Corrosion conduct of Austenitic stainless steel 316L subjected to surface treatment

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Abstract. The influence of low temperature liquid nitriding as a surface heat treatment analogy with laser peening treatment at the various of throbs on pitting corrosion of the “AISI 316L Austenitic stainless steel” is investigated in this paper. According to typical ASTM (G71-31) a number of corrosion examination samples are equipped with the measurements of (15 * 15 * 3) mm which distributed into the many groups. Three sets were exposed to liquid nitriding process at temperatures of (500, 400, 300) °C for one hour. The specimens (without coating) were exposed to a number of the throbs (1,2,3) by laser peening. Microstructure variations, compression residual stress, hardness, were inspected in this work. The corrosion and its variables (potential cell, current density) were also evaluated using the potential stat examination and applying the Tafel method using saltwater solution (3.5% NaCl). Tafle equation was used to compute the corrosion degree. The results revealed that the liquid nitriding participated to raise the corrosion rate at (500) °C, compared to the original metal because of chromium nitride and also laser peening participated to the increase in the corrosion rate due to plastic deformation which led to the heterogeneity in the microstructure but liquid nitriding at temperature (400) °C gave the best result where it was closer to the parent metal’s, also laser peening at one throb showed the lower corrosion rate.

1. Introduction.
The Austenitic stainless steels are a secondhand in manufacturing of diverse parts due to their admirable corrosion resistance and microstructure, though these materials have meager wear counteraction and relatively low hardness. An effort was earlier exerted to elevate “the surface hardness and wear” counteraction of “austenitic stainless steels” using “chemical surface treatment” like nit riding , nitro-carburizing which made to increase in corrosion resistance due to the nitrogen attachment or the carbon with the chromium making nitrides or carbides, and decreasing its amount in the solid solution. Corrosion behavior can be improved by nitriding method at low temperature which is performed at temperatures less than 450°C. These low treatment temperatures release a nitride layer from chromium nitride sedimentation CrN and create a nitride film which contains iron nitrides and a nitrogen supersaturated solid solution, named “extended Austenite phase” (αN) by analogy with the previously expanded austenite [1,2]. stainless steel is subjected to Pitting corrosion due to Acid chlorides which respond with chromium element to form the very soluble chromium chloride (CrCl₃) therefore chromium is extracted from the this film neglecting lone the effective metal . As the chromium is disbanded, the electrically motivated the chlorides to made hole into the stainless steel, originated a round smooth fence pit. The remaining solution in the rap is ferric chloride (FeCl₃), that is in charge of the corrosion to stainless steel [3].

Three impact factors on the pitting corrosion: chloride content, pH, and temperature of the media. In common the probability of pitting corrosion increases when temperature and chloride content are higher and the pH is lower. Leaser shot peening (LSP) is a type of "a mechanical cold working"
technique that throbs shocks all the face by great energy and produced residual compressive stresses nearby, 4–5 times deeper and greater in intensity with homogeneity through the surface that in consequence encourages the refining of the microstructure. The laser spot extent and shape, are significant factors in the peening procedure. Circular shaped laser spots are widely used more than greater compressive residual stresses are awaited for smaller patches because of the reversed proportionality of spot scope and intensity of energy. Manifold laser jolts and overlapping of spots, meant to protect great zones, have exposed important effect on the remaining stress shape. This is because of the actuality that the greater quantity of jolts induced the larger plastic deformation until a soakage dot. In addition, overlapped areas show a relatively constant distribution of compressive residual stresses after LSP, higher laser throbs showed deeper residual stresses than in the case of on its own laser shock, deeper stresses can be attributed to the plastic deformation that created more dislocation movements. The remaining stresses at the face of the plate are lesser in the dual laser shocks, whereas it was greater for on its own laser shock. This can be defined as the stress fullness point is on its own take the laser shock so the stresses would be relaxed due to rise in shocks numbers. Moreover, the sucker film may have been ruined through multiple jolts [4]. Many researchers took on the subject as:-

E. Haruman [1] studied the surface film resulting from liquid nitride of AISI- 316L austenitic stainless steel at low temperatures (400-500 °C) by using X-ray diffraction and the identification of phases as well as the study of electrochemical corrosion behavior at scan potential from ( -1000 + 1000 mv) relative to the open circuit voltage. The obtain result show that the liquid nitrate generated a film containing the extended austenite at a temperature of less than 500°C which contributed to improving the corrosion rate.

