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# Investigation of Mechanical, Microstructural and Corrosion behaviour of Titanium subjected to Laser Peening with and without Ablation

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**Abstract.** Present competitive world is looking for Components with high strength and fatigue resistance finding their applications in aerospace, turbine parts and especially bio-medical devices with high bio-compatibility. Advanced surface engineering techniques are required to produce parts of higher complexities and desirable surface qualities. Laser peening stood first in a row of all various surface treatments of metallic component. This paper discusses about the mechanical properties like hardness and roughness then the surface morphology and the corrosion behaviour of the laser peened titanium samples with and without coating.

**Keywords:** Laser peening, Titanium, Micro structural properties, Mechanical properties, corrosion behaviour

## 1. Introduction

Titanium compounds discover applications in air motor segments as they are light in weight, have vast rigidity and stable at high temperatures. These components experience cyclic loads in such applications. Most of the mechanical properties under those conditions, such as fatigue, are controlled by the defects at the surface consequently attempts to modify the surface by introducing a residual compressive stress near the surface are not uncommon. These stress states would bring about a conclusion impact on the inconvenient breaks, keeping them from generating. Shot peening is generally used to induce compressive stresses into the material Shot peening is generally reasonable, utilizes vigorous process and can be utilized on substantial or little ranges as necessary [1]. Notwithstanding, the shot peening process has its confinements. Peening results in rough surface which should be eliminated while using in wear applications and most of the processes eliminated the compressive layer [1]. Keeping in mind the end goal to positively influence execution, the residual stresses created by laser peening ought to be compressive near critical areas where failure is probably going to happen [2]. Modifying the surface layer properties of metal components primarily and effectively increases resistance to wear and makes the work material resistant for a range of high temperatures [3] amid the laser treatment, the temperature increments with rapid rates fluctuating from 103 to 105 K/s. These extraordinary warming and resulting cooling conditions prompt to complex metallurgical and morphological changes of the metal [4]. Laser matter collaboration is said to rely upon a few parameters: fluence, wavelength, and repetition rate and pulse duration [5]. The real drawback of the laser peening procedure has been its cost. Another disadvantage is the reliability

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problem of high energy laser and its feasibility in commercial usage [6].

The laser source was used to enhance fatigue power in an Al 7085 and Al7050 [8]. Empowering of the surface was accomplished by laser peening process; Samples which were subsequently anodized are enhanced with increased fatigue strength. When compared with an unworked surface, on peened surface hardness improved by five to six times. When compared to anodized layered faces, invulnerability for laser peened enhanced by 60%. Same kind of work on the impact of laser shock peening treatment on enervate resistance was done [9] for 2024 compound. They also proved that a crucial rise in enervate strength in the alloy. Same way [10] earlier researchers showed a bi fold development in fatigue strength by adopting LSP. Another critical application of a laser root is in aluminium foam forming. It has heightened the base of many researchers because of, matchless properties. The method of acquiring similar foams with a laser was discussed in research [11]. The outcomes of these stated studies proved that the heaviness of those products is in 0.88 to 1.04 g/cm<sup>3</sup> range, at porosity of 67% to 32% respectively. Surface modification using LSP is also applied in severely resistant alloys or for those complicated to form, like SiC reinforced phase composites [12, 13]. The super resistive MVTU-6 alloy have Al-Si-Cu-Cd enhanced with the application of laser peening, which shows rise in hardness in the HAZ and also quasi-eutectic emissions [14]. A319 alloy is considered for cylinder pistons and it is achieved a significant increase in strength and lubrication capabilities of channels and reservoirs. Earlier research was done Al alloys using laser treatment, and set of optimal parameters were found for the targeting improved strength and equivalent chemical composition [16-19]. In year 2005, studies were concentrated on Laser alloying of the surface by applying Boro Tec 10009 coating. Metallization spraying method was used for experiments on the above said surface layer with contagious of Boro Tec 10009 through A high power density is necessary For the penetration of the Boro Tec 10009 layer, high power density is required and this results in occurrence of disturbed penetration, on the surface. The face was strengthened in penetration area and rise of hardness at a level of 800HV0 is achieved. This study focused on studying the mechanical, microstructure and corrosion properties [20-25] of laser peened titanium with and without ablation for enhancing the application of titanium in engineering and biomedical fields.

