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RESEARCH ARTICLE

Improvement of mechanical properties and fatigue life by shot peening process on ASTM A516 Grade 70 steel

Mohd Rashdan Isa *, Omar Suliman Zaroog, Kalaikathir Murugan, Sharif Osman Kabashi Guma, Fareg Saeid Ali

Department of Mechanical Engineering, Universiti Tenaga Nasional, Jalan Ikram-Uniten, 43000 Kajang, Selangor, Malaysia

* *Corresponding author:* mrashdan@uniten.edu.my

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Abstract

ASTM A516 Grade 70 is widely used in the industrial sector as it provides very good mechanical properties in tough conditions. The main usage of this material is in moderate and low operating services. This paper focuses on the effect of shot peening process on ASTM A516 Grade 70 on improving the mechanical properties and fatigue life of the material. Samples have been shot peened with steel shot to induce compressive residual stress. Hardness, tensile and fatigue test as well as microstructure were done on the samples before and after shot peening process to study the effects on mechanical properties. The result shows that there is an increment in every test after shot peening process. There is a slight increment of 0.47% in hardness value, 0.39% increment in tensile strength and 6.78% increment in fatigue life of the material after shot peening process applied. The slight increment in every result was due to the low intensity of the shot peening process. Result also shows that the shot peening process compressed the molecules closer to each other as can be seen under SEM. Therefore it was proven that in this study, there is a very significant improvement in mechanical properties and fatigue life by shot peening process on ASTM A516 Grade 70 Steel.

***Keywords*:** Shot peening, hardness, tensile, microstructure, fatigue

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INTRODUCTION

ASTM A516 Grade 70 is widely used in the industrial sector mainly in building with this material as it provides very good mechanical properties in tough conditions. The main usage of this material is in moderate and low operating services. Shot peening process is applied to the material mainly to enhance the performance of the material, hence to increase the fatigue life.

ASTM A516 Grade 70 Steel plate is well-known primarily for service in welded pressure vessels where improved notch toughness brings great significance to the industry (Alias *et al.*, 2013). This material is an excellent choice for service in lower than ambient temperature application, has excellent notch toughness and is used in both pressure vessels and industrial boilers. It offers a greater Yield and Tensile strength when compared to ASTM A516 Grade 65 and can operate in lower temperatures. It's ideally suited for high standard set by the oil, gas and petrochemical industry.

LITERATURE REVIEW

The mechanical properties of ASTM A516 Grade 70 are referring to the high tensile stress, high hardness and long fatigue life. This paper studies the effect of shot peening process on ASTM A516 Grade 70 on improving the mechanical properties and fatigue life of the material. The study also focuses on the change in the microstructure of the material. Shot peening is a cold performed function (does not comprise any type of hot treatment) where the surface of a substance is blasted with certain round named shot (Morabito, Chrysochoos, Dattoma, & Galietti, 2007). This process was proven that it can improve the microstructure and mechanical properties of steel as well as adding corrosion resistance (Dieng, Amine, Falaise, & Chataigner, 2017; Xu, Sheng, Wang, Jiao, & Yuan, 2017).

The fatigue test is a crack or break which is a permanent structural change that results from fluctuating stress and strain that occurs in materials that happen within a sufficient number of fluctuations. The simultaneous action of cyclic stress, tensile stress, and plastic strain cause fatigue fracturing. The crack could not be propagated if there are no any of those factors present. Fatigue would not happen because of a compressive stress but the compression load will make it happen. The crack is initiated from cyclic stress and the propagation which is the crack growth continued by the tensile stress (Bae, Lee, Pyo, & Choi, 2016; Kida, Koga, & Santos, 2017; Martins, Ferreira, Reis, & Chambel, 2016).

This paper studied the effect of shot peening on enhancing the properties of the ASTM A516 grade 70 steel.

METHODOLOGY/MATERIALS

Testing Sample Preparation

The Carbon steel ASTM A516 / SA 516 Grade 70 standard industrial plate were cut using the Computer Numerical Control (CNC) cutting machine in the standard ASME 1989 (Section 9 Code

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QW.462.1) dog bone measurement according to the Tensile and Fatigue test which is the same dimensions for both types of experiment. Figure 1 shows the dimension of the testing sample.

