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ISSN 0543-5846
METABK 59(2) 183-186 (2020)
UDC – UDK 669.715:539.43:620.178.3-620.193:620.178.1:620.197.6=111

SURFACE ROUGHNESS, HARDNESS, AND FATIGUE-CORROSION CHARACTERISTIC OF AISI 316L BY SHOT PEENING

Received – Primljeno: 2019-09-30
Accepted – Prihvaćeno: 2019-12-20
Original Scientific Paper – Izvorni znanstveni rad

The surface of AISI 316L was treated by shot peening at different shot durations. Shot peening variables in this work are shot durations for 0, 4, 10 and 20 minutes, with compressor pressure at 8 kgf/mm^2, steel balls with a diameter of 0,6 mm and shot gun nozzle diameter of 5 mm. The purpose of this research is to investigate the shot peening effect duration on surface roughness, hardness, and fatigue-corrosion characteristic of AISI 316L in 0,9 % NaCl solution. The results show that the duration of shot peening can affect the improvement on surface roughness, hardness, wettability and fatigue-corrosion life of AISI 316L.

Keywords: AISI 316L, shot peening, fatigue-corrosion, hardness, surface roughness

INTRODUCTION

Selection and design of materials are very important for the improvement of orthopedic implants. Austenitic stainless steel cannot be heat-treated, and the mechanical properties could only be improved by cold working [1, 2].

When a surgeon inserts an implant, they must focus on fatigues of the implant for curing the fracture. Initial crack and the pre-mature fracture come as a presence of inclusions. Surface pits occur as a result of fatigue cracks initiation for the 316L in the corrosive media [3 - 5].

Nanocrystalline regions formed by particle impact and air blast shot peening methods have very high hardness with no recrystallization.

Shot peening could cause plastic deformation on surfaces and transforms austenite to martensitic. This technique could improve a significant effect by creating a plastic deformation on the surface of specimen [6 - 8]. Surface hardness was developed by shot peening due to residual stress which was generated on the surface layer during the process of shot peening. Shot peening in austenitic stainless steel generated the distribution of grain boundary with change of grain size [9 - 11]. Shot peening effects on the surface roughness are attributed to the increase of particle size which can decrease the surface roughness and a function of abrasive particle size. The increasing of intensity can raise the surface roughness for a given coverage. The most enormous number of hardness increase at the surface of 316L [12, 13]. Fatigue damage can be calculated by observing the changes in the surface form and tensile properties of the material. The initiation of micro-cracks begins at intrusions caused by the increasing of micro-plasticity in the surface grains. The martensite forms to act against the growth of micro-cracks [14, 15]. The lower fatigue crack growth rates can be estimated by the presence of compressive residual stress. No holes on the surface of the material were detected at the crack initiation site, so the implant design and installation system was treated to reduce the stress concentration [16, 17].

The purpose of this work is to investigate the impact of shot peening duration on surface roughness, hardness, wettability, and fatigue characteristics of AISI 316L in 0,9 % NaCl solution.

EXPERIMENTAL PROCEDURES

Variables in this work are shot duration for 0, 4 10 and 20 minutes, compressor pressure at 8 kgf/mm^2, steel balls with a diameter of 0,6 mm, and shot gun nozzle diameter of 5 mm.

Shot peening used AISI 316L with chemical composition, as shown in Table 1.

Table 1 **Chemical composition / mass. %**

C	Si	Mn	Ni	Cr	Mo	Fe
0,03	0,96	1,07	10,87	16,78	1,894	67,78

In this work, researchers used steel balls S-170 (diameter of 0,6 mm), and the samples were treated with abrasive paper. An airblast machine was applied as a shot peening machine using an air compressor with a pressure of 8 kgf/cm^2. Surface hardness testing was observed by Micro-Vickers indentation using Buchler Micromet according to ATSM E-384, and surface roughness by Surfcom 120A. The process of shot peening was applied on the surface of 316L with a shot angle of 90^o and shot distance of 6 cm. The fatigue specimens

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adhered to the standards of ASTM-E647 and 0,9% NaCl was used as a corrosion media to test for corrosion fatigue. The wettability test was analyzed at the contact angle between the droplet and the sample surface. The droplet image was processed with image software, which resulted in an average contact angle from each sample.The incremental polynomial method was used to analyze the fatigue characteristics that are indicated by the Paris constant in da/dN = C $(\Delta K)^n$ [18]. Where da/dN is fatigue crack growth rate, C and n are Paris constant and ΔK is difference of stress intensity.

RESULTS AND DISCUSSION

The improvement on surface roughness, hardness, wettability, and fatigue strength are shown to produce compressive residual stress on the surface of metal. The residual compressive stress generated by shot peening is the function of material and mechanical conditions.

Figure 1 illustrates the increasing of surface roughness of increases respectively from 0,04 to 1,37 μm for 4 minutes. The duration of shot peening influences the surface roughness, where the longer the shot peening duration, the lower the surface roughness value.