## 2. Experimentation

Sample preparation commercially pure titanium of grade 2 is considered for this experiment. Titanium has found large number of applications since it is light in weight and stable at high temperatures. Titanium sheet ASTM B 265 6mm × 65mm × 200mm is purchased from metal tech India and it is cut into blocks of 20 mm each by using wire cut EDM. Later on these blocks are polished first using emery paper of different grades and then disc polishing with alumina powder as the abrasives. Finally the samples are turned out to be mirror polished. The equipment used for the process of laser peening is Q-switched Nd-YAG Laser (Litron Lasers, UK). The experimental parameters considered for this are the laser energy, repetition rate, frequency, pulse duration, spot size, pulse density and power. Except power and energy all other parameters are kept constant and peening is carried out with and without coating. The utilization of coatings straightforward to the laser energy is found to build the shock wave force proliferating to the material up to two orders of immensity, when contrasted with plasma produced in vacuum. The expansion in shock wave power is accomplished on surface that coated with black tape and transparent glass or water layer. These outcomes in a greater amount of the laser energy as a shock wave to the work material for an Nd: glass laser having wavelength of 1064 nm. Among the absorbent coatings, economically accessible level dark paint has been found to be the most useful and viable, when contrasted with other covering frameworks. At the point when a laser beam with adequate power lights a metal focus with an absorbent coating, the permeable material vaporizes and structures plasma. The hydrodynamic expansion of the hot plasma in the limited space between the metal and the absorbent over lay makes a high range, short time pressure pulse. A Part of the energy is transferred to the metal as shock wave. The pressure of the shock wave out performs the

plastic deformation, dynamic yield strength of the metal upgrades the nearby properties and surface micro structure.



**Figure1.** Laser peened samples

### 3. Results and Discussions

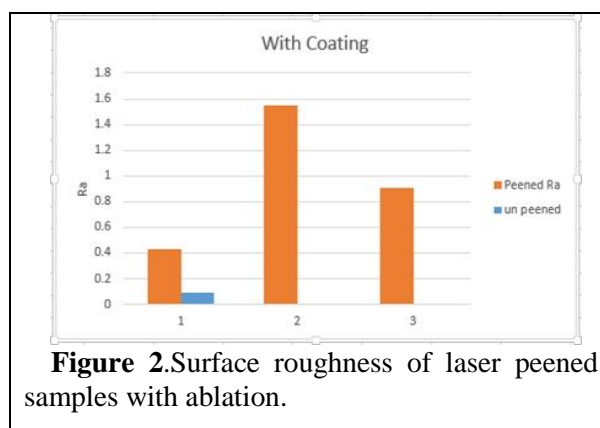
Through laser peening, the impact on titanium in terms of mechanical, microstructural and corrosion properties are discussed in this section.

#### 3.1 Roughness

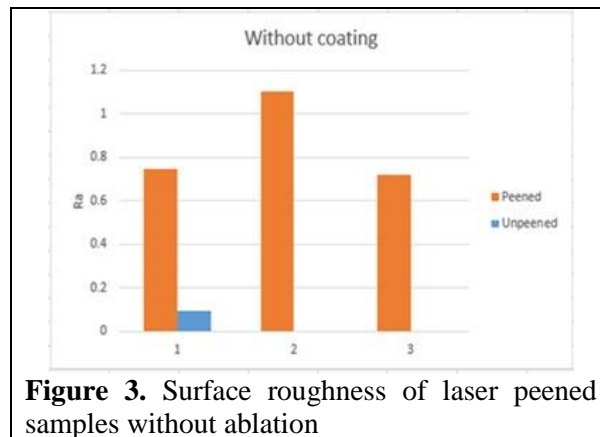
Roughness is measured using Mar surf (GD 120) roughness machine and the values of peened and unpeened samples are compared in table 1. Figure 2 and 3 shows the surface roughness of titanium with laser peening with and without ablation.

