The Influence of Shooting Conditions during Shot Peening of Stainless Steel on Surface Roughness

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Abstract. Stainless steel AISI 316L is a suitable material used for orthopedic purposes. In order to improve the hardness of stainless steel, the heat-treatment process cannot be done, but with a shot peening process. This study aims to determine the roughness of the workpiece surface and investigate the effect of shooting conditions (i.e. angle and time) on the surface roughness during shot peening of Stainless steel AISI 316L. The shooting parameters used are 2, 4, and 6 minute for the duration, and angle of 0^o, 15^o, 30^o and 45^o. The ball material is a type of steel with 0.6mm in diameter. The experimental results presented that the increased shooting time will result in lower surface roughness, and vice versa. Therefore, it can be concluded that the use of varying shooting conditions will greatly affect the quality of the surface produced but needs to be compared with other responses, namely hardness.

Keywords. Shooting Angle, Shooting Time, Shot Peening, Surface Roughness, Stainless Steel.

1. Introduction

Material stainless steel grade AISI 316L is often used for medical equipment is biomaterial. This biomaterial is expected to be resistant to corrosion, low toxicity, and the ability of a material to be easily formed. Some steel materials that have such characteristics are very difficult to obtain, so they need to look for materials that are close to their properties. In the case of connecting broken bones using implant plates, the material often used by orthopedic doctors is titanium or stainless steel. The implant material has a higher resistance to corrosion, due to direct contact with the human body. Human body fluids have many aggressive ions that cause corrosion in the implant material.

Stainless steel is a material have resistant to corrosion but the hardness is below that of titanium material, so it needs to do an additional treatment. Stainless steel has a low carbon content making it difficult to do heat treatment, thus it was more suitable for cold treatment. The treatment processes carried out by cold processes are machining processes such as sandblasting [1][2][3], shot peening, acid etching [1][4], anodizing [1] and surface mechanical attrition treatment commonly abbreviated as

SMAT [5][6]. Stainless steel is also a material that is more easily formed than titanium material, so the cost of its formation can be cheaper.

Previously, Liu et al present that the structure of changes due to the shot peening shooting process results in an increase in deformation thickness and grain increase as the pressure and duration of the shot peening increase [7]. In Jiang's research, it was shown changes in the structure of the layer due to the collision of material [8]. The aims of this work are to study the effect of shooting conditions during the shot peening process of stainless steel 316L on the surface roughness.

2. Shot Peening Process

Shot peening is a method mostly used to treat surface mechanical. This method has some major advantages, i.e.: easy surface cleaning, high processing quality, adjustability of the strengthening effect, and able to establish in the industry. The shot peening process starts with the pressurized air flowing from the compressor with 4-7 bar air pressure flowing into the spray-gun, the steel shot in the spray box will be flowed through the spray-gun due to the vacuum in the flowing steel.

The shot peening process produces a notch on the surface of the material caused by small balls firing on the surface of the material.

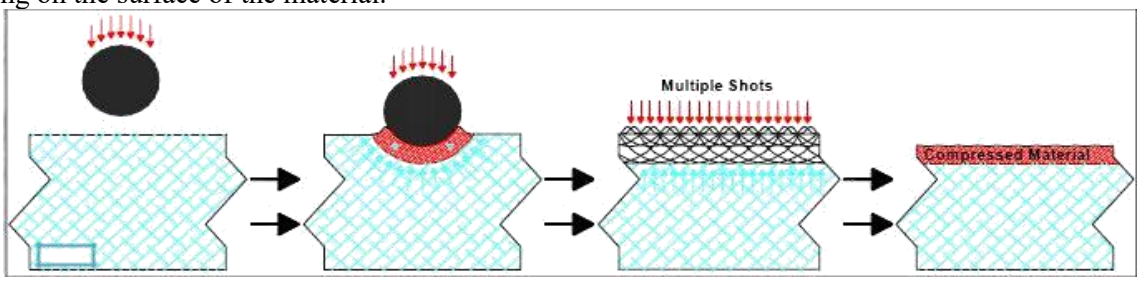

Figure 1. Illustration of shot peening

Relatively small steel balls are fired at high speed on the workpiece surface repeatedly. This process will create compressive residual stress on the entire surface of the object of the same size and is evenly distributed, and changes with depth or thickness of the object. This residual stress is useful for increasing material resistance to loads. Schematic of the shot peening process was shown in Fig. 2.

