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Design and Construction of Sandblasting Tools for Metal Surface Cleaner

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ABSTRACT

As global technology and industry continue to develop rapidly, the manufacturing industry in Indonesia is also becoming increasingly advanced to keep pace with global industrial progress. A good surface metal is one that is clean from all types of contaminants such as dust, rust, oil, paint, and has a uniform surface roughness. Sandblasting is a method used to remove rust, dirt, and other impurities like oil and paint from metal surfaces. This research aims to design a sandblasting tool using Capstone Design analysis. The process includes selecting the type of sandblasting tool, determining its specifications, and calculating the dimensions of the blasting chamber. Additionally, the study involves assembling the sandblasting chamber, installing the required sandblasting components, as well as testing the functionality of the completed sandblasting system. Based on the functional testing results of the designed sandblasting tool, it can be concluded that the sandblasting tool functioned well and can be used by future researchers. From the roughness test results, it was found that the surface roughness after sandblasting is significantly higher compared to the initial condition.
Keywords: Sandblasting, Metal Surface, Blasting Chamber.

ABSTRAK

Seiring dengan perkembangan dunia teknologi dan industri yang semakin pesat, industri manufaktur di Indonesia juga semakin maju dan berkembang mengikuti standar industri dunia. Permukaan logam yang baik harus bersih dari segala jenis kotoran seperti debu, karat dan kotoran lainnya, serta memiliki nilai kekasaran permukaan yang merata. *Sandblasting* adalah salah satu metode untuk membersihkan karat atau kotoran seperti minyak dan cat dari permukaan logam. Penelitian ini bertujuan untuk melakukan rancang bangun alat sandblasting dengan analisa *Capstone Design*, pemilihan jenis alat *sandblasting*, spesifikasi dan perhitungan dimensi *blasting chamber*. Selain itu juga bertujuan untuk melakukan perakitan *sandblasting* chamber dan pemasangan instalasi yang dibutuhkan alat *sandblasting*, serta melakukan uji coba fungsi alat sandblasting yang telah dibuat. Dari hasil uji coba fungsi dari alat *sandblasting* yang sudah dirancang, dapat disimpulkan bahwa alat *sandblasting* berfungsi dengan baik dan bisa digunakan oleh peneliti selanjutnya. Dari hasil uji kekasaran didapatkan nilai kekasaran setelah *sandblasting* lebih tinggi dibandingkan sebelumnya.
Keywords: Sandblasting, Permukaan Logam, Blasting Chamber.

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1. Introduction

In the current era of globalization, the development of global technology and industry is accelerating rapidly. The manufacturing industry in Indonesia is also becoming increasingly advanced to keep pace with global industrial progress. One of the important aspects of the manufacturing industry is the quality of metal surfaces. A good surface metal is one that is clean from all types of contaminants such as dust, rust, oil, paint, and has a uniform surface roughness. One commonly used method for cleaning and conditioning metal surfaces is sandblasting. Sandblasting is a surface cleaning process that involves spraying abrasive materials, usually silica sand, under high pressure. This method is adapted from technology widely used in the painting, oil and gas, fabrication, and other industries to remove contaminants or coatings from metal surfaces quickly and effectively [1].

According to research conducted by Hero Prasetio, et al. [2], surface roughness is a critical factor to consider in metalworking processes, especially for painting and coating applications. The sandblasting process can produce specific roughness levels on metal surfaces. Test results show that variations in blasting time and abrasive particle size affect surface roughness values [3].The study found that the highest surface roughness value of 1.95 µm was obtained at a pressure of 6 bar and a spraying distance of 50 mm, while the lowest roughness of 1.08 µm was obtained at 4 bar pressure and 150 mm distance.

While sandblasting is widely applied, research on alternative abrasive materials such as aluminum oxide remains limited, even though aluminum oxide has promising properties for industrial applications. This lack of in-depth study represents a clear research gap, particularly in relation to optimizing tool design for small- to medium-scale enterprises. MSMEs require cleaning equipment that is efficient, fast, high-quality, and affordable. Therefore, there is a need for a low-cost sandblasting tool that can be built using materials readily available in the market. This study addresses that gap by developing a sandblasting tool that utilizes aluminum oxide as the abrasive medium, something that has not been thoroughly explored in previous research. Based on the explanation above, the author finds it necessary to conduct research and development on the design of a sandblasting tool for removing rust from metal surfaces using aluminum oxide as the abrasive medium [2]. While silica sand is commonly used, this research explores aluminium oxide as an alternative.