**Table 1:** Comparison of surface roughness of peened and unpeened samples

Laser beam power Gw/cm <sup>2</sup>	With coating	Without coating	Un peened
6	0.4302	0.7455	0.0947
7	1.5520	1.1031	
8	0.9032	0.7221	



**Figure 2.**Surface roughness of laser peened samples with ablation.

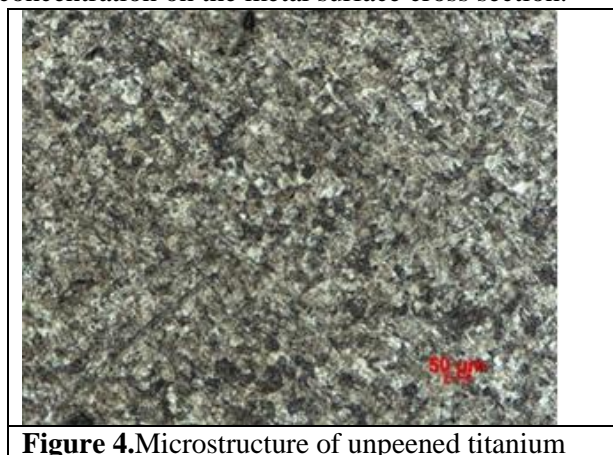


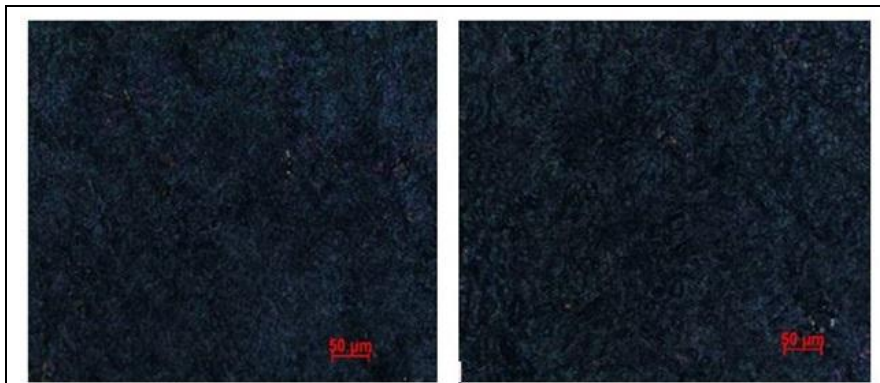
### 3.2. Hardness

Laser shock taking care of can convey changes in Surface hardness of the metal all in all range. The force of surface solidifying relies upon control parameters of the procedure, microstructure of the compounds and mix sort. Enhancing in the Hugoniot elastic point of confinement and adjustments in the metal's energetic yield quality with each waves of laser shock are separated as the two frameworks responsible for the self-restricting hardness changes. With each laser created shock wave, there should be noticeable change in Hugoniot farthest point and element yield quality for outstanding surface hardness. The extreme hardness of the laser peened titanium measured on Vickers hardness analyzer is around 210HV at a load of 100g with a dwell time of 10s.

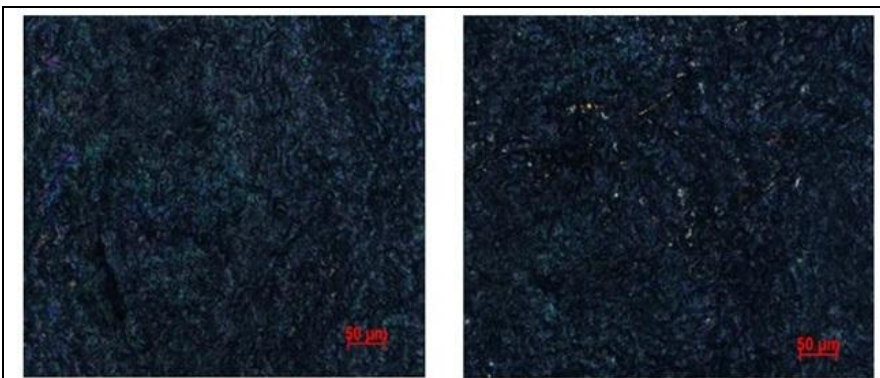
### 3.3. Microstructure

The cross-sectional optical micrographs of the peened samples are given in Fig 5, 6, 7 and analyzed with the unpeened samples in Fig.4. When the Surfaces observed in optical microscopy, it was noticed that there was no noticeable variations which has to be taken into account. However, the curves observed on the laser may be the impact of peening step wise along the Y-axis. There was no closer surface concentration on the metal surface cross section.

