SHOT-PEENING EFFECT IN CORROSION FATIGUE STRENGTH OF STRUCTURAL MATERIALS

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ABSTRACT

In this paper the shot-peening effect on corrosion fatigue strength of structural materials is reviewed mainly on the basis of the author's experimental results. It can be concluded that shot-peening effect can be expected in relatively higher stress level of S-N diagrams. The lower the stress level, the smaller the shot-peening effect is. In the very high cycle regime shot- peening effect cannot be expected when corrosion pit initiate easily even compressive residual stress remains on surface layer of specimen.

1 INTRODUCTION

In general, it is well understood that the shot-peening process produce residual compressive stress in the surface layers of the machine components. Most of the fatigue crack and stress corrosion cracking normally initiate at surfaces stressed in tension. Therefore the residual surface compressive stress usually improve fatigue strength and resistance of stress corrosion cracking [1]. However, corrosion fatigue is a time dependent phenomenon and the shot-peening effect on corrosion fatigue strength is not fully understood. In this paper shot-peening effect on corrosion fatigue strength of structural materials in conventional S-N diagrams and in very high cycle regime is briefly reviewed mainly on the basis of the author's experimental results.

2 SHOT-PEENING EFFECT ON CORROSION FATIGUE STRENGTH OF STRUCTURAL MATERIALS IN CONVENTIONAL S-N DIAGRAMS

The high strength spring steels such as SUP9 and SUP 10M for automobile suspension springs are most frequently exposed to severe environments such as deicing salts. The reduction of fatigue strength of these high strength steels in 3 percent NaCl aqueous solution were 80 percent in both SUP9 and SUP10M steel [2]. In this experiment corrosion fatigue tests for shot-peened specimens were also conducted. The corrosion fatigue test results by three point bending fatigue test are shown in Fig.1. The shot-peening effect on fatigue strength of SUP9 was remarkable in air. The shot peening-effect on corrosion fatigue strength of SUP9 and SUP10M was also found in 3 percent NaCl aqueous solution. The reduction of fatigue strength of SUP9 by 3percent NaCl aqueous solution was 74 percent. The reduction of fatigue strength of SUP10M was same as that of SUP9. Improvement of corrosion fatigue strength by shot- peening was observed for both steels. The residual stress distribution was measured on unbroken specimen of SUP9 and SUP10M after

