FATIGUE STRENGTH IMPROVEMENT OF NORMALIZED 0.53 CARBON STEEL BY LASER SURFACE TREATMENT

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Abstract

Laser surface hardening is now being accepted as effective as other conventional hardening techniques, Laser beam provides the extra advantage of hardening localized region in intricate engineering component.

Fatigue strength is a surface phenomenon, although factors such as microstructure and residual stresses affect the fatigue strength, surface condition if not favorably prepared is detrimental to the fatigue behavior.

ND-YAG Laser pulses were applied to treated 0.53 carbon steel specimens. Microstructure was found to consist of martensite and cementite, however micro hardness up to 900 Hv and depth of hardening 0.9-1.0 mm was obtained due to laser treatment. Overlapping of laser pulses has result in low surface roughness and reduced surface micro-hardness scatter in the laser-affected zone.

Laser treatment was found to be detrimental as far as rotating bending fatigue strength is concerned, the effect increases as the laser intensity increases, However if it is the favorable effect in improving the endurance limit (11%).

Introduction

Laser surface heat treatment has been widely used for case hardening of carbon steel, the process that can offer greater precision and less distortion than more conventional surface hardening techniques.

When the energy and diameter of the beam are adjusted to transforms the surface of austenite, self quenching by conduction into the cold metal beneath the surface transforms the austenite to martensite[1]. The technique gives a hard layer resistant surface with less distortion than that caused by flam or induction hardening and it lends itself to prices numerical control and automation. Prescribing a suitable surface treatment procedure can minimize many fatigue failures of components. Three types of surface modification methods are available to enhance resistance to fatigue. The first involves a change in surface composition by carbarizing, nitriding, anodizing, physical and chemical vapor deposition, cladding, surface alloying and so on. The second is including compressive residual stresses a surface and near surface regions by a mechanical method such as shot beening or surface rolling. A third approach is surface hardening through phase transformation, which includes flame, induction and laser heating techniques [2].

Laser surface treatment is one of the most promising and effective methods to improve the fatigue life and to the presence of compressive residual stresses in laser hardening surface layer. Although laser heat treatment operates on the same metallurgical principle as that of flame and induction hardening [3], [4].

This one however, preferred because it can be applied selectively to high stressed areas, such as groves, notches, etc, furthermore this technique produces higher surface hardness than the other, [5].

Experiment

The material used in this investigation is normalized carbon steel the nominal composition are (0.53 C, 0.695 Mn, 0.292 Si, 0.023 P, 0.018 S), yield strength 450 Mpa , ultimate tensile strength 776 Mpa, reduction area 40%.

The dimension and geometry of a fatigue specimen are described in Figure –1-. Figure –2- showing the geometry of the experiment, the beam diameter 2 mm was usually kept constant.

Fatigue test of treated and untreated specimen was carried out on rotating bending fatigue machine with cantilever bending. Step loading test was adopted throughout the investigation, however probit test [6] was carried out on a few test specimens to verify that there was no effect of step loading on the fatigue strength of the tested steel. Tests were carried out at constant frequency of 1200 rpm.

Failure stress was calculated and corrected for actual spam length and diameter using the following equation:

$$\delta = Mb/w$$

$$Mb = GL\ b/a$$

$$W = \pi\ d^3 / 32$$

Where δ = stress, L = weight displacement , Mb = Bending moment , b=10 cm, when specimen fracture in the middle a=5 cm

G=1.5 Kg and d=specimen diameter.

ND_YAG pulses at 4.2 j and for 300 μs duration were applied to test specimen to form overlapped laser spots along the gauge length.

Result and Discussion

FIGURE -3- shows the hardness distribution in the overlapped double spot specimen. And figure -4- shows representative data for the hardness as a function of depth below the surface.

The transformation of surface sample from liquid state to solid state in very short time may result increase in hardness due to the laser glazing for some area in which glazed phase was formed in addition the fast heating and cooling without melting caused internal compressive stresses [7][8]. Beside these effects with martensite and cementite formation would increase the hardness.

