Applied Chemical Engineering (2026) Volume 9 Issue 2 ISSN: 2578-2010 (O)
doi: 10.59429/ace.v9i2.5922

ORIGINAL RESEARCH ARTICLE

Analysis of the effect of sandblasting on the surface roughness and coating adhesion of ASTM A36 plate

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ABSTRACT

The aim of this research is to examine the effect of variations in spraying pressure and distance on the surface roughness and coating quality of ASTM A36 steel. The method used is by comparing the results of the sandblasting using 60 mesh aluminium oxide abrasive material with a shooting angle of 90° at a distance of 5 cm and 10 cm with pressures of 4, 6 and 8 bar. Surface roughness and paint adhesion test is then done on the specimens. The roughness test showed that increasing sandblasting pressure did not have a direct correlation to the increase in surface roughness. Conversely, as the sandblasting distance increase from 5 cm to 10 cm, affected the surface roughness decreases. The highest mean Ra, Rp and Rz value were obtained from a nozzle distance of 5 cm at pressure of 8 bar with value of 4.125 µm, 11.746 µm and 25,773 µm respectively. Paint adhesion testing showed that the higher surface roughness did not necessarily result in better paint adhesion of the steel plates. Instead, surface morphology and coating thickness played a more dominant role in adhesion strength. These findings indicate that variations in pressure and distance during sandblasting significantly influence the surface texture and coating performance of ASTM A36 steel.

Keywords: sandblasting; surface roughness; coating; ASTM A36 Steel; aluminum oxide

ARTICLE INFO

Received: 27 February 2026
Accepted: 27 April 2026
Available online: 8 June 2026

1. Introduction

Soegijono[1] and Batis[2] have described the surface cleaning is a critical stage, as it influences subsequent manufacturing stages and overall production efficiency. Ebnesajjad[6] has discussed paint adhesion, however, faces significant challenges due to surface contamination, inadequate wettability, and suboptimal surface texture, which can weaken the mechanical interlocking and chemical bonding of coatings. Contaminants such as oil, grease, dust, and oxide layers form weak boundary films that inhibit proper adhesion, leading to peeling or delamination over time. In this context, the sandblasting process is a suitable choice because it can clean the surface of medium-sized and complex workpieces. Sandblasting is a surface cleaning method in which abrasive particles are propelled at high velocity toward a material surface, producing mechanical abrasion through impact. This process cleans and increases the roughness of the material's surface. Ishaka[3] and Prabowo[4] have described the level of roughness can be adjusted according to the size of the abrasive material and the blasting pressure. The coating applied, such as paint, functions to protect plate iron from corrosion, scratches and other environmental influences that can damage the material. Apriwandani[5] has described the sandblasting is a process that aims to make the metal surface rougher, thereby increasing the adhesion of paint and other protective coating, mini minimizing the risk of delamination, and improving corrosion resistance. However, Mulyanto[7] discussed adhesion performance can still be influenced by environmental factors such as moisture, UV exposure, and thermal cycling further degrade the coating–substrate interface. To address these issues, surface preparation techniques such as cleaning, degreasing, and mechanical profiling are essential. In this context, sandblasting serves a dual function: it removes contaminants and optimized surface profile, leading to improved coating performance and longevity.

Although many studies have investigated sandblasting parameters individually, limited research has analyzed the combined effects of pressure and distance on both surface roughness and coating adhesion, particularly for ASTM A36 steel using aluminum oxide abrasives. Addressing this gap, the present study examines how variations in sandblasting pressure and distance influence surface roughness parameters (Ra, Rp, Rz), material loss, coating thickness, and adhesion strength (ASTM D3359). The results aim to identify optimal blasting conditions that enhance surface anchoring and coating durability for industrial applications.

