EFFECT OF SHOT PEENING AND POLYMER COATING ON CORROSION FATIGUE BEHAVIOUR OF CARBON STEELS

M.C. SHARMA & R.N.V.D.M. RAO
MECHANICAL ENGINEERING DEPARTMENT, M.A.C.T.,BHOPAL-462007 (M.P)
INDIA

ABSTRACT

Spring and structural steels were investigated for corrosion fatigue under artificial sea-water. They did not show appreciable improvement under shot peened condition alone. While peened and polymer coated samples showed greater fatigue strength improvement than unpeened coated samples. But for low carbon steel when peening was carriedout after carburising, hardening and tempering, it showed 30% improvement in corrosion fatigue strength with respect to that of carburised hardened and tempered specimens. This shows that shot peening over harder surface has greater advantage. 50% improvement was observed when specimens were shot peened and coated than unpeened coated ones, under corrosion fatigue for both the steels.

KEYWORDS

Controlled peening, carburising, polymer coat, peening intensity, coverage, saturation curve and corrosion fatigue.

INTRODUCTION

Literature provides ample evidance of fatigue strength improvement of various metal parts by shot peening [1]. Majority of the mechanical failures are fatigue failures. Fatigue failure has three distinct stages. viz., 1) plastic deformation and strain hardening, 2) crack initiation at the surface and 3) crack propagation until fracture occurs [2,3]. Hence it is primarily a surface failure, and any method to improve surface condition are inturn useful in improving fatigue strength of the metal parts. Controlled peening is one such method which induces benificial surface residual stresses and improves fatigue strength of the metal parts considerably. The extent of residual stress and its distribution is mainly influenced by peening intensity, coverage and hardness of the work-piece [4].

CONTROLLED PEENING

Parameters affecting shot peening process are size, shape and material of the shots, shot velocity, exposure time, converage, stand-off and angle of impingement. The time of peening a surface is decided by selecting a specified arc height from saturation curves obtained by peening standard Almen strips. Saturation curves are the relationships between the Almen arc height and the time of peening for above set parameters [3]. The time necessary to produce saturation on a test strip is defined as the time required to produce a specified arc height at which doubling of the exposure time will not increase the arc height by more than 10% [4]. However, the conventional method of specifying the desired arc height is not applicable in situations where localised peening is required. In such a case the arc height must be defined by the localised peening of the Almen strip [5]. Further when there is appreciable difference between work piece material and its hardness with Almen strip hardness a suitable material factor need to be determined experimentally.

PEENING OF FATIGUE SPECIMEN

Since the critical cross section of the fatigue specimen is smaller and different than the standard Almen strip the conventional method of specifying arc height is not justified. The following procedure was used to determine the peening time to achieve the specified intensity for circular cross section.

(a) Since impact energy transfer of a shot varies as the Sine value of the angle of impingement, it is decided to establish a multiplying factor to take care of this effect on peening time. The perimeter of critical diameter is devided in to six equal parts for this purpose.

$$\text{Multiplying factor for curvature} = \frac{\text{Time to peen Almen strip at an inclination of 60 with nozzle axis to specified intensity}}{\text{Time to peen Almen strip in a standard way to same specified intensity.}}$$

(b) If the work piece material properties vary too much with the properties of Almen strip, especially hardness, it is necessary to multiply with the material factor as below [6].

$$\text{Material factor} = \frac{\text{Time to peen work - piece to saturation}}{\text{Time to peen Almen strip to saturation}}$$

(c) Peen standard Almen 'A' strip to a required arc height in the standard way.

(d) Mask a Almen 'N' strip exposing only segmental area i.e. 1/6 of perimeter width at critical cross section and length equal to width of Almen strip. Peen this masked strip under similar conditions of (3) and note the arc height.

(e) Mask an another Almen 'N' strip as masked in (4) and peen it locally i.e. neither nozzle is moved nor the work-piece. Note the time required to peen to same arc height as at (4).