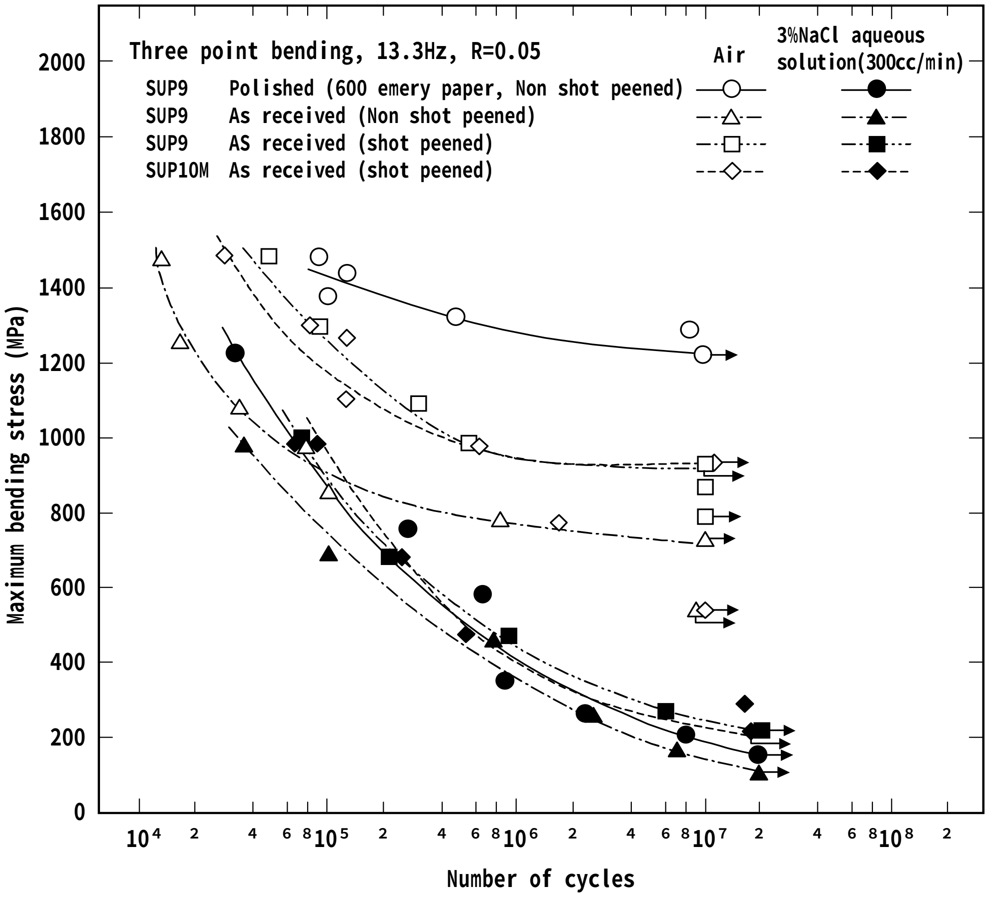

Fig.1 S-N curves of corrosion fatigue strength of spring steels in air and in 3 percent NaCl aqueous solution [2].

$2x10^7$ cycles in 3 percent NaCl aqueous solution by X ray diffraction method. The measured residual stress distribution was almost the same as those of the specimens before fatigue test. The maximum compressive residual stress given at 0.1mm depth from surface was 700 and 750 MPa for SUP9 and SUP10M steel, respectively. It was reported that the most of the fatigue life time of the shot-peened specimen was spent in crack propagation from the surface to the site with maximum compressive residual stress and that shorter the distance between the surface and the site with maximum compressive residual stress, the longer was fatigue life[3]. Baxa et al. investigated on effects of shot-peening on corrosion fatigue strength of AISI 6150 steel in 3 percent NaCl aqueous solution. They observed that the shot-peening treatments did not appear to hinder the corrosion fatigue crack initiation. They concluded that the increase in corrosion fatigue life time exhibited by the shot-peened specimens is attributed to a reduced early fatigue crack propagation rate in the surface compressive residual stress layer [4]. Fig.2 shows initiation area of corrosion fatigue fracture surface of shot-peened SUP9 steel. Many corrosion pits were observed on the specimen surface and the corrosion fatigue crack initiation area was severely corroded. Iron oxides such as α-FeO(OH), γ-FeO(OH) and Fe3O4 are identified by the X-ray diffraction analysis of

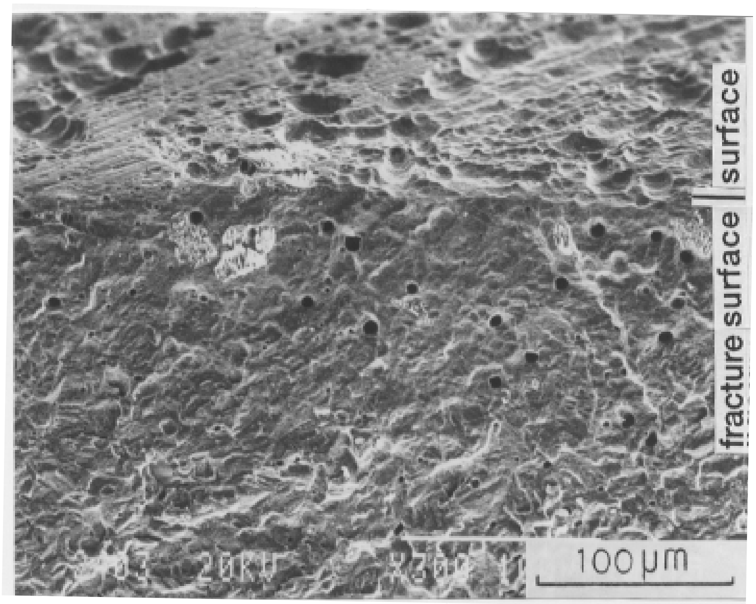

Fig.2 Initiation area of corrosion fatigue fracture surface of shot-peened SUP9 steel

three point bending, 3 percent NaCl aqueous solution,147.1MPa,$2.2x10^5$ cycles

corrosion products. Thus it can be concluded that the positive effect of shot peening is expected in corrosive environment containing Cl^-, if the compressive residual stress remains in the surface layer of the suspension leaf spring. Shot-peening also improved corrosion fatigue strength of 7075 and 7076 aluminum alloys in 3% NaCl aqueous solution [5].