2. Materials and methods

The sandblasting process is shown in the figure below where high pressure air from the compressor flows towards the sand tube, after which high pressure air mixed with sand simultaneously flows towards the nozzle, then the nozzle sprays high pressure sand towards the workpiece as seen in **Figure 1**. The sandblasting machine used was a custom built sandblasting machine constructed for metal surface cleaning[8].

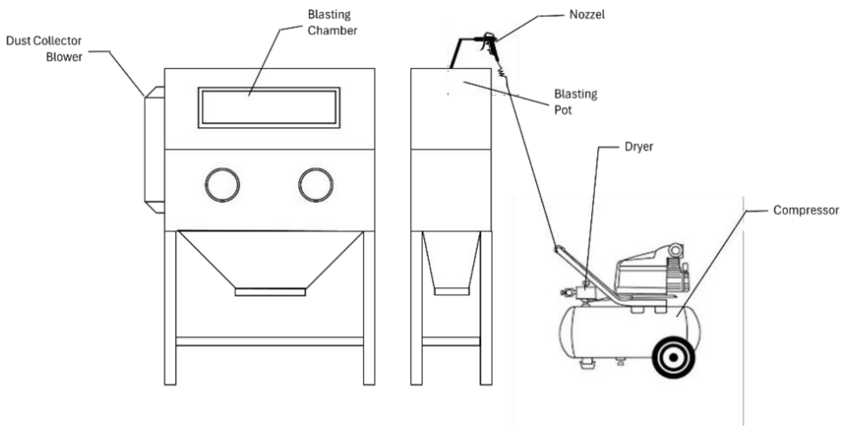


Figure 1. Schematic Diagram of Research Installation.

The study utilized a custom-built sandblasting machine with aluminium oxide abrasive (60 mesh) to blast ASTM A36 steel plates at various pressures (4, 6, 8 bar) and distances (5 cm, 10 cm) with 10 seconds blasting time respectively. The pressure and distance various have shown on **Table 1**. Surface roughness was measured using a Mitutoyo SJ-310 tester at three locations per specimen, in accordance with ISO 21920. Which recommend multiple measurement points to obtain a representative surface roughness value for metallic substrates. Coating adhesion was evaluated through the cross-cut test (ASTM D3359).

Table 1. Pressure and distance of blasting.

Specimen	Pressure (bar)	Distance (cm)
B1	4	5
B3	6	5
B5	8	5
B2	4	10
B4	6	10
B6	8	10

An epoxy primer was then applied onto ASTM A36 steel plates using an air spray system, ensuring uniform coating thickness. After full curing of the primer layer, a polyurethane topcoat was applied using the same spraying method. The thickness of the coating layer is measured using coating thickness gauge. Coating adhesion was then evaluated using the cross-cut test method in accordance with ASTM D3359, Method B[11]. In this procedure, a series of parallel cuts were made through the coating to the substrate using a standardized cutting tool, followed by a second set of cuts at 90° to the first to produce a lattice pattern. An adhesive tape, was firmly applied over the lattice, pressed to ensure uniform contact, and removed rapidly at a consistent angle. The coating removal within the lattice area was assessed visually and rated according to the ASTM D3359 classification scale (0B–5B).

3. Results

3.1. Surface roughness result data

Table 2 and **Figure 2** show that the Ra value after sandblasting increases in all variations performed during the sandblasting process. Variation in blasting pressure does not have a direct correlation to the increase in Ra (mean) value as seen in specimen B1 to B3 but it does have an effect on the final Ra (mean) value. Increase in pressure result in higher Ra (mean) value as the final Ra (mean) value increases from specimen B1 to B3 and B4 to B6. Longer blasting distance however, does result in lower increase in Ra (mean) value.

