Effect of shot peening intensity on rolling contact fatigue life of high carbon chromium steel

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Introduction

Rolling contact fatigue (RCF) is a major failure element of bearings. RCF life can be influenced by several parameters including contact pressure, lubricant condition, and surface condition [1, 2]. As higher lifetime is needed, some of researchers has investigated the effects of shot peening on rolling contact fatigue life [3-6].

Shot peening is a surface treatment technique by projecting shot balls on the surface of the material. This process is reported as an effective way to increase a rolling contact fatigue life by generating compressive residual stress [3], increasing surface hardness [3, 4], and changing microstructures [5]. However, the surface roughness induced by shot peening process may reduce the rolling contact fatigue life [3, 6].

In this study, the effect of shot peening intensity on the rolling contact surface and the rolling contact fatigue life of high carbon chromium steel is investigated. Impeller type of shot peening equipment was used for the shot peening process. Two disk type of specimens with Almen intensity 0.224mmA and 0.580mmA, respectively, were prepared for the rolling contact fatigue test.

Methodology

Test specimen

Test specimens were made of high carbon chromium steel mostly used in bearings. All specimens were turned and lapped after heat treatment as shown in Figure 1. Diameter and thickness of RCF specimen is 60 mm and 5mm, respectively. The Young's modulus and surface hardness is 210GPa and 63HRC, respectively.

Specimens were shot peened by using an impeller type of shot peening machine. A rounded cut wire sot ball having a hardness of about 670 Hv, SWRH 72A, was used in the peening process. The Arc heights of shot peened specimens are 0.224mmA and 0.580mmA, respectively and the coverage is over 100% as shown in Table 1. The chemical composition of a specimen and a shot ball is shown in Table 2.

Figure 1 Photo of a rolling contact fatigue specimen

Table 1 Conditions of shot peening process.

Shot ball diameter	0.8mm	
Impeller diameter	250mm	
Shot velocity	37.2m/s	78.1m/s
Exposure Time	3min	10min
Coverage	Over 100%	
Arc height	0.224mmA	0.580mmA

Table 2 Chemical composition of a specimen and a shot ball(wt%)

	C	Si	Mn	P	S	Cr	Ni
Specimen	0.98	0.20	0.33	0.01	0.002	1.44	0.025
Shot ball	0.69~0.76	0.15~0.35	0.30~0.60	Max 0.030	Max 0.030	-	-

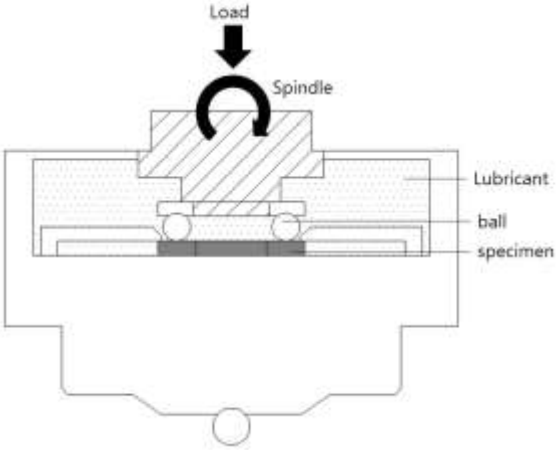


Figure 2 Schematic of a rolling contact fatigue tester

Experimental procedure

In this study, a disk type of rolling contact fatigue tester (Mori type of rolling contact fatigue tester) was used for the experiment. Figure 2 is a schematic of rolling contact fatigue tester. The contact pressure of specimen is about 5.3GPa and rotating speed is 1800rpm. Three bearing balls rotate on a disk type of specimen. Lubricant was supplied at 45ml/min under 60 °C of constant temperature. Debris generated by rolling contact fatigue test was removed by 5μm of filter. The testing machine was set to stop when the acceleration value exceeds the gravity acceleration 1G.

Results and analysis

Observation of specimen surface

Figure 3 shows the surface roughness measured along the track. Figure 4 and 5 shows three dimensional roughness images obtained by using a non-contact 3D measurement system. The data were measured before (BT) and after (AT) rolling contact fatigue test for Non Peened specimen(NP), Shot Peened specimen with 0.224mmA of Arc height (SP_1) and Shot Peened specimen with 0.580

mmA of Arc height (SP_2). Before rolling contact fatigue, the surface roughness for NP, SP_1, and SP_2 is 0.054µm, 0.148 µm and 0.287 µm, respectively. After rolling contact fatigue, the surface roughness for NP, SP_1, and SP_2 is 0.194µm, 0.165 µm, and 0.252 µm, respectively. The roughness of SP_1 and SP_2 does not change significantly before and after rolling contact fatigue test. However, the roughness of NP changes significantly before and after rolling contact fatigue test.