2. Research Method

The data collection methods used in this research are observation and documentation. The purpose of using the observation technique in this study is to observe how the sandblasting tool designed by the researcher operates. In addition, observation is also used to record the performance level of the designed tool so that the researcher can obtain complete and clear data from the design and fabrication process to the testing phase.
The documentation technique in this study is used to record all processes and stages of the research, starting from the design process, tool fabrication, to the testing of the sandblasting equipment. Moreover, documentation also serves as a form of validation for the data obtained from the observations.

Research variables are defined as attributes of the object being studied by conditioning one of its attributes. In this design, there are three types of variables that will be observed and analyzed. Firstly which is independent variables, which are variables that can influence and cause changes in the dependent variable, such as: air humidity and ambient temperature. Then we have dependent variable, which is the variable observed for changes as a result of the independent variables. The dependent variable in this research is the surface roughness test. Finally there is the controlled variables, which are variables that are kept same during testing and remain in controlled conditions. The controlled variables observed in this design are: air pressure, abrasive material size, spray distance, and spray angle.

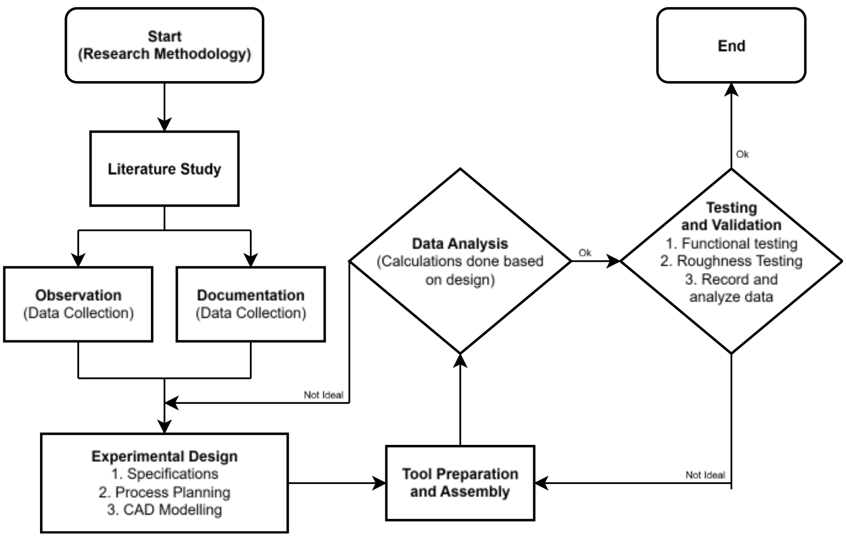


Figure 1. Research Methodology Flowchart

Figure 1 shows that the research starts with a literature study to learn about sandblasting. Next, observation and documentation are used to collect data as previously mentioned. Observation helps the researcher understand how the tool works during operation, while documentation records every step of the process, from design and fabrication to testing. After that, the design is planned. The researcher sets the tool's specifications, creates designs using AutoCAD, and chooses the best option from several ideas.

Next, the tool is built using simple materials. Parts like the frame, nozzle, and blower are assembled to create a working sandblasting tool. Once built, calculations are done to estimate air flow, speed, and how much abrasive material will be used at different pressures. Finally, the tool is tested. It is checked for how well it cleans and how much it improves the surface. The results are then analyzed to see if the tool works as expected.

3. Result and Discussion

The research results and discussion explain that the design and fabrication process of the sandblasting tool was carried out based on specifications and parameters obtained from literature studies and the experimental objectives. The assembly process was conducted systematically, taking into account material selection, component function, and system integration, such as the sandblasting chamber, nozzle system, and air pressure configuration. The following section presents the results of design validation, calculations of air and mass flow rates, as well as functional testing of the tool, followed by a discussion on the surface roughness test results after sandblasting treatment using various types of abrasive materials.