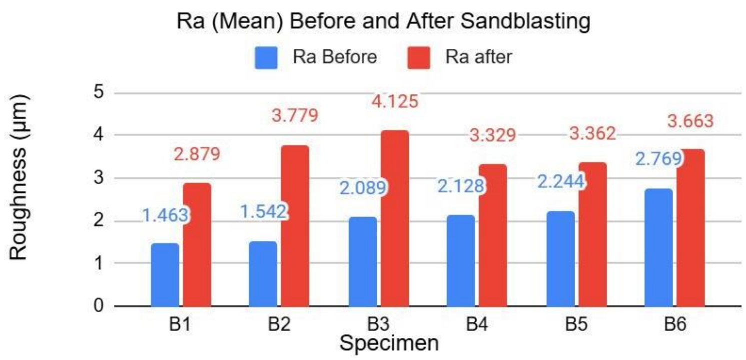


Figure 2. Comparison of Ra (mean) value before and after sandblasting.

Table 2. Ra (mean) Before and After Sandblasting.

Specimen	Ra Before (m)	Ra After (µm)	Increase (%)
B1	1.463	2.879	96.79
B2	1.542	3.779	145.07
B3	2.089	4.125	97.46
B4	2.128	3.329	56.44
B5	2.244	3.362	49.82
B6	2.769	3.663	32.29

Based on **Figure 2**, specimen B1 to B3 where the blasting distance is 5 cm has an increase of Ra (mean) value of 96 % to 145 %. Meanwhile specimen B4 to B6 has an increase of Ra (mean) value of 32 % to 56 %. Ra values of samples B4, B5 and B6 in the sandblasting process with a distance of 10 cm shows a smoother surface. This happens because at a distance of 10 cm the release of aluminum oxide is more spread out and the surface experiences deformation and provides better roughness profile[12]. When discussing all roughness parameters (Ra), it shown the lower distance than 10cm are due to reduced kinetic energy and spread of abrasive particles over the longer distance, leading to less aggressive material removal.

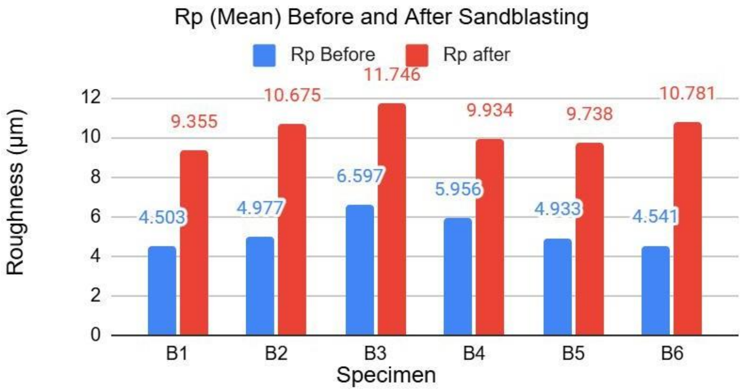


Figure 3. Comparison of Rp (mean) value before and after sandblasting.

Table 3. Rp (mean) Before and After Sandblasting.

Specimen	Rp Before (m)	Rp After (μm)	Increase (%)
B1	4.503	9.355	107.75
B2	4.977	10.675	114.49
B3	6.597	11.746	78.05
B4	5.956	9.934	66.79
B5	4.933	9.738	97.41
B6	4.541	10.781	137.41

Based on **Figure 3** and **Table 3** shows the results of Rp (mean) values. Similar to the Ra (mean) values, the increase in blasting pressure does not have a direct correlation to Rp (mean) values and only affect the final Rp (mean) values. Further blasting distance also result in lower Rp (mean) value obtained. Highest value of Rp (mean) was also obtaioned on specimen B3 (blasting pressure 8 bar, at a distance of 5 cm).

Based on **Figure 4**, specimen B1 to B3 where the blasting distance is 5 cm has an increase of Ra (mean) value of 96 % to 145 %. Meanwhile specimen B4 to B6 has an increase of Ra (mean) value of 32 % to 56 %. Ra values of samples B4, B5 and B6 In the sandblasting process with a distance of 10 cm shows a smoother surface. This happens because at a distance of 10 cm the release of aluminum oxide is more spread out and the surface experiences deformation and provides better roughness profile as discussed by Harmoko[12]. When discussing all roughness parameters (Ra), it shown the lower distance than 10cm are due to reduced kinetic energy and spread of abrasive particles over the longer distance, leading to less aggressive material removal.

