

Simulation of Waste Load Variations on Stress Analysis Results of Incinerator Wheel

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Abstract. *An incinerator is a high-temperature waste-burning device with a closed, insulated combustion chamber, designed to minimize environmental impact [1]. Modern incinerators aim to reduce inorganic waste and smoke emissions, particularly in Metro City, Lampung Province [2]. A key component is the wheel, which reduces friction and enhances mobility [3]. This study focuses on designing the incinerator wheel, determining its geometry and material, and analyzing stress, strain, and deformation through simulation [4]. The design process used Autodesk Inventor Professional, while simulations were performed in SolidWorks [5]. Tests were conducted under three load conditions: no load, 250 kg, and 500 kg. The final wheel design measures 150 mm in diameter, 50 mm in width, and 10 mm in thickness, using cast iron. Simulation results show stress, strain, and deformation remain below material limits, even at 500 kg load, confirming the wheel's safety and reliability for optimal incinerator performance.*

Keywords - *Incinerator; Stress analysis; Finite Element Analysis (FEA)*

INTRODUCTION

Metro City, located in Lampung Province, is characterized by a relatively high population density. The increasing intensity of community activities in shopping centers, educational institutions, and tourist destinations has significantly contributed to the rise in daily waste generation [6]. This situation necessitates an effective waste management system to mitigate environmental issues [7]. One viable method for waste management is incineration, which involves burning waste using an incinerator [8].

An incinerator converts solid waste into ash and exhaust gases. However, current incinerator designs still encounter mobility challenges [9]. The absence of wheels makes the equipment difficult to relocate, thereby reducing operational efficiency. Wheels are essential components that provide mobility, stability, and ease of transportation across various terrains. Incorporating wheels allows incinerators to be used more flexibly and efficiently [10].

The design and material selection for the wheels are critical to ensuring the incinerator's strength and operational safety [11]. Manual design analysis (hand calculations) is generally time-consuming and often less accurate, particularly for complex structures. Therefore, the adoption of computer-based modeling and simulation technologies is highly recommended [12].

Parametric software such as Autodesk Inventor Professional and SolidWorks streamlines the design process while enabling analysis through the Finite Element Analysis (FEA) method [13]. FEA facilitates the identification of stress distribution, strain, deformation, and safety factors more quickly, efficiently, and accurately compared to conventional methods [14]. Consequently, applying simulation in the design of incinerator wheels is expected to produce components that are safe, reliable, and capable of supporting optimal incinerator performance [15].

METHOD

Most prior studies have concentrated on the overall incinerator design or frame analysis, whereas this research specifically focuses on the design and structural strength evaluation of incinerator wheels. The study integrates Autodesk Inventor for the design phase and SolidWorks for simulation, enabling a more efficient and accurate workflow. This dual-software approach represents an advancement over previous research, which typically relied on a single tool or conventional methods.

The research adopts a simulation-based design strategy to systematically address the study objectives [16]. A 3D model of the incinerator wheel was developed and analyzed using the Finite Element Method (FEM) [17]. Load variations were applied to the wheel model through Autodesk Inventor Professional [18], and the analysis emphasized stress, strain, and deformation using computer-aided tools [19].

Field observations were conducted at the Environmental Agency (DLH) of Metro City, the Final Waste Disposal Site (TPAS), and the Recycling Center (PDU) to gather data for designing an environmentally friendly incinerator.

The study was carried out from November 2023 to May 2024. Observations took place at DLH, TPAS, and PDU Metro City, while the design and Finite Element Analysis (FEA) simulations were performed at the Mechanical Engineering Laboratory, Universitas Muhammadiyah Metro.

The process involved designing the incinerator and its wheel using Autodesk Inventor, followed by assembly. The CAD model was then exported in .STEP format for further analysis in SolidWorks.