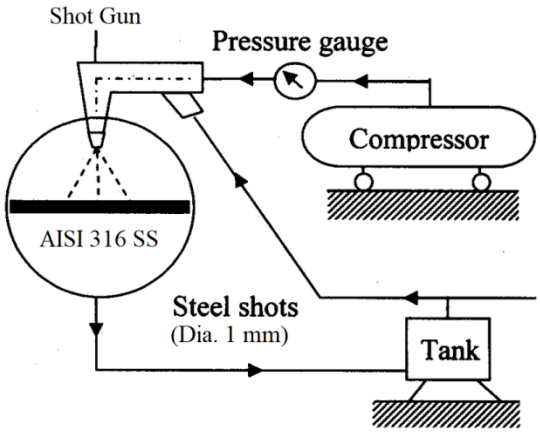

Figure 2. Schematic of the shot peening process

3. Experimental Setup

3.1. Materials

AISI 316 stainless steel of 5 mm thickness was used as workpiece material. The composition of AISI 316 stainless steel is shown in Table 1.

Table 1. Chemical composition of AISI 316 SS

Composition	C	Mn	Si	Cr	Ni	Mo	P	S	N	Fe
Weight (%)	0.08 max	2.00 max	0.75 max	16-18	10-14	2 - 3	0.045 max	0.03 max	0.10 max	Bal.

3.2. Shooting Parameters

In this study, the steel shot used was ball type with a diameter of 1 mm. The experimental setup was using the shooting parameters as follow:

Table 1. Parameters for the shot peening process

Parameters	Range
Shooting Time, S_T (minute)	2, 4, and 6
Shooting Angle, S_A (degree)	0, 15, 30, and 45

Surface roughness testing was performed using surface roughness tester SURFTEST SJ-310. Data on Surface roughness was measured five times for each position.

4. Results and Discussion

The surface roughness after the shot peening process is shown in Table 2.

Table 2. The result of surface roughness

No	S_T (minute)	S_A (degree)	Surface Roughness (µm)					
			Ra_1	Ra_2	Ra_3	Ra_4	Ra_5	Average
1	2	0	1,320	1,649	1,923	1,979	1,954	**1,765**
2	2	15	1,801	1,494	1,715	1,786	1,67	**1,693**
3	2	30	1,517	1,578	1,445	1,619	2,077	**1,647**
4	2	45	1,965	2,15	1,928	1,789	1,836	**1,934**
5	4	0	1,65	1,601	1,601	1,902	1,727	**1,696**
6	4	15	1,807	1,446	1,473	1,452	1,55	**1,546**
7	4	30	1,608	1,65	1,724	1,437	1,689	**1,622**
8	4	45	1,235	1,235	1,235	1,235	1,235	**1,235**
9	6	0	1,649	1,368	1,232	1,312	1,409	**1,394**
10	6	15	1,652	1,532	1,552	1,599	1,743	**1,616**
11	6	30	1,663	1,675	1,673	1,779	1,417	**1,641**
12	6	45	1,278	1,278	1,278	1,278	1,278	**1,278**

In order to gain a clear understanding, the experimental results data can be illustrated in Figs 3 and 4.

