

Study of Improvement in Fatigue Properties of AISI 304 Stainless Steel Using Shot Peening Process

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Abstract

This study investigated the effect of 100%, 150%, and 200% shot peening coverage on the bending strength, wear resistance, corrosion behaviour, and microstructure of AISI-304 stainless steel. Experimental results showed that the 150% shot-peened specimen exhibited the best overall performance, with higher bending strength, lower wear, improved corrosion resistance, and refined microstructure compared with the untreated specimen. These improvements are attributed to surface work hardening, grain refinement, and compressive residual stresses induced by shot peening. Therefore, 150% shot peening coverage is identified as the optimum condition for enhancing the mechanical and corrosion performance of AISI-304 stainless steel for engineering applications.

Keywords: AISI 304 stainless steel, Shot peening, Surface modification, Bending strength, Wear resistance, Corrosion-resistance and Microstructure.

1. INTRODUCTION

AISI-304 austenitic stainless steel is widely used owing to its excellent mechanical properties and corrosion resistance. Surface work hardening and grain refinement further improve fatigue strength and bending performance, making shot peening a widely used surface enhancement technique for fatigue-critical components in aerospace, automotive, railway, and power-generation industries [1–3]. Shot peening is a cost-effective surface treatment that improves hardness, fatigue, wear, and corrosion resistance through work hardening, grain refinement, and compressive residual stresses. The performance enhancement depends on shot peening parameters, particularly coverage, making parameter optimization essential. Optimum shot peening coverage is essential to maximize bending strength and fatigue life while avoiding excessive surface roughness and over-peening [5–7]. These findings indicate that corrosion behaviour depends on achieving an appropriate balance between microstructural refinement and surface scenery [8-9]. Although previous studies have reported improvements in individual properties, inadequate investigation has widely evaluated the combined possessions of shot peening exposure on bending strength, wear, corrosion behaviour, and microstructural evolution under identical conditions. This study investigates the influence of 100%, 150%, and 200% shot peening coverage to identify the optimum condition for maximizing the overall performance of AISI-304 stainless steel.

2. Properties of Tested Specimen

AISI-304 stainless steel is a versatile austenitic alloy acknowledged for its excellent corrosion resistance, high-quality mechanical properties, and formability. The chemical composition, mechanical properties, and proportions of the test specimens are obtainable in Table 2.1 and Figure 2.1 respectively.

Table 2.1 Properties of the tested specimen

Component	Chromium (%)	Carbon (%)	Iron (%)	Manganese (%)	Nickel (%)	Silicon (%)	Phosphorus (%)	Sulfur (%)	Density (g/cm ³)	Tensile Strength (MPa)	Yield Strength (MPa)	Elongation at Break (%)	Modulus of Elasticity (GPa)
Stainless Steel (AISI-304)	18 – 20	Max 0.08	66.3 45–74	Max 2	8-10.5	Max 1	Max 0.045	Max 0.03	7.8–8.03	500–750	200–250	30–45	193

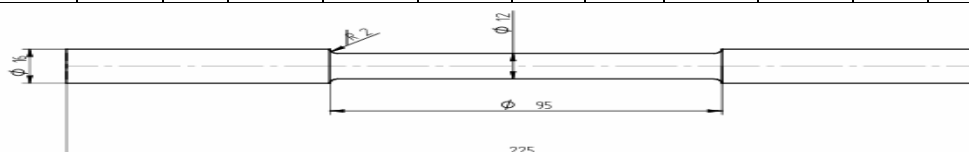


Figure 2.1 The dimensions of round bar specimen (AISI 304 Stainless Steel)

3. Experimental Methodology

AISI-304 stainless steel testing specimens were prepared according to standard dimensions and subjected to shot peening at 100%, 150%, and 200% coverage using a blast velocity of 31.49 m/s. The shot peening process induced surface plastic deformation and compressive residual stresses, while the peening intensity (0.21–0.45 mmA) was controlled using Type A Almen strips. The mechanical performance was evaluated throughout three-point bending tests using a computerized axial fatigue testing machine. Wear performance was assessed by means of a pin-on-disc wear tester by measuring weight loss under different normal loads. Corrosion resistance was investigated by immersing the specimens in a 20 wt. % NaCl solution for 15 days, with load measurements in use each 24 h to establish the percentage weight loss. The experimental procedure enabled a comparative evaluation of the persuade of shot peening exposure on the bending strength, wear resistance, and corrosion behaviour of AISI-304 stainless steel.



