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AN EFFECT OF PEENING ON FRETTING FATIGUE

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ABSTRACT

A study has been made on the effect of shot peening on fretting fatigue, a complex deterioration phenomenon caused by the small amplitude relative motion of two metallic surfaces. To investigate this effect, two types peened specimens, having different surface roughness, and peened - annealed specimens were prepared. It was confirmed that shot peening improved fretting fatigue, and fretting fatigue strength increases with increasing roughness.

Keywords: Shot peening, Residual Stress, Fretting Fatigue, Roughness

INTRODUCTION

Fretting[1] is caused by small amplitude cyclical movement of two solid bodies in close contact and under pressure. The debris produced may not escape from their point of origin due to exerted high pressures and small movement. Fretting causes shear peaks by means od friction between the contact zones and the non-contact zones onto which are superposed local plastic deformations of the asperity. Then the minute relative displacement of contact surfaces subsequently causes the rupture of asperity, which then oxidizes. The phenomenon of metallic fragment dislocation will accelerate under the amplification influence of the oxidized particles. Severe surface damage will soon appear due to the influence of the applied service stresses of the moving parts added to the shear stress due to friction. Fatigue microcracks will develop and propagate leading to eventual part rupture.

Shot peening is widely recognized as a proven, cost-effective process to enhance the fatigue characteristics of metal parts, especially automotive parts[2]-[3]. It is generally recognized that one of the reasons for improvement on fatigue durability by shot peening is that the surface compressive residual stress is increased and the work hardening is occured. Shot peening is also applied to the improvement of stress corrosion cracking and pitting fatigue. However, there is little investigative research which has considered the effect of shot peening on fretting fatigue.

To investigate this effect, two types peened specimens, having different surface roughness, and peened - annealed specimens were prepared. It was confirmed that shot peening improved fretting fatigue, and fretting fatigue strength increases with increasing roughness.

EXPERIMENTAL PROCEDURES

The chemical composition of test specimens made of JIS SNCM439 is shown in Table 1. Roughly machined specimens were austenitized at 850°C for 90 min and oil quenched. Tempering treatments were performed at 620°C for 2 h. Table 2 shows the mechanical properties of specimens after heat treatment. Three groups of specimens were prepared to clarify the effect of shot peening on fretting fatigue. The first group of specimens were polished to obtain the surface roughness of approximately 0.5Rz after quenching and tempering; there are called QNP. In the second group, specimens were shot peened at two types of conditions to achieve different roughness; there are called QSPL=Rz:10μm and QSPH=Rz:40μm. The third group specimens, after shot peening, were reannealed to remove compressive residual stress induced by peening; called QSPAL and QSPAH. The geometry of fretting fatigue specimens and the testing method are shown in Fig.1 and Fig.2. Fretting fatigue tests were conducted by an electric servo hydraulic fatigue testing machine at frequency 20Hz and stress ratio R=0.1. Specimens were loaded with cyclic stress and small amplitude cyclical movement was occured at contact zone due to a plastic formation on specimens.

Shot peening was carried out by air type peening device, using two different shot media to obtain the different surface roughness. Shot peening conditions and surface roughness of each specimen are shown in Table 3. The surface residual stress of specimens after shot peening was measured by an X-ray diffractmeter with the 2θ-sin2Ψ method. Stress distribution was obtained by repeating the X-ray measurement and electrochemical polishing successively.

Table 1 Chemical compositions (wt%)

C	Si	Mn	P	S	Ni	Cr	Mo	Cu
0.40	0.26	0.71	0.023	0.017	1.73	0.77	0.16	0.001

Table 2 Mechanical properties

Yield Strength (MPa)	Tensile strength (MPa)	Elongation (%)	Reduction of area (%)	Hardness (HV)
947	1040	15.6	60.4	346

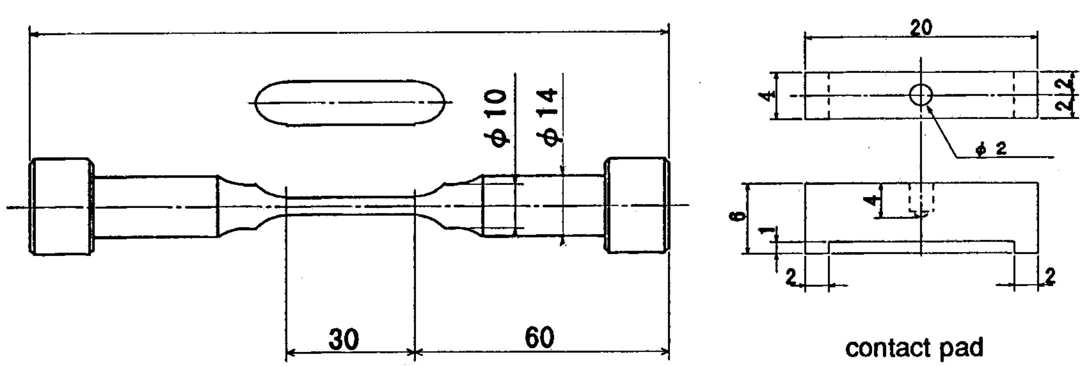


Fig.1 Geometry of specimen (contact pad)

