The Improvement of Fatigue Durability of Carburized Steels with Surface Structure Anomalies by Shot Peening

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ABSTRACT

Shot peening was applied to improve the fatigue durability of carburized steels with surface structure anomalies (internal oxides precipitated along the grain boundaries and accompanied nonmartensitic microstructure near the surface). Rotating bending fatigue tests were carried out on the shot peened specimens both with and without surface structure anomalies. The fatigue strength of both the specimens were successfully increased by shot peening and was comparable to each other. Thus, it was confirmed that the shot peening was extremely effective to improve the fatigue durability of carburized steels with surface structure anomalies.

KEY WORDS

carburized steel, surface structure anomalies, fatigue strength, residual stress.

INTRODUCTION

It is well known that the surface structure anomalies (s.s.a.) of carburized steel are very harmful to its fatigue properties (Gunnarson,1963. Robinson,1957. Nakanishi, Ueda and Kajiura,1977. Arkhipov, Polotskii, Novikova, Yorasov and Nikonov,1967) and can not be sufficiently avoided during industrial carburizing process (R. Chatterjee-Fisher,1978. Koslovskii, Talinin, Novikova, Levedeva and Feofanova,1967).

In this study, the influence of s.s.a. on the fatigue behavior of carburized steel was evaluated through rotating bending fatigue tests. Then, shot peening was applied to improve the fatigue durability of carburized steel with s.s.a. Rotating bending fatigue tests were carried out on the shot peened carburized specimen with s.s.a. A several peening conditions were employed to evaluate the optimum condition for the fatigue strength. The results were compared to that for the shot peened specimen without s.s.a.

EXPERIMENTAL PROCEDURE

The Cr-Mo steel (JIS SCM415) used in this study is specified in Table I (all numbers in wt.-%).

Table 1

C	Si	Mn	P	S	Cr	Mo
0.16	0.26	0.74	0.012	0.013	1.01	0.18

After normalizing at 950 C, 1 hour, the 20 mm in diameter steel bar was machined to the shape of the specimen described in Fig.1 and finished by griding using No.320 sand paper. The condition of heat treatment is shown in Fig.2. The presence of s.s.a. was confirmed by micro hardness measurements near the surface and the observation of microstructure. The depth of s.s.a. was about 30 µm.

Shot peening machine used in this study is rotating blowing type.

Specimens without s.s.a. were prepared by electropolishing the surface layer about 50 µm in depth after heat treatment.

Fatigue test employed a rotating bending fatigue test machine of 10 kg-m in load capability and 3000 r.p.m. in cyclic speed. Tests were performed at room temperature in laboratory air atmosphere.

EXPERIMENTAL RESULTS

1 Influence of s.s.a. on the fatigue behavior of carburized steel

Fig.3 shows the difference of fatigue behavior of carburized steel with and without s.s.a. The S-N diagram of the specimen with s.s.a. revealed two knees and was divided into two portions i.e. the experimental results with $Nf<10^5$ and that with $Nf>10^6$. The fatigue limit could not be obtained in the stress cycles tested in this study. In contrast, the S-N diagram of the specimen without s.s.a. did not reveal a knee. The fatigue strength of the specimen without s.s.a. is much higher than that of as carburized specimen. The cause of the characteristic fatigue behavior of carburized steel with s.s.a. was discussed from the difference of crack propagation mode near the fracture origin between two portions of S-N diagram (Naito, Ueda and Kikuchi, 1983, 1984).

2 Effect of shot peening

a. Hardness, residual stress and retained austenite distributions near the surface

Fig.4 shows the Vickers hardness, residual stress, and retained austenite distributions near the surface of the specimen with s.s.a. The results of before and after shot peening are both presented as an example of the change of surface properties. The measurements of retained austenite was made on 10x10x20 mm square bar specimen which was heat treated in the same condition as fatigue test specimen.

In this case, these changes are observed to the depth of about 130 µm.

b. Fatigue behavior of the shot peened specimen with s.s.a. (Effect of shot size)

Fig.5 shows the results of rotating bending fatigure test on specimens shot peened with three sizes of shot (0.3, 0.6, 0.8 mm in diameter). Shot speed employed here was 46 m/sec. and peening time was 10 min.

The fatigue strength (applied stress at 10^7 and $5x10^7$ stress cycles, not the fatigue limit) of the shot peened specimens are quite higher than that of as carburized specimen and increase with increasing the shot size as follows.