The energy distribution of laser pulse is not uniform there for, micro-hardness values varied with significant scatter, overlapping technique can be used to obtain better micro-hardness distribution (up to 900 Hv).

Fatigue test result are presented in the form of S-N curve in figure –5- it can be seen from the figure that laser treatment resulted in improved fatigue behavior in this respect the endurance limit was found to increase by about 11% over that due to non-treated specimens, this is believed to be due to laser effect which could have favorably induced compressive stresses and therefore improve the fatigue resistance.

Fracture fatigue specimens were examined by SEM and it was found that initiation zone was oftenly at the deformed (due to laser) region see figure –6- where the Transgranularity of initiation can be observed, it was also noticed that crack has initiated at many sites on the propagated front has progressed further to cause final fracture. It should be noted that the outer surface (at minimum cross section) all point will be subjected to maximum fiber stress, therefore it is equally likely that fatigue crack initiation could occur at any of those points.

Conclusion

Laser processing, ND-YAG of the surface of 0.5% carbon-steel give a hard martensitic structure.

Overlapping technique can be used to obtain better micro-hardness distribution (up to 900 Hv).

The endurance limit of the tested steel was found to be increased by 11% due to laser treatments.

References

[1] A. Sona “Laser and there application”, Gordon and Beach science publisher Ltd.(1976).

[2] R. Bradly John and Kim Sooho “Laser transformation hardening of iron and iron carbon-chromium steel” , Metall. Trans. Vol.19A,pp 2013-2025, August (1988).

[3] C.Chen , C. Altsletter and J.Rigsbec . “ Laser surface modification of ductile iron : part 1 micro structure “ Metall. Trans.Vol.15A, pp 719-728 (1984).

[4] S.K. Al-ani "Improvement of were resistance of laser treated carbon steel", journal of college of education for women, Baghdad university, Vol.10 No.1, pp 84-91, (2000)

[5] L. B. Hussain L,M. A. Majid,F.S. Mohammed and S.K. Al-ani S" Laser structure transformation of carbon steel " , 3-rd European conference on laser treatment of metals, Erlangen , (1990).

[6] S. K. Al-ani ,A. K. Ahmed and S. A. Hasoon " Effect of laser beam energy in the hardness of carbon steel " Al-nahrain university journal, Iraq , Vol.4 No.1, pp 73-81 ,(2003).

[7] H. J. Heggand J. Hosson " The relationship between hardness and laser treatment of hypo-eutectoid steels", Scripta metallurgica, Vol.21, pp 1737-1742, USA, (1987).

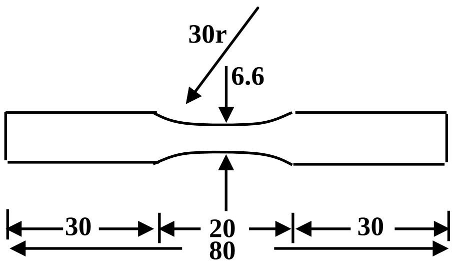

Figure-1- Test specimen geometry and dimensions (all in mm).

