Design of a Micro Scale Incinerator as a Solution for Handling Waste in Cisolok Village

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Abstract. The waste problem in Kampung Cigoler RW.03 Cisolok Village is increasingly worrying, with a volume reaching 659,08 kg/day. One of the proposed solutions is a micro-scale incinerator with the main components of a burner, combustion chamber, and filtration system using mineral rocks and activated carbon. The de- sign of this incinerator considers its strength and structural safety factors, to en- sure it can withstand operational loads. Analysis using Autodesk Inventor 2023 software and ASTM A36 material shows that the stress on the incinerator frame is far below the UTS and the material yield limit, indicating that the design is safe and able to withstand the load of components and waste being burned. FEA anal- ysis shows a von Mises stress distribution with a maximum stress of 8,8976 MPa, a maximum displacement of 0,039456 mm and a safety factor of 15ul. The design of this micro-scale incinerator is expected to be an innovative solution for waste management in Cisolok Village, with adequate safety factors based on structural analysis. The incinerator design is safe in terms of structural strength so that the manufacturing process can be carried out. The design that was created has also been calculated to be able to resolve 33,98% of daily waste production.

1 Introduction

Based on data obtained from the National Waste Management Information System (SIPSN) Website of the Ministry of Environment and Forestry (KLHK), the results of the input carried out by 135 Regencies and Cities throughout Indonesia in 2023 showed that the amount of national waste accumulation reached 16.148.385,68 tons/year, with the amount of waste that can be managed 11.171.968,44 tons/year or 69,18% of the total national waste accumulation, and 4.976.417,24 tons/year or 30,82% of the total national waste accumulation is unmanaged (Ministry of Environment and Forestry (KLHK) 2024). Judging from the data from the national waste team, of course the waste produced from each region is not small, in Sukabumi itself in 2019 it reached 177,96 tons/day, this amount increases every year until in 2023 it reaches an average of 180 tons/day. Waste accumulation occurs because natural processes and community behavior patterns to participate in waste management are considered lacking [1,2] From data from 15 houses in Cigoler village rw.03 Cisolok village, Cisolok district,

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with the majority of the community working as traders, they can produce waste reaching 659,08 kg/day, the waste comes from trade and household waste.

Waste management in remote villages like Cisolok Village is often a challenge. Poorly managed waste can lead to a range of environmental problems, including soil and water pollution, and the spread of disease. One solution that is receiving increasing attention is the use of micro-scale incinerators, which can burn waste at high temperatures, thereby reducing the volume of waste and eliminating the risk of infection from medical waste or other hazardous waste [3,4]. One of the challenges in the design of small-scale incinerators is the often-higher installation and operation costs compared to other methods such as waste management in landfills. However, technologies such as Rankine organic cycle have been applied to reduce the operational cost of incinerators, especially in terms of electrical energy production from the heat of combustion [5,6].

In addition to being an effective solution for waste management, small-scale incinerators are also designed with energy efficiency and minimal environmental impact in mind. In the development of open incinerators, combustion systems with high-speed air nozzles have been shown to increase the combustion rate and achieve high temperatures, thus ensuring more complete combustion [7,8]. Further research shows that rotary-based incinerators, with optimized air control, can ensure stable and efficient combustion of municipal waste [9]. In addition, portable incinerators have also been developed as an alternative for waste management, especially in areas that require sustainable and energy-efficient solutions for solid waste disposal [10].

Based on the waste problem, of course, a handling method is needed that can be done in the Cisolok village environment, one of which is by burning it using an incinerator. The purpose of this study is to design an incinerator as a simple step in reducing the volume of waste in Cisolok village. The incinerator has main components, namely a burner that functions to burn by atomizing fuel, a combustion chamber that functions as a place to burn waste, and a filtration component to overcome exhaust emissions using rock minerals and activated carbon.

The design of an incinerator must consider its strength and structural safety factors to ensure that the incinerator can withstand its operational loads, including high tem- peratures and internal pressures generated during the combustion process. The Finite Element Analysis (FEA) method is an appropriate approach to analyze how the incin- erator's structural response to certain loads and forces [11]. Incin- erators tend to experience dominant static loads during their operational cycle. The pur- pose of this FEA simulation is to compare the yield strength aspect with the Von Misses stress to obtain the safety factor and displacement vector that arise due to the loading on the incinerator.

2 Material and Methods

This incinerator design was created using Autodesk Inventor 2023 software with the aim that before the tool is made, we can find out the maximum load and the level of safety factors that are appropriate for the user of the incinerator. This incinerator con- sists of several main components such as the frame, main combustion chamber, burner, wet scrubber and absorber. The overall design of the micro-scale incinerator made (Figure 1).