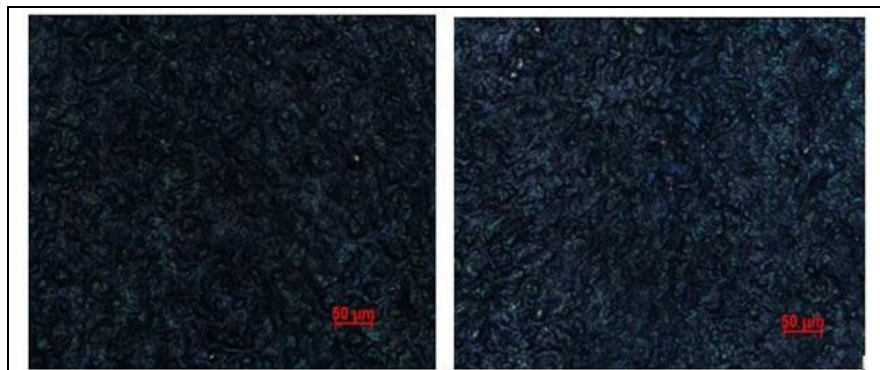




**Figure 5.** Laser peening using 6Gw/cm<sup>2</sup> with and without coating



**Figure 6.** Laser peening using 7Gw/cm<sup>2</sup> with and without coating

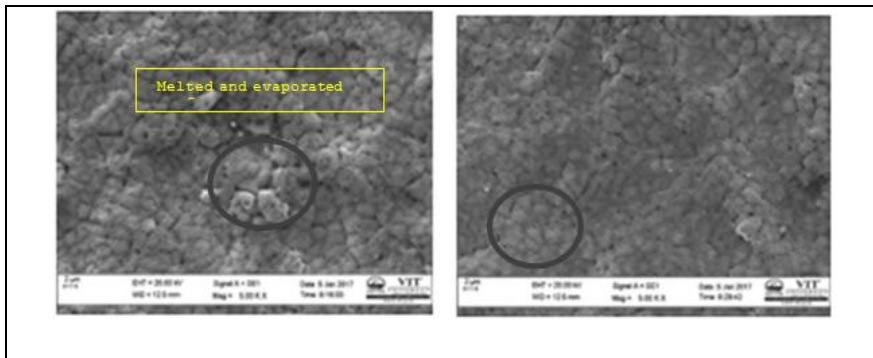


**Figure 7.** Laser peening using 8Gw/cm<sup>2</sup> with and without coating

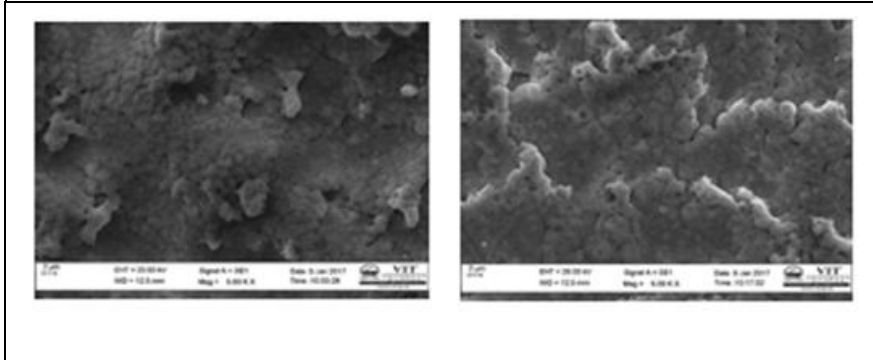
#### 3.4. Changes in Surface Morphology

The surface structure of metals greatly affects fatigue behavior. Numerous examinations identified with the surface structure of laser shock handled materials are performed with SEM (Fig 8) perceptions and surface roughness estimations the point when there is no coating on the surface causes serious surface melting and vaporization because of the laser shock. This can bring about re solidified Droplets and holes prompting to unpleasant surfaces. Because of the shock wave compression, there was a difference in peened and unpeened surfaces. The lion's share of the report on micro structural

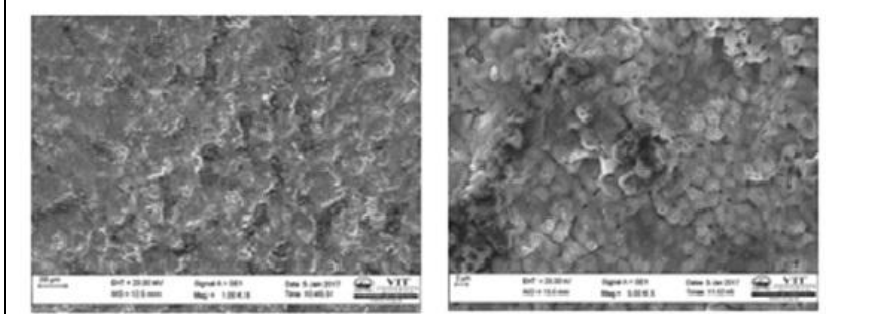
change has been subjective with couple of quantitative subtle elements, for example, dislocation density.



