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Effect of Laser Shock Peening Without Coating on Surface Morphology and Mechanical Properties of Nickel-200

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Keywords: Nickel-200 specimen, X-Ray diffraction, AFM, peening process.

ABSTRACT. This paper delineates the after effects of low energy Laser shock peening without coating on Nickel-200 specimen. Comparative study of X-Ray Diffraction analysis of the treated specimen with untreated specimen suggests the presence of compressive residual stress and grain refinement. The residual stress analysis was carried out using the $\sin^2 \Psi$ method of X-ray Diffraction. The results of which indicate compressive residual stress values have increased. The AFM results tell us that there is a considerable increase in the surface roughness after the laser peening process. There is a grain refinement which is also supported by AFM, XRD data. The hardness profile of the material was increased by a substantial amount. The crystalline size and the micro-strain have been calculated for peened and unpeened samples using the Scherrer's equation from the X-ray diffraction data.

Introduction. Surface is the outermost layer of the material which is in contact with other materials hence, it is essential for us to know the properties of the surface and upgrade them for streamlining of the mechanical properties of the surface to guarantee the long life of the materials. It is highly important to know about the surface because most of the cracks are generated on the surface of the material and then propagate within the material thus giving birth to fatigue. Where ever may the material be used, fatigue weakens the material thus ultimately leading to failure of the material. [1]

Laser processing of materials in liquid media has been gaining importance in recent years. The effects of laser shock peening on the material have been extensively studied by Sano et al [2]. Laser shock Peening (LSP) has been extensively examined for its significant increment in both the fatigue strength and the life time of metal, which along these lines takes care of the issue of high cycle fatigue (HCF) breaking of aircraft engines, by creating an substantial residual compressive stress on the surface of metal through the action of a laser shock peening. The residual compressive stress generated due to Laser shock peening process can have a large impact on coating mechanical properties and durability. Compressive residual stresses at the surface hinder the development of surface-started cracks to which enormously increases the life-time of the material. The likelihood of producing residual tensile stress on the overhead of surface of the sample is a major disadvantage of the laser shock peening without coating technique which is because of the higher sweltering effect, the surface dissolving and re-solidification occur a couple of microns on the metal surface.[3]

The fundamental principle behind laser shock peening with material in water confinement can be clarified as takes after. At the point when a laser pulse is focused around a target material which is submerged in water, the material surface layer vaporizes immediately [1]. The energy of the laser pulse is constantly taken by the water vapour for the entire pulse duration. This procedure changes over the vapour to high temperature plasma. The water layer keeps the profoundly extending plasma towards the material surface which in turn incites an exceptional shock wave of high pressure [3, 4].

Experiments and methods.

Laser shock peening without coating (LSPwC). A specimen of dimensions 4cm × 2cm × 2mm were prepared by cutting a 30 mm thick Nickel -200 sheet by Electric Discharge Machining (EDM) wire cutting. The mechanical properties of the base material is given in table 1. The specimen was highly polished to mirror finish before treating the specimen with LSPwC technique. The process of LSPwC was carried out using a Q-Switched Nd:YAG laser operating with a fundamental wavelength of 1064nm was used as a laser source. The parameters for LSPwC process is provided in table 2. The full width at half maximum (FWHM) was 10 ns with a repetition rate of 10 Hz, which was carried to the target material by using a dichroic mirror and a Plano convex lens of focal length 300mm. A confinement layer is produced on the surface of the sample by a layer of water on work piece by water jet arrangement. The lens is protected from the water spilling during the time of peening by an electric drier which is placed near the lens. The specimen is fixed in a holder which is computer controlled, making the specimen move in the X and Y direction during the irradiation of the laser pulse. The laser pulse density (Np) of the laser can be controlled by controlling the velocity of the transitional stage. The pulse density was kept constant in this experiment [1].

Table 1. Laser shock peening without coating parameters.

Pulse Energy	Pulse duration	Repetition rate	Power density	Pulse density	Spot diameter
350 mJ	10 ns	10 Hz	6.96 GWcm ⁻²	800 pulses cm ⁻²	0.8 mm

Characterization procedure. The sample is subjected to X-ray diffraction (XRD). Crystallographic analysis was carried out using Scherrer's formula:

$$T = \frac{K \lambda}{\beta \cos \theta} \quad (1)$$

where T is crystallite size, λ is the wavelength of X-ray, β is the Full width half maxima and θ is the glancing angle [5].