(f) Time to peen a fatigue specimen is given by,

Peening Time = 6 X Time obtained as in (5) X peening factor for curvature as in (1) X material factor as in (2)

It is needless to say that 98% - 100% coverage must be achieved.

EXPERIMENTAL WORK

In the present investigation two types of carbon steels were used and their compositions were as follows:

Spring steel C = 0.68 - 0.70%; Mn = 0.76%
P = 0.03%; S = 0.05% ; Si = 0.10%

Structural Steel C = 0.27 - 0.29%; Mn = 0.50%
P = 0.3%; S = 0.05%; Si = 0.25 - 0.28%

Mechanical properties in annealed condition

Spring steel U.T.S.= 750-770 N/mm^2;% Elongation = 10-15% ; HRC 13

Structural Steel U.T.S.= 450-500N/mm^2;% Elongation = 25% ; HRC 55

Peening Parameters

Spring Steel Shot size = S330 ; Air Pressure = 0.6 MPa
Stand-off = 30mm; Peening intensity = 0.20A

Structural Steel Shot size = S280 = Air pressure = 0.5 MPa
Stand-off = 30mm; Peening intensity = 0.25A

Peening time was 2 minutes for spring steel as calculated from above method (See step f).

Peening Time = 6 X20 X 1.45 X 0.67 = 116.58 Sec $\approx$ 120 Sec(2 Min).

Similarly for structural steel the peening time was 3 minutes.
Pneumatic peening chamber and schematic of Nozzle used for peening is as shown in Fig.1. In both the cases fatigue samples were rotating at 60 r.p.m.

Surface roughness consideration

Since surface roughness plays significant role on fatigue strength of a specimen, it is decided to keep the surface roughness as low as possible. For this three shots were tried (S280, S330 and S390) for the same specified intensity for spring steel, there was no appreciable difference in surface roughness. This might be due to the Syphonic system which was a low intensity system of peening. But S330 shot was selected for peening since it gave more fatigue strength than other shots in this particular case. This might be attributed to the effect of the shot diameter on the depth of work hardened strata [4]. For structure steel S280 shots were found suitable.

Material factor for work piece material of various hardness values under local peening were established experimentally, the material factor for spring steel was 0.67. For structure steel which was investigated for various hardness values, the variation of material factor with hardness was plotted in figure 2. It also shows variation of surface roughness and residual stress with respect to different hardnesses of work-piece to achieve saturation.

Surface roughness increases with higher exposure time and shot velocity [7]. Greater surface roughness has a negative effect on endurance and corrosion resistance [8]. For better adhesion of polymer coat, surface roughness and pre heating is advantageous up to certain limit, so that negative effect may not be there [9]. In the present investigation fatigue specimens as shown in fig.3a were tested for rotating bending. Fig.3b shows fractured specimen and its fractograph. Structural steel specimens were carburised to a total depth of 1.1mm and condition of heat treatment is shown in fig.4.

To study the effect of coating of polymer adhesives on corrosion fatigue M-Seal compound consisting of Resin MS 802 and Hardener MSH 274 were mixed in 10:1 by weight ratio and fatigue specimens were coated with uniform thickness of 0.1 mm at room temperature, 25°C.

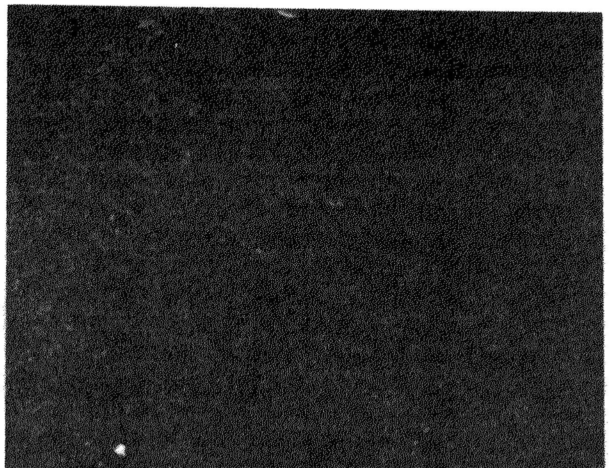
For studying corrosion fatigue behaviour, the cantilever rotating bending type fatigue testing machine with a special arrangement for corrodent pumping over the specimen was used. The entry of atmospheric oxygen was not restricted. It was observed under 3N, NaC1 Corrodent no survival was observed for both the steels. Effect of M-Seal coating was also investigated with out peening and with peening and experimental results for both the steels were presented in table 1.