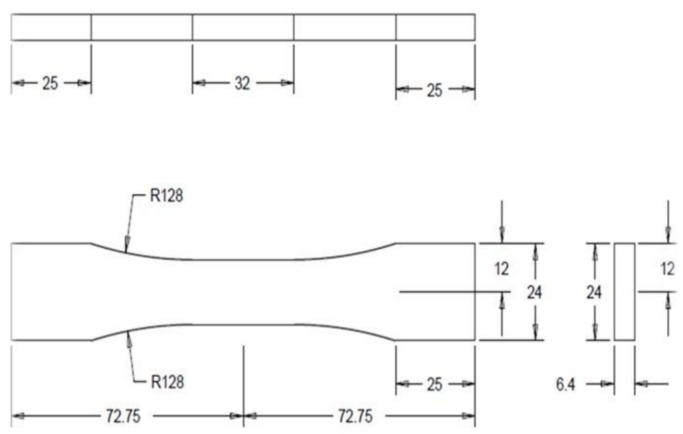


Fig. 1 ASTM A516 Grade 70 testing sample.

Shot peening process

Shot peening using steel balls with the size of 0.8 to 1.0 mm was applied on the samples. Table 1 illustrates the detailed parameters of the process.

Table 1 Shot peening parameters.

Parameter	Value	Unit
Arc height	0.4	mm
Peening coverage	100	%
Rotation	5~10	Amp
Steel shot grade	S330	-
Steel shot size	0.8~1.0	mm
Steel shot hardness	45~55	HRC
Nozzle angle	37.5	Degree

Mechanical Test

Mechanical test such as hardness, tensile and microstructure was done on the samples before and after shot peening process to study the effects on mechanical properties. Hardness test was carried out using Rockwell Hardness Tester by taking the measurement on 8 different points on the samples. The measurement was taken by applying indenter under a preliminary minor load of 10kgf according to ASTM E18 standard. The tensile test was performed on a universal tensile testing machine which could bear up to 50kN of the load applied and hence the Ultimate Tensile Strength of the material was determined. Fatigue Test was done by applying cyclic loads of 85% and 75% of the Ultimate Tensile Strength. The frequency of the test was 10~15Hz. Scanning Electron Microscopy (SEM) was performed on the samples after the fracture of tensile and fatigue test using a microscope with the magnification of 1500x.

RESULTS AND FINDINGS

Hardness test

The result of the hardness test is tabulated as in Table 2. The average value of the hardness after shot peening shows an increment of 0.47% in comparison of the hardness before shot peening. Based on the literature review, the hardness after shot peening should significantly increase. One of the possible reason that the increment is not so high is due to low shot peening intensity. The higher intensities of the shot peening, the higher hardness of the material.

Table 2 Hardness value of ASTM A516 Grade 70 before and after Shot Peening.

Points of measurement	Rockwell Hardness value, HRB (Before Shot Peening)	Rockwell Hardness value, HRB (After Shot Peening)
1	79.6	78.2
2	80.5	82.7
3	81.8	79.7
4	82.2	81.1
5	81.4	80.4
6	81.0	83.1
7	80.6	83.4
8	80.9	82.5
Average	81.0	81.38

Tensile test

The tensile test result is tabulated as in Table 3. The tensile stress after shot peening is slightly higher than before shot peening. There is an increment of 0.39% for tensile stress after shot peening. This result reflects the change in hardness as there is an only minor increment in tensile since the intensity of the shot peening process that was performed on the samples was quite low.

Table 3 Tensile stress value of ASTM A516 Grade 70 before and after Shot Peening.

Property	Before Shot Peening	After Shot Peening
Tensile stress at maximum load (Mpa)	47544.00	47728.67
Maximum load (N)	464.30	466.10
Tensile strain (%)	38.21	38.10

Fatigue test

For the fatigue life test, 85% and 75% of the Ultimate Tensile Strength (UTS) was taken as the maximum stress for the fluctuating load force to be applied on the all specimens before and after shot peening.