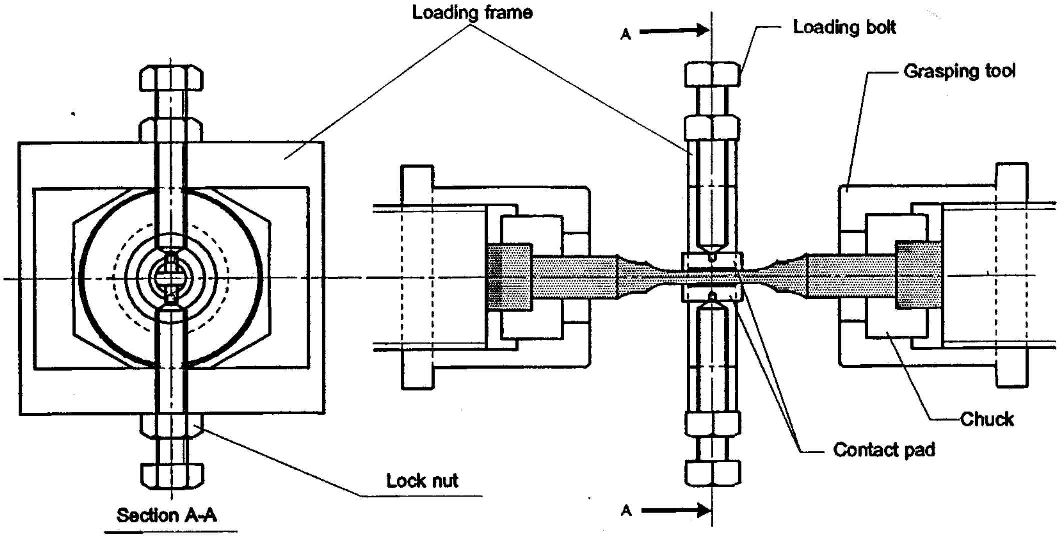


Fig.2 Testing device

Table 3 Shot conditions and surface roughness

Type of specimens	QSPL & QSPAL	QSPH & QSPAH
Diameter(mm)	0.3	1.0
Hardness(HV)	480	800
Air pressure(MPa)	0.3	0.4
Peening time(s)	30	30
Rotating speed(r.p.m.)	12	12
Surface roughness(Rz)	10	40