One needs to set up an exceptionally close surface of the cross-sectional thin thwart so as to comprehend the genuine changes created by LSP. The depth wise compressive stress estimations are taken as indicated by the X-beam diffraction $\sin^2 \Psi$ technique. The X-ray beam of 4 mm² at the diffractive edge of 44° is measured by X'pert Pro framework (PAN alytical, Netherlands) [6] at a working voltage of 45 kV and current of 40 mA utilizing Cu K α -radiation with PRS X-beam locator. The electrolyte polishing progressive layer removal procedure is received for depth examination of compressive residual stress. It is proceeded by applying 80% methanol and 20% perchloric acid solution by controlling the voltage (18V) with steady electro polishing time duration. The surface roughness profile measured utilizing surface profilometer [1] (MarTalk). According to ASTM: E384 standard, the transverse cross-sectional examples are utilized to quantify Vickers micro hardness estimations with a steady load of (50gf) was applied for 10 sec duration. The chemical composition of the Nickel 200 is given in table no. 3.

Table 3. Chemical composition of Nickel-200.

Alloy	C	Mn	S	Si	Cu	Fe	Ni
Max	0.15	0.35	0.01	0.35	0.25	0.40	99.0

Results and Discussions

XRD analysis. The presence of major peak at 44° of 2θ angle indicates the existence of retained austenite in both the peened and unpeened sample [5, 7]. There is also a shift in the peak in the treated sample, indicating that the LSPwC treatment results in the induced lattice strain. The crystallite size was calculated using Scherrer's formula and is found to be reduced significantly after the LSPwC treatment, hence indicating grain refinement.

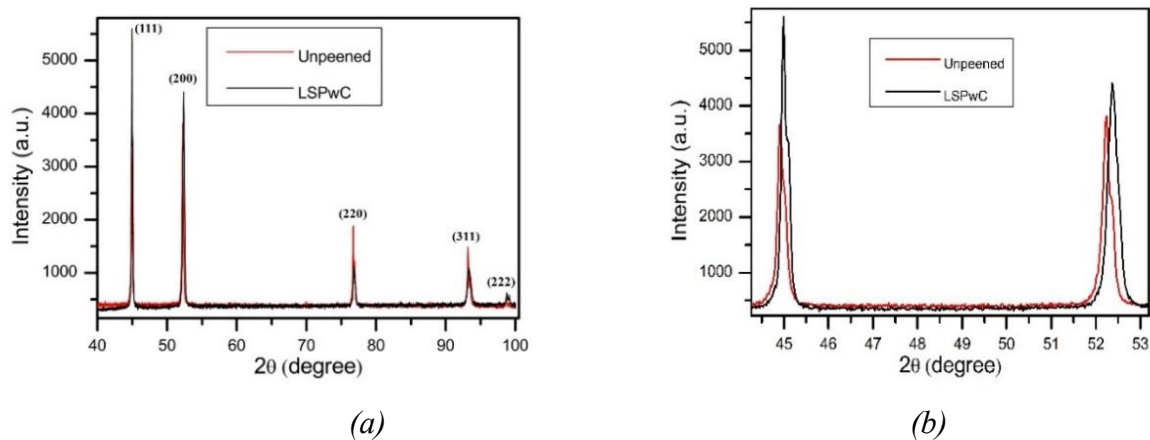
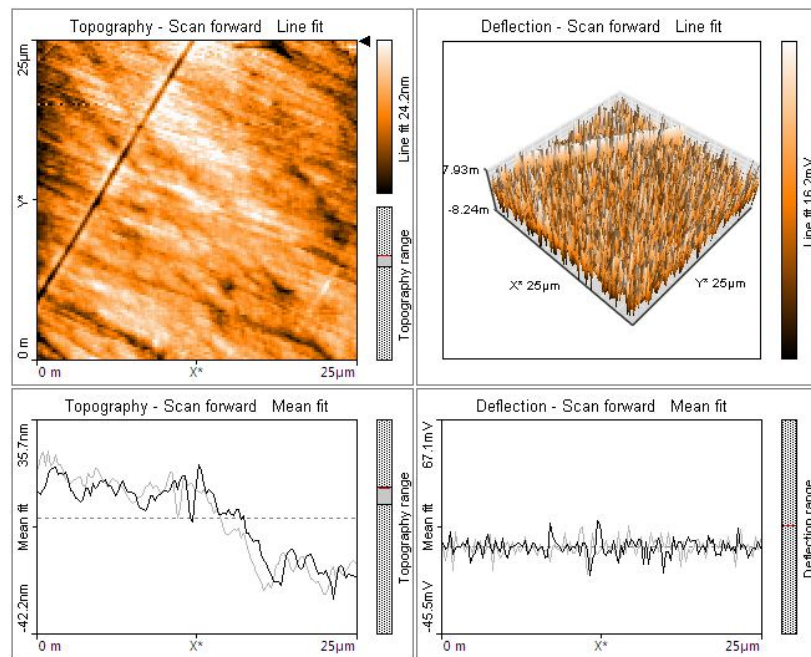
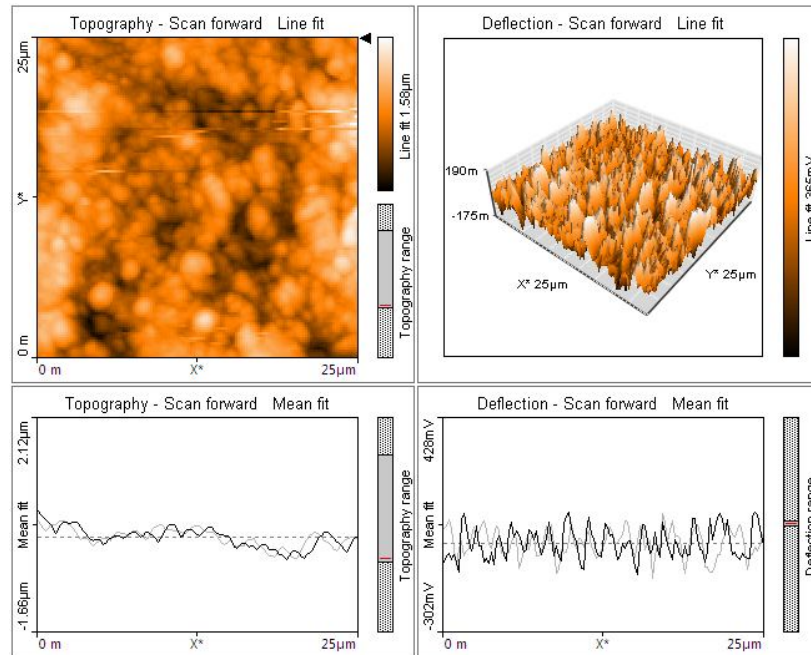