Figure 3.1 Fatigue Testing Machine

Table 3.1 Specification of Computerized Fatigue Testing Machine

Parameter	Specification
Capacity	50 KN
Type	Dynamic Servo Hydraulic Model
Max. Load	+ 50 KN
Max. Load for Dynamic Fatigue	+ 10 KN
Max. Displacement	+50 to 100 mm
Max.Frequency	2 HZ
Load resolution	1 KGF
Displacement Resolution	0.01 mm
Width Between column	200 mm
Max length of specimen	300 mm
Control system	PID-Based Controller
Hydraulic system	150 bar, 2 LPM system
Duct Cycle	40%
Oil Capacity	50Litres
Load cell type	Pan Cake
Displacement Sensor Type	High-resolution non-contact linear magnetic scale

4. Results and Discussion

Experimental investigations, including bending, wear, and corrosion tests, were performed on AISI-304 stainless steel among non-shot peened and shot peened (100%, 150 % and 200 % coverage), respectively .

4.1 Analysis of bending Strength with and without shot peened process

Figure 4.1 presents the load–deflection curves of untreated (NSP) and shot-peened AISI-304 stainless steel specimens. Shot peening appreciably enhanced the bending performance compared with the untreated specimen. The 100% shot-peened specimen exhibited a moderate increase in load-carrying capacity, while the 150% and 200% shot-peened specimens showed the highest bending strength due to surface work hardening and compressive residual stresses. Among the tested conditions, 150% shot peening coverage demonstrated the maximum load-bearing capacity, with an improvement of approximately 18–20% over the untreated specimen. Overall, the outcome substantiate that shot peening efficiently enhances the flexural behaviour of AISI-304 stainless steel by delaying crack initiation and improving resistance to plastic deformation.

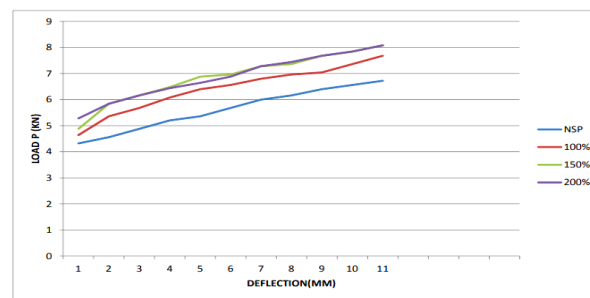


Figure 4.1 Load–Deflection Curves of Untreated and Shot-Peened AISI-304 Stainless Steel Specimens

4.2 Comparison of Wear Behaviour between Untreated (NSP) and 150% Shot-Peened AISI-304 Stainless Steel

Figure 4.2 compares the weight loss and wear rate of untreated (NSP) and 150% shot-peened AISI -04 stainless steel under normal loads of 1000 g, 2000 g, and 3000 g. The untreated specimen exhibited privileged weight loss with rising load, whereas the 150% shot-peened specimen showed significantly lower material loss due to surface hardening, grain refinement, and compressive residual stresses induced by shot peening. The wear rate amplified with load for both specimens, but the shot-peened specimen maintained a more stable wear response at higher loads. Overall, the results demonstrate that 150% shot peening effectively enhances the wear resistance of AISI-304 stainless steel by reducing material removal during sliding wear.