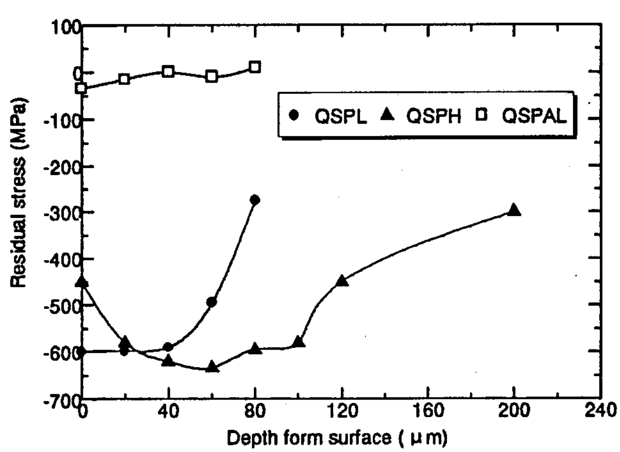


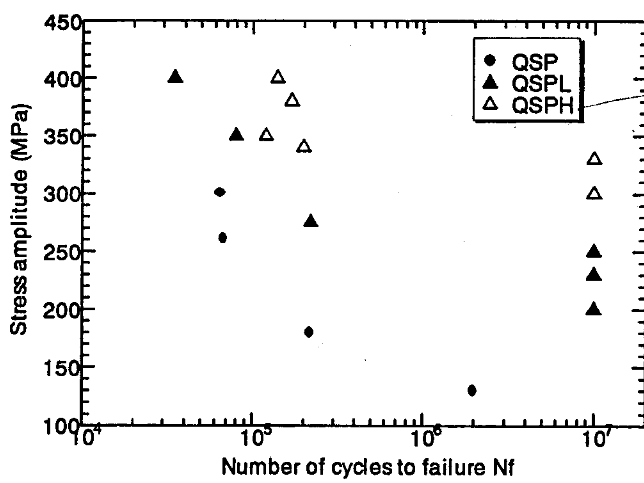
Fig. 3 residual stress distribution

RESULTS

Fig.3 shows the residual stress distribution after shot peening. The maximum compressive residual stress in QSPL and QSPH specimens were almost same, at approximately 600MPa even if the shot hardness were quite different. The reason is that both shot hardness were sufficiently high compared to the hardness of specimen. The magnitude of the stressed layer peened with the larger shot is deeper than that peened with the smaller shot. The residual stress of reannealed QSPAL specimen was well removed, as shown in this figure.

Fig.4 shows the results of the fretting fatigue test for each quenched and tempered specimen. The results for reannealed specimens are shown in Fig. 5. Shot peened specimens fail after a much longer loading time than quenched and tempered specimens. It was confirmed that the shot peening treatment improves the fretting strength. At comparisons between both shot peened specimens, the strength of QSPH specimens were higher than any other specimens. The fretting strength of reannealed specimens was remarkably low, compared with that of peened specimens. This means that the residual stress induced by shot treatment is one of the reasons for the improvement of fretting resistance. Similar to the resultsof Fig.4, roughened specimen was still higher than that of non-roughened specimen after removing residual stress. Therefore, it was considered that the surface roughness has an influence on the fretting fatigue.

Fig. 6 shows the relation between the stress amplitude and the tangential force using a strain gage that was placed on the center of contact pad. For all groups of specimens, the tangential force increases with increasing stress amplitude. Tangential force of roughened specimens, QSPH and QSPAH, were lower than that of QSPL and QSPAL. The fretting fatigue of roughened specimens was higher compared to non-roughened apecimens as mentioned above. As the results, in the case of roughened surface, it is considered that the sharp protuberances on surface should absorb tangential force through elastic transformation. This reduced tangential force contributes to improve the fretting fatigue strength.



