# EFFECT OF ULTRA SHOT PEENING ON CONTACT SURFACE STRENGTH

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## ABSTRACT

For carburized gear, shot peening treatment is widely recognized for improvement of bending fatigue strength. However the effect of shot peening on tooth surface strength gears have not been clarified due to complicated mechanism. On the other hand, recently, Ultrasonic Shot Peening (USP) technology was developed by SONATS, France. The main characteristic of USP could be the smooth surface after operating compared to the conventional shot peening (CSP). In this study, roller fatigue test using a disk machine with rolling and sliding was carried out. As a result, surface strength of roller is deteriorated by shot peening treatment. But at the comparison between CSP and USP, the strength of USP would be remarkably higher than CSP.

## SUBJECT INDEX

Ultrasonic Shot Peening, Fatigue strength, Micro pitting, Residual Stress, Spalling

## INTRODUCTION

Shot peening treatment is used for automotive transmission gear in order to improve the bending fatigue strength economically. In addition, shot peening is recently adopted and studied for the improvement of contact surface strength. So, the effect of shot peening on the bending fatigue strength for carburized steel has been clarified[(1)-(2)], but the influence against the contact surface strength had not been developed due to complicated mechanism, as some studies announced that the increasing surface roughness is not effective to improve the contact strength.

Shear stress is considered as main stress to dominate the contact fatigue, because Hertzian stress creates compressive stress field and the influence of friction is considered. On the other hand shot peening treatments induces high compressive stress to affect the crack initiation and propagation. This high compression is considered to superpose the contact stress and Hertzian stress is considered to increase.

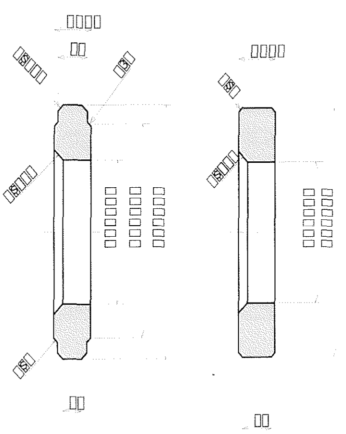
In this study, the authors investigated the effect of the shot peening on surface strength of roller using a disk machine with rolling and sliding. Fatigue test were carried out with carburized SCM420 steel roller specimen that was peened at two type conditions; Conventional air type shot peening and Ultrasonic shot peening. Here, Ultrasonic Shot Peening, named Stressonic® technology [(3)], was developed by

SONATS, France. The main characteristic of Stressonic® could give the smooth surface after operating compared to the conventional shot peening because of using polished bearing ball. So, specimens peened by Ultrasonic technology would be expected to show high contact surface strength compared to conventional air peening due to the smooth surface. Generally speaking, the failure at this testing type is considered to be caused by spalling, however it is necessary to study the micro pitting damage especially at case hardened steel like carburized gear. So, we also investigated the relation between spalling and micro pitting.

## EXPERIMENTAL PROCEDURE

The material of roller specimens in this study was JIS SCM420, which is equivalent to SAE4120. Roughly machines specimens were carburized and then machined to the roller shape. And after quenching and tempering, roller specimens were polished by grinder to improve the surface roughened by machining. The geometry of specimen is shown in Figure 1. Here the surface hardness of material was 700HV and the depth of carburized layer was 0.9mm. Shot peening was carried out by Stressonic® and conventional air peening device. Table 1 shows the shot peening conditions. In this study, we used polished bearing ball 1.4g weight for Stressonic® peening device. The amount of shot at Ultrasonic shot peening (hereunder USP) was extremely low compared to that at conventional air type peening (hereunder ASP) device. However, shot peening treatment time at ASP was one tenth of USP, because the density of shot projection stream was quite small at USP.

Figure 2 shows the schematic drawing of testing machine. Load stress was controlled by load spring and trusting screw. The viscosity of lubricator in this study was 206.3csT at 311K and the petrol pump controlled the amount of lubricator 4.17ml/s during testing. Temperature was 318K. In order to clarify the effect of shot peening treatment, the contact fatigue testing was carried out with Not-peened specimens (hereunder UNP), ASP and USP as mentioned before.