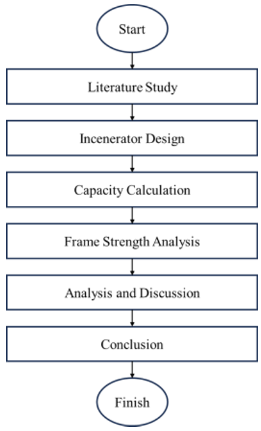
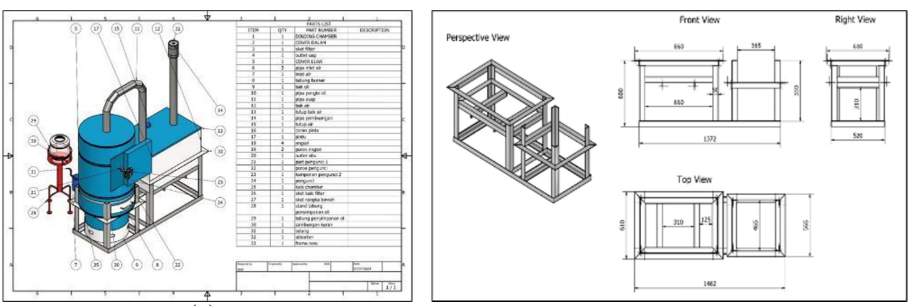


Fig. 1. Research flowcart

The material used in the incinerator frame is ASTM A36 L-profile steel with dimen- sions of 50 mm x 50 mm x 5 mm. The frame components in the incinerator receive loads from the combustion chamber, burner, and wet scrubber. The detailed design is shown in the image below.



(a) (b)

Fig 2. (a) Micro-scale Incinerator Design (b) frame design

The FEA testing process uses the Stress analysis feature in Auto-desk Inventor 2023,stress analysis is a feature that allows researchers to simulate and analyze how an in- cinerator design will behave under certain loads and conditions. This aims to ensure that the incinerator design is strong, durable, and safe before being produced, the stagesof stress analysis are as follows. The material used in this frame is ASTM A36 Steel which has ductile characteristics, the carbon content in this steel is 0,26% so it is included in low carbon steel. The me- chanical properties of ASTM A36 steel (table 1).

Table 1. Mechanical Properties of ASTM A36 Steel

Name	Steel ASTM A36	Value
General	Mass Density	7,85 g/cm^3
	Yield Strength	248,225 MPa
	Ultimate Tensile Strength	399,9 MPa
Stress	Young's Modulus	199,959 GPa
	Poisson's Ratio	0,3 ul
	Shear Modulus	76,9073 GPa

Constraints are an important complement to ensure the accuracy of stress analysis simulations in Autodesk Inventor. Constraints limit or prevent the movement of the model in a certain direction, thus enabling accurate stress analysis simulations. The constraints given to the frame use the fixed type, these constraints hold the model at one point, thus preventing movement and rotation in all directions.

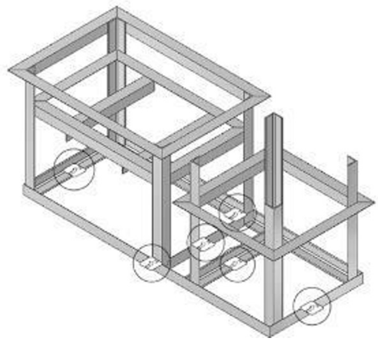


Fig 3. Placing fixed constraints on the frame

The load used in this stress analysis test comes from the weight of the components and the load of the waste carried. The component load is obtained from the design that has been made using Autodesk Inventor software, which can be seen in the properties menu in the physical section below. The overall load assumption of the incinerator components can be seen in the table below.

Table 2. Component weight assumptions

Component	Part's Name	Weight (kg)
Chamber insinerator	Chamber wall	1,984
	Inside cover	2
	Ash filter	13,9
	Steam outlet	0,414
	Outside cover	55
	Burner tube	21,7
	Oil tank	5,74
	Oil filling pipe	0,116
	Smoke pipe	6,588
	Shut	12,3
	Ash outlet	1,54
Wet scrubber	Water tub	23,7
	Water tub cover	6,5
	Exhaust pipe	3,93
	Absorber	1,7

3.1. Water Mass Calculation

$$m = \rho \text{ x } V \quad (1)$$

Which m is indicating mass, ρ is s density, and V is volume. Mass of the wastethen can be calculated by equation (1)

$$m = 0,997 \text{ x } 30 \quad (2)$$
$$m = 29,91\ kg \quad (3)$$

3.2. Waste Mass Calculation

$$\rho_s = \frac{m_s}{V_p} \quad (4)$$

$$m_s = \rho_s . V_p \quad (5)$$

ρs = Organic waste density
ms= Waste mass
Vp = Waste volume

$$ms = \rho s.\ Vp \quad (6)$$

Formula (6) shows how to calculate the mass of waste to be burned using an incin- erator.

