Surface Characteristics of Low Carbon Steel JIS G3101 SS400 after Sandblasting Process by Steel Grit G25

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WORD COUNT	3893	TIME SUBMITTED	06-JAN-2022 05:20AM
		PAPER ID	81057288

Surface Characteristics of Low Carbon Steel JIS G3101 SS400 after Sandblasting Process by Steel Grit G25

DOI : 10.36909/jer.10091

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ABSTRACT

This research aims to study the surface characteristics of low carbon steel JIS G3101 SS400 processed by sandblasting using steel grit G25. The sandblasting process is conducted at a fixed nozzle pressure of 5 bar and pressure angle of 90°, and varying nozzle-to-surface distances at 15, 25, and 30 cm, and blasting durations of 25, 45, and 120 s. Surface characterization is firstly carried out by conducting observation on the surface's morphology by SEM and chemical composition by EDS. Subsequently, visual inspection and measurement on surface roughness and hardness profile identification by Rockwell and micro-Vickers hardness tests are conducted. A paint thickness test using ASTM D7091 was undertaken to observe the surface characteristics related to the coating process. Based on the result, SEM found valleys, granules, micro-cracks, and grits embedded on the surface. The visual inspection shows the roughness is within the range of Sa2 - Sa3 of ISO 8501 with values are

Ra 18.1 and Ra 21.4 μm. The hardened layer exhibits a maximum hardness value of 332 HV and a depth of more than 50 μm by sandblasting parameters of 15 cm distance and 120 s duration. Both roughness and hardness profiles are confirmed, increasing with closer nozzle-to-surface distance and longer blast duration. It is concluded that sandblasting using steel grit G25 is effective in improving the mechanical strength and surface hardness of low carbon steel SS400. These mechanical properties are essential in the paint coating of machinery applications such as pump, tank, ship, and pipeline.

Keywords: Sandblasting, steel grit G25, low carbon steel SS400, surface roughness, surface hardness.

INTRODUCTION

Surface treatment is widely used in many engineering applications to improve the strength and lifetime of a mechanical component under particular operating conditions. The purpose of surface treatment is usually to increase the strength, hardness, corrosion resistance, wear resistance, and fatigue life (Khorasanizadeh, 2010, 2005, Triawan et al., 2018, Trisnanto et al., 2019, Saptaji et al., 2019, Bedjaoui et al., 2019 & Wu et al., 2015). Sandblasting is one of the surface treatments that is usually applied for modifying the component's strength by improving the surface quality (Khorasanizadeh, 2010, Saptaji et al., 2019, Bedjaoui et al., 2019, Wu et al., 2015 & Arifvianto et al., 2010). Sandblasting uses a high-velocity abrasive particle with pressurized air that can clean a surface from rust, paint, and oil. Sandblasting also can create a roughness profile on the metal surface to ease the color to stick perfectly (Khorasanizadeh, 2010). Moreover, surface roughing can increase the surface area and provide undercuts that provide mechanical interlocking between substrate and coating to increase bonding strength (Bobzin et al., 2015).

The blasting particles that are commonly used are Al_2O_3, ZrO_2, TiO_2, SiO_2, silica, and bioceramic. The particle should be made of hard and non-toxic materials and can be quickly blasted by the compressed gas flow. The high-pressure collision of abrasive materials causes a plastic deformation on the surface of the target material. The deformation results in unique surface topography and properties depending on the blasting parameters, such as nozzle pressure, nozzle-to-surface distance, and blasting duration (Arifvianto et al., 2012, Dikici, et al., 2017 & Ho et al., 2015).

Some previous works have reported the effect of various blasting particles on the target materials. Arifvianto et al. (2012) studied the impact of continuous usage of Al_2O_3 on medical grade 316L stainless steel (Arifvianto et al., 2012). Maio et al. (2017) investigated Al_2O_3 abrasive material with a diameter of 0.35 mm (Miao et al., 2017). Multigner et al. (2010) studied the combination of abrasive blasting materials, ZrO2 + SiO2 (125 µm - 250 µm) and Al_2O_3 (750 µm) when blasted against target metal of 316 LVM stainless steel (Multigner et al., 2010). From those works, Alumina (Al_2O_3) could be considered as prospective particles used in the sandblasting process. However, alumina particle has some drawbacks such as expensive, dusty, and produces irregular cavities, scratches, and coarse morphology (Arifvianto et al., 2012 & Chander et al., 2009).