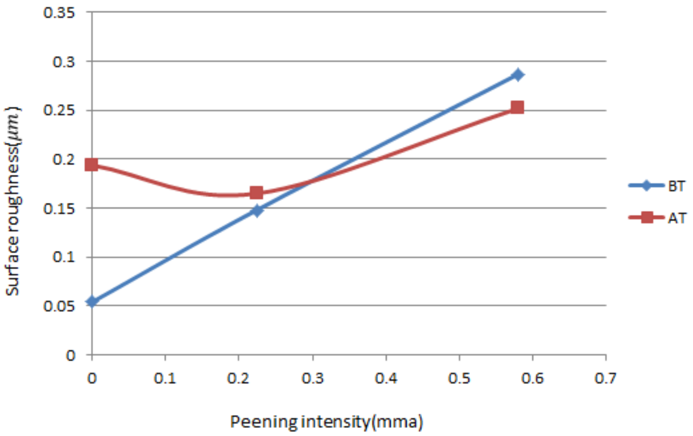
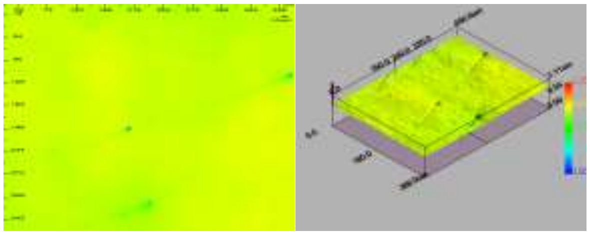
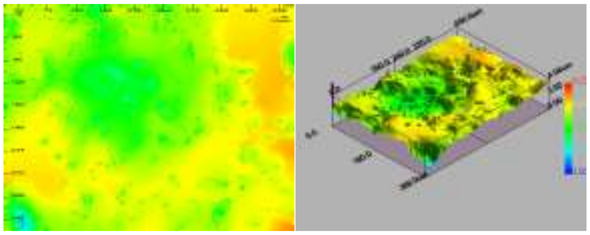


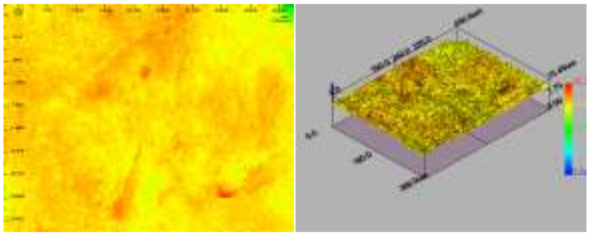
Figure 3 Surface roughness according to peening intensity



(a) NP

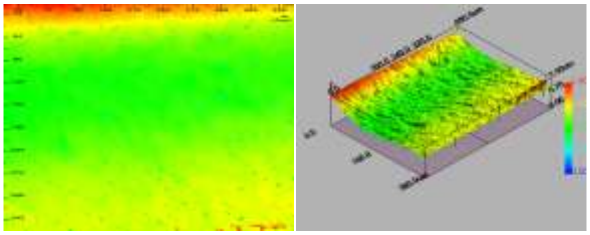


(b) SP_1

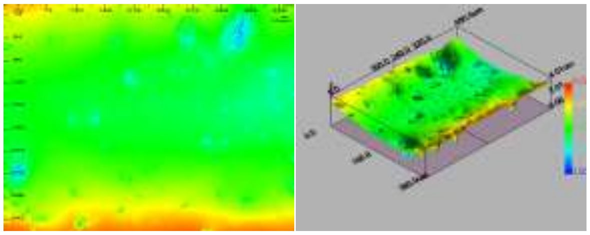


(c) SP_2

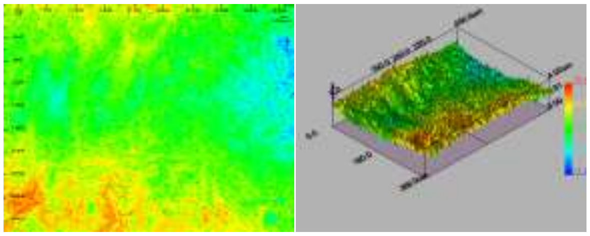
Fig 4. Nano 3D images of track surface before the RCF test



(a) NP



(b) SP_1



(c) SP_2

Fig 5. Nano 3D images of track surface after the RCF test

Table 3 Rolling contact fatigue test results

Type of specimen	$\boldsymbol{L_{10}(Number\ of\ cucles)}$
NP	$\boldsymbol{1.747\times 10^{6}}$
SP_1	$\boldsymbol{6.595\times 10^{6}}$
SP_2	$\boldsymbol{3.778\times 10^{6}}$

