Effect of Work-piece Hardness on Peening Intensity Under Local Peening

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Introduction

The time for peening a component depends upon the intensity of peening required. For which first peening intensity under a set of peening parameters such as stand off, shot size and its material, angle of impingement, air pressure and nozzle size (in pneumatic system) need to be established. Generally for establishing peening intensity Almen strips are peened under similar conditions as that of work piece for different time, and Almen arc height is measured (1). Saturation curves are then plotted as relationship between the Almen arc height and time of peening. The time necessary to produce saturation on the Almen strip is defined as the time required to produce a specific arc height at which doubling of the exposure time will not increase the arc height by more than 10%. However, the saturation curves must be obtained by peening one side of the Almen strip uniformly over the length which is achieved by providing relative movement between the nozzle and the strip. There may be cases like notches of the test pieces, roots of the small gear teeths, fillets, tips of the venting slots of the stator of turbogenerator etc. Where local peening over selected regions may serve the purpose. During local peening relative movement between surface to be peened and the peening nozzle may not be essential. This condition is referred here as local peening, it is further divided under two categories one for masked samples to expose small regions as well as to protect flow of metal at the edges, and other for unmasked samples.

For work piece materials of similar hardness to that of Almen strip, the data of saturation curve obtained is applicable directly to component. However, where marked difference in hardness between the component material and test strip exist, some other method of determining the peening condition for obtaining saturation in component is required. Several methods are in use such as (i) applying a suitable multiplication factor (ii) the use of test strips manufactured from the component in place of standard Almen test strips and (iii) the determination in the component by visual estimation of the time to produce complete coverage. All methods are in use (2).

In the present investigation both the types of local peening over various hardness test strips were further explored.

Experimental Work

Experiments were carried out using shot peening equipment reported earlier (3). The work piece material used was En 42 - spring steel strips, 0.7 mm thick and 20.1 mm wide of composition :- C = 0.81%, Mn = 0.71%, Si = 0.22%, P = 0.016%, S = 0.006%, Ni = 0.13%, Cr = 0.16%. The mechanical properties were as follows :- Tensile strength = 640 N/mm2 (Maximum), Yield strenth = 290 N/mm2 (Maximum), Elongation on 50mm G.L. = 25% (Maximum).

The work pieces were cut to strips of size 76mm length. A bunch of strips were heated to a temperature of 860° C in a thin steel box covered from bottom and top with cast iron chips for one hour and then air cooled. The hardness of this lot obtained was HRC-10. Now these strips were peened in three different ways under same peening parameters, which were as follows :

(i) Shot size - S-280 (ii) Stand off = 30mm (iii) compressed air tank pressure = 6.0 kg/cm2. (iv) Nozzle axis 90° to work piece.

Three different saturation curves under three different types of peening were obtained as shown in Fig.1.

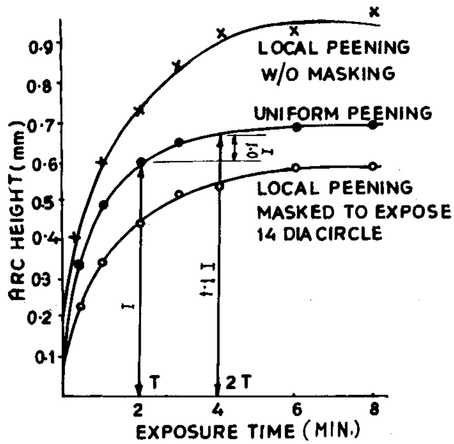

Fig.1 : Saturation curves for 0.7mm thick (HRC-10) strips under uniform and two different local peening conditions.

The saturation curves thus obtained clearly showed that under local peening masked to expose only - 14mm diameter circle the saturation curve was below and towards the right of the saturation curve for uniform peening. It is obvious that due to masking with rubber, part of kinetic energy of the shots was absorbed by the rubber, which will lower down the arc height of the work piece as compared to uniform peening without masking. The saturation curve for local peening without masking was observed above the saturation curve for uniform peening. It was reported in the earlier work that saturation curve for spot (local) peening without masking have shown drooping and were also above and on the left of the saturation curve under uniform peening (3). The effect of drooping was reported to be negligible in case of thicker samples (4). In this investigation the results reported in Fig.1. were of similar nature.