The present work aims to evaluate the application of steel grit G25, which can be considered as an alternative sandblasting particle that is relatively cheaper and cleaner than alumina. As the target material, low carbon steel JIS G3101 SS400 is selected due to its frequent application in engineering machinery. There is still limited research reported about the effect of steel grit G25 on the surface characteristics of low carbon steel SS400 specimens after the sandblasting process. Observation on the surface by SEM and EDS is done to understand the surface morphology and chemical composition. Moreover, visual roughness inspection, surface roughness measurement, and hardness tests are carried out to assess the effectiveness of the particle in creating a hardened layer. A paint thickness test is then applied to investigate the effectivity of the surface characteristics of the sandblasting process. By understanding these data, the potential application of steel grit G25 for sandblasting applications can be assessed.

MATERIALS AND METHOD

The specimen used as the target material was a plate of low carbon steel JIS G3101 SS400 with chemical composition, as shown in Table 1. This material is chosen because it is commonly used as a structural material in machinery, such as pump, ship, tank, and pipeline. The specimen was in the plate shape with a dimension of 150 x 150 x 6 mm, in which 6 mm is the thickness. The blasting particle used is steel grit G25 with chemical composition and specification tabulated in Tables 2 and 3. Figure 1 shows the G25 steel grits used in the experiment.

Table 1 Chemical composition of JIS G3101 SS400

Elements (max)	Fe	C	Si	Mn	P	S
Weight (%)	0.81	0.0066 – 0.026	-	0.206	0.050	0.050

Table 2 Chemical composition of steel grit G25

Material	Elements	C	Si	S	P
Steel Grit G25	Min.	0.8	0.4	-	-
	Max.	1.2	-	0.04	0.04

Table 3 Properties of steel grit G25

Shapes	Angular
Grain Color	grey
density	7.4 kg/dm3
Microstructure	Tempered martensite
Hardness	>60 HRC
Grain size	0.71 – 1.19 mm

Figure 1 Steel grit G25 particle (particle size: 0.71 – 1.19 mm)

The sandblasting processes were carried out under several predetermined parameters, as tabulated in Table 4. The experimental set up is shown in Figure 2. During the sandblasting process, the nozzle pressure was kept constant at 5 bar, and the angle of blasting was maintained at 90° to the surface. The varying parameters were the nozzle-to-surface distance and blasting duration. The distance between nozzle and surface of 15, 25, 30 cm, and blasting duration of 25, 45, 120 s were implemented. Thus, a total of nine specimens were tested in the experiment.

Table 4. Sandblasting experimental condition

Nozzle pressure/blasting angle	**Nozzle-to-surface distance (cm)**	**Blasting duration (second)**
5 bars / 90°	15	25
	25	45
	30	120

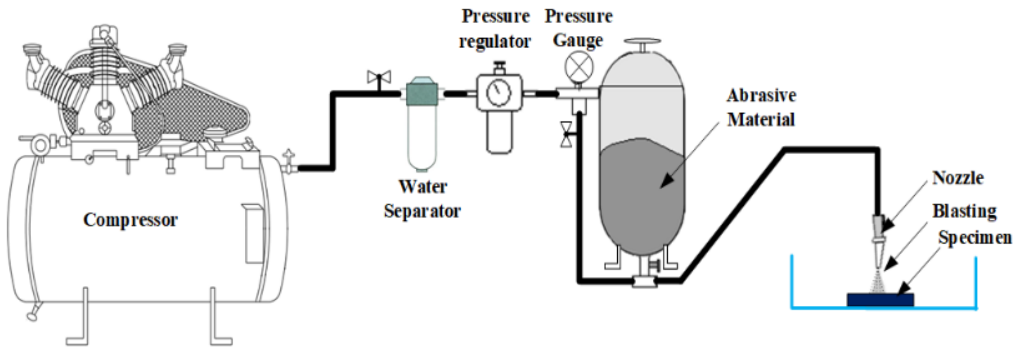


Figure 2 Schematic figure of sandblasting set-up

After the sandblasting process, surface characterization on every specimen was carried out. Firstly, surface observations by SEM and EDS, using the Phenom Pharos Desktop SEM machine, were conducted to analyze the surface morphology and chemical composition. Subsequently, to understand the surface roughness and hardness, visual roughness inspection based on ISO 8501 and roughness measurement based on ASTM D 7127-13 were performed. Moreover, hardness measurements by Rockwell and Micro-Vickers hardness tests were carried out. The Rockwell hardness test of ASTM E18-15 Scale B was implemented directly (without ground and polished processed) to measure the surface hardness profile across the surface from left to right at 25, 45, 65, 85, 105, and 125 cm in one straight line. The micro-Vickers hardness test was done using ASTM E384-11 with 10gf load at depths of 50, 100, 150, 200, 250, and 300 μm to understand the extent of the hardened layer. A paint thickness test is then applied to measure the effectivity of the surface characteristics of the sandblasting process.