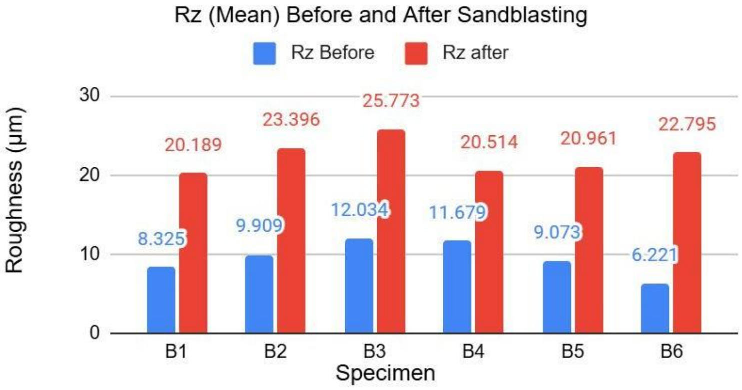


Figure 4. Comparison of Rz (mean) value before and after sandblasting.

Table 4. Rz (mean) Before and After Sandblasting.

Specimen	Rz Before (m)	Rz After (µm)	Increase (%)
B1	8,325	20,189	142.51
B2	9,909	23,396	136.11
B3	12,034	25,773	114.16
B4	11,679	20,514	75.65
B5	9,073	20,961	131.03
B6	6,221	22,795	266.42

Based on **Figure 4** and **Table 4** shows the results of Rz (mean) values before and after the sandblasting process. The result is still consistent to the Ra and Rp tests where blasting pressure only affect the final Rz (mean) values and does not have a direct correlation with the increase in Rz (mean) value. Further distance also creates lower Rz (mean) values.

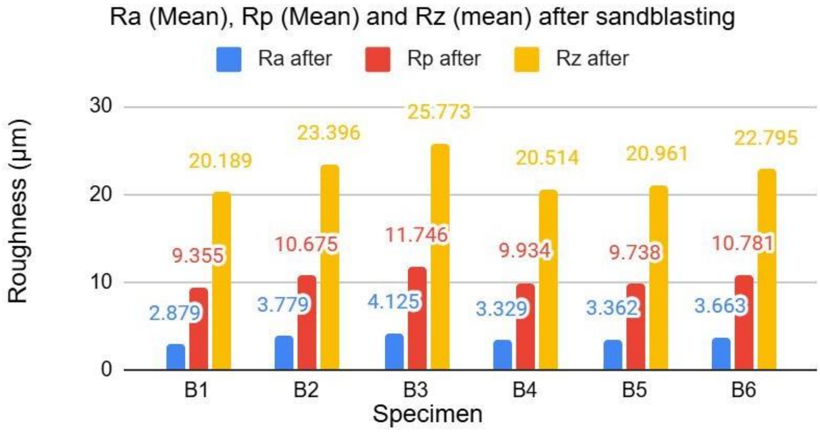


Figure 5. Comparison of Ra (mean), Rp (mean) and Rz (mean) value before and after sandblasting.

Based on **Figure 5** shows the final Ra (mean), Rp (mean) and Rz (mean) values. We can see that the Rp (mean) and Rz (mean) values are significantly higher than Ra (mean) values. The surface roughness measurements after sandblasting showed that the mean Rp values for all specimens were approximately 2.8–3.25 times higher than the corresponding Ra values, while the mean Rz values were approximately 6–7 times higher than Ra. This disparity indicates that the blasted surfaces exhibited pronounced peaks and deep valleys, resulting in a strongly textured profile. Notably, specimens B1, B2, and B3, which were blasted at a shorter distance of 5 cm, recorded the highest Rp and Rz values, suggesting a more aggressive material removal and peak formation due to the higher impact energy of the abrasive particles as discussed by Bechikh[13]. In contrast, specimens B4, B5, and B6, blasted at a distance of 10 cm, exhibited lower Rp and Rz values, indicative of a less pronounced surface profile. These differences highlight the influence of blasting distance on the resulting surface morphology, where closer distances tend to produce rougher and more irregular profiles.