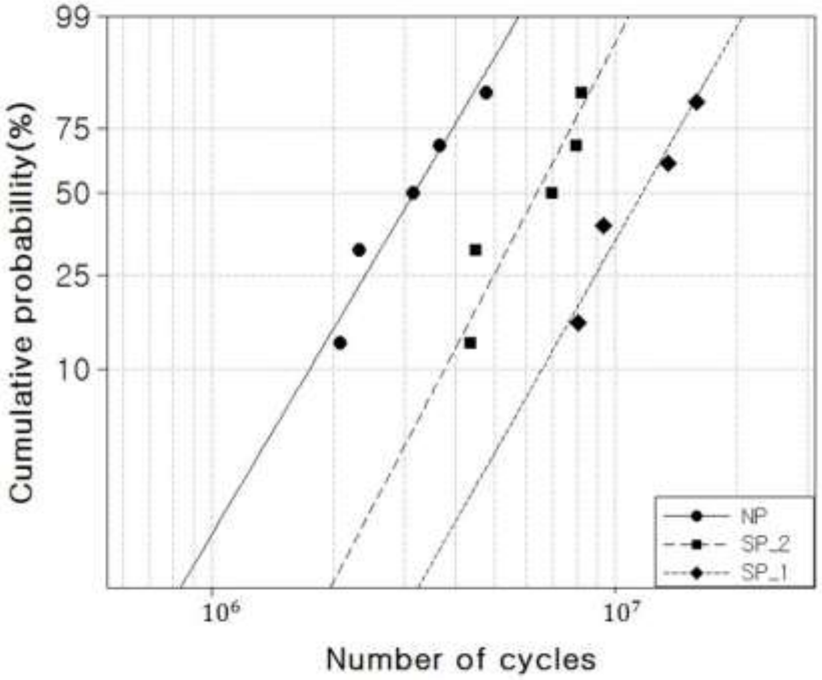


Figure 6 Weibull RCF life results

Results of the rolling contact fatigue life

Table 3 and Figure 6 show the rolling contact fatigue life. Rolling contact fatigue life of shot peened specimens increases by comparing non peened specimens. Fatigue life of SP_1 and SP_2 is 278% and 116%, respectively, longer than that of NP. However, the rolling contact fatigue life with high Arc height (SP_2) is shorter than that with SP_1. It seems that the surface roughness formed by shot peening process reduces the rolling contact fatigue life.

Conclusions

The rolling contact fatigue test was accomplished for non-peened specimen, shot peened specimen with 0.224mmA of Arc height and 0. 580mmA of Arc height. The results can be summarized as follows:

- Rolling fatigue life of SP_2 is shorter than that of SP_1. It seems that the surface roughness formed by shot peening process reduces the rolling contact fatigue life.
- The surface roughness of NP specimen increases during the rolling contact fatigue test. In contrary, the surface roughness of SP_2 specimen decreases during the rolling contact fatigue test.
- Shot peening process increases the rolling contact fatigue life, even though the life is not proportional to Arc height.

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References

[1] Farshid Sadeghi et al., "A Review of Rolling Contact Fatigue", Journal of Tribology, Vol. 131, No. 4, 2009
[2] D. Girodin et al., "Role of Inclusions, Surface Roughness and Operating Conditions on Rolling Contact Fatigue", Transactions of the ASME, Vol. 121, pp.240-251, 1999
[3] Zeyong Yin et al., "Rolling Contact Fatigue Life of Case–Hardened Steel Treated by Shot Peenings with Shot Diameters of 0.05 mm and 0.30 mm ", Advances in Power Transmission Science and Technology, Vol. 86, pp. 645-648, 2011
[4] Masanori SEKI et al., "Rolling Contact Fatigue Life of Steel Rollers Treated by Cavitation Peening and Shot Peening", Journal of Solid Mechanics and Materials Engineering, Vol. 6, No. 6,pp. 478-486, 2012
[5] Hongbin Xiao, Qing Chen, Eryu Shao, "The effect of shot peening on rolling contact fatigue behaviour and its crack initiation and propagation in carburized steel", Wear, Vol. 151, No. 1, pp. 77-86, 1991
[6] M. Vrbka et al., "Effect of shot peening on rolling contact fatigue and lubricant film thickness within mixed lubricated non-conformal rolling/sliding contacts", Tribology International, Vol. 44, No. 12, 2011, pp. 1726–1735