RESULTS AND DISCUSSION

Surface morphology

The surface morphology of SS400 steel after the sandblasting process using steel grit G25 was analyzed using a Scanning Electron Microscope (SEM). To investigate the experiment parameter effects to surface morphology, SEM was applied into two-experiment setup, i.e., experiment with nozzle-to-surface of 15 cm (the shortest distance) and a blasting time of 120 s (the longest time), and the experiment setup with nozzle-to-surface of 30 cm (the most extended length) and a blasting time of 25 s (the shortest time).

The typical surface morphology image observed by SEM in these setups are shown in Figure 3 and Figure 4. Figure 3 shows the SEM image resulted from the experimental setup of 30 cm nozzle distance and 25 s blasting time. On the other hand, Figure 4 shows the SEM image produced from the sandblasting process of 15 cm nozzle distance and 120 s blasting time. Granular, valleys, grit embedded in the surface, and micro-cracks are observed in both pictures. The valleys are formed by the high impact energy of particle collision on the surface. The micro-scale roughness observed in the surface was created by the abrasive mechanism that occurred during particle collision, which then causes the surface to be partially cut.

Based on the SEM analysis, the shortest distance and the most prolonged blasting duration result in deeper valley formations on the surface (see Figure 4). On the other hand, shallow valleys formations on the surface result from the long distance and the short blasting duration result (see Figure 3). The micro-cracks structure is most likely due to collision (impact) during the sandblasting process. The number of micro-cracks and valleys were affected by the intensity of the abrasive material that hit the surface. Moreover, some grits can embed in the surface during the blasting process because grit attaches the soft area of the surface.

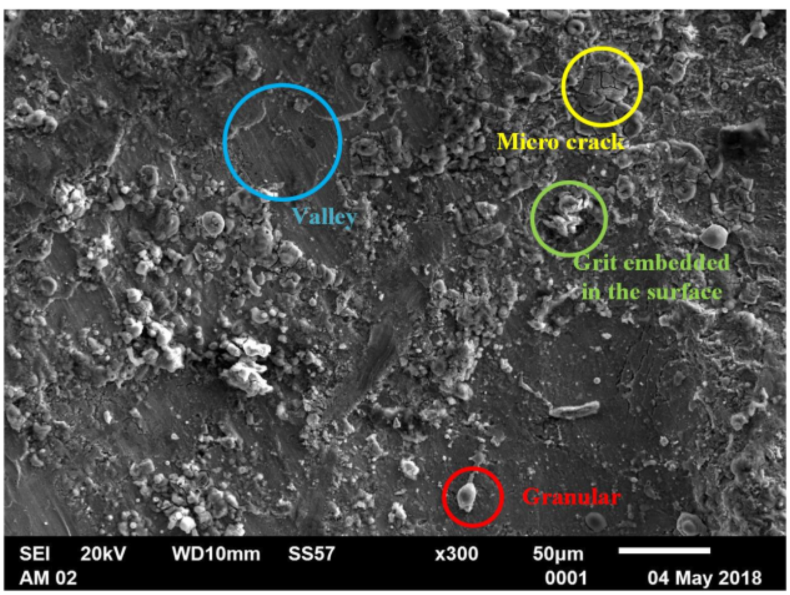


Figure 3 SEM image of surface morphology with the nozzle-to-surface distance of 30 cm and blasting duration of 25 s

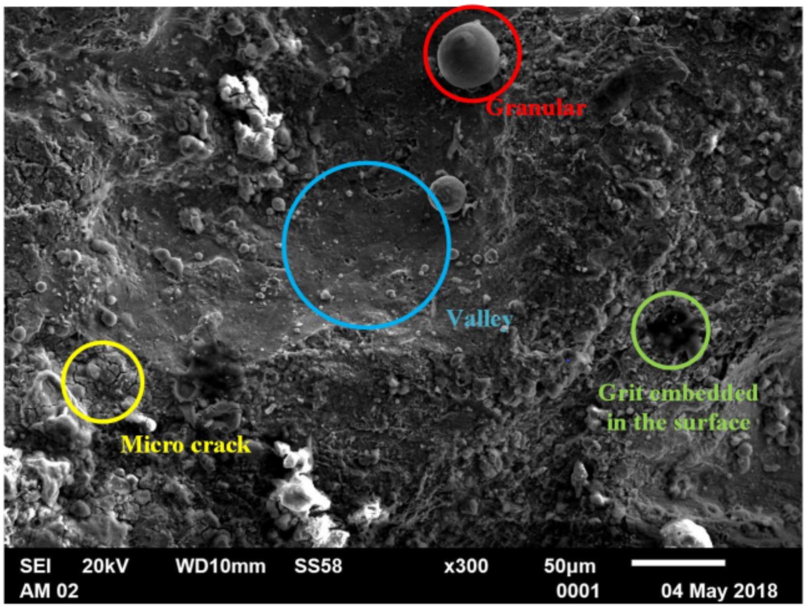


Figure 4 SEM image of surface morphology with the nozzle-to-surface distance of 15 cm and blasting duration of 120 s

Figure 5 shows the typical chemical composition of the specimen surface after the sandblasting process at 30 cm blasting distance and 25 s blating time. Based on the EDS result, the chemical content of 6.62% C, 17.20% O, and 76.14% Fe. It was found that by employing steel grit G25 as the abrasive material, besides a collision, steel grit was also deposited in the surface during the sandblasting process. As a result, the carbon content increase in the surface.

