Influence of shot peening and carbon content for low cycle fatigue strength of carburized steel

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Introduction

In recent year, strengthening of automotive gear is required by many automotive manufactures to reduce the weight of parts. [1] Bending fatigue strength and contact fatigue strength are required on automotive gear. Shot peening is used as strengthening method for automotive gear. [2)-3] Shot peened automotive gear is gotten higher fatigue strength at high cycle fatigue region. On the other hand, low cycle fatigue is required at differential gear by inducing load when car start. Dr. Shiga[4] reported that medium–carbon martensite steel was gotten high low cycle fatigue strength by compressive residual stress. However, shot-peened medium-carbon martensite steel was not considered in the paper. In this study, we carried out the investigation of low cycle fatigue strength against shot peened medium–carbon martensite steel.

Methodology

Specimens

In this study, we used JIS-SCM420H used in Japanese automotive industry for transmission gear. Chemical component is shown in Table 1. Shapes and dimension of specimen is shown in Fig.1. Specimen shown in Fig.1 was machined from SCM420H with diameter 32[mm]. Specimen was gas carburized. Gas carburizing condition was adjusted so that each carbon contents of each specimen were 0.4%, 0.6% and 0.8%. Carburizing conditions are shown in Fig.2. Tempering condition was 120min at 273K against all specimens after each carburizing. Fig.3 shows Carbon content distribution of each carburized specimens by EPMA. In this study, each carbon specimen was achieved carbon content distribution as planned.

Table 1 Chemical Component (wt%)

C	Si	Mn	P	S	Cr	Mo	Fe
0.21	0.26	0.81	0.016	0.019	1.16	0.21	Bal.

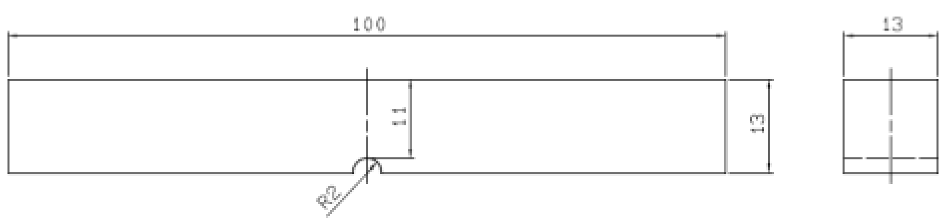


Fig.1 Shapes and dimension of specimens

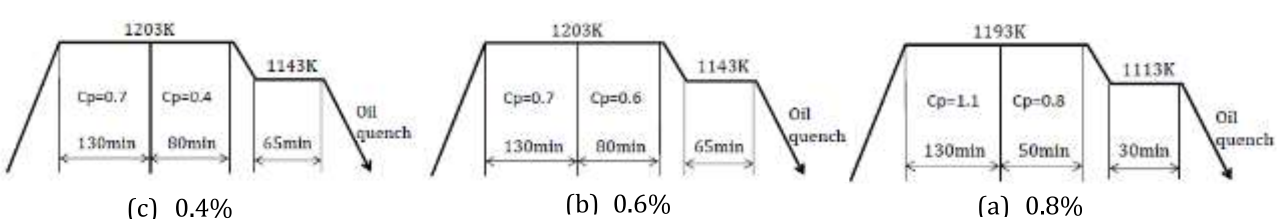


Fig.2 Carburizing Conditions

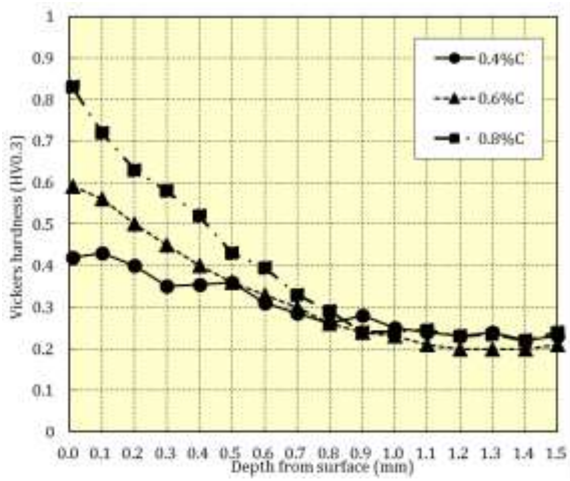


Fig.3 Carbon content distribution

Shot peening condition

Shot peening was selected the dual shot peening condition used in Japanese automotive industry. Shot peening conditions is shown in Table2. Symbol of each specimens are shown in Table3.