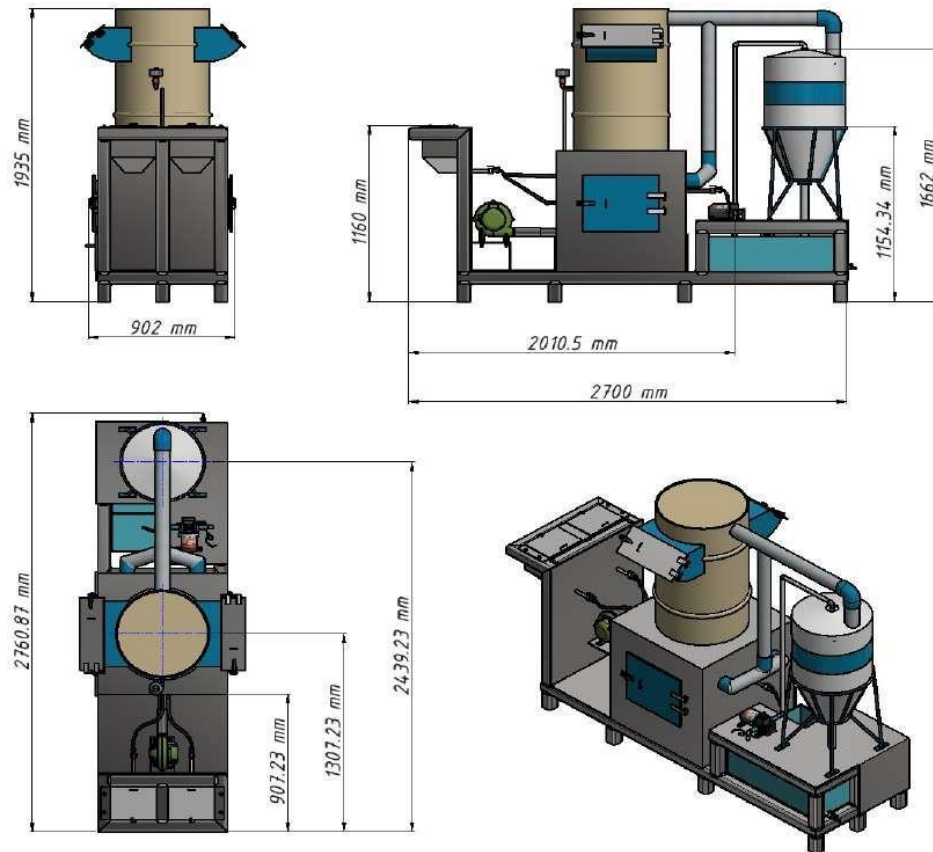


Figure 1. Incinerator Tool Design

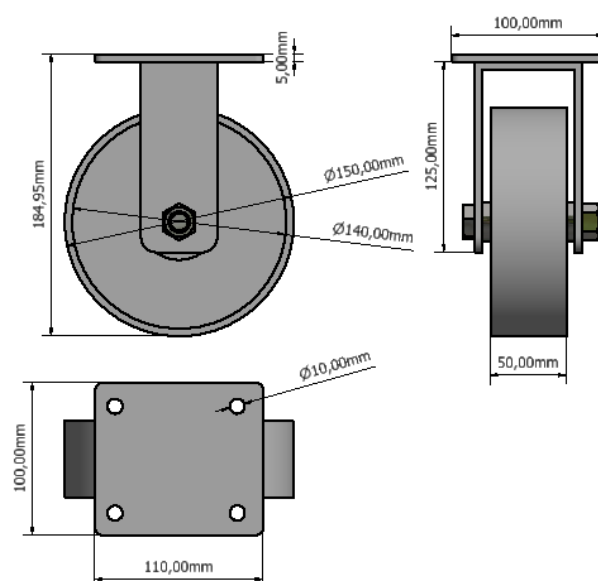


Figure 2. Incinerator Wheel Design

The simulation process consists of the following steps [20]:

1. Opening the CAD file in SolidWorks and creating a new study (static analysis).
2. Selecting the wheel material (Cast Iron).
3. Applying fixed supports (fixed geometry).
4. Applying loads according to variations (incinerator load, 250 kg waste, and 500 kg waste).
5. Generating mesh and running the simulation.
6. Analyzing results including stress, strain, deformation, and safety factor.
7. Generating the simulation report.

This stage is divided into two phases:

1. Planning: Determining the design, dimensions, and material selection.
2. Execution: Installing software, creating the wheel design, assembly, conducting simulations (stress, strain, displacement), and preparing the analysis report.

Operational Definition of Variables

1. Independent Variable: The wheel design, circular in shape, with a diameter of 150 mm, width of 50 mm, and thickness of 10 mm.
2. Dependent Variable: The simulation results, including stress, strain, and deformation.
3. Controlled Variable: The applied load variations, namely the incinerator without waste, with half waste capacity, and with full waste capacity.

The data collection process includes:

1. Preparing the required hardware and software.
2. Designing the incinerator wheel.
3. Conducting stress, strain, and deformation analysis.
4. Documenting analysis results.
5. Storing design files and reports in an organized manner.