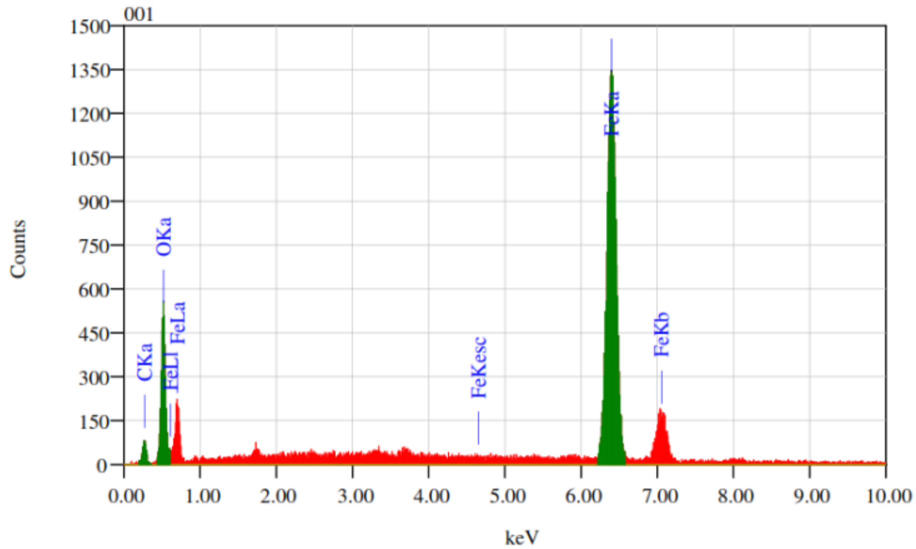


Figure 5 Chemical composition analysis by Energy Dispersive Spectrometry (EDS) with nozzle-to-surface distance of 30 cm and blasting duration of 25 s

Figure 6 shows the typical chemical composition of the specimen surface after the sandblasting process at 15 cm blasting distance (the shortest distance) and 120 s time (the most prolonged duration). Based on the EDS result, the chemical content of 8.60% C, 17.84% O, and 73.55% Fe. It was found that carbon deposited on the surface in this experimental setup is higher than the carbon content of the experimental setup of the sandblasting process at 30 cm blasting distance and 25 s time.

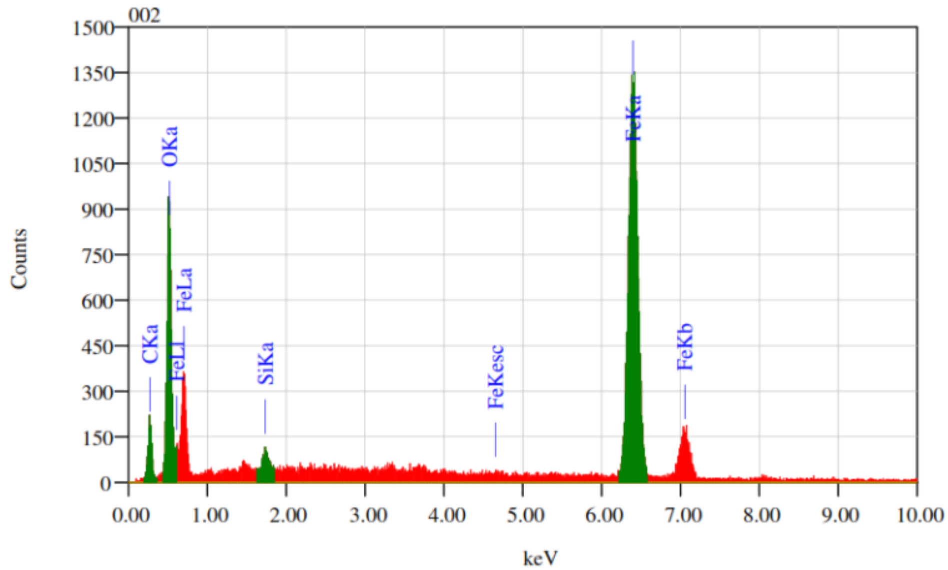
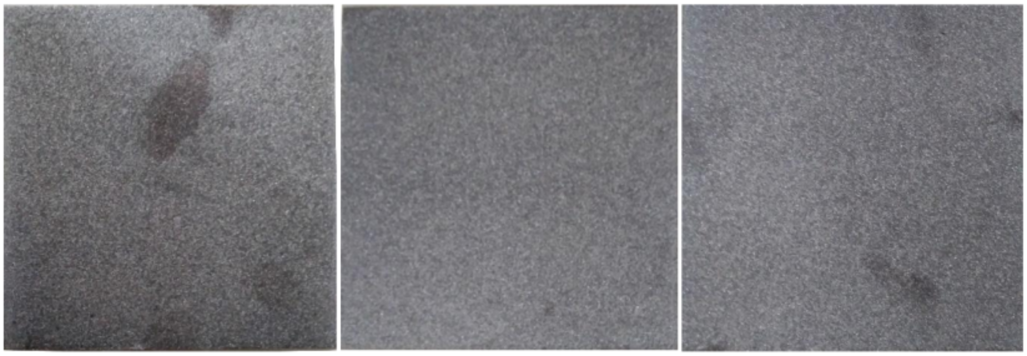