Askar Triwiyanto [5] studied the importance of chemical, thermal factors on the surface hardness of Austenitic stainless steel type 316L. Thermal chemical treatments of carbonate, nitrate and carbo-nitride at low temperatures of less than 450 °C to get an oxidized film of extended Austenite phase without sedimentation of chromium carbide or nitride during carbonization or Nitrate and the thickness of the layer is irregular as it reached 83 µ m by nitriding for a time of 8 hours while by carbonization and carbonate give more depth for the same period and confirmed that the depth of the film can be greater than before when increasing the time for all thermal dealings and the resulted surface hardness amounted to 1600HV for the method of nitride and 1150 HV and 500HV for carbonizing which participated to improving wear resistance and corrosion compared to metal without treatment.

Abdullahi K. Gujba [6] take the surface hardening by the laser and its effect on the surface finishing and the depth of the hardened layer and the amount of stresses produced and focused on the impact of laser to improve the properties of the metal, including the structure of microscopic and corrosion resistance, and the age of fatigue and compared the results with ultrasound, The selection of shock conditions were mainly velocity, wavelength, frequency.

G. S. Frankel [4] make an offers overview of the criticality elements which effected on the pitting corrosion of metals. The phenomenology of pitting corrosion is debated, containing the special effects of alloy composition, environment, potential, and temperature. abstraction is then assumed of studies that have focused on many steps of the pitting procedure, containing the fracturing of the inactive layer, metastable pitting, and pit growth.

Yuji SANO, Koichi AKITA [7]. studied the improvement of fatigue characteristics using rotating-bending for several metals, austenitic stainless steel 316L, titanium alloy(Ti-6Al-4V) and cast aluminum alloy using LPWC which informs compressive residual stress deprived of any external arrangements. Materials are peened in waterish setting with laser pulses of about 100mJ. Fatigue lives increase even though the rise in surface eliminated SCC susceptibility of sensitized austenitic stainless steels, nickel-based alloys and their weld metals. LPWC has been utilized to prevent SCC.

The influence of nitride surface treatment at different temperature and laser peening at different pulse on pitting corrosion of AISI 316L- stainless steel are manipulated.
2. Experimental work.

2.1. Metal select.
The AISI 316L Austenite stainless steel have a hug kinds of applications such as the chemical industry of petroleum, food industry, shipping and house equipment. The analysis of the elements which are exposed in table.1 were made using ARL spectrometer tool.

| Element %wt | Fe | C  | Si  | Mn | Cr | Mo. | Ni  | Al | Co | Cu | N  | Ti | V  | W  |
|-------------|----|----|-----|----|----|-----|-----|----|----|----|----|----|----|----|
| Actual value| 68.8| 0.068| 0.429 | 1.63 | 16.9 | 2.57 | 8.49 | 0.005 | 0.363 | 0.379 | 0.006 | 0.012 | 0.179 | 0.082 |
| Normal value| - | 0.3 | 0.75 | 2 | 18.5 | 2-3 | 10-14 | - | - | 0.1 | - | - | - |

2.2. Samples Preparation.
Numerous samples were prepared from AISI 316L stain less steel sheet metal for pitting corrosion examination depending on the ASTM (G 71-31) standard with the dimensions of (15*15*3 mm).

2.3. Samples distribution.
Pitting corrosion specimens were divided to seven groups which were listed in table 2.

| Groups of samples | Specimens symbol | stat |
|-------------------|-----------------|------|
| A                 | as received     |      |
| B                 | liquid nit riding at 500°C° |      |
| C                 | liquid nit riding at 400°C° |      |
| D                 | liquid nit riding at 300°C° |      |
| E                 | laser peening one pulse |      |
| F                 | Tow pulse laser peening |      |
| G                 | Three pulse laser peening |      |

2.4. Laser peening.
The specimens having symbols (E, F, G) in table (2) are subjected to laser peening at wave length (λ=1064nm), power=500m/ joule, plus time 10sec. number of (1,2,3) pulse respectively.

2.5. Salt Bath Nitriding.
Liquid nitriding was performed on groups (B,C,D) of specimens as shown in Table(2). The nitriding solution was prepared from (61% sodium cyanide, 24% sodium chloride and 15% potassium carbonates) salts by weight, which were put in a stainless steel vortex then in a furnace at 500°C to melt together before inserting the specimens, which were suspended by thin steel string then were heated in another furnace at 150 °C to become free from moisture to avoid agglomeration due to moisture in case of placing it inside to melt, then the vortex was taken out from furnace, and the specimens put in it and returned to the furnace for one hour and quench in water.
2.6. Residual stress measurements.
X-ray diffraction sin2ψ method was used to determine the remaining stresses. The process is used to evaluate the strains at particular diffraction angles and lattice planes, according to “Bragg’s law”. Hardness by Rockwell method using steel ball was also used for hardness test. The obtained results are shown in Table 3.