Shot size	Applied stress at 10^7 cycles	Applied stress at $5x10^7$ cycles
As carburized	800 (N/mm^2)	700
0.3 mm	1050	-----
0.6	1150	1000
0.8	1150	1050

The S-N diagram of each specimens are divided into two portions like as carburized specimen. Regarding the specimen treated with 0.3 mm shot, all were fractured from the surface origins. The other specimens treated with 0.6 and 0.8 mm shot were fractured from subsurface fish eye type origin in high cycle fatigue region ($Nf>10^6$).

c. Fatigue behavior of the shot peened specimen with s.s.a. (Effect of peening time)

Fig.6 shows the results of rotating bending fatigue tests on specimens treated with several peening time (0.5, 1, 3, 5, 10 min.). The shot size used here is 0.6 mm in diameter. The experimental results in high cycle region were classified two portions by the position of fracture origin. The position of fracture origin has changed from the surface to subsurface (fish eye) with increasing the peening time. Fig.7 shows the relation between the peening time and the fatigue strength of shot peened specimen.

d. Fatigue behavior of the shot peened specimens both with and without s.s.a.(Comparison of the fatigue strength)

Fig.8 shows the results ofrotating bending fatigue tests on shot peened specimens both with and without s.s.a. The condition of shot peening are as follows; shot size=0.6 mm, shot speed=46 m/sec and peening time=10 min. The fatigue strength of both the specimens were increased and become comparable after shot peening.

CONCLUSION

(1) The s.s.a. decreased the fatigue strength of carburized steel.

(2) Shot peening increased the fatigue strength of carburized steel with s.s.a.

(3) The fatigue strength of carburized steel both with and without s.s.a. became comparable to each other after shot peening.

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FIGURE

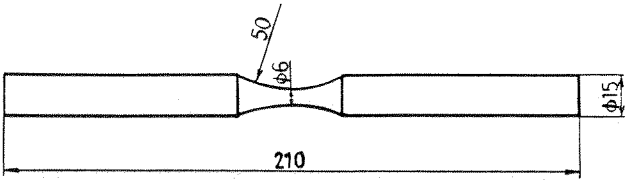

Fig.1 Shape and dimension of rotating bending fatigue test specimen.

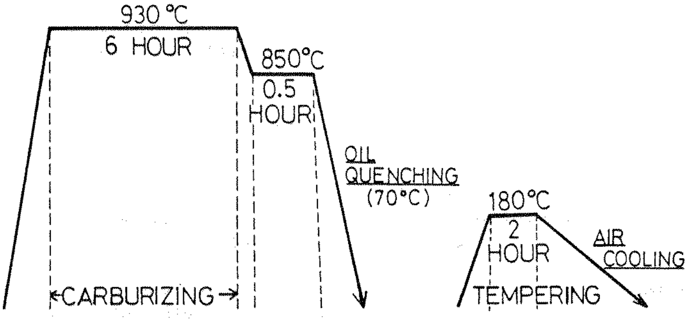

Fig.2 Condition of heat treatment.

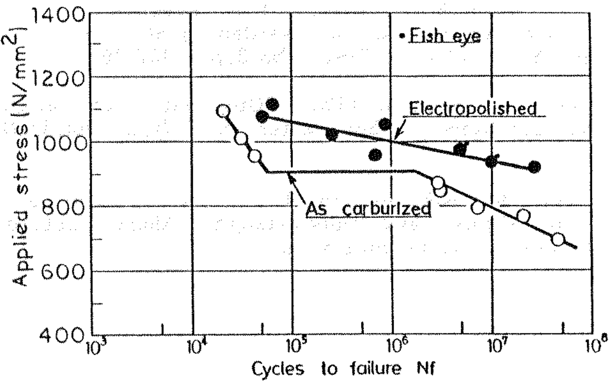

Fig.3 S-N diagram of rotating bending fatigue tests on carburized steel both with and without s.s.a.