Fig. 1. XRD analysis of unpeened and laser shock peened nickel 200 specimens. (a) Indexed graph (b) Magnified image.

AFM analysis and surface roughness. The topographical analysis of the sample that underwent LSPwC was done using Atomic Force Microscope (AFM). Sampling area of $2\mu\text{m} \times 2\mu\text{m}$ and sampling length was set as 0.5mm for the measurements. Owing to deterioration of the surface quality most of the structural component failure starts at the surface. The surface integrity of treated sample and as well as the untreated sample was evaluated as surface roughness and surface topography. The surface topography of the sample surfaces is shown in the figure (Fig.2). From the above figure it can be observed that after LSPwC, the valleys are more in unpeened sample. The laser shot indentation is the main reason for the suppression of peak to valley. Thus from AFM surface topography [1] it can be seen that the laser peened sample surface shows more surface roughness than unpeened sample surface. Laser Peening without Coating prompts higher surface roughness contrast with conventional laser peening[9].



(a)



(b)

Fig. 2. AFM Surface morphologies of (a) unpeened and (b) laser shock peened nickel 200 specimens.

Residual stress analysis.

The Residual stress measurement of the peened and unpeened sample was investigated by X-ray diffraction $\sin^2\psi$ method, where ' ψ ' is the angle between the normal to the surface and the normal to the diffraction plane. The residual stress was measured in the sigma-x direction. It was observed that the laser peened surface showed higher compressive residual stress compared to that of the unpeened surface [1]. The initial value of the residual stress is due to the manufacturing process and thus residual stress was induced in the sample [8]. The residual stress at the surface as well as at depth of 50 microns has increased by a substantially large amount which is reflected in table 3.

Table 3. Residual Stress data.

Nickel 200	Surface (MPa)	50 Microns (MPa)
Unpeened	-32.6	-17.6
Peened	-323.4	-436.0

Table4. Residual stress measurement parameters.

Characteristic X ray	CuK α
X ray tube Voltage	20KV
X ray tube Current	5mA
Diffraction plate	222
Diffraction angle 2 θ	76°
X ray irradiated area	2 mm
X ray detector	PSSD

Micro-hardness analysis.