RESULTS AND DISCUSSION

Table 1. Stress, strain and deformation test results

No	Force	Simulation	Minimum	Maximum
1.	1,376.5686 N	Stress	0 N/mm ²	5.499 N/mm ²
		Strain	0	0.00005701
		Deformation	0 mm	0.001565 mm
2.	1,989.6347 N	Stress	0 N/mm ²	7.948 N/mm ²
		Strain	0	0.00008240
		Deformation	0 mm	0.002263 mm
3.	2,602.8284 N	Stress	0 N/mm ²	10.398 N/mm ²
		Strain	0	0.00010780
		Deformation	0 mm	0.002960 mm

Model name:Part1
Study name:Static 1(-Default-)
Plot type: Static nodal stress Stress1
von Mises (N/mm² (MPa))

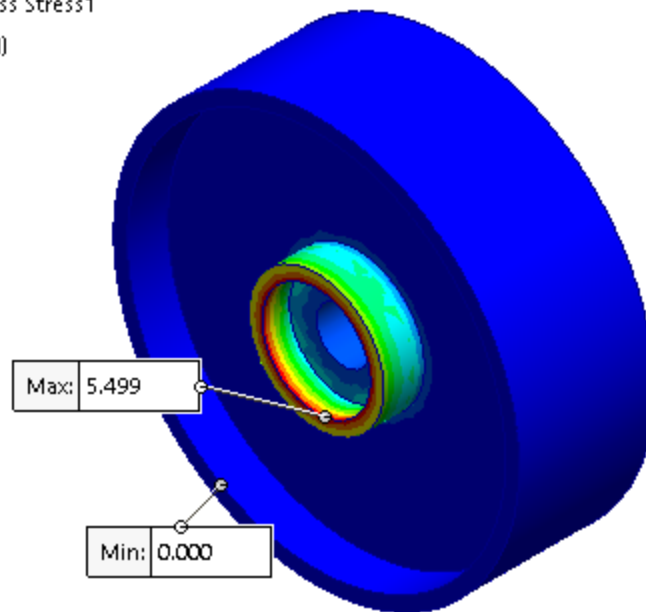
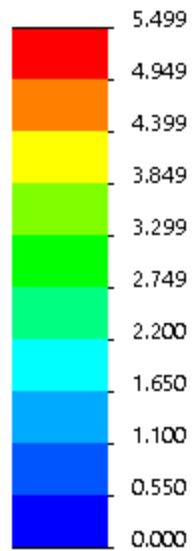


Figure 3. Stress Without Load

Model name:Part1
Study name:Static 1(-Default-)
Plot type: Static nodal stress Stress1
von Mises (N/mm² (MPa))

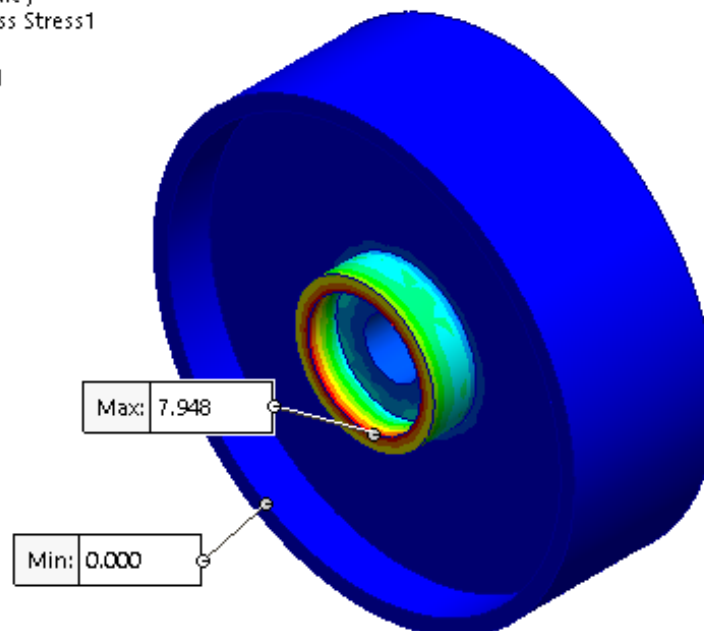
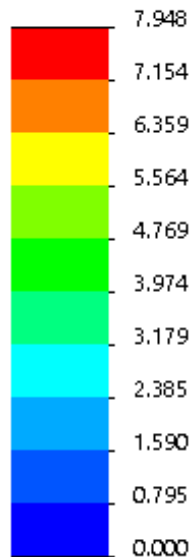