Takeuchi and Honma investigated on shot-peening effect on corrosion fatigue strength of Si-Mn spring steel in distilled water and in various contents of H_2SO_4 aqueous solution. They considered that the surface stressing by shot-peening is always effective in the view of prevention of fatigue failure under practical service condition which is usually accompanied by a somewhat corrosive atmosphere. They also found that the shot-peening effect was most remarkably observed in distilled water and that it decreased as the contents of H_2SO_4 increased in 0.001, 0.01 and 0.1N in order. They found that the more corrosion fatigue cracks were observed in severer aggressive environment. They also found that shot-peening effect decreased as the number of cycles increased [6].

3 SHOT-PEENING EFFECT IN CORROSION FATIGUE STRENGTH OF STRUCTURAL MATERIALS IN VERY HIGH CYCLE REGIME

As afore mentioned that increasing the number of cycles the shot-peening effect decreases.

Therefore the emphasis is focused upon the shot-peening effect on corrosion fatigue strength in very high cycle regime. Fig3 shows the results of ultrasonic corrosion fatigue testing of 12 Cr stainless steel in various concentrations of NaCl aqueous solution. Positive effect of shot-peening can be observed in the high stress and low cycle region. The shot-peening effect decreased as number of cycles increased. In the low stress and high cycle region the positive effect could not be observed at all [7]. The same tendency was also reported on shot peened specimen for Type 403 steel[8].The vanishing number of cycles for shot-peening effect were $7\text{x}10^8$ cycles in 3% NaCl aqueous solution and $2\text{x}10^9$ cycles in $3\text{x}10^{-2}$ percent NaCl aqueous solution. The vanishing number of cycles moved to the higher number of cycles as NaCl concentration decreased. Corrosion pit at the initiation area and intergranular fracture at propagation area were observed on fracture surfaces of the shot-peened 12 Cr stainless steel. Shot- peened depth was estimated 0.2 to 0.3mm from the specimen surface by hardness on cross section of the specimen. The subcracks associated with tiny corrosion pits were also observed on the unbroken specimen surface after 10^{10}cycles.

Fig.4 shows typical subcracks associated with corrosion pit found on shot-peened specimen [7].The residual compressive stress measured on specimen as shot-peened was -333.4MPa. While in the very high cycle regime of 10^{10} cycles after corrosion fatigue test in the stress amplitude of

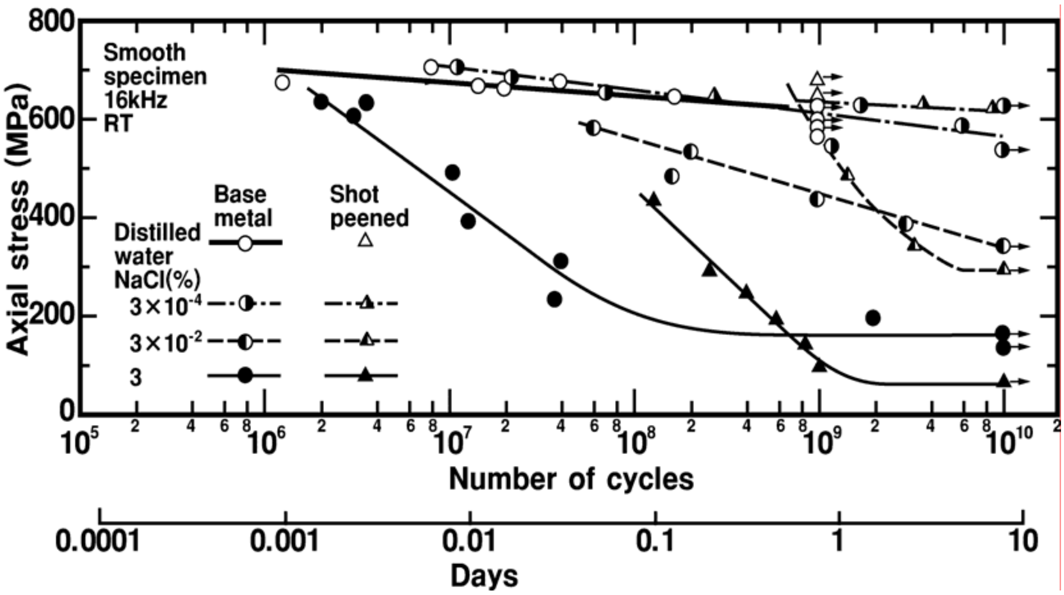

Fig.3 S-N curves of 12 Cr stainless steel in various content of NaCl aqueous solution [7]