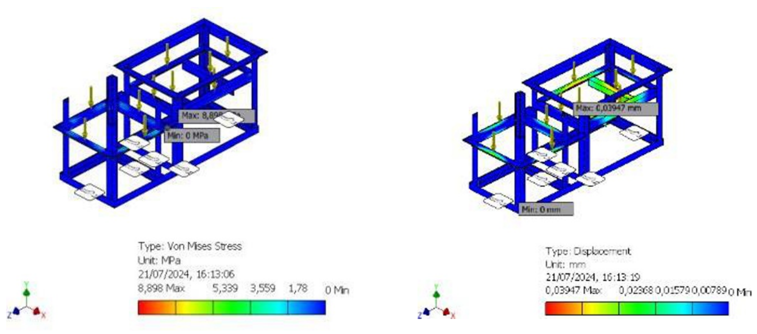
3 Results and Discussion

Using the results of the simulation analysis, simulation values were obtained re- garding the structural strength of the micro-scale incinerator using ASTM A36 ma-terial. The resulting data includes stress analysis on the incinerator frame.

Table 3. Incinerator frame analysis results

Parameter	Minimum	Maximum
Volume	8469910 mm^3	
Mass	66,4888 kg	
Von mises stress	0,0000000527605 MPa	8,8976 MPa
Displacement	0	0,0394656 mm
Safety factor	15ul	15ul

Based on the FEA (Finite Element Analysis) analysis, the stress value on the in- cinerator frame is still far below the UTS (Ultimate Tensile Strength) and the yield limit of ASTM A36 Steel material. This shows that the designed incinerator frame is safe and able to withstand the load of components and waste to be destroyed. Theimage below is produced from the FEA analysis showing the distribution of von Mises stress and displacement on the incinerator frame. The yellow color indicates the area with the maximum von Mises stress of 8,8976 MPa, while the light blue color indicates the area with the smallest von Mises stress. The maximum displace-ment on the frame is marked in red and has a value of 0,039456 mm.



(a) (b)

Fig 4. (a) von mises stress analysis (b) displacement analysis

$$V = \pi r^2 . t$$
$$V = 3{,}14 \, X \, 30^2 \, X \, 60$$
$$V = 3{,}14 \, X \, 900 \, X \, 60$$
$$V = 169.560 \, cm^3 = 0{,}000169560 \, m^3 \quad (7)$$

Based on formula (7), the volume of the incinerator combustion chamber is 169,560cm^3. Find the mass of waste in 1 combustion.

$$\rho_s = \frac{m_s}{V_p} \quad (8)$$

$$m_s = \rho_s . V_p$$
$$m_s = 164{,}77 \, kg/m^3 . 0{,}000169560 \, m^3$$
$$m_s = 27{,}90 \, kg \approx 28 \, kg \quad (9)$$

The calculation of the mass of waste is calculated using formula (5), the capacity of1 burning in this incinerator is 28 kg. The data we obtained from the waste collected per day by the community from 15 houses adjacent to the waste incinerator is 659,080kg / day. and the waste incinerator operates for 30 minutes for 1 burning from 10.00 - 14.00 which means that every day it can burn 8 times.

m_S = 28 kg
t = 8 times burning
m_{total} = 659,080 kg

$$m_s = 28 \times 8 = 224 \, kg \quad (10)$$

The efficiency of the incineration capacity for daily waste production in Cisolok Vil-lage is

$$\eta = \frac{224 \, kg}{659{,}080 \, kg} \times 100 = 33{,}98\% \quad (11)$$

After the creation of this waste incinerator, it can reduce waste by 33.9868% of thetotal waste collected.

4 Conclusion

The design of a micro-scale incinerator is an innovative solution to overcome the problem of waste management in Cisolok Village, which faces significant challenges in waste management. Based on the structural analysis using the Finite Element Anal- ysis (FEA) method, the incinerator frame design shows an adequate safety factor of 15 ul, with a maximum von mises stress value 8,8976 MPa which is far below the yield limit of ASTM A36 steel material. The incinerator's burning capacity is capable of processing around 28 kg of waste in one burning cycle, and is operated 8 times a day so that it can burn 224 kg of waste and this incinerator can reduce the volume of waste by 33,98% with a high operating fre- quency, this tool can reduce waste collected in the community.

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