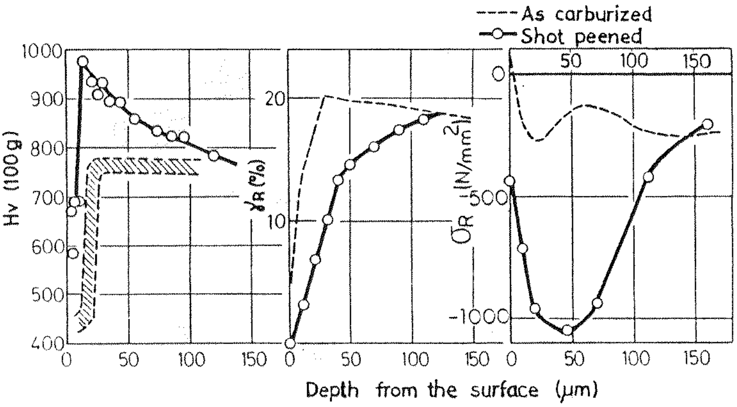

Fig.4 Vickers hardness, residual stress and retained austenite distribution near the surface of the specimen with s.s.a. The results of before and after shot peening are both presented. (Peening condition; shot size=0.6 mm, shot speed=46 m/sec., peening time=10 min.)

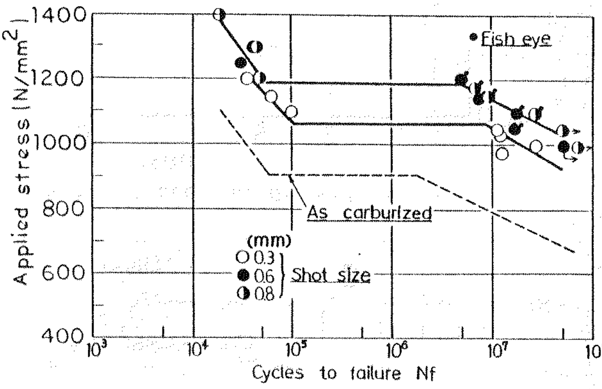

Fig.5 S-N diagram of rotatimng bending fatigue test on the shot peened specimen with s.s.a. (Effect of shot size)

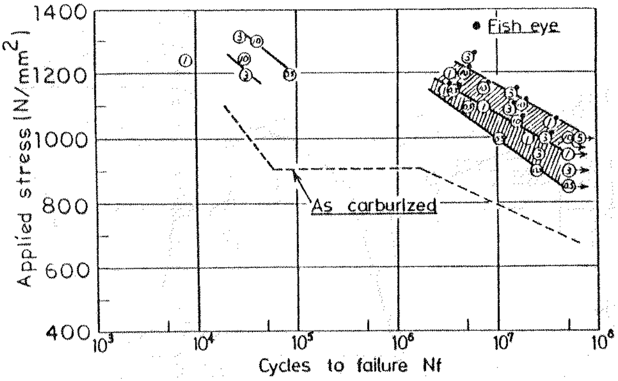

Fig.6 S-N diagram of rotating bending fatigue test on the shot peened specimen with s.s.a. (Effect of peening time)

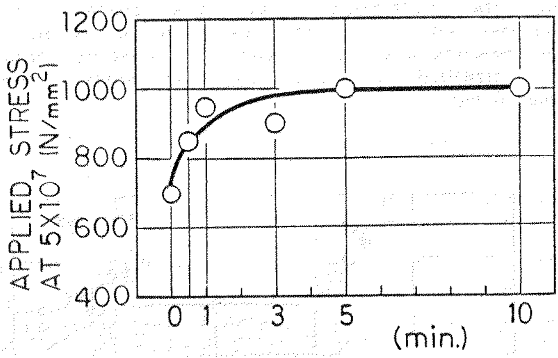

Fig.7 Relation between peening time and the fatigue strength.

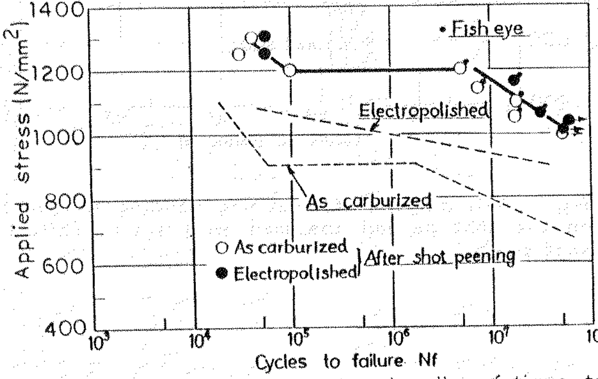

Fig.8 S-N diagram of rotating bending fatigue test on the shot peened specimen both with and without s.s.a. (Comparison of fatigue strength)