RESULTS AND CONCLUSIONS

The corrosion fatigue results for two types of steels investigated were presented in table 1. Practically no survival was observed in both the varieties of steels. In spring steel, the coating after shot peening considerably increased the fatigue strength of the specimen than that of coated without peening. In structural steel i.e., low carbon steel shot peening combined with case carburising, hardening and tempering was benificial for increasing corrosion fatigue strength by 30% compared with carburised, hardened and tempered one. But carburised, hardened, tempered, shot peened and coated one has showed 50% improvement for above comparision.

This clearly showed that shot peening over harder surface has greater advantage. Hard polymer coating has delayed formation of corrosion pits and thus enhances corrosion fatigue of virgin as well as treated samples. But in both the cases coating after shot peening has greater advantage than that of unpeened coated samples. The S-N Curves were as shown in Fig.5 and 6. Fatigue fractographs were as shown in fig.7 a,b and c. In the present investigation coating was applied over the gauge length of specimen only. It was observed that after certain number of revolutions corrodent could enter through the interface but it was not so that early in case of shot peened and coated ones for same stress level. Hence it is concluded that shot peening has given better adhesion.

Further scope of work:- the effect of coating thickness and effect of grit peening and coating on corrosion fatigue behaviour can be investigated.



Micro structure of carburised structural steel showing 1.1mm thickness of caburised layer.

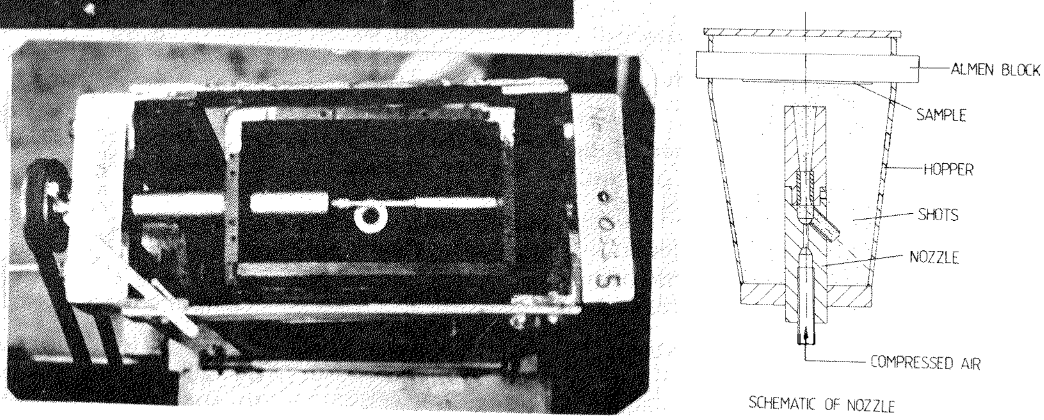


Fig.1 Pneumatic peening chamber and schematic of nozzle.