3.2. Weight Loss

Table 5 shows the mass comparison of the specimens before and after the sandblasting process. The mass loss during sandblasting was approximately 0.3 g for all specimens, regardless of blasting distance. This indicates that, within the tested range (5 cm and 10 cm), blasting distance had a negligible effect on the total volume of material removed. The observed differences in surface roughness between groups can therefore be attributed primarily to variations in surface morphology—such as peak height and valley depth—rather than differences in erosion rate.

Table 5. Weight Loss.

Specimen	Before Sandblasting	After Sandblasting
B1	115.3 g	115.1 g
B2	107.4 g	107.2 g
B3	106.9 g	106.5 g
B4	110.0 g	109.5 g
B5	112.5 g	112.4 g
B6	114.1 g	113.9 g

3.3. Paint layer thickness test results data

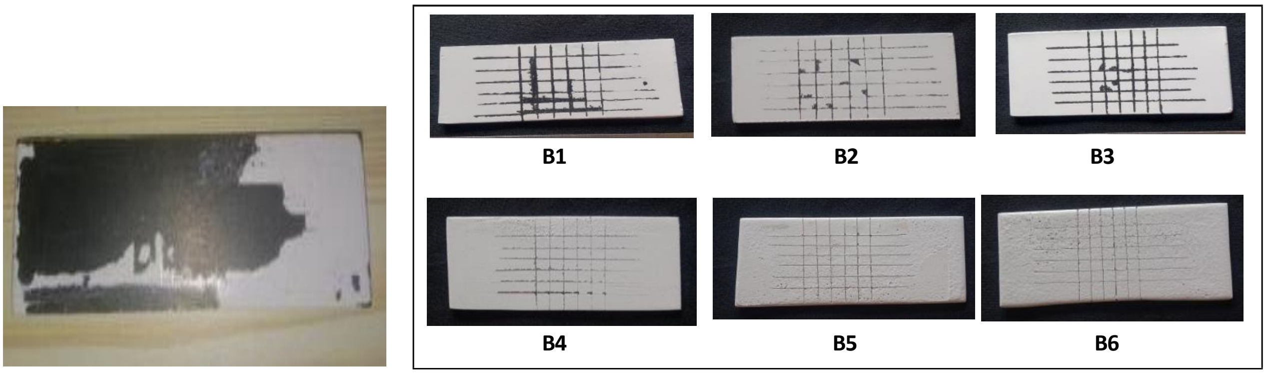
In **Table 6**, it was observed that specimens subjected to sandblasting at a distance of 10 cm exhibited greater coating thickness compared to those blasted at 5 cm. Similarly, as discussed by Rudawska[14] that the specimens treated under higher blasting pressure also demonstrated increased coating thickness. This trend can be attributed to the influence of surface morphology on coating deposition. The 10 cm blasting distance produced a less pronounced surface profile, characterized by lower peak heights (Rp) and valley depths (Rz), allowing the coating to wet and level more effectively. Explicitly connect the smoother morphology at 10 cm is key to film thickness uniformity and coating performance. Syamsuir[15] described as a result, more coating material remained on the surface rather than filling deep surface valleys, leading to higher measured coating thickness. Increased blasting pressure, within the parameters tested, likely enhanced surface cleanliness and generated an optimal anchor pattern, improving coating wetting and promoting a thicker and more uniform film.

Table 6. Coating Thickness.