Shotpeen higher intensity

Fig.4 S-N curve of quenched and tempered specimens

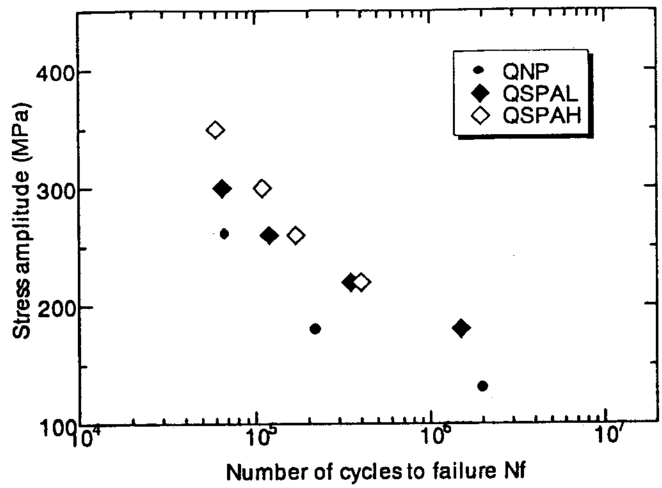


Fig.5 S-N curve of reannealed specimens

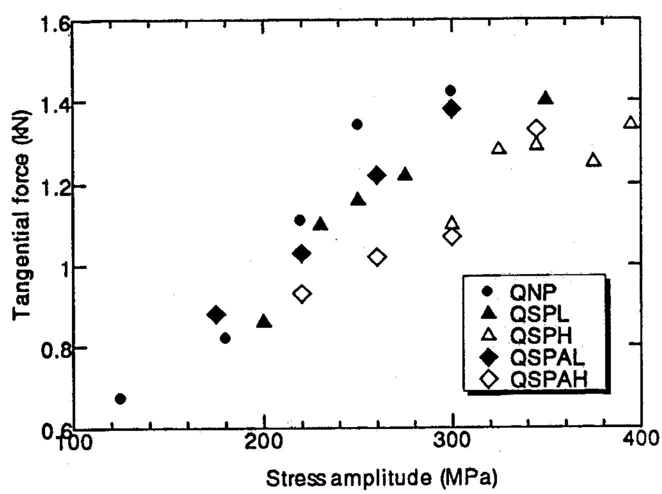


Fig.6 Relation between stress amplitude and tangential force

DISCUSSION

Fig.7 shows the results of SEM observations of fretting contact surfaces of QNP, QSPL and OSPH specimens, respectively. In the QNP specimen, a nonslip area was observed in which no relative slip was caused on the test specimen at the contact pad inner side. Moreover, on the outer side of the nonslip area, the occurrence of relative slip between the specimen and the contact change was observed, In that area, together with the reddish oxidation wear particles, there was a part where the wear particles accumulate in a lameller condition. This is the region in which all of the cracks appear. The QSPH specimen, which exhibits the greatest strength, has two regions, slip and non-slip region, like the QNP specimen. Due to great surface roughness, there tends to be little localized slippage. Moreover, even where wear might develop, there would be minimal abrasive wear due to the wear particles. On the other hand, the QSPL specimen has less surface roughness than the QSPH specimen, making it more apt to show abrasive wear, and which resembles thr QNP specimen.

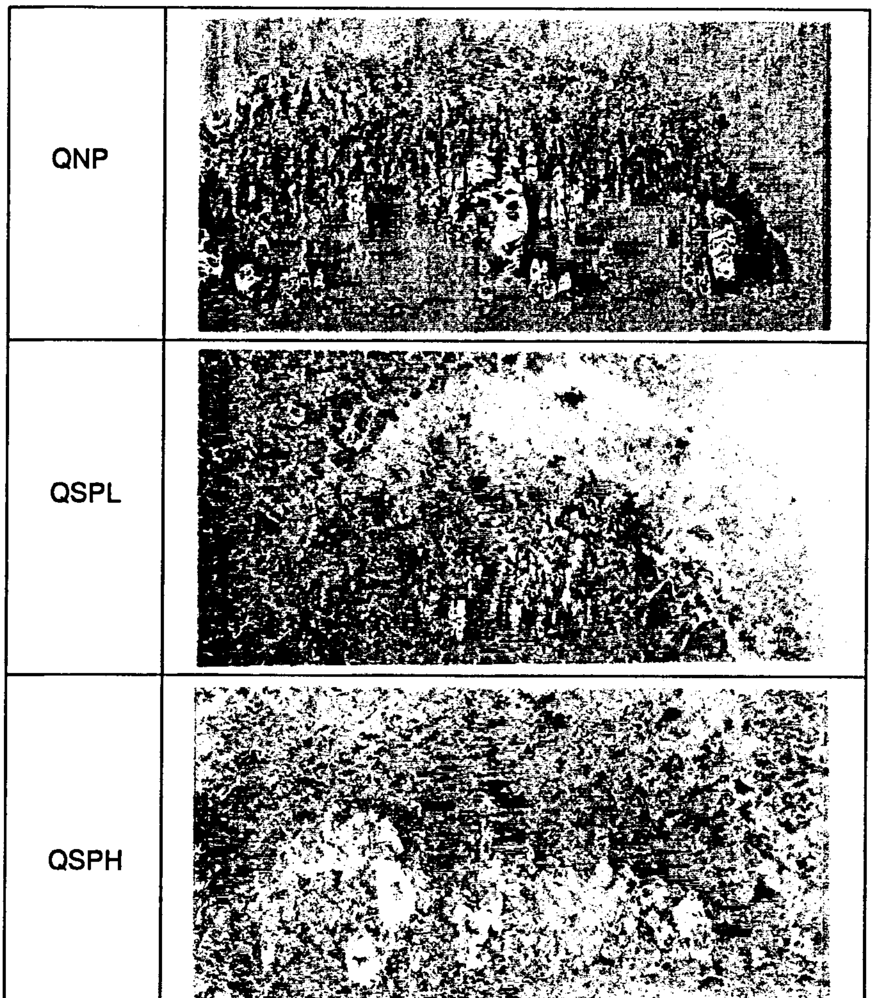


Fig.7 SEM observation

In light of these results and from confirming the position at which cracks emerge on the contact surface, the mechanism by which cracks developed in the present experiment is considered to be as follows. Fig. 8, 9 and 10 show models of the mechanism thought to be at work. First, with the QNP specimen, wear particles adhere due to the repeated stress amplitude, causing a tangential force to develop locally at the point where the adhered portion meet with the contact pad. Thus, a local force develops in the test specimen, causing cracks in the adhered portion where stress is concentrated. In the first stages with the QSPH material, the contact surface area is small and cracks do not emerge. However, as the wear progresses this contact area grows in size, tangential force increases, and cracking eventually occurs. Nevertheless, because of the considerable surface roughness, the effect of adherence found with the QNP specimen is small. Therefore, due to the length of time until accumulation, the life until breakage is long. Finally, with the QSPL specimen, there is initially the same trend as with QSPH specimen. Still, because of little surface roughness, the contact area grows sharply as wear progresses. Finally, adhesion similar to that of the QNP specimen occurs, breakage will then take place after cracks develop.