TABLE 1 - Corrosion Fatigue Results

S.No.	Test piece condition	Mean fatigue limit Kg/mm^2	% improvement
FOR SPRING STEEL			
1.	Virgin in annealed condition	31.5	
2.	Virgin shot peened	40	27
3.	Virgin under 3N NaCl corrodent	No fatigue limit observed	
4.	Virgin shot peened under 3N NaCl corrodent	"	
5.	Virgin M-Seal coated under 3N NaCl corrodent	12	
6.	Shot peened and M-seal coated under 3N NaCl corrodent	18	50% improvement compar ed to S.No.5
FOR STRUCTURAL STEEL			
1.	Virgin in annealed condition	19.25	-
2.	Virgin shot peened	26.20	36
3.	Virgin under 3N-NaCl corrodent	No fatigue limit observed	-
4.	Shot peened under 3N NaCl corrodent	"	
5.	Carburised & Hardened	20.97	8.93
6.	Carburised, Hardened and peened	27.50	42.85
7.	Carburised, hardened and tempered, under 3N-NaCl corrodent	7.00	--
8.	Carburised, hardened, tempered and shot peened under 3N, NaCl corrodent	9.10	30 compared to S.No.7
9.	Virgin M.Seal coated	No fatigue limit observed	Fatigue life improved by 20% as compared to the condition at S.No.3
10.	Carburised, hardened, tempered, shot peened and M.Seal coated tested under corrodent 3N-NaCl.	10.50	50% improve compared to S.No.7

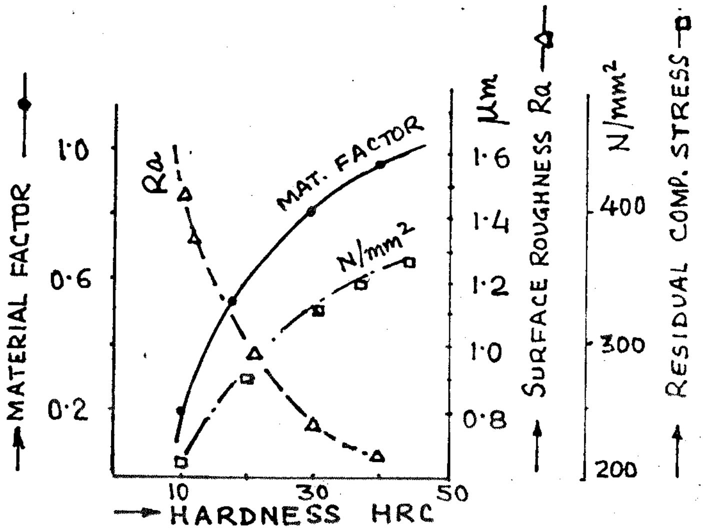
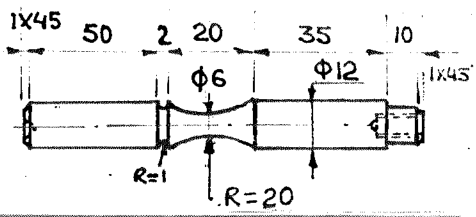
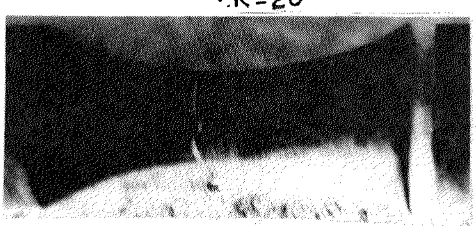


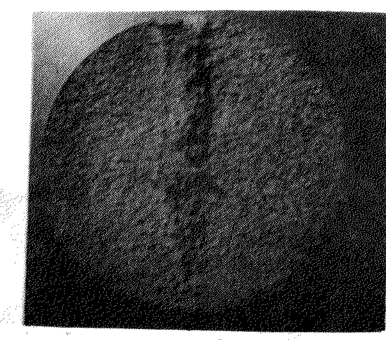
Fig.2 Variation of material factor, residual compressive stress and surface roughness with respect to hardness for structural steel



3(a) Details of fatique specimen



3(b)



3(c)

3(b) Broken fatigue specimen 3 (c) fractograph of 3(b)