Table 2 Shot peening condition

Step of Shot peening	Media	Diameter (mm)	Hardness (HV)	Air pressure (MPa)	Coverage (%)	Arc height
1stSP	CCW	0.6	700	0.35	500	0.564mmA
2ndSP	Cast steel	0.1	800	0.2	500	0.311mmN

Table 3 Symbol of each specimen

Symbol	Heat treatment	Carbon content (%)	Shot peening
0.4%C	Carburizing-Tempering	0.4	×
0.6%C	Carburizing-Tempering	0.6	×
0.8%C	Carburizing-Tempering	0.8	×
0.4%C+SP	Carburizing-Tempering	0.4	○
0.6%C+SP	Carburizing-Tempering	0.6	○

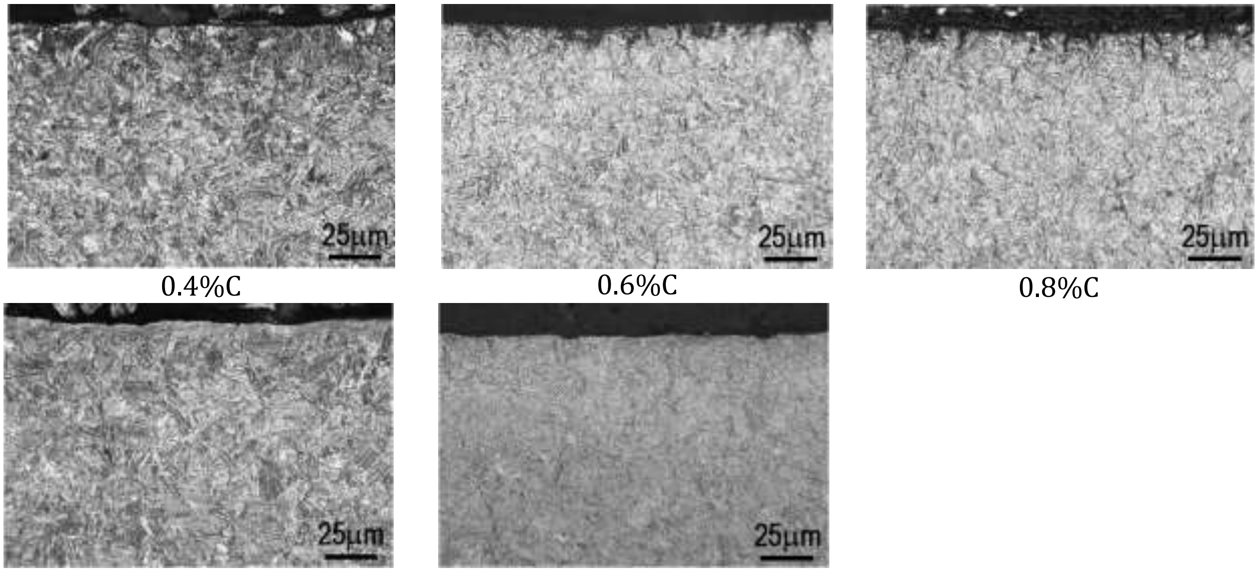
Evaluation method

We evaluated the microstructure observation, hardness distribution and residual stress distribution to evaluate peening characteristics against specimens. Low cycle fatigue strength was carried out 4 point bending test. Stress ratio was R=0.1.

Results and discussion

Microstructure

Fig. 4 shows Results of microstructure observation. 0.4%C, 0.6%C and 0.8%C specimen had surface abnormal layer by carburization in oxidizing atmosphere. The depth of surface abnormal layer was about 10 μm. 0.4%C+SPand 0.6%C+SP specimens did not have surface abnormal layer. This is because the surface abnormal layer was removed by shot peening.



0.4%C 0.6%C 0.8%C

0.4%C+SP 0.6%C+SP

Fig.4 Microstructure observation

Hardness distribution

Fig.5 shows hardness distribution of all specimens. The higher carbon content by carburization increase, the higher hardness increased. Effective case depth by carburization is almost same on each specimen. 0.4%C+SP and 0.6%C+SP was hardened by shot peening. 0.6%C+SP was higher hardening volume than 0.4%C+SP. This is because the 0.6%C+SP was higher volume of deformation induced martensite than the 0.4%C+SP to have high retained austenite in 0.6%C.[5)]

Residual distribution

Fig.6 shows residual stress distribution of shot peened specimens. 0.6%C+SP was higher maximum compressive residual stress than 0.4%C+SP. This is because 0.6%C+SP was higher hardness than 0.4%C+SP.

