranvari, “Failure analysis of automatic coupler SA-3 in railway carriages,” *Eng Fail Anal*, vol. 14, no. 5, pp. 903–912, Jul. 2007, doi: 10.1016/j.engfailanal.2006.11.039.

[2] Z. Xu, W. Ma, Q. Wu, and S. Luo, “Analysis of the rotation angle of a coupler used on heavy haul locomotives,” *Proc Inst Mech Eng F J Rail Rapid Transit*, vol. 228, no. 8, pp. 835–844, Nov. 2014, doi: 10.1177/0954409713496766.

[3] M. Afdhil Salim, “ANALISIS PENGARUH BRAKE SHOE TERHADAP KERUSAKAN GROOVED WEAR PADA RODA MRT JAKARTA,” *Jurnal Syntax Admiration*, vol. 1, no. 4, 2020.

[4] A. Syaifudin, B. M. Kalista, and D. A. Windharto, “Analisis deformasi pada coupling element dari automatic mechanical coupler: studi kasus LRT Palembang,” 2019.

[5] D. A. Santoso and M. Fitri, "Analisis Pengaruh Roda Benjol Terhadap Kekuatan Shaft Pada M-Car Trainset PT. MRT Jakarta," *Jurnal Teknik Mesin*, vol. 11, no. 2, p. 111, 2022.

[6] P. Voltr, "Simulation Of Wheel-Rail Contact Conditions On Experimental Equipment."

[7] J. Gerlici, T. Lack, and J. Harušinec, "Rail Vehicles Wheels And Brake Blocks Wear Laboratory Test Stand Utilization. 101 Transport 2014."

[8] S. Iwnicki, *A Handbook of Railway Vehicle Dynamics*. 2006. doi: 10.1201/9781420004892.ch1.

[9] X. Ge, L. Ling, Z. Chen, J. Zhang, K. Wang, and W. Zhai, "Experimental assessment of the dynamic performance of slave control locomotive couplers in 20,000-tonne heavy-haul trains," *Proc Inst Mech Eng F J Rail Rapid Transit*, vol. 235, no. 10, pp. 1225–1236, Nov. 2021, doi: 10.1177/0954409721993618.

[10] T. Zhu, B. zhu Yang, C. Yang, S. ne Xiao, G. wu Yang, and B. Yang, "The mechanism for the coupler and draft gear and its influence on safety during a train collision," *Vehicle System Dynamics*, vol. 56, no. 9, pp. 1375–1393, Sep. 2018, doi: 10.1080/00423114.2017.1413198.