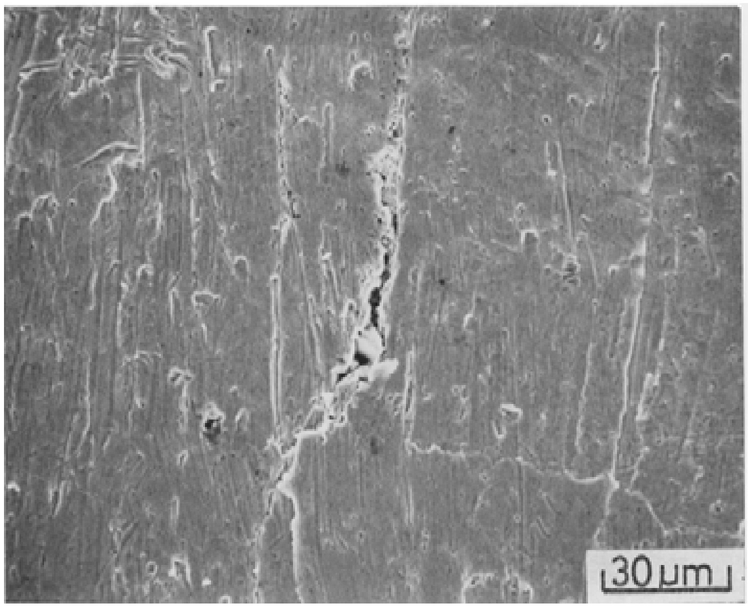

Fig.4 Subcrack associated with corrosion pit found on unbroken shot-peened specimen after 10^{10} cycles[7], 3 percent NaCl aqueous solution, 73.5MPa

73.5MPa, the compressive residual stress was -331.8MPa. Thus it was observed that the compressive residual stress was almost same as when shot-peened after corrosion fatigue testing up to 10^{10} cycles. The reason why the shot- peening effect vanished in the very high cycle regime can be explained by the shot-peened specimen surface being sensitive to corrosion and corrosion fatigue crack initiated earlier.

4 CONCLUDING REMARKS

The shot-peening effect in corrosion fatigue strength of structural alloys was briefly reviewed mainly on the basis of the author's experimental results. It can be concluded that shot-peening effect can be expected in relatively high stress level of S-N diagrams. The lower the stress the smaller the shot-peening effect is. In the very high cycle regime shot-peening effect cannot be expected when corrosion and corrosion pit initiate easily even compressive residual stress remains on surface layer of the specimen.

REFERENCES

1.J.E.Cambell, Shot Peening for Improved Fatigue Properties and Stress-Corrosion Resistance, MCIC Report, MCIC-71-02, Metals and Ceramics Information Center, 1971

2.Y.Kurihara,S.Takasaki, M.Kobayashi,R.Ebara,Y.Yamada and Y.Murakami, Proc.Intern.Sympo. Impact of Improved Material Quality on Properties, Product Performance, and Design, MD-Vol.28, pp.51-62.,1991

3. A.Tange,T.Akutsu and N.Takamura, Proc. JSSR,pp.1-6.,1990

4. M.S.Baxa,Y.A.Chang and L.H.Burck, Metallurgical Transactions,9A(1978)pp.1141-1146.

5.K.Takeuchi,K.Sasaki and H.Yamamori, J.Material Science,Japan,15(1966),pp.492-498.

6.S.Takeuchi and T.Honma, J.Jpn.Inst.Metals,59(1958),pp.59-63.

7.R.Ebara, Y.Yamada and A.Goto, Ultrasonic Fatigue, Proc.First Intern.Conf. Fatigue and Corrosion Fatigue Up to Ultrasonic Frequencies, J.M.Wells,O.Buck,L.D.Roth and J.K.Tien Eds. Metall.Soc.AIME, pp.394-364.,1982

8. A.F.Conn and N.A.Nielsen, Fatigue at Elevated Temperature, ASTM STP520, pp.273-281.,1973