| Symbol | Residual Stress | Surface Roughness (µm) | Rockwell (B) Hardness in Kg/mm² |
|--------|-----------------|------------------------|-------------------------------|
| A      | -18             | 0.03                   | 38                            |
| B      | -265.889        | 0.029                  | 78                            |
| C      | -241.917        | 0.018                  | 75                            |
| D      | -273.636        | 0.017                  | 68                            |
| E      | -287            | 0.006                  | 84                            |
| F      | -342            | 0.009                  | 84.5                          |
| G      | -372.732        | 0.001                  | 87                            |

2.7. Microstructure Examination.
All specimens were prepared in a series of steps comprised of, grinding by using SiC paper having the diverse grits of (240,320,600,800 &1000), Polishing which was done using cloth made of polishing with alumina oxide (Al₂O₃) of size (0.3µm) after that they were washed with water and alcohol and dried, then Etching being performed using solution consists of (49 CuSO₄ml + 20ml HCl + 20ml distilled water). After that the samples were washed with water and alcohol and dried by air. The specimens were tested using Nikon ME-600 optical microscope provided with a NIKON camera, DXM-1200F as shown in figure (1A,B).

![Figure 1. ESM micrograph of nitride specimens (B, C and D).](image-url)
2.8. Corrosion test.
Specimens for corrosion examination were prepared according to standard ASTM G71-31 immersed in the (sea water) 3.5% NaCl solution. The current cell perusals were getting through scan of the potential from (-250 to +250) mV relative to (OCP). Scan rate describes the rapidity of the potential sweep in mV/sec and it is fasting (10 mv). The examinations were made by a WENKING Mlab with potentiostat and SCI-Mlab corrosion measuring system from Bank Electronics-Intelligent control GmbH, Germany 2007, which shown in figure 2. Tafle equation was used to compute the corrosion degree. The results revealed in table (4) and figure 4.
Table 4. Corrosion examination consequence

| Specimens symbol | I corr. µA  | Potential mv | Corrosion rate m.p.y |
|------------------|-------------|--------------|----------------------|
| A                | 1.57        | -304         | 0.69                 |
| B                | 47.39       | -559.7       | 20.85                |
| C                | 1.65        | -97.5        | 0.726                |
| D                | 17.13       | -59.7        | 7.53                 |
| E                | 2.06        | -359.2       | 0.91                 |
| F                | 19.82       | -546         | 8.72                 |
| G                | 25.99       | -428         | 11.435               |

Figure 4. Polarization Curve for all specimens.
3. Discussion.
Figure 1 demonstrates the influence of liquid nitriding at various temperatures (300, 400, 500 °C) on the microstructure in comparison with parent metal (1.2 A) composed of austenite and ferrite phases that obtainable high corrosion resistance, table 3. Nitriding surface treatments at great temperature 500 °C and with increasing existence of nitrogen and from the hardening medium exuberant sedimentation of chromium nitrides happens as a film on the surface. This layer is white colored and has high hardness due to the presence chromium nitride (CrN) as shown in figure 1., sample (B). But the microstructure under this layer is similar to that (1.2) of sample (A), chromium nitride (CrN) causes appreciable deterioration of the corrosion counteraction of Austenitic stainless steel and this is clear in sample (B) table 3. this feature can be enhanced by the nitriding method at low temperature (300, 400) °C to abolish the formation of chromium nitrides and alternatively, the strengthening influence will be changed by great sattety of interstitial species in austenite matrix which leads to the hardening of the surface area several tens micro meter thick. This sedimentation -free nitride film not only exhibits relative high hardness but as well possesses good corrosion resistance due to the availability of retaining chromium in solid solution for corrosion protect. Extended austenite without nitrides is gained as soon as great quantities of atomic nitrogen are melted in stainless steel at temperature under 450 °C. The nitrogen atoms are supposed to reside in the octahedral interstices of the F.C.C. lattice. Because of the efficiency of the inciter compressive remaining stresses using LSP in refining the microstructure, the corrosion behavior of materials will be developed. Studies have shown that this behavior depends on the LSP process variables like the numbers of pulse and its effect on corrosion behavior which gives less corrosive damage at one pulse that presented in sample (E) in table 3. This is due to the fact that the greater numbers of shocks the larger induced plastic deformation until a saturation point is reached this is clear in samples (F, G) in the same table as a result of the compressive RS. The common consensus confirms that the used of leaser shot peening (LSP) is an significant technique for optimization the corrosion behavior of materials by decreasing the current of corrosion at the anodic with reduced the number of pulses. This can be attributed to the refinement of the grains and the reduction of the effect of the compressive residual stress (RS) film.

4. Conclusion.
From the investigated results in this paper showed that surface layer formed using nitriding surface treatment at (400 C°) was contributed in decreasing the pitting corrosion rate nearly from the base of the stainless steel AISI 316L and laser peening at one pulse gave the same effect on corrosion rate compared with base metal.

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