Figure 6 Chemical composition analysis by Energy Dispersive Spectrometry (EDS) with nozzle-to-surface distance of 15 cm and blasting duration of 120 s

Surface Cleanliness

Surface cleanliness is essential in surface preparation of steel structure by paint coating. ISO-8501 accomplishes the visual surface cleanliness test. According to this standard, blasting surface cleanliness is Sa grade. Figure 7 shows the typical surface cleanliness after sandblasting processes. Figures 7(a), (b), and (c) can be classified as Sa2, Sa $2^1/2$, and Sa 3, respectively. The Sa 2 grade was obtained by sandblasting at nozzle-to-surface distance of 15 cm regardless of the duration. The Sa $2^1/2$ surface was obtained at nozzle-to-surface lengths of 25 and 30 cm with blasting durations of 45 and 120 s. The S a3 surface was created at nozzle-to-surface distances of 25 and 30 cm with a blasting duration of 25 s.



(a) Sa2 (b) Sa2½ (c) Sa3

Figure 7 Visual inspection of surface roughness (Length 150 mm x width 150 mm). Sa2 is thorough blast-cleaning; Sa2 ½ is very thorough blast-cleaning; Sa3 is blast-cleaning to visually clean steel

Surface roughness

The surface roughness measurement results are summarized in Figure 8. The highest roughness was Ra 21.4 μm (roughness level of M10-M11), which was obtained from nozzle-to-surface distance of 15 cm and blasting duration of 120 s. On the other hand, the lowest value of Ra 18.1 μm (roughness level of M10-M11) was obtained from the sandblasting process at nozzle-to-surface distance of 30 cm and blasting duration of 25 s. In other words, the closer the distance between nozzle and surface, the higher the surface roughness.

These results quite are expected because a closer distance of nozzle and surface will produce a higher momentum between particle and exterior, which then generate high impact energy. Thus, it was observed that the surface roughness tends to be smoother as the nozzle-surface distance increases, as also described by Ho et al. (2015). The blasting duration also contributed to the increase in surface roughness. It was observed that the longer a material's surface was exposed to the sandblasting process, the more collision and erosion occurred. Therefore, the surface roughness of the material increases proportionally with increasing blasting duration. Based on these results, it can be concluded that roughness tests result are in good agreement.

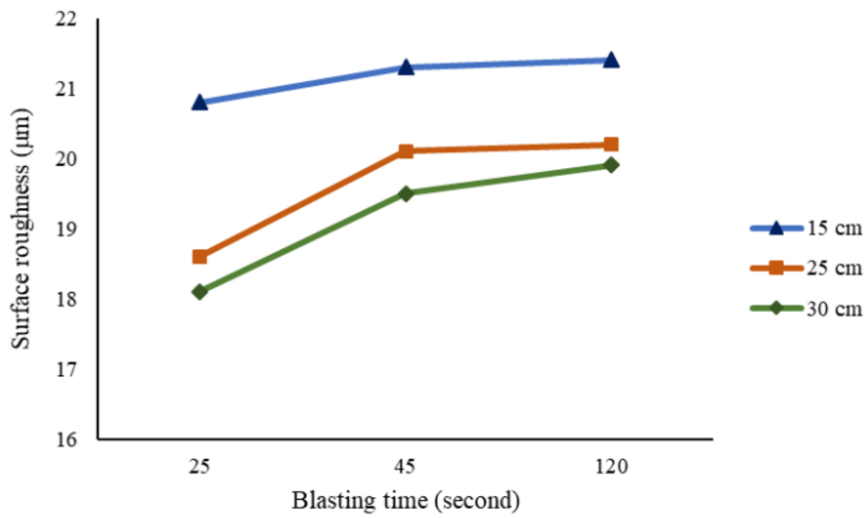


Figure 8 Surface roughness measurement results at different variable of sandblasting