3.1. Process Planning and Equipment Assembly

The steps in manufacturing the sandblasting tool begin with designing the sandblasting equipment, assembling the components of the sandblasting system, and performing painting/finishing on the sandblasting unit.

3.1.1 Process Planning

The design of the sandblasting chamber was carried out using AutoCAD software, with dimensions adjusted based on literature studies and field surveys conducted by the author.

Sandblasting is generally used in the automotive sector as a method for cleaning metal surfaces and removing paint or corrosion attached to those surfaces. In this sandblasting tool design, the researcher focuses on the needs of users running small to medium-scale repair workshop businesses. To achieve optimal sandblasting results, the tool must be designed to deliver adequate air pressure and abrasive material output speed in order to effectively remove unwanted material from the surface of the test object.

The sandblasting machine specifications that are needed to get the optimal results for the user are:

- Air delivery ≥ 7.2 cfm
- Mass flow rate ≥50 cm/s
- Abrasive mass flow rate ≥ 5 g/s

After determining the required specifications for the sandblasting tool, the next step is to create a design concept draft. This stage involves developing initial design ideas based on the functional requirements, available materials, and operating conditions. Table 1-3 shown that consideration and the final concept were designed as shown in Figure 2.

Table 1. Design Concept Draft

Concept A	Concept B	Concept C	Concept D
- Nozzel is integrated with its reservoir - This design concept uses a blower	- Nozzle is fixed (stationary) - This design concept uses a blower - Reservoir is located separately (not integrated with the nozzle)	- Blasting process is carried out under the chamber - This design concept uses a blower - Nozzel seperated from the reservoir	- Abrasive material placed at the back of the chamber - This design concept uses a blower - Nozzel seperated from the reservoir

Table 2. Concept Screening

Selection Criteria	Concept Variants			
	A	B	C	D
Ease of Handling	0	0	-	0
Ease of Use	0	0	-	-
Readability of Settings	0	0	+	0

Selection Criteria	Concept Variants			
	A	B	C	D
Dose Metering Accuracy	+	+	+	+
Durability	0	0	0	0
Ease of Manufacturing	+	0	-	-
Portability	+	-	-	+
Plusses	3	1	2	2
Sames	4	5	1	3
Minuses	0	1	4	2
NET	3	0	-2	0
RANK	2	4	3	1
Continue?	No	No	No	Yes

Table 3. Concept Scoring

Selection Criteria	Weight	Concept Variants							
		A		B		C		D	
		Rating	Weight Score	Rating	Weight Score	Rating	Weight Score	Rating	Weight Score
Ease of Handling	5%	3	0.15	3	0.15	4	0.2	4	0.2
Ease of Use	15%	3	0.45	4	0.6	4	0.6	3	0.45
Readability of Settings	10%	2	0.2	3	0.3	5	0.5	5	0.5
Dose Meter Accuracy	25%	3	0.75	3	0.75	2	0.5	3	0.75
Durability	15%	2	0.3	5	0.75	4	0.6	3	0.45
Ease of Manufacture	20%	3	0.6	3	0.6	2	0.4	2	0.4
Portability	10%	3	0.3	3	0.3	3	0.3	3	0.3
	Total Score	2.75		3.05		3.1		3.45	
	Rank	4		3		2		1	
	Continue	No		Develop		No		No	

Figure 2 shows that the design was developed based on future user needs and realized in the form of technical drawings using AutoCAD software, serving as a guide for the assembly process of the sandblasting tool.

