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The Influence of Air Pressure on Surface Roughness Values in the Sandblasting Process of ST-37 Steel Plates †

Muhammad As'ad [1], Bambang Waluyo Febriantoko [1,*], Tri Widodo Besar Riyadi [1] and Ryan Fitrian Pahlevi [2]

1 Mechanical Engineering, Universitas Muhammadiyah Surakarta, Jl. Ahmad Yani, Surakarta 57162, Indonesia; d200221058@student.ums.ac.id (M.A.); tw187@ums.id (T.W.B.R.)
2 Sistem Informasi, STMIK Muhammadiyah Paguyangan Brebes, Brebes 52276, Indonesia; iankpahlevi@stmikmpb.ac.id
* Correspondence: bwf276@ums.id
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Abstract: This research explores the influence of air pressure on the surface roughness of ST-37 steel plates in the sandblasting process. Sandblasting is a common method in industry to enhance material surfaces. This study focuses on the effects of varying air pressure on surface roughness, crucial for achieving the desired quality. ST-37 steel plates, known for their strength and versatility, are used in various applications. The research involves a sandblasting process with different air pressures, analyzing surface roughness and contact area. The results indicate a direct correlation between increased air pressure, surface roughness, and contact area.

Keywords: sandblasting; ST-37 steel plates; surface roughness; air pressure influence

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1. Introduction

The sandblasting process is a common method used in industry to enhance the strength and quality of material surfaces. In this context, research on the influence of air pressure on the surface roughness value in the sandblasting process has becomes essential to understand the factors that can affect the final outcome of this process. Sandblasting involves the use of high-pressure sandblasting or other abrasive materials to smooth, shape, or clean a surface. This technique is commonly employed in industrial and construction environments to remove paint, rust, or other layers from surfaces or to create a rough surface for painting or adhesion. Sandblasting can be a hazardous process as it may produce airborne particles that are harmful if inhaled, and it can also generate a significant amount of dust and debris. Proper safety precautions, including the use of protective clothing, respiratory protection, and control measures, are crucial when performing sandblasting operations [1].

The iron or ST-37 steel plate is a low-carbon steel equivalent to AISI 1045 [2]. It is a structural steel with a tensile strength of 37 kg/mm^2 (362.84605 MPa). ST-37 is made of mild steel, produced through the hot-rolled process. ST-37 steel plates are commonly used in various industrial applications due to their strength and resistance to deformation. The use of ST-37 steel ranges from household appliances to the needs of factories and industries. Its reliable characteristics, suitability for various heat treatments, ease of welding, and good machining capabilities make it a versatile material.

A study on the mechanical anisotropy of cold-rolled ST-37 steel plates aims to understand the anisotropic behavior and sensitivity to material strain rates. The study's results indicate that anisotropy in yield strength can be observed in both quasi-static and high-strain rate conditions. The highest strength is observed in specimens perpendicular to the rolling direction [1].

In a research study on the mechanical properties of double side friction stir welding (DS-FSW) welding with Cu particle reinforcement. The main materials used are AA6061 aluminum alloy and 12 μm Cu powder. The process of adding Cu particles is carried out in single grooves and double grooves. It was found that an increase in hardness value of 23.39% occurred in the double groove material [3].

In a study on the development of gray cast iron, experiments were carried out to evaluate the effect of adding magnesium alloy using the fire hardening method. The research results showed that by adding the FeSiMg compound, the flake graphite structure changed to spherical graphite, while the hardness increased from 130 HV to 313.22 HV. The fire hardening process of nodular cast iron results in the formation of a martensite phase and removes graphite from the surface of the material. The surface hardness of the material after fire hardening increased by 82.4% compared to the original substrate [4]. To meet specific quality standards, the surface roughness of ST-37 steel plates also needs to be considered. In this context, the use of air pressure in the sandblasting process plays a crucial role in creating the desired surface roughness by shooting abrasive particles perpendicular to the metal surface at high pressure. The air pressure applied in the sandblasting process significantly affects the degree of roughness and the erosion rate on the steel plate. Sandblasting is influenced by various factors, including human factors, air pressure, shooting time, and shooting distance. Meanwhile, the erosion rate is influenced by the mechanical properties of the metal and the workpiece process itself. Therefore, controlling the air pressure in the sandblasting process is crucial to achieve the desired surface roughness of ST-37 steel plates.