Surface hardness

The results of Rockwell hardness tests on specimens sandblasted at 15 cm blasting distance and 15, 25, 120 s blasting durations are plotted in Figure 9. From the result, it was found that the surface hardness could be improved by plastic deformation, as indicated in Figure 9. The plot also shows that the hardness profile across the surface is uniformly distributed from one edge to another edge. The generation of residual stress produces increasing surface hardness due to the collision of particles with the surface (Saptaji et al., 2019). The high-velocity collision between steel grit and surface also produced strain hardening on the surface that can increase the surface hardness.

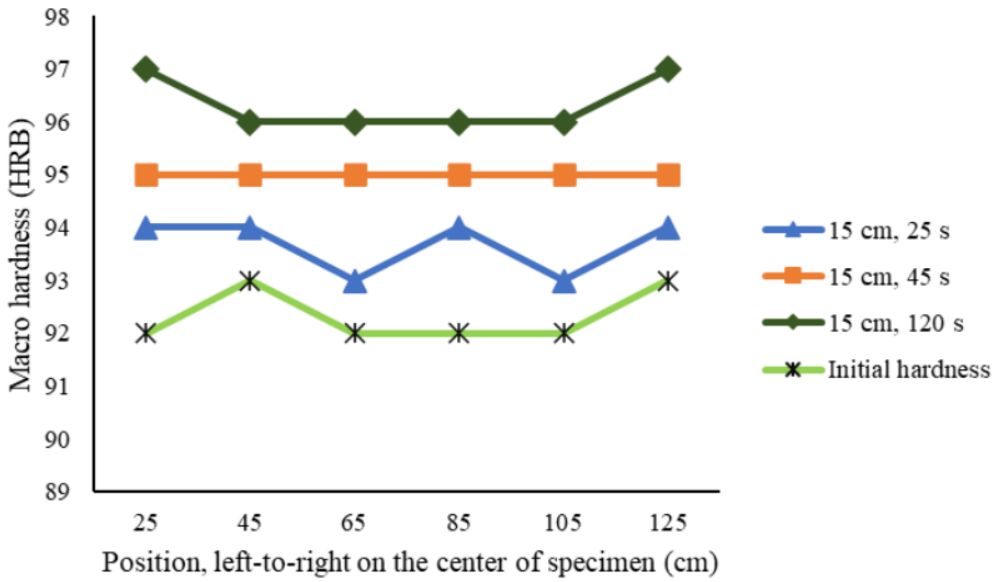


Figure 9 Rockwell-hardness test results

Measurement result on the hardness profile in-depth direction is shown in Figure 10. Based on the outcome, it was confirmed that the sandblasted surface was hardened until a certain depth before finally reaching the hardness of the base metal. This condition is the affected layer by heat generated due to colliding particles, while the base metal did not receive any heat. The microhardness increases by decreasing the nozzle-surface distance and increasing the blasting duration. The maximum value of microhardness was found to be 332 HV (equal to 108 HRB) with a depth of more than 50 μm for the specimen that was processed at 15 cm blasting distance and 120 s duration.

Comparing the micro-Vickers (on below the surface) with the Rockwell hardness values (on the surface), it appears that hardness measured by Rockwell hardness on the surface is underestimated. The maximum surface hardness value in Figure 9 is around 97 HRB, while the microhardness below the surface can reach as high as 332 HV (108 HRB) as shown in Figure 10. This phenomenon might be caused by the presence of valleys, hills, and granules on the surface, which decreased the total Rockwell hardness.

