EFFECT OF SHOT PEENING ON FATIGUE STRENGTH OF NOTCHED SPECIMENS

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ABSTRACT

Bending fatigue tests were carried out on smooth and notched (stress concentration coefficient K_t=1.5 and 3.0) specimens of 40Cr steel to determine the the fatigue strength for $5X10^6$ by up-and- down method. The specimens were shot peened and ground after heat treatment(quenched and tempered at 200℃ and 550℃). Special attentions were paid to determined the positions of crack sources on the specimens with the longest lifes in each group. It is realized that for specimens with K_t =1.50, the shot peening pushes the crack sources to subsurface and results in higher improvement in fatigue strength. The apparent fatigue strength of notched specimens tempered at 550℃ even reaches that of smooth specimens after shot peening. For notched specimens with K_t=3.0, the crack source after shot peening still initiates at the root of the notch from the surface and the improvement of fatigue strength is not so siganificant as in above case.

KEYWORDS

Shot peening, Fatigue strength, Notched specimen

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NOMENCLATURES

CRS (F)	Compressive residual stress (field)
TRS (F)	Tensile residual stress (field)
Z_o	Depth of CRSF
Z_s	Distance of fatigue source to surface
σ_{ws}	Surface fatigue strength of un-hardened specimens
σ_{wa}	Apparent fatigue strength of shot peened specimens
T_t	Tempering temperature
σ_{wi}	Internal fatigue strength

INTRODUCTION

Shot peening is an effective method to improve the fatigue strength of components and structures, especially for notched ones [1] [4]. In our previous works, the effects of shot peening on the fatigue strength of smooth specimens have been discussed in detail [2] [3]. Here, some works about the effect of shot peening on the fatigue strength of notched specimens will be investigated.

EXPERIMENTAL PROCEDURES

The investigations were carried out with a low alloy steel 40Cr (chemical composition in wt %: 0.41C, 0.72Mn, 0.19Si, 0.03P, 0.009S, 1.0Cr, 0.08Ni). The smooth specimens and notch specimens with notch R=16mm (K_t =1.5 and R=1.0mm (K_t=3.0) were shot peened and electro-polished after heat treatment (quenching and then tempering at 200℃ or 550℃). The shot peening were conducted with an air-blast machine. Cast steel shots with hardness of 44 to 48 HRC were used at a pressure of 3.0 bar and the coverage is 200% with Almen intensity 0.4mm.

The compressive residual stress distributions along the hardened layer from the notch root were determined. The depth of compressive residual stress Z_o were measured and are listed in Tab. 1.

Three-point bending fatigue test were carried out determine the fatigue strength for $5X10^6$ by using up- and- down method [5] . The positions of crack sources on the specimens with the longest lifes in each group of shot peened specimens were determined under scanning electron microscopy and the distance of crack source from the surface Z_s were measured. In this paper, the fatigue strength of unhardened specimens is called surface fatigue strength σ_{ws} and that of hardened specimens is called apparent fatigue strength σ_{wa}.

EXPERIMENTAL RESULTS AND DISCUSSION

All testing results are listed in Tab. 1. As expected, shot peening improves the fatigue strength in all cases.

Tab. 1 The Experimental Results

Steel	Symbol of specimens	Tt ℃	K_t	Z_o um	Z_s um	σ_{ws} MPa	σ_{wa} MPa	σ_{wa}/σ_{ws}
	A1	200	1.00	330	470	1060	1340	1.26
	A2	200	1.50	250	300	930	1210	1.30
40Cr	B1	550	1.00	240	280	820	1020	1.24
	B2	550	1.50	300	350	730	1080	1.48
	B3	550	3.00	320	0	520	700	1.34

By comparing the values of σ_{wa}/σ_{ws} of notched specimens (A2, B2, B3) with those of smooth specimens (A1, B1), it can be seen that the former ones acquire greater improvement in fatigue strength. It should be also be indicated that, in contrast with the fact that for unhardened specimens, the fatigue cracks always initiate at the surface, the fatigue sources of shot peened specimens may be located either at surface (B3) or in the subsurfaceregion (A2, B2).

As pointed out in [7], the improvement of fatigue strength after shot peening should be related with different effects in these two cases.

For blunt-notch specimens with K_t=1.50, the better improvement in fatigue strength after shot peening may be related with the change of the fatigue source locations. In these specimens(A2, B2) , the fatigue sources are all located in subsurface regions beneath the hardened layer $Z_s>Z_o>0$ (Tab. 1). The improvement of fatigue strength of smooth specimens when fatigue source is located in subsurface region has been discussed in detail in [7]. It is believed, that in this case, the main effect responsible for improvement is the fact that the internal fatigue strength σ_{wi} is much higher than the surface fatigue strength σ_{ws} of the same material[7].This effect should also be valid for notched specimens. But for notched specimens, another effect should considred. When the fatigue sources are located in internal regions, the stress concentration caused by notching at these poings should be weaker than that at the surface. This fact provides further improvement for notch specimens. Obviously, the deeper the crack source is located, the higher improvement in fatigue strength obtained. Under some shot peening conditions, the Z_a of 550℃ tempered specimen is higher than that of 200℃ tempered ones, so their σ_{wa}/σ_{wa} is higher and its σ_{wa} even reaches the level of σ_{wa} of smooth specimen after shot peening.

For the sharp-notch specimens with K_t=3.0, the fatigue source is still located at the surface of notch root even after shot peening. The better improvement in fatigue strength after shot peening may be due to the concertration of rasidual stress induced by shot peening [1]. But in this case, the improvement of σ_{wa} is not so significant as for blunt -notch specimens.

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