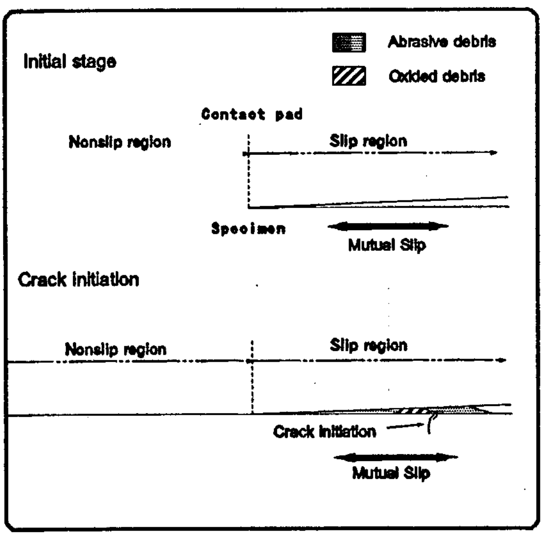


Fig.8 Mechanism of fretting (QNP)

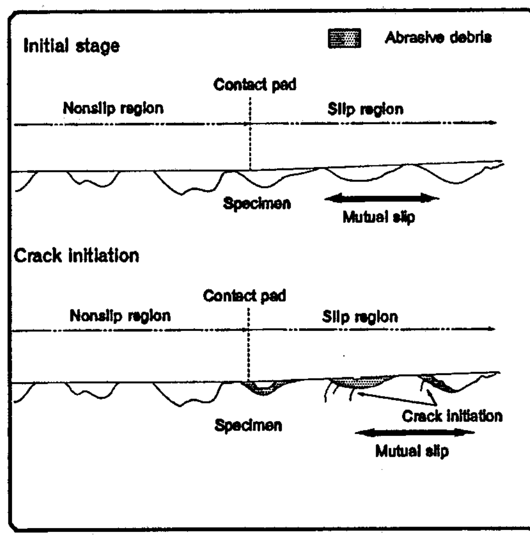


Fig.9 Mechanism of fretting (QSPH)

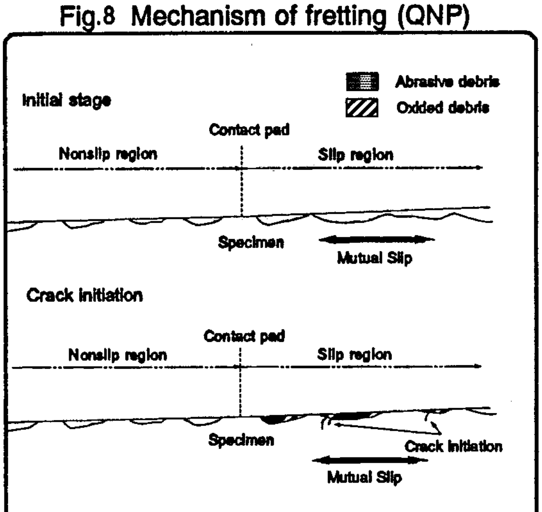
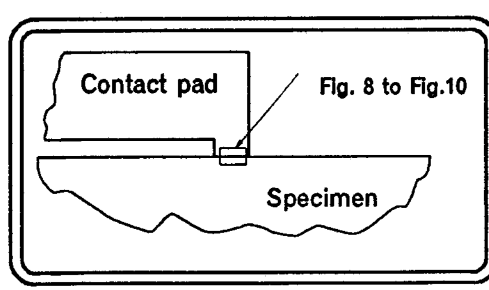


Fig.10 Mechanism of fretting (QSPL)



CONCLUSION

In the present study, to confirm the effect of shot peening on fretting fatigue life, three different groups of test specimens were employed to conduct tests using an electric servo hydraulic fatigue testing device. Moreover, the mechanism by which cracks develop was investigated on the basis of the tangential force in relation to fretting strength, along with the results of SEM observations of contact surfaces. Following is a summary of the results obtained:

1. Fretting strength is enhanced by shot peening. This is an effect of the compressive residual stress. Also with peening, the greater the surface roughness is, the greater the fretting strength. From the measurement of tangential force, cracks take longer to develop later where the surface roughness is great and the tangential force is small.
2. Fretting due to crack occurrence develops from concentration of the local tangential force.

The triggering of this tangential force is affected by the adhesion of wear particles to the test specimen and by dents.

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