Lower Faster

Fig.1 Shape and dimension of test roller

Table 1 Shot peening conditions

| Shot-peening method | Ultrasonic type shot-peening unit | Air type shot-peening unit |
|---|---|---|
| Abrasives | SUJ2 □□.82 mm | CCW08PS □□.81 mm |
| Weight of shot grain injections | 1.4 g | 4.75 kg |
| Projection distance | 30 mm | 150 mm |
| Sonotrode amplitude | 90 μm | --- |
| Projection pressure | --- | 0.25 MPa |
| Revolutions per minutes for work | 6 rpm | 12 rpm |
| Blasting time | 360 sec | 30 sec |

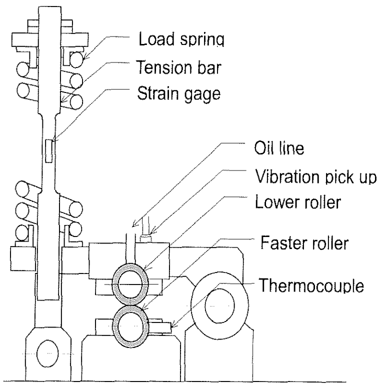



Fig.2 Schematic drawing of testing machine

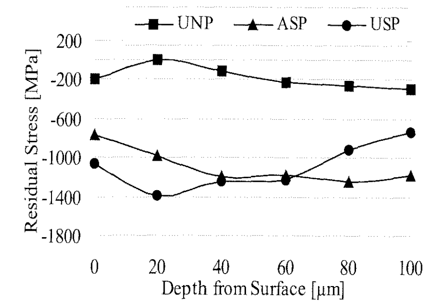
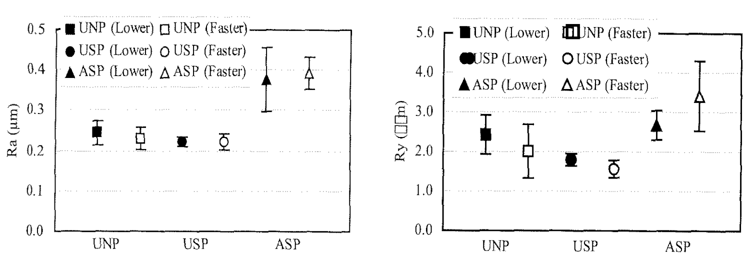



Fig.3 Residual Stress distribution




(a) Ra

(B) Ry
maximum height at roughness curve

Fig.4 Surface roughness of each test specimen

The rotating speed was 1,500r.p.m. and slip ratio was 0.162 at Lower roller and 0.139 at faster roller. The maximum load was 1.6, 1.8, 2.0GPa and observed the surface damage at every 2.0 X$10^6$ cycles.

Fig.3 shows the residual stress distribution of each specimens. The residual stresses were determined by X-ray diffractometer using the $\sin^2\psi$ - method. The residual stress distribution was obtained by repeating the X-ray measurement and electrochemical polishing. The surface residual compressive stress of USP was higher than that of ASP. The difference was about 200 MPa and surface value reached to –1,000MPa. However the effective layer at USP was considered to be smaller than ASP. This difference was caused by shot peening energy. In any case, both shot peening treatment induced higher compressive residual stress compared to UNP. Surface roughness after peening is shown in Fig.4. As shown in the figure, the surface roughness of USP specimen was smoothest compared to other specimens. And the roughness value of ASP was almost twice than USP. As mentioned before, the reason of this result was considered to be the polished ball at USP treatment with low shot velocity.