In order to compare the saturation curve under uniform peening, non-standard 0.7 x 20.1 x 76mm^3, strips of hadness HRC 10 and HRC 44 and standard Almen - N strips were shot peened under similar peening parameters and their results were plotted as shown by their saturation curves in Fig.2. The nonstandard strip though having same hardness as that of Almen N strip has shown higher arc height since its cross section was slightly lower than Almen strip and it was also not stress free like standard strips. The initial stresses along the length were -128 N/mm^2 (compressive).

Further in order to investigate the effect of work piece hardness on the nature of saturation curve under two different conditions of work piece, masked and unmasked, local peening was carried out with S-330 shots on different hardness and thicker work piece of 1.1 mm thickness. The results were plotted as shown in Fig.3.

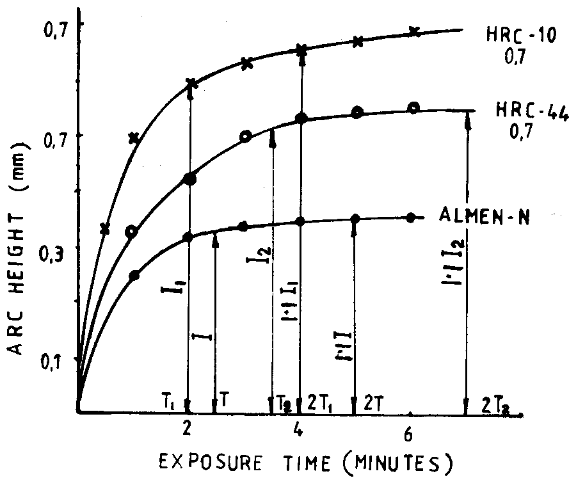

Fig.2 : Saturation curve under uniform peening of standard Almen N and Non-standard strips of hardness HRC 10 & 44.

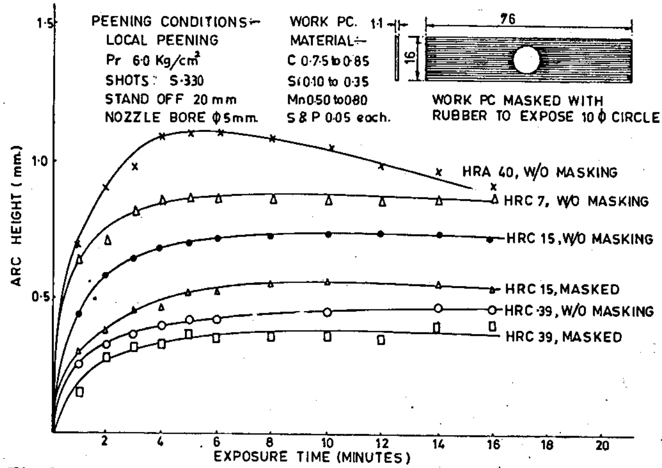

Fig.3 : Saturation curves for 1.1 mm thick strips of various hardnesses under local peening with and without masking.

It is clear from these results that in local peening, hardness of work-piece ranging from HRC-39 to HRC 15, did not show any drooping under both the conditions. Work piece of hardness HRC 7 also did not show any drooping under without masked condition. But work piece of lower hardness values, that is, HRA 40 have shown drooping under without masked condition. Thus for local peening drooping in saturation curve may not occur if test strip have higher hardness values or thickness.

The obvious reason observed for drooping in saturation curve for less hard strips under local and unmasked peening was that surface metal was free to flow towards edges from centre, and in localised peening this effect was more pronounced compared to uniform peening. Once the localised peening reduces the thickness of the sample due to flow or over peening at the centre, further peening will give rise to drooping or reduction in arc height for thin samples. While in case of masked samples under local peening surface metal could not flow upto the edges but it could flow only upto the periphery of exposed circle. Thus a ring sort of projection was observed at the centre of the strip which could act as stifner and drooping in saturation curve or reduction in arc height did not occur even after over peening.

Further to ascertain saturation time for different hardness work piece under local and masked peening condition , 0.7mm thick strips were heat treated to different hardness values HRC-10, 17, 22, 26, 32 and 44. Then after peening, saturation curves obtained for all these strips were as shown in Fig.4. The peening conditions were same as indicated in the beginning.