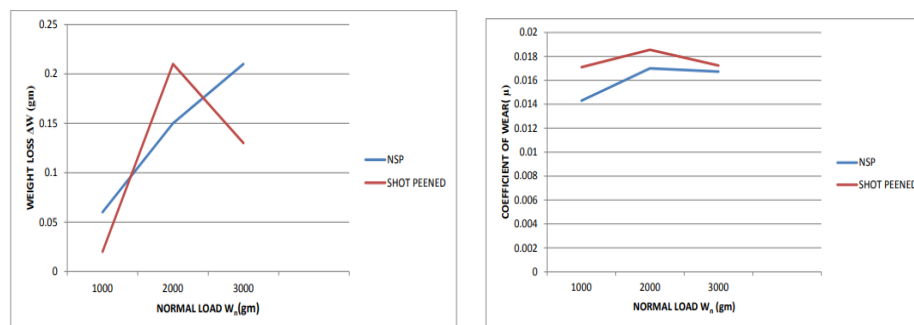


Figure 4.2 Compares the weight loss and **wear rate** of untreated (NSP) and **150% shot-peened** AISI-304 stainless steel specimen

4.3 Variation of Specimen weight with exposure time for untreated and Shot-Peened specimen

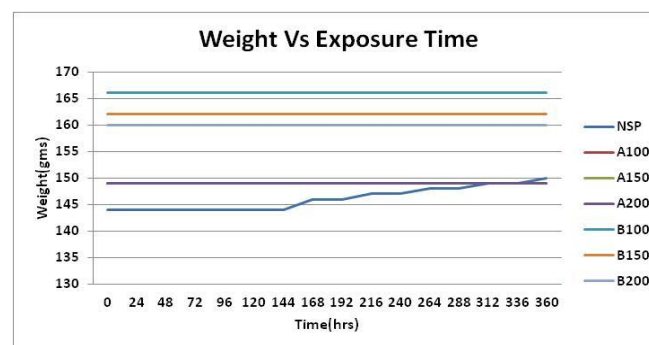


Figure 4.3 Variation of Specimen Weight with Exposure Time for NSP and Shot-Peened specimen

Figure 4.3 shows the corrosion behaviour of untreated (NSP) and shot-peened AISI-304 stainless steel during a 360-hour salt exposure test. The untreated specimen exhibited a gradual weight increase after 168 hours owing to the configuration of corrosion products, reaching approximately 6 g of weight gain after 360 hours. In contrast, all shot-peened specimens (100%, 150%, and 200%) maintained nearly constant weights throughout the test, indicating negligible corrosion. The improved corrosion resistance is attributed to the formation of compressive residual stresses, grain refinement, and a stable passive film induced by shot peening. The results

demonstrate that shot peening considerably enhances the corrosion resistance of AISI-304 stainless steel compared with the untreated condition.

4.4 Microstructure Analysis of Non-Shot-Peened (NSP) and 150% Shot-Peened AISI-304 Stainless Steel

Figure 4.4 compares the optical microstructures of untreated (NSP) and 150% shot-peened AISI-304 stainless steel at 250× magnification. The untreated specimen exhibited a coarse, equiaxed austenitic grain structure, whereas the 150% shot-peened specimen showed significant grain refinement, deformation bands, and strain-induced martensite due to severe plastic deformation. These microstructural changes enhanced surface work hardening, resulting in improved hardness and superior mechanical, wear, and corrosion performance.

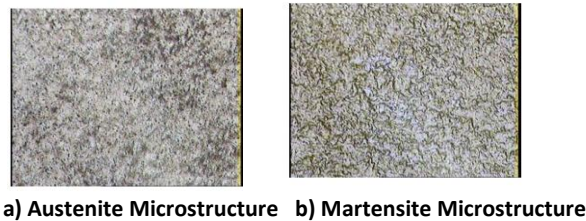


Figure 4.4 Optical Microstructures of Non-Shot-Peened (NSP) and 150% Shot-Peened AISI-304 Stainless Steel

5. Conclusions

The present study demonstrates that 150% shot peening significantly enhances the performance of AISI 304 stainless steel by improving bending strength, wear resistance, and corrosion resistance. These improvements are attributed to surface work hardening, grain refinement, deformation bands, strain-induced martensite, and beneficial compressive residual stresses. The refined surface microstructure effectively reduces material removal and promotes the formation of a stable passive layer. Overall, 150% shot peening is an effectual surface treatment for increasing the durability, reliability, and service life of AISI-304 stainless steel components operating under cyclic loading, wear, and corrosive environments.

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