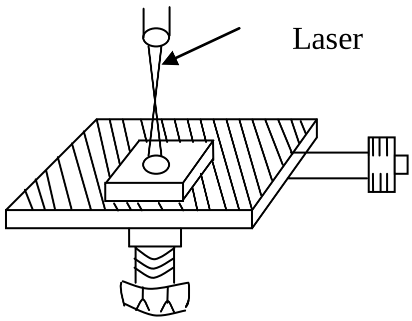

Figure-2- Schematic illustration of a laser heat treatment configuration

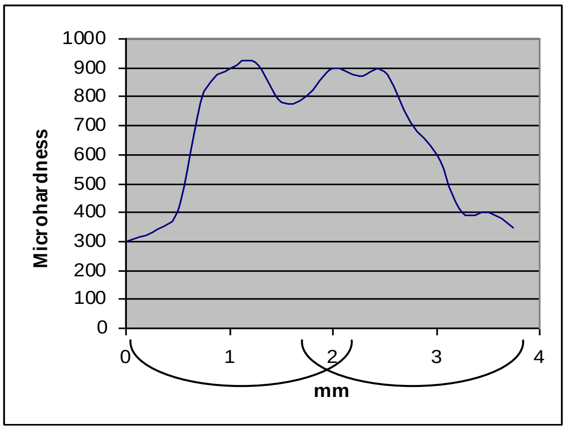

Figure-3- Hardness distribution in the overlapped double pass specimen.

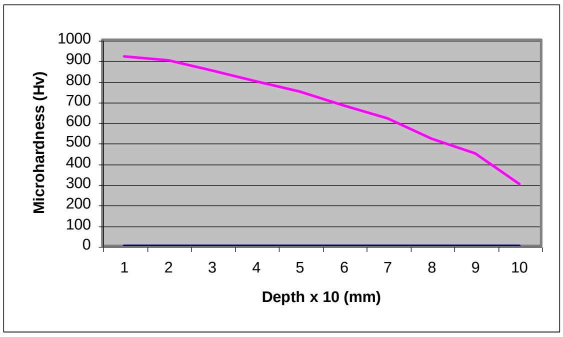

Figure-4- Depth of hardening.

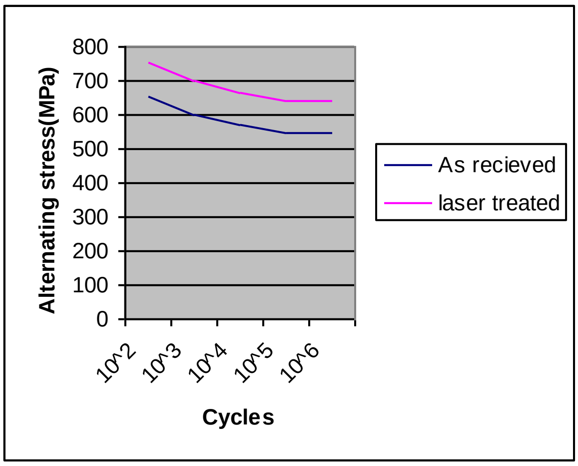

Figure –5- Relation between applied cyclic stress and number of cycles.

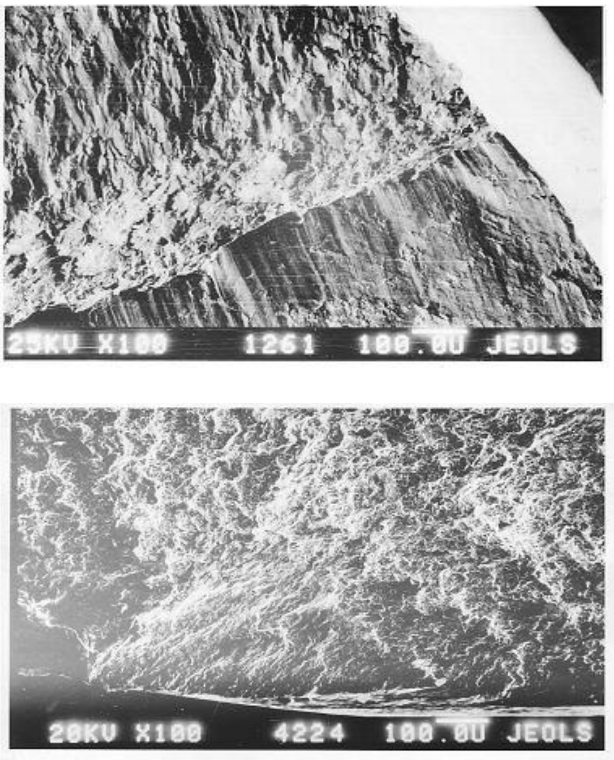

Figure-6- Microphotograph of fatigue fracture surface