## RESULTS

### DAMAGE OF ROLLER SPECIMENS

After fatigue test, we observed a lot of micro pitting on the surface and lack at the edge of roller. In recently studies, it was pointed out that micro pitting is an important phenomenon for the fatigue damage of gears and also the lack at the corner could not be ignored. So in this study, micro pitting and the lack was observed to investigate the effect of shot peening treatment. In order to evaluate the damage ratio, we observed the surface situation at every 2.0 X $10^6$ cycle as mentioned before. The damage ratio was determined as (the area of all damage / all contact area). Further, to obtain the precise data, we used the computed image analyzer to calculate the damage ratio at 1,200dpi definition. Fig. 5 shows the relation between damage ratio and the numbers of cycle at each Hertzian stress. The results show the same tendency at every Hertzian stress. Namely, as increasing the number of cycles the damage ratio increased. And obviously, the damage ration at ASP was highest compared to another specimen's condition. Further, at all conditions of contact stress, the damage ratio at 1.0 X$10^7$ cycle was about 30% in ASP, about 10% in USP and roughly 5% in UNP. Once micro pitting was induced, the amount of total pitting number was increased until the specimen would be destructed. Fig.6 shows the number of cycles at 5% damage ratio. The contact fatigue strength can be easily compared using S-N curves. The contact fatigue strength of Not-peened specimen was higher than that of every shot peened specimens. And we could find that strength of Ultrasonic peened specimens was higher than conventional peened specimens.

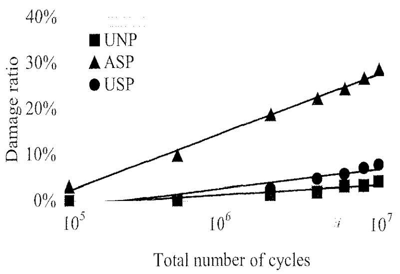



Fig.5 (a) 1.6GPa

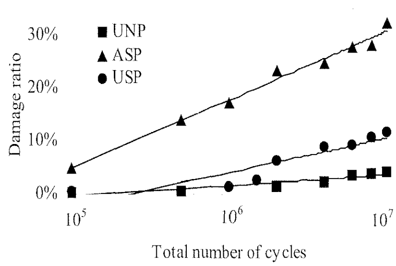



Fig.5 (b) 1.8GPa

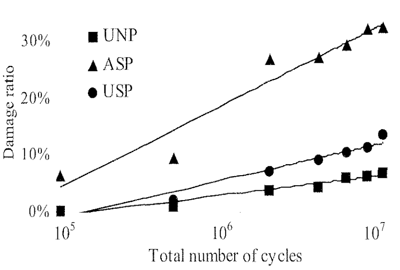



Fig.5 (c) 2.0GPa

Fig.5 The results of damage ratio

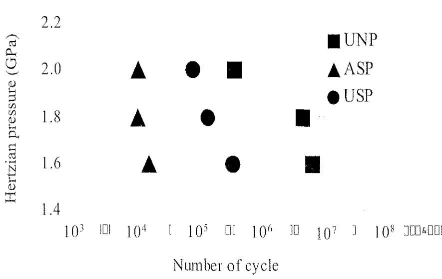
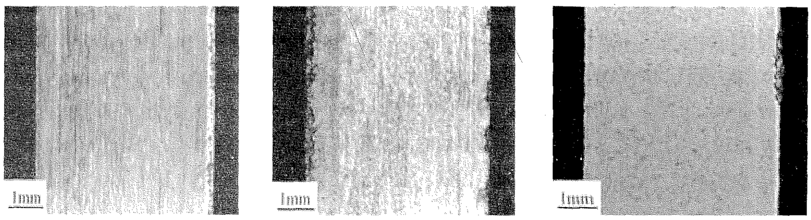
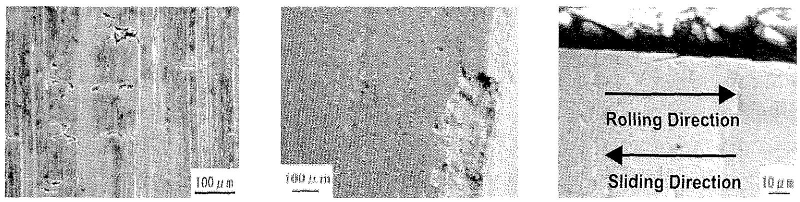