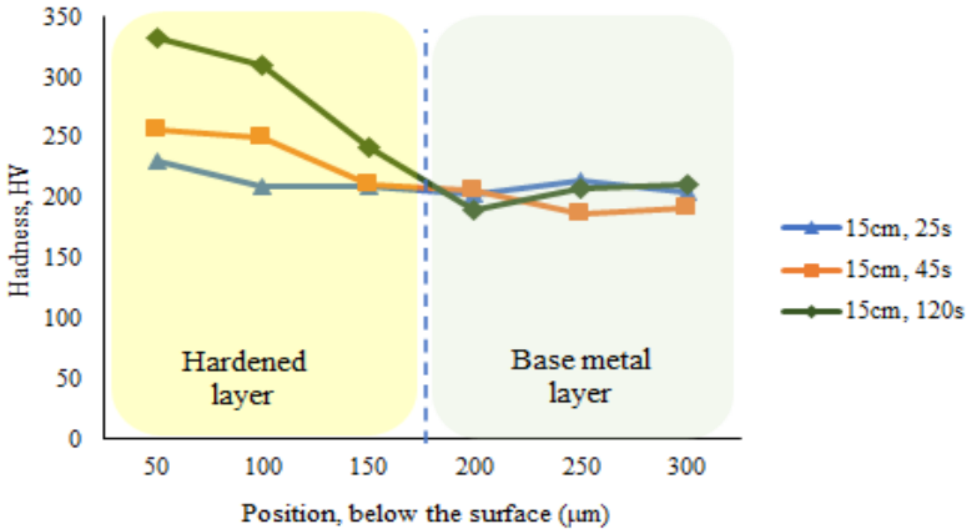


Figure 10 Micro-Vickers hardness test results

Paint coating thickness test

The sandblasting process will produce the roughness profile formation on the material surface in the form of hills and valleys. The roughness profile on the surface affects the bonding strength between the substrate of the surface and paint coating. More profound valleys and higher elevation on the surface will obtain a wide area and more durable interlocking between substrate and paint coating. Therefore, the rough surface produces thicker and more durable paint coating than a smooth surface.

In this study, to validate the surface characteristics resulted from the sandblasting process, a paint thickness test was performed. Sandblasting surface roughness affects the thickness of the paint that can be coated on a surface, for example, in the application of paint coating for cavitation damage prevention in fluid machinery [Hibi et al., 2018, Triawan et al., 2019]. Paint coating thickness was measured by the Elcometer 456 used ASTM D7091 standard. The width of the paint layer of the sandblasted surface used in this study is shown in Figure 11 as follows.

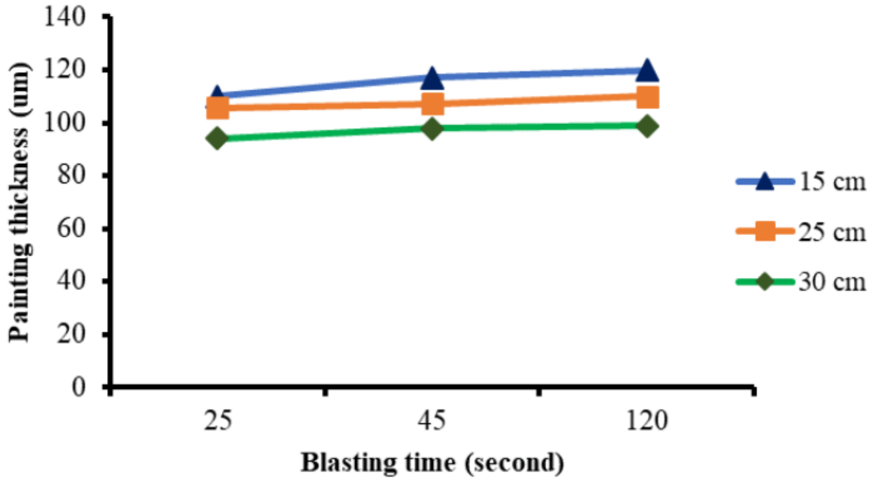


Figure 11 The result of paint coating test

Based on Figure 11, the highest paint thickness value occurs when the shooting distance is 120 μm that obtained from an experimental setup of 15 cm, and the duration time is 120 seconds. While the lowest paint thickness value is 94.14 μm obtained from the shooting distance is 30 cm, and the shooting time is 25 seconds. Based on Nazir, Khan, and Stokes (2015) research, it was found that debonding driving forces decrease with increasing interface roughness and coating thickness. It was also found that the critical value of point surface roughness value was Ra 4 μm, and the threshold of coating thickness was 34 um (Nazir, Khan, Stokes, 2015). Therefore, the lowest coating depth in this research (94.14 μm) is higher than the critical value (34 um), and the lowest surface roughness (Ra 18.1 μm) is better than the threshold value (Ra 4 μm).

CONCLUSION

A study on the surface characteristics of low carbon steel JIS G3101 SS400 after the sandblasting process by steel grit G25 has been carried out in this research. The sandblasting pressure and angle are kept constant at 5 bar and 90°, respectively. The modified blasting parameters are nozzle-surface distance and blasting duration in order to investigate the effect of steel grit G25 as sandblasting particles. Based on the obtained results, it can be concluded that the steel grit G25 particle offered a good sandblasting effect on base metal low carbon steel SS400, which was indicated by the increasing surface hardness from 200 to 332 HV with the depth of more than 50 μm. Moreover, the collision between particles and surface produced surface roughness, which may provide good bonding strength for painting applications. However, from the SEM observation, some micro-cracks are generated on the surface. This might decrease the surface strength and become the origin of crack initiation. The highest paint thickness value when the steel grit abrasive material is 120 μm with the nozzle-to-surface distance of 15 cm and a blasting time of 120 seconds, and the lowest paint thickness value is 94.14 μm obtained from the nozzle-to-surface distance of 30 cm and a blasting time of 25 seconds. Both surface roughness and the thickness are higher than the critical values.