For the samples before shot peening, the 85% UTS sample failed after 7 hours of the applied cyclic load with a max elongation of 2.433 mm. The 75% took 9.4 hours with a max elongation of 3.195 mm. For the samples after shot peening, the 85% UTS sample failed after 7.5 hours of the applied cyclic load with a max elongation of 2.446 mm. The 75% took 10 hours with a max elongation of 3.212 mm.

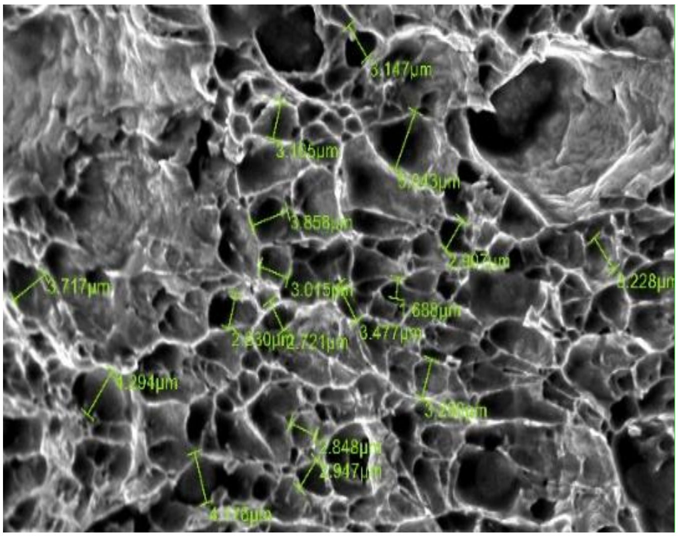
Table 4 shows the final result for a number of cycles before and after shot peening samples. The average increment of 6.78% in a number of cycles before fatigue fracture shown in this test. This proves that the fatigue life of the material was increased by shot peening process. However, the slight increment in the fatigue life is again due to the low intensity of the shot peening process which reflects the result of hardness and tensile test.

Table 4 Number of cycle fatigue test before and after Shot Peening.

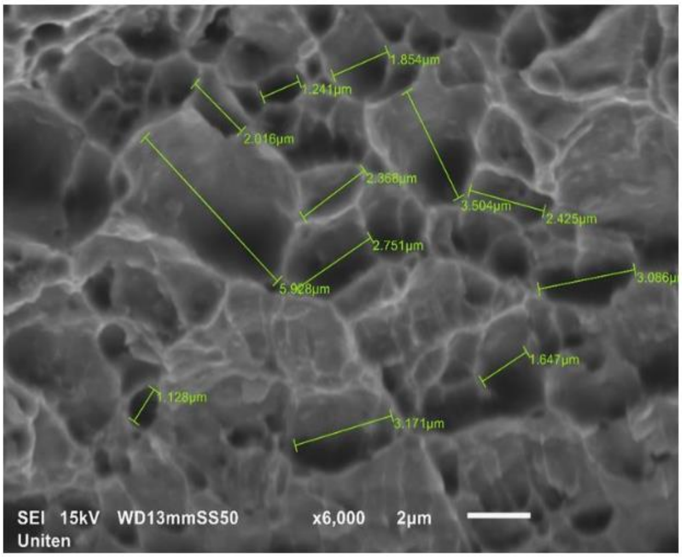
Samples	Number of Cycle Before SP	Number of Cycle After SP	Increment
85% UTS	252029	270032	7.14%
75% UTS	338440	360005	6.37%

SEM

Based on the microscopic photos of the samples, it could be observed that the molecules of the material after shot peening are closer to each other. This shows that the shot peening process compressed the molecules closer to produce compressive residual stress in the surface of a material.



a) SEM before Shot Peening



b) SEM after Shot Peening

Fig. 2 Grain size of ASTM A516 Grade 70 microstructure. Tensile fracture before and after shot peening

CONCLUSION

The compressive residual stress introduced by shot peening affects the mechanical properties of ASTM A516 Grade 70 Steel. This was shown by the result of increment in hardness value, tensile and fatigue life of the material after shot peening process. The slight increment in every result was due to the low intensity of the shot peening process. To have a more significant changing in the result, higher shot peening intensity should be applied to the samples**.**

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