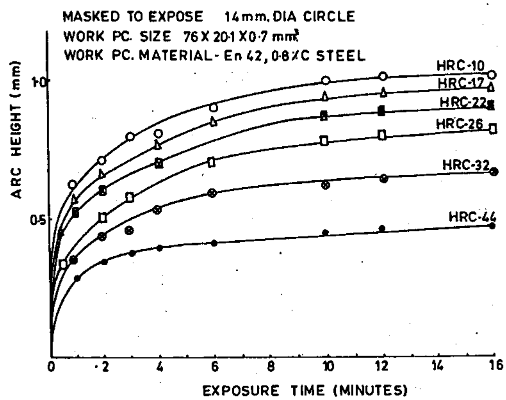

Fig.4 : Effect of work piece hardness on peening intensity under local peening of masked samples.

Residual stress and surface roughness - Ra for each exposure time at the centre of the strip was measured,plotted as shown in Fig. 5 & 6 respectively. With the help of saturation curves and visual examination of coverage, saturation time for strips of different hardness were noted down.

Due to peening first the surface roughness was reduced to a certain level then it remained constant for a small duration and on further peening it started increasing. Therefore under local peening of masked samples there seems to be particular duration after which further peening gives rise to anover peening. This condition gives an idea that saturation time must be near the transition point of change in surface roughness. With this consideration saturation time for various hardness samples was determined and also 98% coverage was ascertained by peen scan. It is clear from the figure 5 that after a certain duration of local peening residual stress will attain a peak value and there after further increase in duration will reduce the residual stress magnitude. Thus this duration, corresponding to peak value, must give saturation time and beyond which over peening will give rise to errosion and reduction in surface finish as well. With above considerations following results were obtained for saturation time for different hardness work pieces.

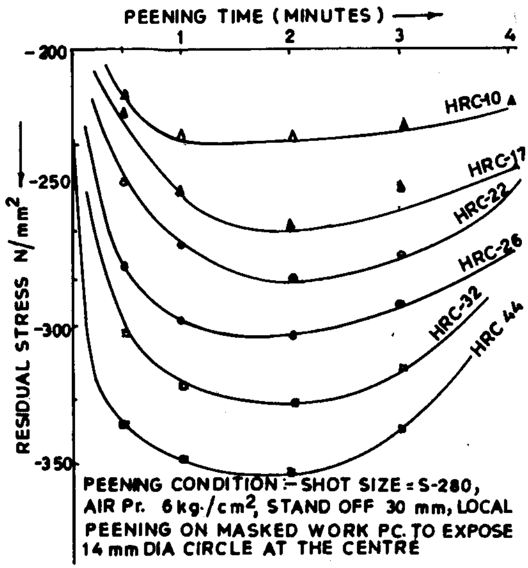

Fig.5 : Effect of peening time on magnitude of residual stresses induced in local peening.

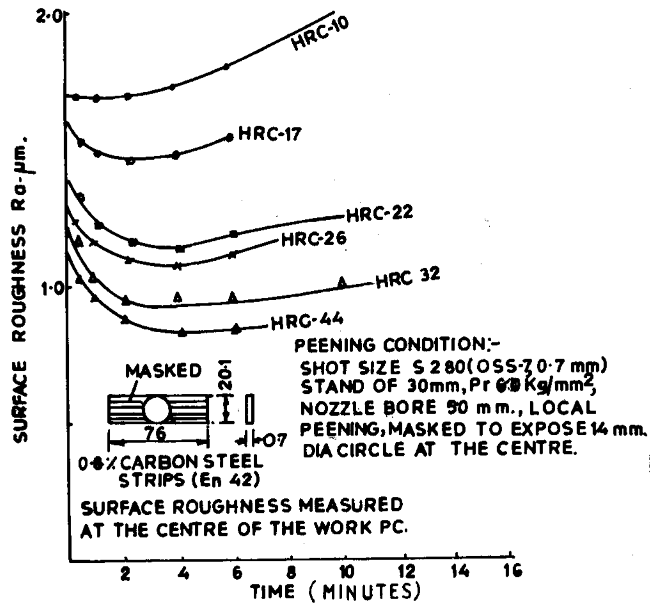

Fig.6 : Effect of local peening on surface roughness of different hardness strips.

Results and Conclusion

Hardness of test piece HRC	Saturation time at about 98% coverage Secs.	Corresponding peening intensity mm.	Surface roughness corresponding to saturation (peak values) µm.	Residual stress at the saturation (peak value) N/mm^2
44	180	0.37	0.84	-350
32	150	0.50	0.93	-330
26	135	0.55	1.02	-305
22	120	0.62	1.10	-280
17	90	0.64	1.46	-265
10	60	0.60	1.67	-230

Table 1 : Results of locally peened En 42 steel strips 0.7mm thick under masked condition.