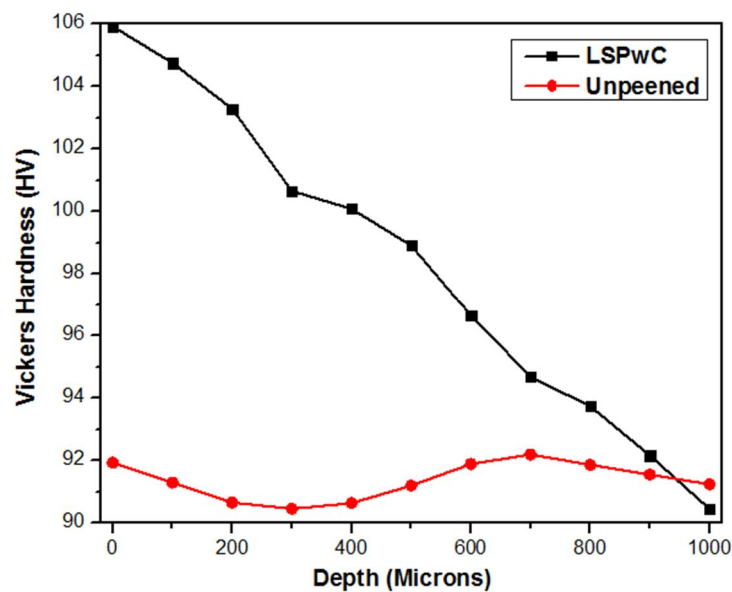


Fig. 4. The Vickers microhardness profile for unpeened and LSPwC nickel specimens.

The micro-hardness test was carried out using Vickers-micro-hardness tester for both the peened and the unpeened sample and their results were compared and it was observed that the laser peened sample showed an increased in the micro-hardness value of compared to that of unpeened sample value. Fig.4 indicates clearly that there is improvement in the hardness values till a depth of 900 microns [10].

Summary. Laser peening without coating studies on Nickel 200 showed an improvement in the surface stress from -32.6 MPa to a maximum of -323.4 MPa. The micro hardness test confirmed that the LSPwC process resulted in work hardening as well as the increase in the depth of hardened layer. Increase in the surface roughness was reported after the laser peening process the surface roughness analysis reported an increase in the surface roughness

after laser peening indicating an increase in the corrosion resistance of the material. More confirmation study is required to identify the improvement in fatigue and wear resistance. Low energy Nd:YAG laser is feasible to perform Laser Shot Peening. When using low energy laser, peening without sacrificial coating is more beneficial to induce higher magnitude compressive stress. Depending on the material properties the higher surface roughness may cause deterioration in corrosion resistance, this can be investigated further.

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References

- [1] S. Sathyajith, S. Kalainathan, S. Swaroop “Surface modification of 17-4 PH stainless steel by laser peening without protective coating process” *Surface & Coatings Technology* 278, 2015, 138–145.
- [2] Yuji SANO, Koichi AKITA, Kiyotaka MASAKI, Yasuo OCHI Igor ALTENBERGER and Berthold SCHOLTES “Laser Peening without Coating as a Surface Enhancement Technology” *JLMN-Journal of Laser Micro/Nanoengineering* Vol. 1 (3), 2006.
- [3] S. Kalainathan, S. Prabhakaran “Recent development and future perspectives of low energy laser shock peening” *Optics & Laser Technology* 81(2016), 137–144.
- [4] S. Prabhakaran, S. Kalainathan “Warm laser shock peening without coating induced phase transformations and pinning effect on fatigue life of low-alloy steel” *Materials and Design* 107 (2016) 98–107.
- [5] Xizhang Chen, Jingjun Wang, Yuanyuan Fang, Bruce Madigan, Guifang Xu, Jianzhong Zhou “Investigation of microstructures and residual stresses in laser peened Incoloy 800H weldments” *Optics & Laser Technology* 57, 2014, 159–164.
- [6] Majumdar, Jyotsna Dutta, Evgeny L. Gurevich, Renu Kumari, and Andreas Ostendorf. "Investigation on femto-second laser irradiation assisted shock peening of medium carbon (0.4% C) steel." *Applied Surface Science* 364, 2016, 133-140.
- [7] P. Mukherjee, A. Sarkar, P. Barat, T. Jayakumar, S. ahadevan and Sanjay K. Rai “Lattice Misfit Measurement in Inconel 625 by X-Ray Diffraction Technique”. 2006
- [8] S. Sathyajith, S. Kalainathan “Effect of laser shot peening on precipitation hardened aluminum alloy 6061-T6 using low energy laser” *Optics and Lasers in Engineering* 50, 2012, 345–348
- [9] Gill, Amrinder S., Abhishek Telang, and Vijay K. Vasudevan. "Characteristics of surface layers formed on inconel 718 by laser shock peening with and without a protective coating." *Journal of Materials Processing Technology* 225, 2015, 463-472.
- [10] Li, Yinghong, Liucheng Zhou, Weifeng He, Guangyu He, Xuede Wang, Xiangfan Nie, Bo Wang, Sihai Luo, and Yuqin Li. "The strengthening mechanism of a nickel-based alloy after laser shock processing at high temperatures." *Science and Technology of Advanced Materials* 2016.

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