Particle abrasion in the sandblasting process is also utilized in dental technology. Its primary function is to remove excess material, shape treated elements, and create an appropriate surface on dentures. This processing method utilizes the kinetic energy of abrasive particles in compressed gas flow, typically air. The accelerated abrasive particles impact the surface of the processed element, resulting in the generation of abrasive particle particles that cut the micro substrate, leading to material loss.

In a study on the influence of air abrasion on the quantity of particles embedded in zirconia, a highly significant difference was observed in the surface area of the abrasive material depending on the grain size. At a pressure of 0.20 MPa, the quantity of embedded abrasive material was 6.63, and at a pressure of 0.35 MPa, it increased to 7.17. Most abrasive material particles are embedded during sandblasting with a grain size of 60 μm. No significant difference was observed in the surface area of the abrasive material depending on the pressure. The quantity of embedded abrasive material depends on the type and size of the grains, as well as the applied pressure [5].

In a study on the influence of organic powder on surface quality in the abrasive blasting process, the use of three different organic wastes (walnut shells, olive pomace, and seashells) obtained through recycling in abrasive blasting was investigated. It was found that the blasting distance and time had the most significant impact on surface roughness [6].

In a study on the influence of sandblasting parameters as well as the type and hardness of material on the number of embedded Al_2O_3 particles, the question arises as to whether abrasive blasting is accompanied by the phenomenon of pushing abrasive particles into the conditioned material. It was found that an increase in grit size and pressure represents a systematic increase in the number of embedded particles. After abrasive blasting, abrasive particles were found on the material surface. The quantity of abrasive material moved depends on the hardness of the processed material [7]. Adequate consideration of environmental variables, such as particle type, nozzle diameter, pressure, standoff distance, and injection time, is a prerequisite for achieving the appropriate level of roughness. To find the optimal conditions, statistical methods of variable analysis are used to investigate the maximum values of depth, diameter, width, and so on, of the blasting surface. Many factors have a significant influence on the conditions of surface roughness [8].

Research involving computer simulations can explore the impact of physical properties on the process of coating materials. The Stoney and Tsui model was employed as the analytical method to validate the simulation outcomes using Abaqus 6.14–5 software, leading to successful and favorable results [9].

This study fundamentally aims to explore the extent to which air pressure can influence the surface roughness values of ST-37 steel plates in the context of the sandblasting process. It is expected that a deeper understanding of this relationship will provide valuable insights to enhance the efficiency and quality of the sandblasting process. By investigating variations in air pressure and their impact on surface roughness, this research is anticipated to make a significant contribution to improving the industrial sandblasting process. The study's results are expected to provide a better understanding of the factors influencing the surface roughness of ST-37 steel plates during the sandblasting process. The implications of these findings can be used as a guide to enhance quality control in industrial processes that involve ST-37 steel plates. Despite certain limitations in the study, such as restricted variations in tested air pressure and the scope of surface roughness observations, the primary focus remains on the concept that air pressure in the sandblasting process is a key factor influencing the surface roughness of ST-37 steel plates. Therefore, an in-depth analysis of the relationship between air pressure and surface roughness is the main focus of this research.

2. Materials and Methods

2.1. Materials and Samples

Mechanical properties such as material strength, impact resistance, fracture resistance, fatigue, wear resistance, and material hardness are crucial under certain conditions. Therefore, soft carbon steel with a martensitic structure has been developed since the early 1980s [10]. Material hardness is one of the mechanical properties that can be altered, for example, through tempering processes at specific temperatures. This can be illustrated in research on the hardness characteristics and microstructure of extraction forceps for oral and dental treatment made of stainless steel. Microstructure testing using an optical microscope reveals the presence of ferrite, pearlite, and martensite structures. The test results on the material surface indicate that as the tempering temperature increases, the dimensions of the microstructure become larger [11].

The proper selection of specimens is a crucial step in the testing process (Table 1). In this study, the chosen specimens are ST-37 steel plates intended for the walls of train carriages. The chemical composition of the material includes *C*: <0.2%, *Si*: <0.5%, *Mn*: <0.8%, *Cu*: <0.25%, and *S*: <0.05%. The mechanical properties of these specimens include a tensile strength of 370 N/mm^2 or approximately 37 kg/mm^2 (362.84605 MPa).