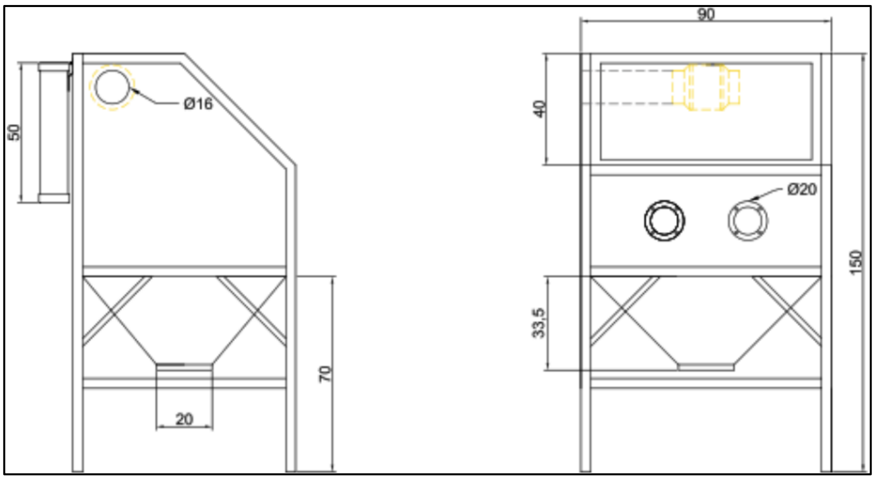


Figure 2. Sandblasting Chamber Design

The design development is a key activity that transforms concepts based on customer needs into an initial sketch of the most promising solution. This concept development stage involves formulating a solution concept, which includes identifying customer needs, defining product specifications, generating concepts, selecting concepts, and testing the chosen concept.

Based on earlier studies reviewed by the author, the sandblasting tool is designed according to DFMA (Design for Manufacturing and Assembly) principles, resulting in a compact, modular, and easy-to-assemble structure. This enhances portability and makes the tool highly suitable for diverse working environments, particularly in small-scale industries. Building on this foundation, the current study specifically targets budget-friendly applications for MSMEs (Micro, Small, and Medium Enterprises). In addition to being mobile, the tool is designed to collect and reuse abrasive media, significantly reducing future material expenses and operational costs. This closed-loop approach not only minimizes waste but also supports sustainable practices. As demonstrated through experimental observations in this paper, the tool maintains high efficiency and cleaning performance while being cost-effective and accessible compared to conventional sandblasting machines, thus making it a viable option for small businesses seeking affordable surface treatment solutions [4].

Based on findings in [5], the researchers focus on post-process recycling. More specifically, reusing sandblasting waste as a fine aggregate substitute in concrete. Their experiments highlight how sandblasting residue, rich in silica (up to 94%), can be partially substituted (up to 30%) into concrete mixtures to enhance compressive strength and reduce voids, offering a sustainable alternative to dumping abrasive waste. This design, on the other hand, emphasizes real-time media reuse by enabling the collection and recycling of abrasive particles directly during or after blasting, keeping the media within the same operational loop.

3.1.2 Preparation of Tools and Materials

In this research process, the researcher prepared the tools and materials used to design a sandblasting device for rust removal, as previously explained. This preparation includes the selection of key components such as the sandblasting chamber, nozzle, blower, as well as abrasive media and frame structure.

3.1.3 Assembly Process

The assembly and fabrication process of the sandblasting tool was carried out in the Mechanical Technology Laboratory. The steps in constructing the sandblasting tool are as follows.

The frame construction (shown in Figure 3) used materials that serve as the frame or skeleton of the sandblasting chamber, which is made from iron elbow (angle iron) with dimensions of 3.5 cm and a thickness of 3 mm. This frame functions as the main structure that supports all the components of the sandblasting tool, ensuring it is strong and stable during use.

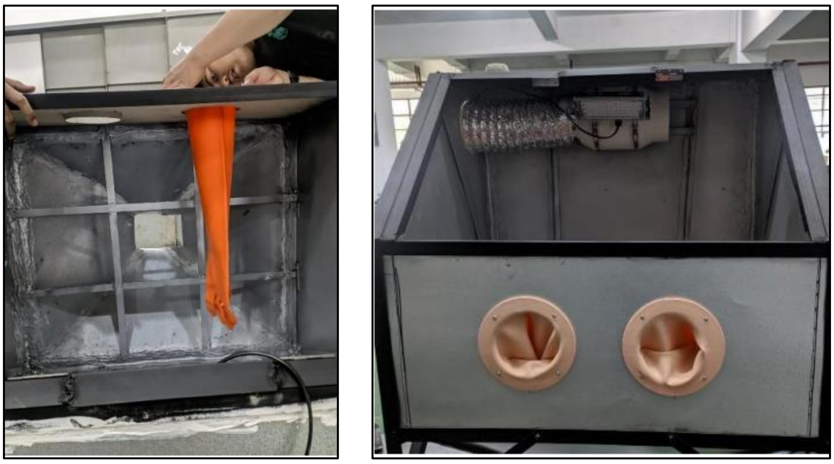
Figure 3. Frame Construction

Next, the frame coating process was carried out to protect the frame from corrosion (shown in Figure 4a), thereby increasing the durability of the sandblasting tool. This painting serves as a protective coating against environmental factors such as humidity and air exposure, which can accelerate the oxidation process in metal materials.