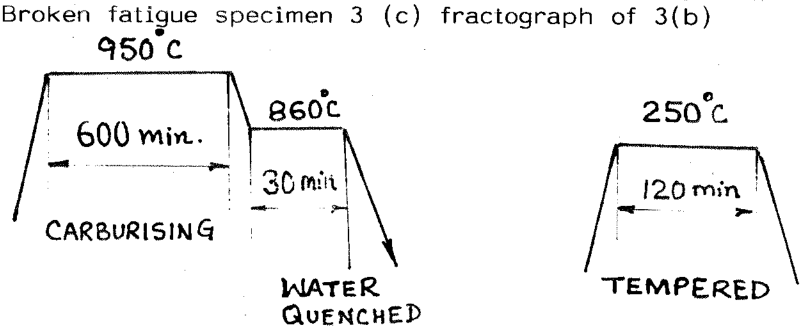


Fig.4 Condition of heat treatment

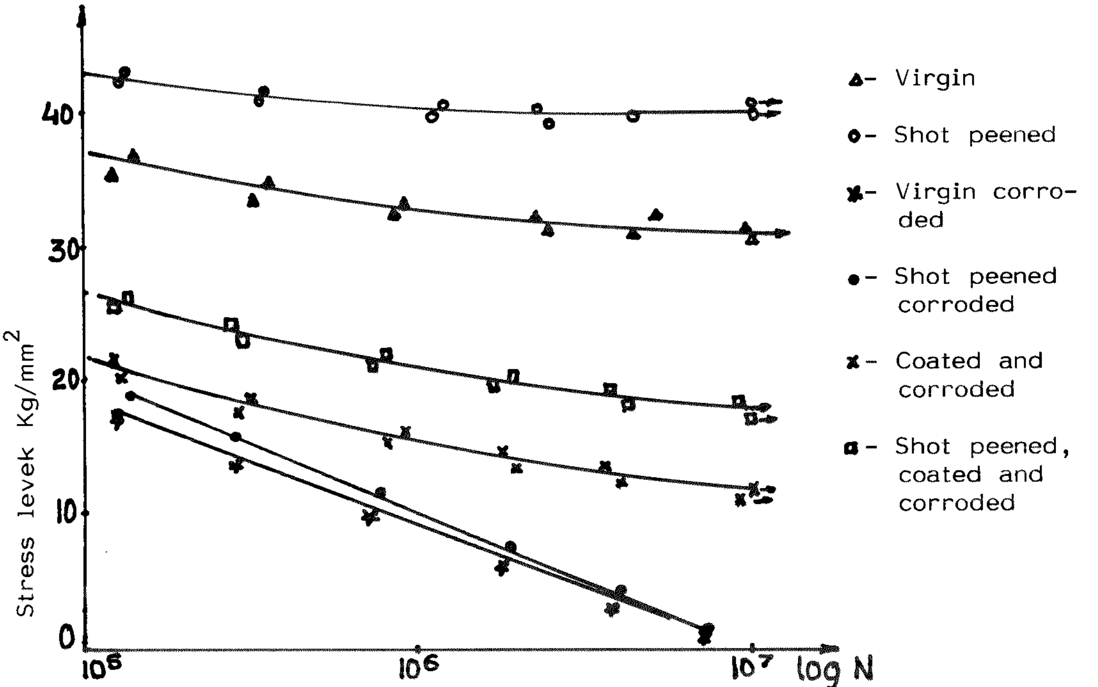


Fig.5 S-Log N Curves for spring steel

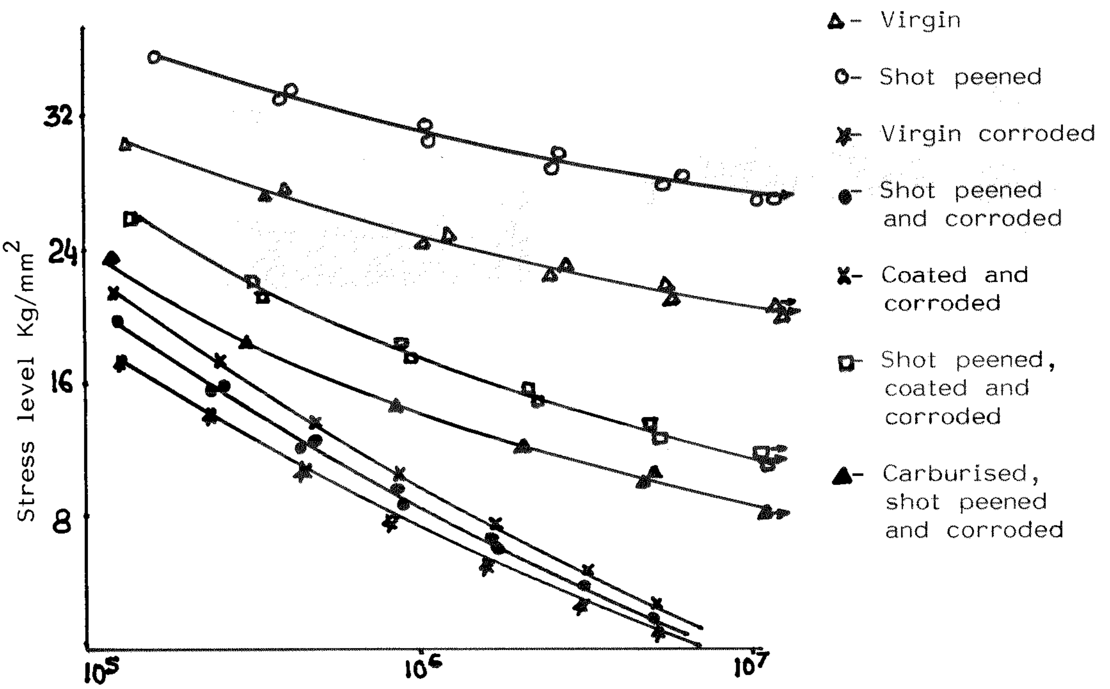
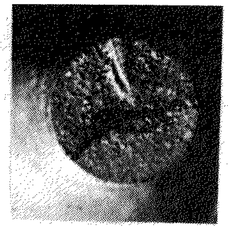
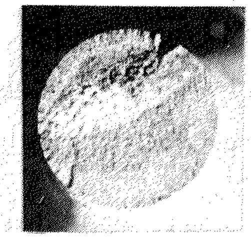


Fig.6 S-log N Curves for structural steel

7(a) (i)

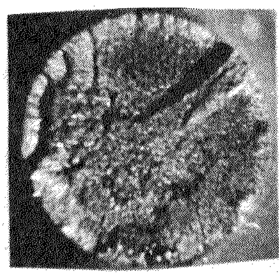


7 (a) (ii)

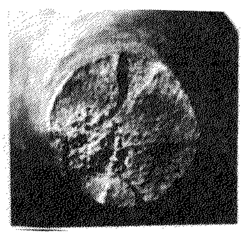


7 (a) (iii)

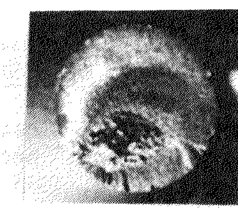
Fig.7 (a) Fractographs of spring steel X4-X5
(i) Virgin under corrodent (ii) Virgin coated under corrodent
(iii) Shot peened, coated under corrodent.



7 (b) (i)



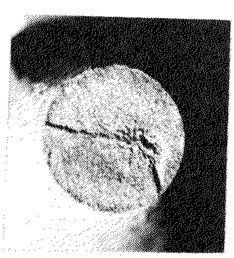
7 (b) (ii)



7 (b) (iii)

Fig.7 (b) Fractographs of structural steel X4-X5
(i) Virgin under corrodent, X7 (ii) Carburised under corrodent
(iii) Carburised, shot peened under corrodent

7 (c) (i)



7 (c) (ii)

Fig.7 (c) Structural steel contd.. (i) Virgin coated under corrodent,
(ii) Shot peened and coated under corrodent

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