Figure 4. Stress with a waste load of 250 kg

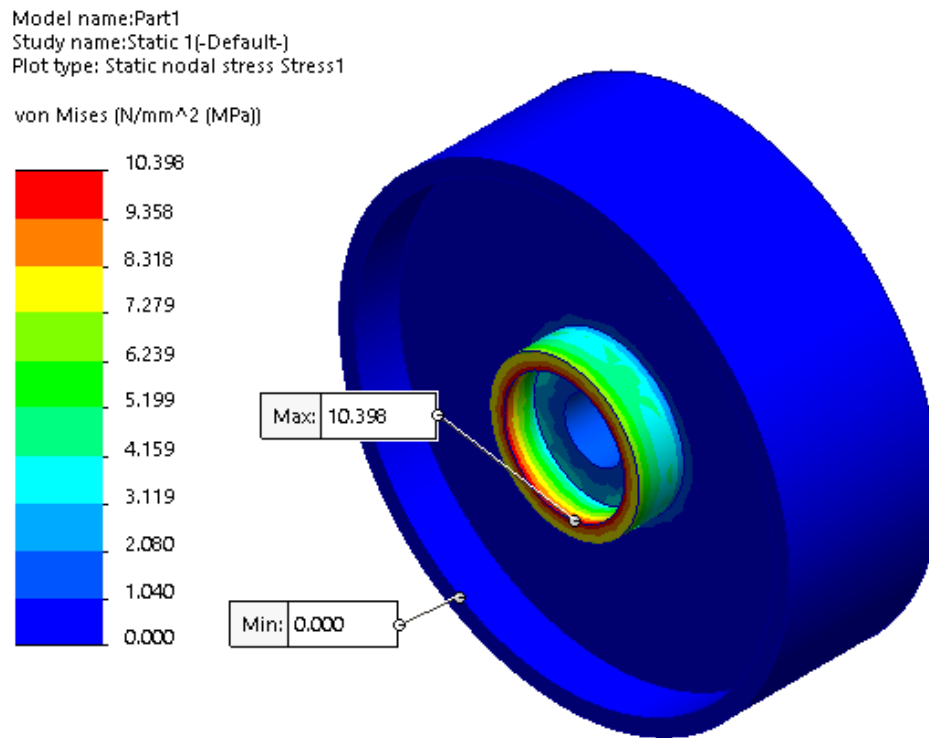


Figure 5. Stress with a waste load of 500 kg

The simulation results indicate a maximum von Mises stress of 10.398 MPa under the highest load condition (500 kg). This value is significantly below the yield strength of cast iron, which typically ranges between 130–200 MPa. Therefore, the safety factor can be calculated as follows:

$$\text{Safety Factor} = \frac{\text{Yield Strength}}{\text{Maximum Stress}} \approx \frac{130 \text{ MPa}}{10.398 \text{ MPa}} \approx 12.5$$

This means the wheel design has a very high safety margin, making the risk of failure under static load conditions extremely low. The highest stress occurs in areas with geometric discontinuities, such as support points or shaft contact regions. This aligns with the theory of stress concentration. Adding fillets or smoothing sharp corners could further reduce peak stresses. The maximum deformation is only 0.00296 mm, which is negligible compared to the wheel's diameter (150 mm). This indicates excellent structural stiffness, ensuring that mobility performance will not be compromised. Since the stress level is far below the yield strength, the wheel is not only safe under static loads but also likely to have a long service life, even under repeated loading cycles (fatigue). However, a dedicated fatigue analysis could be a valuable follow-up study. Given the very high safety factor, the wheel dimensions could be optimized to reduce weight and manufacturing costs without sacrificing strength. Alternative materials with lower density could also be considered.

CONCLUSIONS

The von Mises stress distribution across the part varies significantly, with values ranging from 0 MPa (unloaded or fully constrained regions) to a maximum of 10.398 MPa (the highest critical point). Intermediate analyses also recorded peak stresses of 5.499 MPa and 7.948 MPa, indicating variability under different load conditions.

The maximum stress locations represent potential failure points where yielding or deformation is most likely to occur. These areas typically correspond to geometric discontinuities, load application points, or constrained regions.

The safety and reliability of the design depend on comparing the maximum von Mises stress to the yield strength of the material. If the peak stress (e.g., 10.398 MPa) remains well below the material's yield strength, the design can be considered safe. However, if the stress approaches or exceeds the yield limit, design modifications are necessary.

Recommendations for Optimization:

1. Geometric refinements (e.g., adding fillets, reducing sharp corners) to mitigate stress concentrations.
2. Material substitution if the current material's yield strength is insufficient.
3. Load redistribution or structural reinforcements in high-stress zones.
4. Further iterative analysis to validate design changes.

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