Table 1. Research parameter data.

Type	Information	Source
Specimen	ST-37 steel plate	PT INKA
Particles	Grit sand very fine 80 mesh	ISO 9001 Standard [12]
Air pressure	4 kg/cm^2; 4.5 kg/cm^2; 5 kg/cm^2; 5.5 kg/cm^2; 6 kg/cm^2	
Blasting distance	10 cm	
Blasting time	20 min	
Contact angle	7°	PT INKA Standard National Indonesia [13]

2.2. Methods

The sequence of the sandblasting research process is illustrated in Figure 1, starting with the preparation of specimens. This involves cutting large steel plates into 10 × 5 cm pieces, totaling 10 specimens. The plates are cleaned using thinner A (faster drying, economical, and easy to use), followed by measuring mass with a scale and thickness with a micrometer. Two measurements yield an initial mass of 250 g and a thickness of 7 mm.

Figure 1. Test flow.

Sandblasting is conducted for the first finishing level, aiming to remove rust, eliminate paint and oil residues, and level the plate surface before proceeding to the next finishing level. The process involves varying air pressure from 4 to 6 kg/cm^2. Specimen shooting is performed at a distance of approximately $\pm$10 cm, with a maximum shooting angle tolerance of 45^2, and a time parameter of 20 s.

Specimen testing takes place in the manufacturing laboratory using a surface roughness testing instrument, allowing for the determination of surface roughness results for each specimen with different air pressure variations. In the analysis and calculations, data are collected from the test results with labeling and calculations using formulas from reference books and journals. If the analysis results are invalid, a reassessment is conducted starting from specimen preparation to the sandblasting process. However, if the analysis results are valid, the process continues.

The SI-950CR blasting machine is one of the machines that utilizes iron sand as its abrasive. The sequence of the blasting process is as follows:

- Iron sand is introduced into the upper storage compartment using a screw conveyor operated by an operator. In this upper storage compartment, there are two valves serving as bypass for the filter and grit level to prevent spillage. The bypass directs the grit to the storage tank.
- From the upper storage, it is transferred to the grit mixing tank or lower container through two sets of valves. The first valve is operated manually, directly by the operator. In this case, the operator must be able to determine when the mixing tank is full so that the valve can be promptly closed. The second valve operates automatically, functioning with a switch-level system for grit height located in the mixing tank. If the mixing tank is full, it presses the switch level, which sends a signal to close the valve.
- From the mixing tank, it flows towards the grit addition and reduction valves. These valves operate automatically and are controlled using a cylindrical-shaped air tube. The air tube regulates the grit output from the mixing location by balancing air with grit. If the air mixture is more abundant than the grit, the valve will add grit, and vice versa.
- An additional component in the pipeline is the blow valve, which functions if the pressure inside the pipe is too high. Next, it reaches the pipe where an electrical current is applied to separate water from air using the evaporation method. The vapor is then filtered with a multi-level filter on the outlet pipe. There is a total pressure measuring device filtered as a final step before the air is directed to the next level.

3. Results and Discussion

3.1. Data Analysis of the Effect of Air Pressure on Surface Roughness

Grit blasting uses very fine sand with particle sizes following ISO 9001 standards, specifically 80 mesh, with a maximum profile height of 1.5 m for the specimen (Figure 2). The use of this grit results in finer abrasion, providing a smoother and more even surface for the specimen. In the first spraying phase, grit is employed to clean off deposits such as scale, oil, and rust. Subsequent sprayings utilize the grit for surface smoothing and leveling (Figure 3).

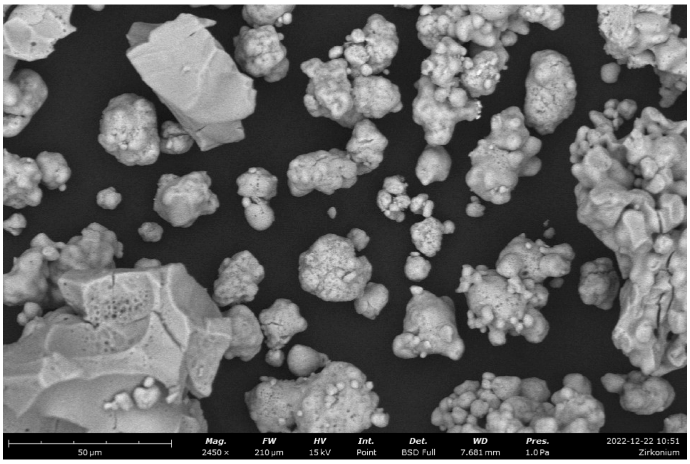

Figure 2. Grit blasting after 20× magnification.