(4a) (4b)

Figure 4 (4a) Frame Coating ; (4b) Installation of Cover Plate and Acrylic Pane

Next, the installation of metal plates and acrylic panels for the sandblasting chamber was carried out (shown in Figure 4b). The plates function as enclosing walls that separate the sandblasting work area from the surrounding environment, allowing the sandblasting process to proceed safely and in a controlled manner without dispersing abrasive particles outside. Meanwhile, the acrylic panel serves as a viewing window to directly monitor the sandblasting process inside the enclosed chamber, enabling the operator to observe the results without opening the workspace, thereby maintaining safety and process efficiency.



(5a) (5b)

Figure 5. (5a) Glove Installation ; (5b) Blower and Lamp Installation

The installation of gloves serves as protective equipment for the operator during the sandblasting process on the sample. These gloves are integrated into the sandblasting chamber (shown in Figure 5a) to prevent the operator's hands from coming into direct contact with abrasive particles, while also ensuring safety and comfort when handling or positioning the workpiece inside the chamber.

Finally, the blower and lighting were installed. The blower functions to extract dust generated during the sandblasting process, preventing it from obstructing the operator’s visibility while the tool is in operation. This system also helps maintain cleanliness in the workspace and prevents the accumulation of abrasive particles inside the chamber. Meanwhile, the lamp serves as a lighting source within the sandblasting chamber.

3.2. Flow Rate Calculation

The air flow rate that can be generated by the compressor can be calculated using the following formula:

$$Q = A \times v \tag{1}$$

Where:
$Q =$ Air Flow Rate (cm^3/s)
$A =$ Cross-Sectional Area (cm^2)
$v =$ Air Velocity (cm/s)

Based on the compressor specifications:

Air Delivery (Q) $= 7.2\ cfm$
$= 339.8\ cm^3/s$

Cross-sectional Area (A) $= \pi r^2$
$= 3.14 \times (1.25\ cm)^2$
$= 4.91\ cm^2$

Thus, Air Flow Velocity (taken from equation 1):

$$v = \frac{Q}{A}$$

$$v = \frac{339.8\ cm^3/s}{4.91\ cm^2}$$

$$v = 69.205\ cm/s$$

The mass flow rate can be calculated using the following formula:

$$q_m = \frac{m}{t} = \rho \times v \times A \tag{2}$$

Where:
q_m = Mass Flow Rate (g/s)
m = Fluid Mass (g)
ρ = Fluid Density (g/m^3)
t = Time (s)
v = Air Velocity (m/s)
A = Cross-sectional Area (m^2)

Mass flow rate of Aluminium oxide could be calculated:
Given:
Density of Aluminium oxide (ρ) $= 3.99\ g/cm^3$
Air Velocity (v) $= 69.205\ cm/s$
$= 0.69205\ m/s$
Cross-sectional Area (A) $= 4.91\ cm^2$
Thus:

$$q_m = \rho \times v \times A$$
$$q_m = 3.99 \times 0.69205 \times 4.91$$
$$q_m = 13.577\ g/s$$

Mass flow rate of Silica sand could be calculated:
Given:
Density of Silica sand (ρ) $= 1.54\ g/cm^3$

Thus:

$$q_m = \rho \times v \times A$$
$$q_m = 1.54 \times 0.69205 \times 4.91$$
$$q_m = 5.232 \text{ g/s}$$

3.3. Air Pressure Calculation

To calculate the velocity of mass flow based on air pressure, it is necessary to know the mass and type of element being delivered. In this study, the air pressure was varied at 2 bar, 4 bar, and 6 bar. The compressor air pressure can be calculated using the following formula:

$$1 \text{ bar} = \text{cfm} \times 0.472 \quad (3)$$

Given:

Compressor Air Delivery = 7.2 cfm
= 339.8 cm^3/s

Therefore:

$$1 \text{ bar} = 339.8 \times 0.472 = 160.38 \text{ cm}^3/\text{s}$$

Table 4. Air Pressure Calculation Results

Pressure Variance	Cfm (cm^3/s)
2 bar	320.77
4 bar	641.54
6 bar	962.31

Air flow rate at 2 bar:

$$v = \frac{Q_1}{A}$$
$$v = \frac{320.77 \text{ cm}^3/\text{s}}{4.91 \text{ cm}^2}$$
$$v = 65.329 \text{ cm/s}$$
$$v = 0.65329 \text{ m/s}$$

Air flow rate at 4 bar:

$$v = \frac{Q_2}{A}$$
$$v = \frac{641.54 \text{ cm}^3/\text{s}}{4.91 \text{ cm}^2}$$
$$v = 130.65 \text{ cm/s}$$
$$v = 1.3065 \text{ m/s}$$

Air flow rate at 2 bar:

$$v = \frac{Q_3}{A}$$
$$v = \frac{962.31 \text{ cm}^3/\text{s}}{4.91 \text{ cm}^2}$$
$$v = 195.98 \text{ cm/s}$$
$$v = 1.9598 \text{ m/s}$$

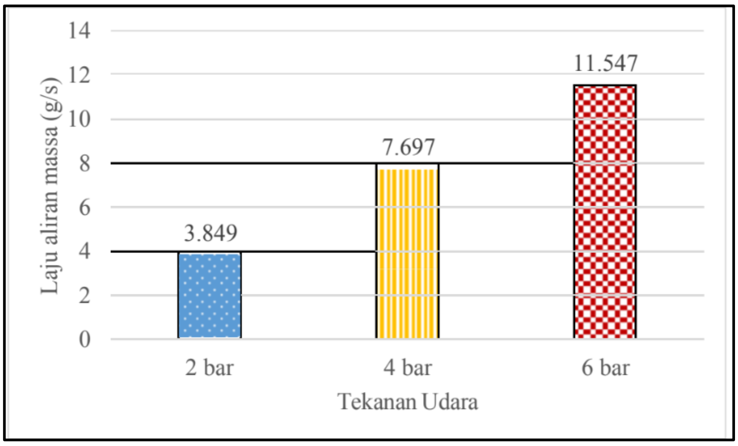


Figure 6. Air Mass Flow Rate with Pressure Variations ($\rho = 1.2\ kg/m^3$)

Figure 6 shows that the air velocity at 2 bar pressure is 3.849 m/s, at 4 bar it is 7.697 m/s, and at 6 bar it reaches 11.547 m/s. The diagram shows that the air flow velocity increases as the applied air pressure increases. Figure 6 shows that the air velocity at a pressure of 2 bar is 12.789 m/s, at 4 bar it is 25.595 m/s, and at 6 bar it reaches 38.394 m/s. The diagram shows that the air flow velocity increases as the applied air pressure increases.

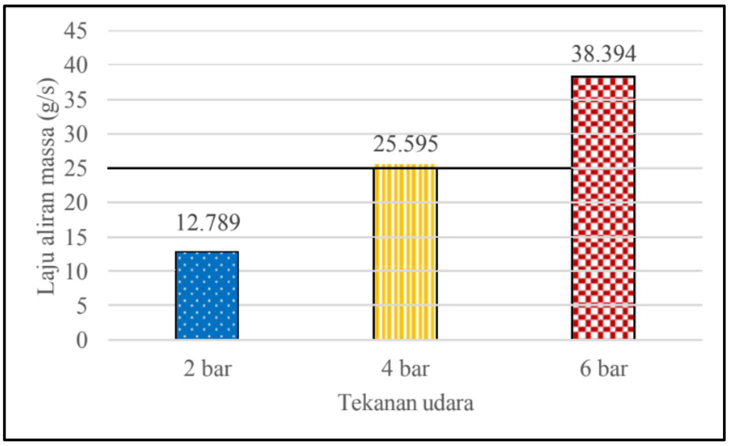


Figure 7. Aluminium oxide Mass Flow Rate with Pressure Variations ($\rho = 3.99\ g/cm^3$)

Figure 7 shows that it can be seen that the air velocity at 2 bar pressure is 4.939 m/s, at 4 bar it is 9.878 m/s, and at 6 bar it reaches 14.818 m/s. The diagram indicates that the air flow velocity increases as the applied air pressure increases.