Acknowledgment

The authors greatly acknowledge the support from PT. Gunung Baja Konstruksi, Indonesia, by providing the research facility and material for testing.

REFERENCES

Khorasanizadeh, S. 2010. The effects of shot and grit blasting process parameters on steel pipes coating adhesion. World Academy of science, engineering and technology, 66: 1304-1312.

Triawan, F., Nandiyanto, A. B. D., Abdullah, A. G., & Aziz, M. 2018. Plasma nitriding time on the hardness and crystal structure/phase of SUS403 and SCS6 martensitic stainless steels: an analytical study. Journal of Engineering Science and Technology, 13(8): 2369-2378.

Trisnanto, S. R., Setiawan, I., Sunnardianto, G. K., & Triawan, F. 2019. Stearic Acid-Modified CuO Coating Metal Surface with Superhydrophobicity and Anti-Corrosion Properties. Journal of Engineering Research, Special Issue (2019): 63-75.

Saptaji, K., Afiqah, S. N., & Ramdan, R. D. 2019. A Review on Measurement Methods for Machining Induced Residual Stress. Indonesian Journal of Computing, Engineering and

Design (IJoCED), 1(2): 106-120.

Bedjaoui, A., Belaadi, A., Amroune, S., & Madi, B. 2019. Impact of surface treatment of flax fibers on tensile mechanical properties accompanied by a statistical study. International Journal of Integrated Engineering, 11(6): 10-17.

Wu, M., Chen, M., Zhu, S., & Wang, F. 2015. Effect of sand blasting on oxidation behavior of K38G superalloy at 1000 C. Corrosion Science, 92: 256-262.

Arifvianto, B., Suyitno, K. A., & Mahardika, M. 2012. Influence of grit blasting treatment using steel slag balls on the subsurface microhardness, surface characteristics and chemical composition of medical grade 316L stainless steel. Surface and Coatings Technology, 210: 176-182.

Bobzin, K., Ote, M., Linke, T.F., Sommer J., & Liao, X. 2015. Influence of process Parameter on Grit Blasting as a Pretreatment Process for Thermal Spraying. Journal of Thermal Spray Technology: 1-9.

Dikici, T., Demirci, S., & Erol, M. 2017. Enhanced photocatalytic activity of micro/nano textured TiO2 surfaces prepared by sandblasting/acid-etching/anodizing process. Journal of Alloys and Compounds, 694: 246-252.

Ho, B. J., Tsoi, J. K. H., Liu, D., Lung, C. Y. K., Wong, H. M., & Matinlinna, J. P. 2015. Effects of sandblasting distance and angles on resin cement bonding to zirconia and titanium. International Journal of Adhesion and Adhesives, 62: 25-31.

Miao, B., Song, L., Chai, Y., Wei, K., & Hu, J. 2017. The effect of sand blasting pretreatment on plasma nitriding. Vacuum: 136, 46-50

Multigner, M., Ferreira-Barragáns, S., Frutos, E., Jaafar, M., Ibáñez, J., Marín, P., Perez-Prado, M. T., González-Doncel, G., Asenjo, A., & González-Carrasco, J. L. 2010. Superficial severe plastic deformation of 316 LVM stainless steel through grit blasting: Effects on its microstructure and subsurface mechanical properties. Surface and Coatings Technology, 205(7): 1830-1837.

Chander, K. P., Vashista, M., Sabiruddin, K., Paul, S., & Bandyopadhyay, P. P. 2009.

Effects of grit blasting on surface properties of steel substrates. Materials & Design, 30(8): 2895-2902

Hibi, M., Triawan, F., Inaba, K., Takahashi, K., Kishimoto, K., Hayabusa, K., & Nakamoto, H. 2018. Cavitation damage of epoxy resin subjected to uniaxial tensile loading. Mechanical Engineering Journal, 17-00151.

Triawan, F., Budiman, B. A., Nurprasetio, I. P., & Sunnardianto, G. K. 2019. Direct and indirect measurement techniques of cavitation intensity: A brief review. Journal of Physics: Conference Series, 1402(4), 044048.

Nazira, M.H., Khana Z.A, and Stokes K. 2015. Optimisation of interface roughness and coating thickness to maximise coating–substrate adhesion – a failure prediction and reliability assessment modelling, Journal of Adhesion Science and Technology, Vol. 29, No. 14, 1415–1445.

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