Figure 3. Surfcorder SE 1700 (surface roughness measuring instrument), Automation and Metrology Inc., Mentor, OH, USA.

The results from the sandblasting test on ST-37 steel are obtained and presented in Table 2.

Table 2. Average roughness experiment results for each specimen.

Pressure (P) kg/cm^2	**Roughness Average ($\overline{Ra}$) µm**
4	7.674
4.5	7.909
5	8.963
5.5	9.310
6	9.996

3.2. Discussion

A graph based on the table is then created, as seen in Figure 4.

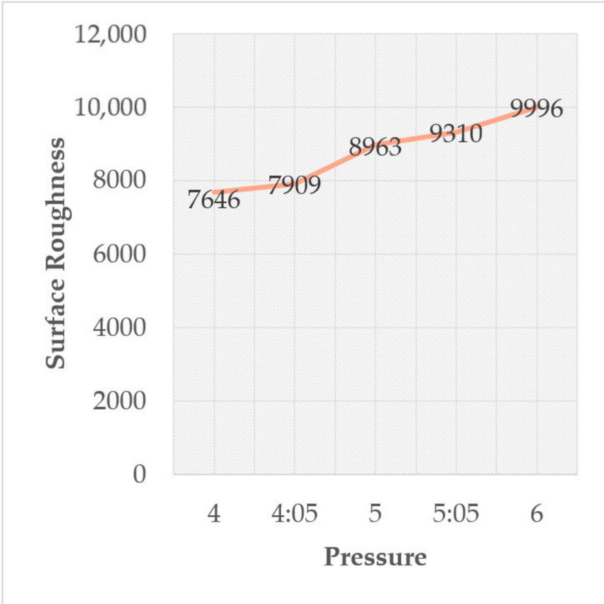

Figure 4. Graph of the relationship between roughness and pressure.

From the above graph, it can be observed that as the pressure increases, the surface roughness also increases. For instance, in specimen 1 with a pressure of 4 kg/cm^2, the surface roughness is 7.674 µm. In specimen 2 with a pressure of 4.5 kg/cm^2, the surface roughness increases to 7.909 µm, and it continues to rise until specimen 5 with a pressure of 6 kg/cm^2, which has a surface roughness of 9.996 µm. From these results, it is evident that the lowest surface roughness occurs in specimen 1 with a pressure of 4 kg/cm^2 at 7.674 µm, while the highest surface roughness is in specimen 5 with a pressure of 6 kg/cm^2 at 9.996 µm.

This phenomenon is related to the pressure and the number of grit particles adhering to the surface. As the compressor pressure increases, the contact between grit particles and the specimen surface becomes more frequent, resulting in larger impacts. This achieves the ideal particle jet velocity according to the ISO 9001 standard used by PT. INKA Madiun.

4. Conclusions

From the calculation results and discussions, it can be concluded that the average surface roughness for each specimen with pressures of 4 kg/cm^2, 4.5 kg/cm^2, 5 kg/cm^2, 5.5 kg/cm^2, and 6 kg/cm^2 are as follows: 7.674 µm, 7.909 µm, 8.963 µm, 9.310 µm, 9.996 µm. From these calculations, it can be observed that the higher the pressure applied, the greater the level of surface roughness.

The contact area between the specimen surface and grit for each specimen with pressures of 4 kg/cm^2, 4.5 kg/cm^2, 5 kg/cm^2, 5.5 kg/cm^2, and 6 kg/cm^2 is as follows: 0.275 cm^2, 0.309 cm^2, 0.344 cm^2, 0.378 cm^2, 0.413 cm^2. As the pressure increases, the contact between grit particles and the specimen surface becomes more frequent, resulting in larger impacts.

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