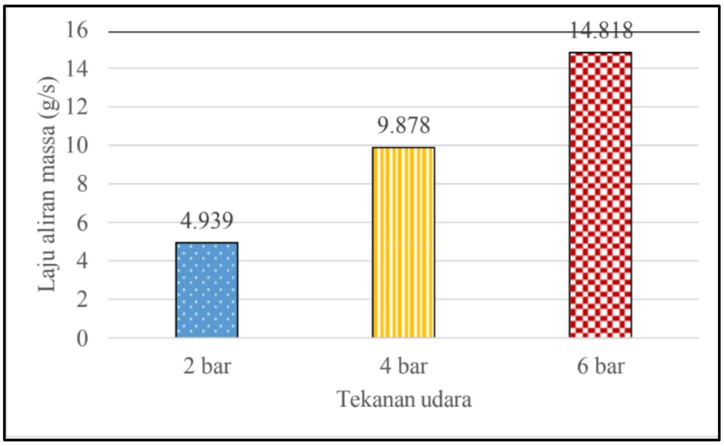


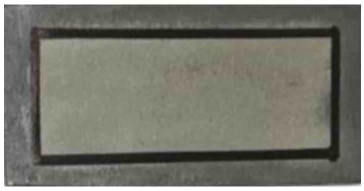
Figure 8. Silica Sand Mass Flow Rate with Pressure Variations ($\rho = 1.54\ g/cm^3$)

3.4. Results of Function Testing and Roughness Testing on Samples

After the sandblasting equipment was completed, functional testing was conducted by adjusting the predetermined parameters, including the abrasive material, spray angle, distance between the nozzle and the test material, and the air pressure from the compressor. For the material testing in this study, silica sand and aluminum oxide were used, with a 90˚ spray angle, a nozzle distance of 5 cm, and pressures of 2 bar, 4 bar, and 6 bar. Once the test materials underwent the sandblasting process, roughness testing was subsequently performed.

The roughness test aims to measure the surface roughness value. To conduct the roughness testing process, the test specimen is placed on a flat table, and the surface roughness is measured using a Surface Roughness Tester. The device is positioned on the sampling area of the specimen, and the detector reads the roughness level.

Table 5. Roughness Test Results

	Silica Sand	Aluminium oxide
Before Sandblasting	 $Ra = 2.100$ $Weight = 114.8\ g$	 $Ra = 1.806$ $Weight = 116.6\ g$
After Sandblasting	 $Ra = 2.686$ $Weight = 114.8\ g$	 $Ra = 2.593$ $Weight = 116.3$

From the test results in the table above, it can be observed that the roughness value of the material after the sandblasting process is higher compared to its roughness before sandblasting. The (Ra) roughness value of the material sandblasted with silica sand increased from 2.100 to 2.686, while the roughness of the sample sprayed with aluminum oxide rose from 1.806 to 2.593. The increase in roughness after sandblasting ranged between 21–30%. Additionally, the sandblasting process also caused a reduction in material weight, with an average decrease of 0.3 grams.

4. Conclusion

In this study, the author successfully designed a small-scale sandblasting system with thermodynamic parameters including a water flow rate of 7.2 cm or 339.8 cm^3/s, an airflow rate of 69,205 cm/s, and mass flow rates of aluminum oxide and silica sand at 13.557 g/s and 5.232 g/s, respectively. The dimensions of the sandblasting equipment consist of a chamber width of 90 cm, a chamber height of 180 cm, a nozzle cross-sectional area of 4.91 cm^2, and a blasting chamber volume of 3.926 cm^3. The assembly process of the sandblasting chamber and the installation of necessary components were completed according to the initial calculations and design, resulting in a fully functional sandblasting system. As shown in Figure 5, the equipment has been perfectly assembled and adjusted based on the previously designed methodology. After conducting functional testing, it can be concluded that the sandblasting equipment operates effectively and is ready for use by subsequent researchers. Surface roughness test results demonstrated an increase in roughness values after the sandblasting process compared to the initial condition, confirming the tool's effectiveness in modifying metal surfaces.

5. Acknowlegdements

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