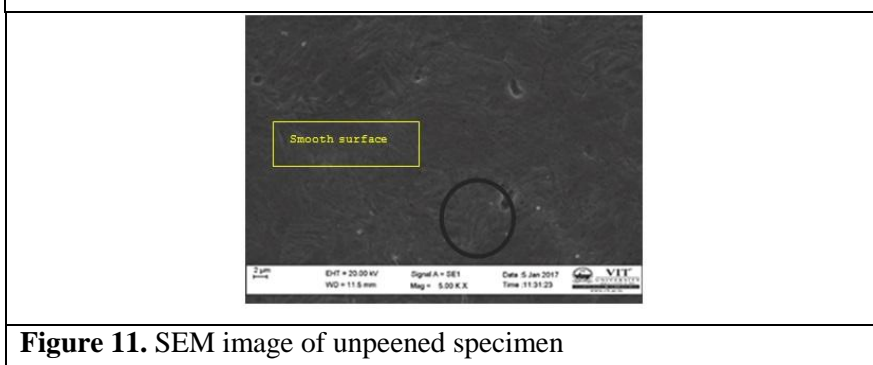
**Figure 8.** SEM image of peened samples at  $6Gw/cm^2$



**Figure 9.** SEM image of peened samples at  $7Gw/cm^2$



**Figure 10.** SEM image of peened samples at  $8Gw/cm^2$



**Figure 11.** SEM image of unpeened specimen

As observed from SEM images the peening which is done without coating melting of the top surface layer as observed From Fig 11 a relatively smooth polished surface of unpeened specimen. When the elemental analysis is considered traces of carbon and oxygen are also observed.

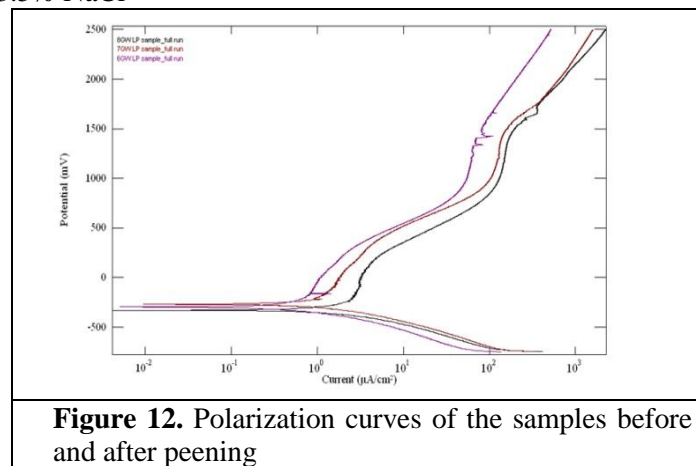
*3.5 Corrosion studies*

Titanium and Ti compounds are broadly utilized as a part of aviation, navigation, and dental inserts in view of their low density, superb mechanical properties, and biocompatibility. The passive films formed on the titanium and its alloys upgrade corrosion resistance. In any case, Ti alloys still regularly experience disappointment when connected, and most disappointments, including stress break, wear, and erosion, happen on the surface of the materials. Along these lines, fortifying the surface properties has an extraordinary noteworthiness in enhancing the general conduct of Ti alloys