Fig.6 Number of cycle at 5% damage ratio



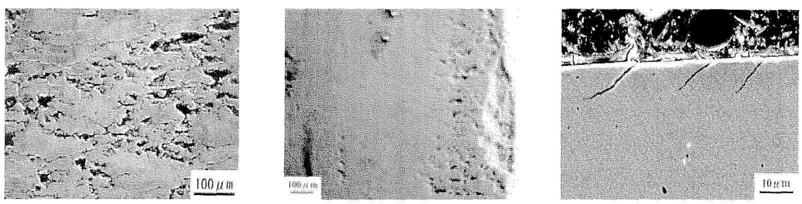

(a) UNP roller (b) USP roller (c) ASP roller

Fig.7 Optical micrograph of roller surface in lower roller



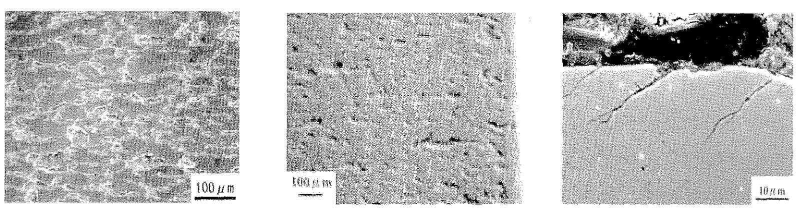

(a) Central part of roller (b) Edge of roller (c) Side of sectioned roller

Fig.8 SEM micrograph of UNP specimens




(a) Central part of roller (b) Edge of roller (c) Side of sectioned roller

Fig.9 SEM micrograph of USP specimens




(a) Central part of roller (b) Edge of roller (c) Side of sectioned roller

Fig.10 SEM micrograph of ASP specimens

**MICROGRAGH AFTER FATIGUE TESTING**

Fig.7 shows the optical micrograph of test specimens after fatigue testing at 2.0GPa. At every condition it was observed that the damage mainly occurred at edge of roller specimen and also micro pitting at entire contact area. Especially we could find a lot of micro pitting on shot peened specimens, so surface brightness disappeared compared to Not-peened specimen.

SEM micrograph of central part and edge of roller and side view of sectioned roller tested at 2.0GPa is shown in Fig. 8, 9, 10. At UNP specimens, a few micro pitting was observed on the central surface of the roller (a). On the other hand, big damage like lack was observed at the edge of roller as shown in this figure (b). Further the base of chipped part was almost parallel to the surface of roller. The reason of this phenomenon was explained by a cracks initiation at its maximum shear stress site due to stress concentration at the edge of roller. Photo (C) displays a few small crack that initiate at the surface and a length of 2 to 3 micrometers. This means that the crack occurs at the surface and propagates in sliding direction. And finally micro pitting occurred due to the lack of material at crack site.

On the other hand, a lot of micro pitting is observed on the center area of USP specimens (Fig.9 (a)). And chipped edge of specimen about 100 micrometers long and also a lot of micro pitting at the corner edge with the width of 300 micrometer was observed. Fig. 9(c) shows a crack like for UNP specimens as mentioned before. This means that micro pitting at USP occurs by the same mechanism as the UNP condition.

Further at ASP specimen (Fig.10 (a)) a lot of micro pitting is observed, as for USP specimen, however the chipped edge was not confirmed. The different mechanisms can be considered depending the specimens. Namely, micro pitting occurs due to increased friction coefficient by large uneven surface instead of the concentration at the edge of roller, because the surface roughness of ASP was highest as shown before figure.

## CONCLUSION

The present study aims at confirming the effect of ultrasonic shot peening treatment, Stressonic®, on contact fatigue properties, fatigue tests were conducted by using a disk machine with rolling and sliding at two types of shot peening conditions.

Following is a summary of the results obtained:

(1) It was confirmed that micro pitting occurs before creating the spalling formation and the chipped edge was observed at the roller.

(2) The damage ratio of shot peened specimens was bigger than the not-peened specimen. That means that the contact fatigue strength declines due to shot peening treatment.

(3) Especially the damage ratio of ASP corresponding to the highest roughness at the surface was worst. It was considered that micro pitting occurs due to increased friction coefficient by uneven surface instead of the concentration at the edge of roller.

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