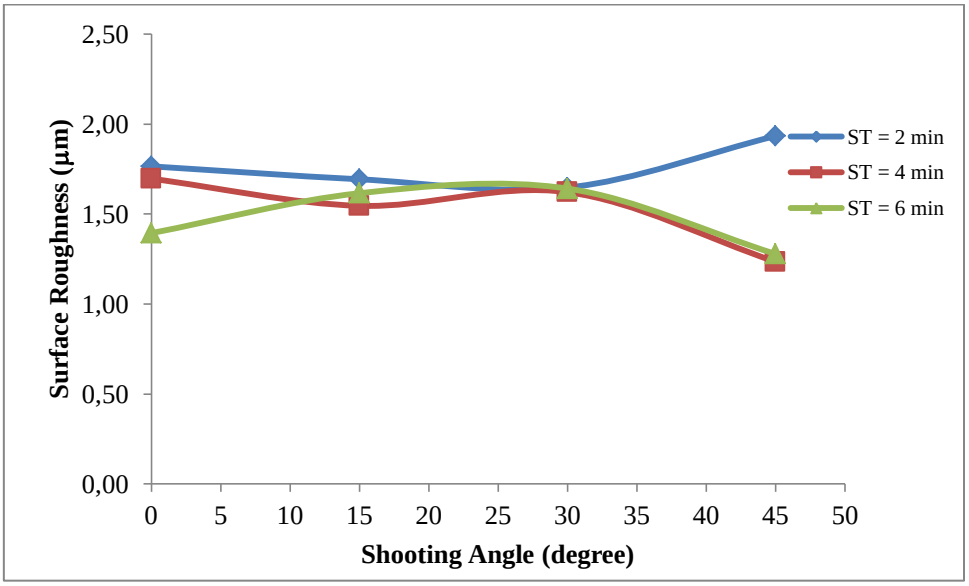

Figure 3. Data on surface roughness for different shooting time (S_T).

Fig. 3 presents that surface roughness will decrease with increasing angle of shoot, except for 2 minutes shot duration. It is very clear that the surface roughness decreased for longer shootings. The highest of surface roughness (1.934 m) was obtained at 2 minutes of duration and 45° of shooting angle. The surface smoother (1.278 m) was gained at similarity angle with 6 minutes.

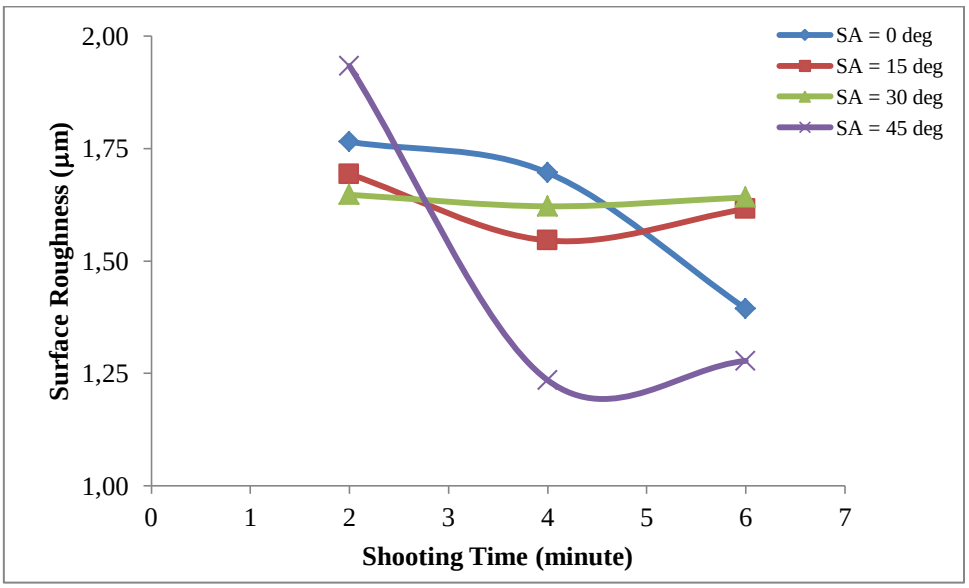

Figure 4. Data on surface roughness for different shooting angle (S_A).

Fig. 4 presents that surface roughness is strongly affected by the duration of shot for both shooting time of 0° and 45°. It is very clear that the surface roughness decreased for longer shootings. But for the shooting angle of 15° and 30°, surface roughness has a similarity result for all durations.

These results had been proven by Hasan et. al. in their investigation. It was found that increasing shot peening leads to increase residual stress, surface roughness for shot peening of austenite stainless steel 316L [9]. This can be attributed to the fact that as the pulsed current decreases, discharges strike

the surface of the sample less intensely, and the resulting better erosion effect leads to the smoother surface. Furthermore, as the pulse-on duration decreases, the amount of heat energy transferred to the sample surface decreases, and so less material melts. The fact that the surface roughness decreases with decreasing discharge energy has been described in the literature [8, 9, 10].

5. Conclusion

Based on the experimental results through the shot peening process of stainless steel AISI 316L, it can be concluded that the shooting time (duration) gives a significant effect on surface roughness. Meanwhile, the shooting angle of 0^o and 45^o will be making the surface roughness is higher. But for the shooting angle of 15^o and 30^o, the surface roughness has a similarity results.

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