Specimen	Air Pressure (bar)	Distance (cm)	Coating thickness (mm)
B1	4 Bar	5 cm	0.55
B2	6 Bar	5 cm	0.60
B3	8 Bar	5 cm	0.65
B4	4 Bar	10 cm	0.75
B5	6 Bar	10 cm	0.80
B6	8 Bar	10 cm	0.95

3.4. Paint adhesion test results

From **Figure 6**, it can be seen that the sample without sandblasting process, a large part of the paint peels off. While the specimens that undergo sandblasting process has a significant decrease in peeling paint area.



(a) (b)

Figure 6. Results of cross cut paint adhesion test. (a) Without sandblasting (b) After blasting.

Table 7. Area of peeling paint of each specimen that undergo sandblasting.

Specimen	Pressure	Distance guess	Area of Peeling Paint	Classification
B1	4 Bar	5 cm	35-65%	1B
B2	6 Bar	5 cm	15-35%	2B
B3	8 Bar	5 cm	15-35%	2B
B4	4 Bar	10 cm	5-15%	3B
B5	6 Bar	10 cm	5%	4B
B6	8 Bar	10 cm	5%	4B

Based on **Figure 6** and **Table 7** and referring to the ASTM D3359 standard, and followed by Pratama's[16] discussion, it was seen that paint adhesion test result is consistent with the coating thickness measured on specimens blasted at a 10 cm, the adhesion outcomes improved markedly with distance and, secondarily, with pressure. At 5 cm, specimens B1–B3 (4–8 bar) showed 35–65% (1B) down to 15–35% (2B) coating removal, indicating weak adhesion. In contrast, at 10 cm, specimens B4–B6 exhibited only 5–15% (3B) to 5% (4B) removal, with the best ratings (4B) at 6–8 bar. These trends suggest that the 10 cm distance produced a less extreme surface profile (lower Rp/Ra and Rz/Ra).

4. Discussion

Overall, the relationship between surface roughness and coating adhesion in this study aligns with theoretical and experimental findings from previous works. As reported by others researcher, sandblasting parameters such as pressure and distance significantly influence the morphology and surface energy of metallic substrates[13,14]. The results here confirm that while shorter distances and higher pressures increase roughness (due to stronger abrasive impact and higher kinetic energy), they do not necessarily improve adhesion. This can be explained by the mechanical interlocking and surface energy mechanisms: moderate roughness enhances coating wetting and bonding, whereas excessive roughness introduces stress concentration and poor coating uniformity. Thus, the 10 cm distance at 6–8 bar represents the most balanced condition, producing an optimal surface profile for durable adhesion.

5. Conclusion

The study found that shorter sandblasting distances (5 cm) and higher pressures (up to 8 bar) increase the surface roughness of ASTM A36 steel. It means the metal surface becomes more textured and suitable for mechanical bonding. However, when it comes to paint adhesion, the 10 cm blasting distance produced better results than 5 cm. At this distance, the smoother surface profile allowed the coating to spread evenly and bond more effectively. Moreover, higher pressures (6–8 bar) improved surface cleanliness and created an ideal anchor pattern, leading to thicker coatings up to 0.95 mm and stronger adhesion ratings (4B) according to ASTM D3359 standards.

Refer to practical value for coating processes, these findings provide a clear guideline for optimizing surface preparation before coating steel. For practical coating applications, using a 10 cm blasting distance and 6–8 bar pressure achieves the best balance between roughness, cleanliness, and coating adhesion. This combination ensures a uniform, durable coating layer that resists peeling and corrosion, improving the longevity and performance of industrial coatings. Adopting these parameters can enhance coating efficiency, reduce material waste, and minimize maintenance costs in manufacturing and infrastructure industries.

Acknowledgments

The work was supported by the Universitas Sumatera Utara with Grant number: 9781/UN5.2.4.D/SK/PT/2025.

Conflict of interest

The authors declare no conflict of interest.

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