Roughness decreases from 1,37 μm for 4 minutes, 1,21 μm for 10 minutes, and 1,16 μm for 20 minutes. The decrease in surface roughness as a result of increasing the duration of shot peening can occur because the intensity of the shot increases with increasing shot duration.

Shot peening effects on surface hardness as shown in Figure 2 in which this treatment can raise the value of surface hardness. Surface hardness increases respectively from 284 kgf/mm^2 (non-treatment), to 360 kgf/mm^2 (4 minutes), 512 kgf/mm^2 (10 minutes) and 624 kgf/mm^2 (20 minutes). The duration of shot peening could also affect the surface hardness, due to the fact that the longer durations of shot peening result in higher values of hardness being obtained.

The decreasing in hardness at the cross-section was measured from the surface of the specimen to the inside of the 316L metal as illustrated in Figure 3. The deeper into metal, the hardness value of the 316L that has been shot-peened will be the same as the hardness of base metal, where the expected effect is the change in properties only on the surface of metal. The depth of deformed layer and hardness were increased with shot peening intensity. The hardness has increased depending on the shot peening intensity as a result of the increasing of shot duration.

Figure 4 shows that the shot peening decreases the droplet contact angle.

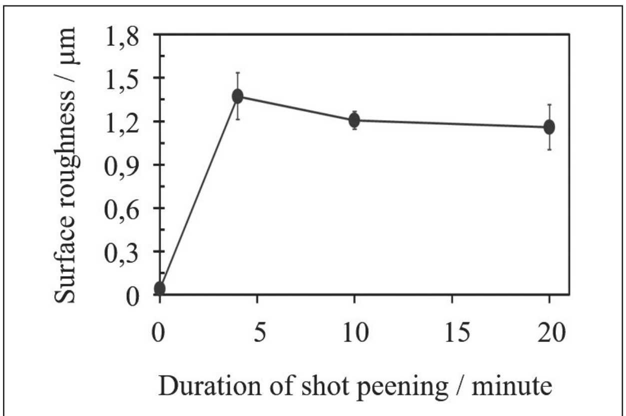


Figure 1 Relationship between duration and surface roughness

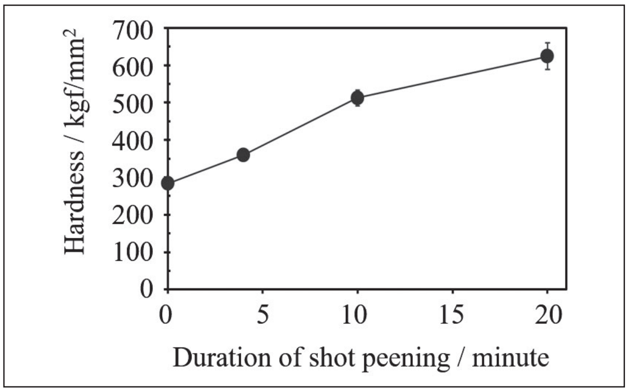


Figure 2 Relationship between duration and surface hardness

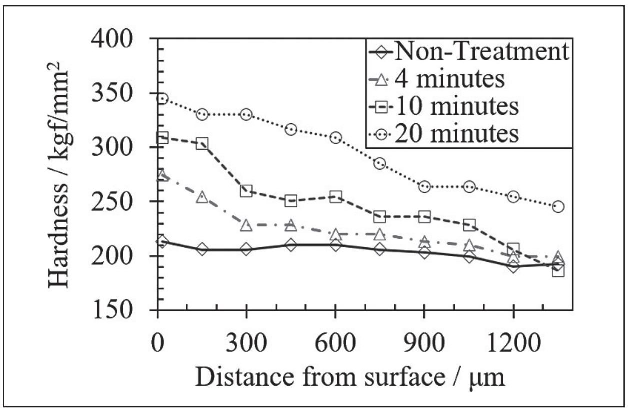


Figure 3 Shot peening effects on the cross-sectional hardness

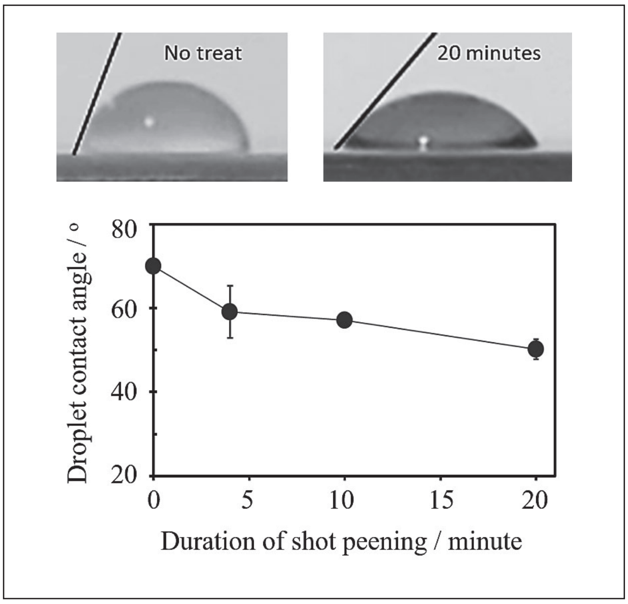


Figure 4 Surface condition contact angle (top) and shot peening effects on the wettability (bottom)