For local peening under masked condition, considering HRC-44 test strips to be standard one, material factor for other non-standard strips of different hardness was determined which can be used to multiply the basic time.

$$\text{Material factor} = \frac{\text{Time to peen work piece material strips to saturation}}{\text{Time to peen standard strips to saturation}}$$

(a) For uniform, peening for HRC-10 work piece $= \frac{1.0}{3.5} = 0.57$

(b) For local peening

i) Under mask condition for HRC-10 $= \frac{1.0}{3.0} = 0.33$

ii) Under mask condition for HRC-17 $= \frac{1.5}{3.0} = 0.50$

iii) -do- HRC-22 $= \frac{2.0}{3.0} = 0.66$

iv) -do- HRC-26 $= \frac{135}{180} = 0.75$

v) -do- HRC-32 $= \frac{2.5}{3.0} = 0.33$

The material factor variation with respect to work piece hardness is as shown in Fig.7.

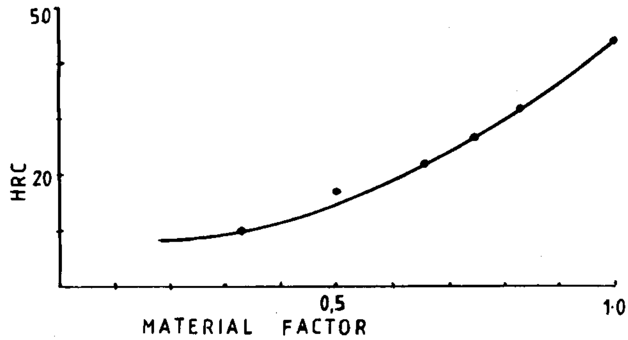

Fig.7 : Variation of material factor with respect to hardness, under local peening in masked condition.

At saturation (98% coverage) variation in magnitude of residual stresses induced, surface roughness, peening intensity and saturation time with respect to hardnesses is as shown in Fig.8.

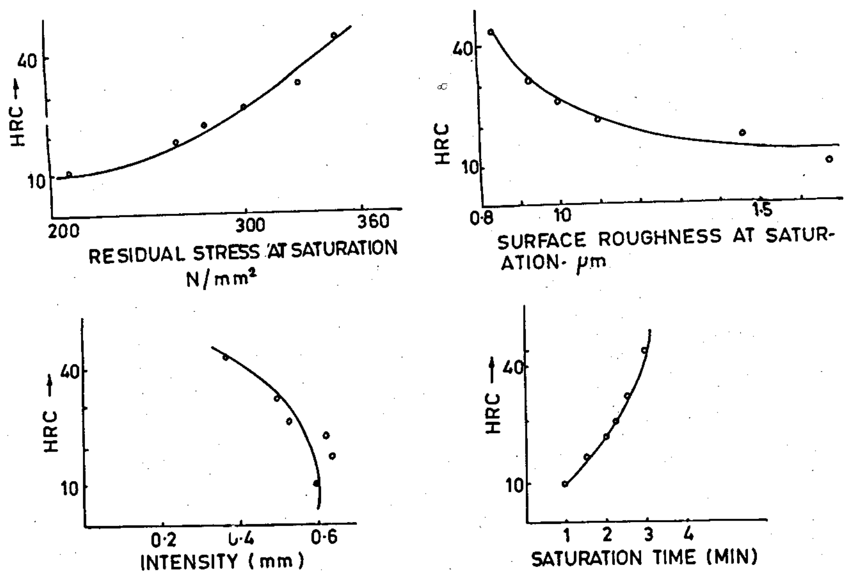

Fig.8 : Results showing variation in residual stress, surface roughness, intensity and saturation time at 98% coverage, with respect to work piece hardness under local peening of masked strips to expose 14mm diameter.

Conclusion

(i) Conventional method of specifying the required peening intensity is not generally applicable where local peening is involved, and the localized peening of the Almen strip is advised in such instances.

(ii) Saturation curves for local peening under masked and unmasked condition are different. To ascertain saturation time, coverage and residual stress measurement must be done.

(iii) Harder the material, saturation time and residual stresses induced would be higher.

(iv) Surface roughness due to overpeening would be affected lesser for harder material.

References

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