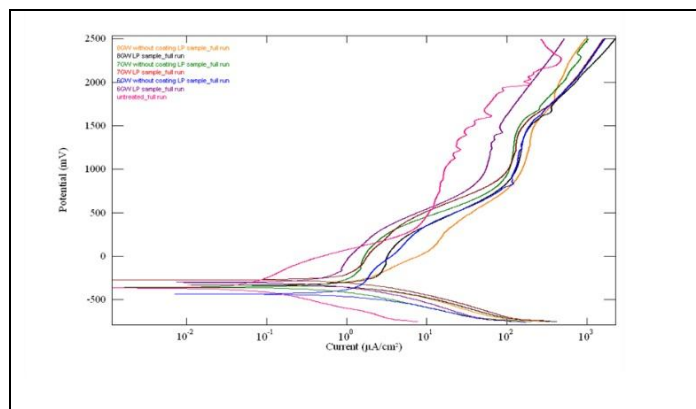
The components affecting corrosion conduct are perplexing, and the outcomes acquired by various creators are dubious. The four major factors are given as follows:

- Grain size is a basic factor for the corrosion resistance of metallic materials
- Compressive residual stress is another calculates expanding corrosion resistance.
- Roughness is also a critical factor in corrosion resistance smoother surface gives better corrosion resistance. The surface active zone ended up plainly bigger and the corrosion rate turned out to be quicker with the expansion in surface hardness
- The handling techniques and corrosion conditions.

Potentiodynamic polarization is employed to investigate the electrochemical properties of Ti before and after peening in 3.5% NaCl

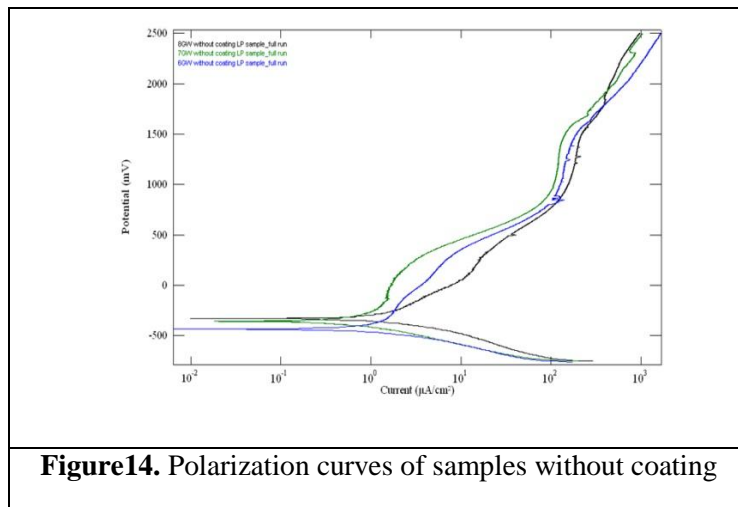


**Figure 12.** Polarization curves of the samples before and after peening



**Figure 13.** Polarization curves of samples with coating





**Figure14.** Polarization curves of samples without coating

Electrochemical parameters obtained from the polarization curves for the samples before and after peening

**Table 2:** Electrochemical Parameters

Sample	$i_{corr}$ (ma/cm <sup>2</sup> )	Rest potential (mv)	Intercept corrosion rate (mm/year)
UN peened	0.005456	-368.66	0.0004636
8gw with coating	0.0215516	-329.35	0.0124866
8gw without coating	0.0028663	-329.35	0.00174
7gw with coating	0.0216665	-271.45	0.0077172
7gw without coating	0.0148298	-355.51	0.0049982
6gw with coating	0.0175856	-440.88	0.0082671
6gw without coating	0.0014271	-300.89	0.0006536

The corrosion current density is generally regarded as an important parameter in evaluating corrosion reactions in kinetics. In order to find out the optimized parameter from the corrosion studies corrosion current density and rest potential are taken into account. Corrosion current density must be low and rest potential must be high. From Table II it can be inferred that 7GW with coating where corrosion current density is 0.0216665mA/cm<sup>2</sup> and rest potential is -271.45 mV, 8GW without coating where the corrosion density is 0.0028663mA/cm<sup>2</sup> and rest potential is -329.71 mV can be the optimized parameters. When taken corrosion rate also into account 8GW without coating can be preferred.

**4. Conclusion**

Laser peening has been successfully done and the following conclusions are drawn. There is an increase in the roughness and hardness of the peened specimen. Laser peening has appeared to solidify the surface and enhance the mechanical properties. The increased compressive residual stress profundity created by laser peening can essentially enhance properties and handle the improvement and development of surface fracture. When SEM images are compared it is found that there is a greater amount of melting and vaporization of the coated specimen when compared with the uncoated specimen. Corrosion studies based on corrosion current density and rest potential are discussed.

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