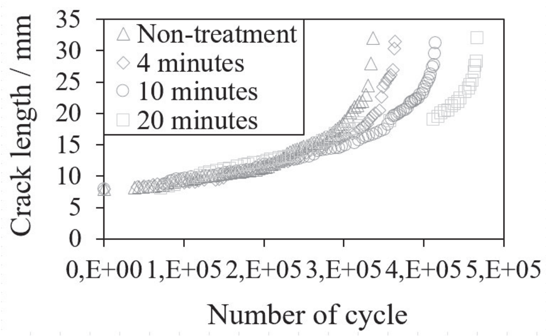


Figure 5 Relatioship between the number of cycles and crack length

The shot peening reduces the droplet contact angle from ± 70° (control sample) to a droplet angle of approximately 60-50. Shot peening's material has droplet contact angles ranging from 70-50o (θ <90°), so it has hydrophilic properties.

Figure 5 illustrates shot peening effect on crack growth and the number of fatigue cycles, where shot peening could inhibit the growth of fatigue cracks, resulting in a significant increase in the number of fatigue cycles (increasing from 336 610 to 467 155 cycles). The number of cycles increases with increasing duration of the peening shot for 4 minutes (363 009 cycles), 10 minutes (414 969 cycles) and 20 minutes (467 155 cycles). This happens because shot peening can inhibit the initial crack. This causes a raise number of fatigue cycles which minimizes the crack propagation.

Figure 6 shows the shot peening effects on the crack propagation rate, where shot peening can inhibit the crack propagation rate, which is characterized by a smaller Paris n constant (Table 2).

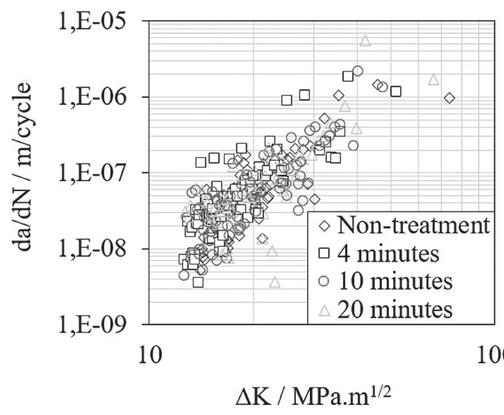
Tabel 2 **Paris constant**

Shot peening Treatment	Number of cycles	Paris constant	
		C	n
No treat	336 610	2 x 10^{-13}	4,19
4 minutes	363 009	10^{-12}	3,57
10 minutes	414 969	10^{-12}	3,55
20 minutes	467 155	8 x 10^{-12}	2,94

Fatigue crack propagation occurs in area II, where the shot peening process affects this area. Shot peening gives the effect of slowing down the rate of propagation of fatigue cracks. The corrosive environment also affects the rate of fatigue crack. NaCl solution also accelerates the rate of fatigue crack propagation. Shot peening is able to increase fatigue resistance by protecting metal surfaces from corrosion attacks.

CONCLUSIONS

Shot peening effect on surface roughness, hardness and fatigue of AISI 316L had been investigated. Shot peening can improve hardness, surface roughness, wettability and fatigue of AISI 316L by increasing the shot



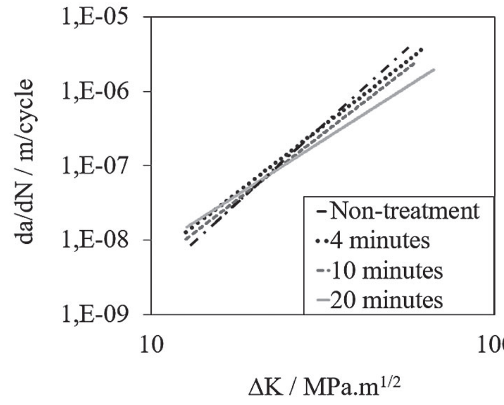


Figure 6 Shot peening effects on fatigue crack growth rate (top) and trend line (bottom)

duration. Shot peening can inhibit the initiation of fatigue crack by plastic deformation on the surface of the specimen and also protects the metal in a corrosive environment.

Acknowledgments

This research was supported by The Ministry of Research, Technology and Higher Education of The Republic of Indonesia (Hibah PDUPT) Universitas Gadjah Mada.

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Note: The responsible English translator is Braxton Pace – the Languange Center, Syiah Kuala University, Indonesia