The relationship between wear behavior caused by shot peening and surface hardening effects depending on chromium contents

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1. Introduction

Although chromium alloy steel has been used in various applications such as mechanical parts, automobiles, and aircrafts due to its excellent corrosion and wear resistance, its physical properties could be deteriorated when it exposed to harsh environments for a long time. In these fields, shot-peening has been highlighted as one of solutions as it could effectively improve fatigue strength and hardness by simple process. Diverse studies on the hardening effect of the size and distribution of precipitates after shot-peening have been actively conducted. Lee et al.[1] reported the change in hardness depending on the carbon contents after shot-peening, which could be attributed to dissolution of cementite into surface matrix by plastic deformation. Cho et al.[2] conducted shot-peening with Al-Si alloy specimens whose Si contents were different to find out the changes in mechanical properties. Depending on the added Si contents, the amount and size of the Si phase was changed and dislocation movement was suppressed, which lead to increased surface hardness. Even though there have been lots of studies focused on shot-peening effects, studies on the Cr carbide behavior in steel after the shot-peening process are insufficient. In this study, Cr alloy steels were manufactured with different Cr composition to find out how the size and amount of Cr carbide could affect the microstructure and hardness after shot-peening.

2. Experimental procedure

All specimens were manufactured by Ingot after dissolution at 1550°C for 1 hour by Vacuum Induction Melting (VIM). Their chemical compositions are shown in Table 1. Hot rolling was performed at 1100°C to remove the dendrite structure, and then samples were prepared with a size of 30 ϕ*10 mm. Shot peening processes were conducted under for 10, 30, 60, 90, 120, 240 seconds at a pressure of 0.6 MPa with a high speed steel (HSS) ball whose diameter is 50μm and hardness is 800Hv. The direction of shot ball was perpendicular to the specimen surface, and the test distance was 100mm. Surface hardness according to the shot-peening time was measured with 20g of load and 10 seconds of dwell time, and the average values were derived. Microstructures of before- and after shot-peened specimens were compared by Field Emission-Scanning Electron Microscope (FE-SEM), and microstructures in 0, 10% Cr steel surface were observed through Transmission Electron Microscopy (TEM). Ball-on-disk tests were carried out to measure wear resistance of before- and after shot-peened specimens, and wear rates were derived through wear depth and wear width.

3. Results and discussion

Fig. 1 shows hardness of matrix and the hardness changes in surface according to the shot-peening process time. Hardness of each material before shot peening was measured as 211, 220, 237, and 255 Hv. After shot peening, it was increased to 415, 444, 479, and 582 Hv, respectively. The maximum hardness was also increased as the chromium contents were increased, which result from the increased dislocation density of chromium carbide. Surface microstructures of 0%Cr and 10%Cr specimens observed by TEM are shown in Fig. 2. The average grain size of 0%Cr was 178 nm, and cementite, the main precipitate, existed in the form of very small particles between the nanocrystal grains. The main precipitate of 10%Cr steel was chromium carbides, and dislocation density was high around the carbides. It is clear that the Orowan strength effect result in high dislocation density, which could accelerate nanocrystallization on the surface [3]. A graph summarized the result after ball on disk test is shown in Fig. 3. As the chromium contents increase, wear depth, wear width and wear rate tend to decrease. This is because chromium carbides which has high hardness were refined by shot peening, which could effectively enhance wear resistance.

4. Conclusion

1) As the chromium contents increased, the surface hardness significantly improved after shot-peening treatment. Especially in the case of 20% chromium alloy steel, the surface hardness was about 582HV, which showed that hardness elevated more than twice than that of chromium-free alloy steel.

2) More chromium carbides were formed according to increase of chromium contents, and dispersed as finer particles after shot-peening. It is indicated that finer carbides could effectively improve mechanical properties by restraining dislocation movement.

3) After shot-peening, wear resistance were gradually enhanced as chromium contents increased, which could result from improved surface hardness by shot-peening.

Reference

1) W.B. Lee, K.T. Cho, K.H. Kim, K.I. Moon & Y. Lee: Acta Mater., 527 (2010) 5852.
2) K.T. Cho, S. Yoo, K.M. Lim, H.S. Kim & W.B. Lee: J. Alloys Compd., 509S (2011) S265.
3) Z. Zhang & D. L. Chen: Contribution of Orowan strengthening effect in particulate-reinforced metal matrix nanocomposites, Mater. Sci. Eng. A, 483-484 (2008) 148.

Table 1. Chromium alloy steel chemical composition.

Sample	C (%)	Mn (%)	Si (%)	P (%)	S (%)	Cr (%)
0% Cr Steel	0.45	0.61	0.23	0.03	0.03	0.11
5% Cr Steel	0.42	0.52	0.21	0.03	0.02	4.98
10% Cr Steel	0.47	0.63	0.21	0.03	0.03	9.87
20% Cr Steel	0.49	0.71	0.24	0.01	0.02	19.79

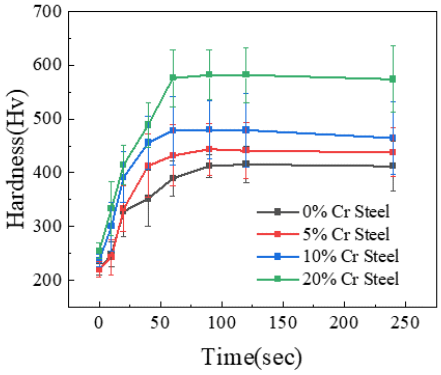

Fig. 1 Surface hardness profile with shot peening time

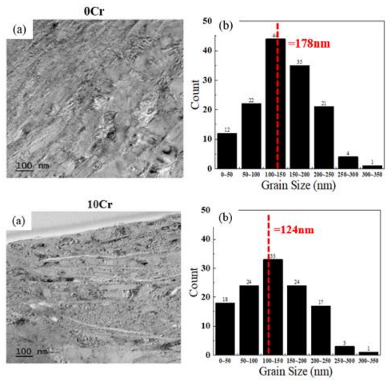

Fig. 2 TEM image of 0,10% Cr area after shot peening and average grain size

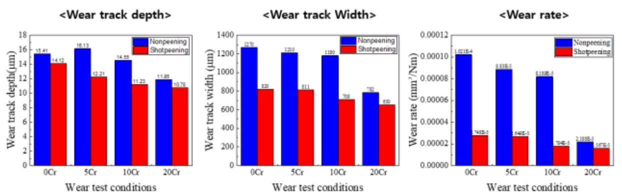

Fig. 3 Summary of the wear depth, width, rate depending on Cr %