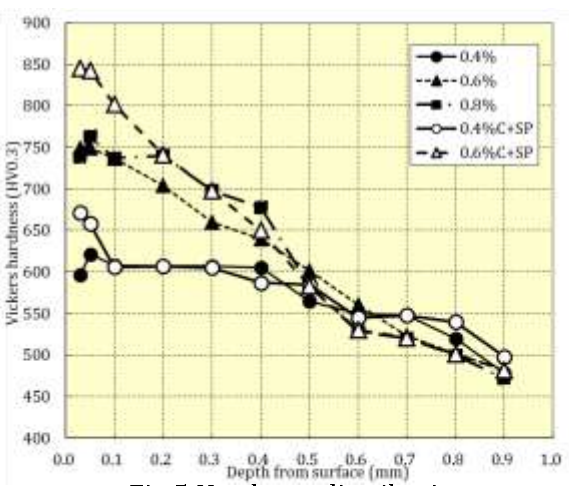


Fig.5 Hardness distribution

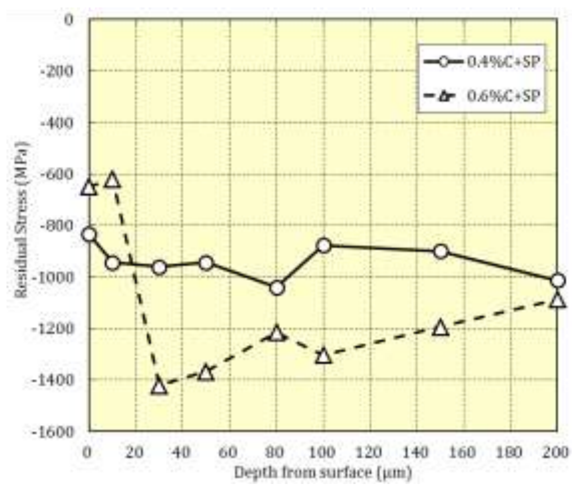


Fig.6Residual stress distribution

Fatigue test results

Fig.7 shows fatigue test results. In unpeened specimens, fatigue strength increased with decreasing carbon content. Shot peened specimens were higher fatigue strength than unpeened specimen. Fig.8

shows fracture surface of all specimens. In unpeened, 0.4%C was transcrystalline fracture. On the other hand, 0.6%C and 0.8%C was grain boundary fracture. Therefore, 0.6% and 0.8%C were brittle fracture. Furthermore, specimens increased grain boundary rate with increasing carbon content. Consequently, high carbon materal was easy to break at low cycles due to occur quickly brittle fracture by applied stress. Shot peened specimens were transcrystalline fracture of all specimens, although 0.6%C was grain boundary fracture. This is because the fatigue crack was inhibited by compressive residual stress, and the fracture surface was smooth by wearing between fracture surfaces. As a result, Fatigue strength of shot peened specimen was increased by compressive residual stress.

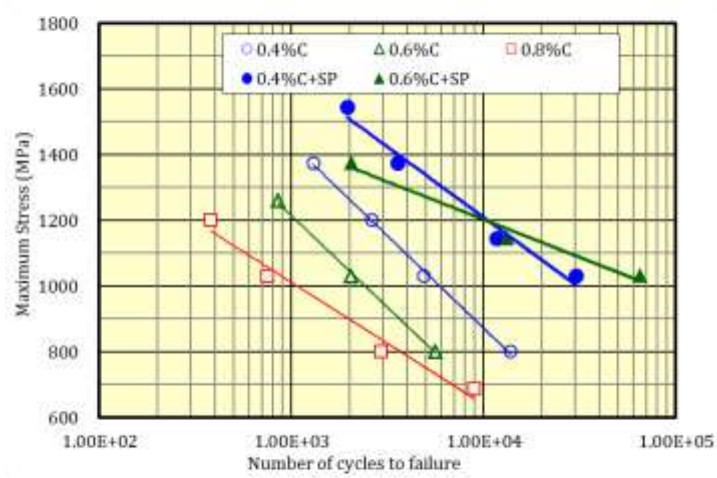
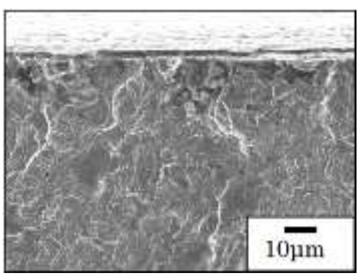
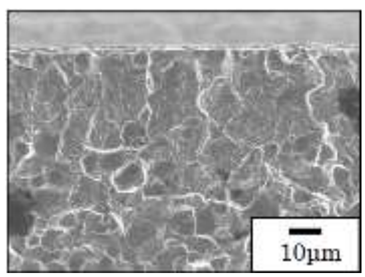


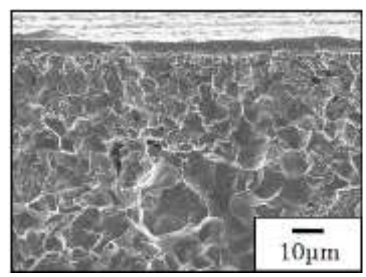
Fig.7 S-N curves.



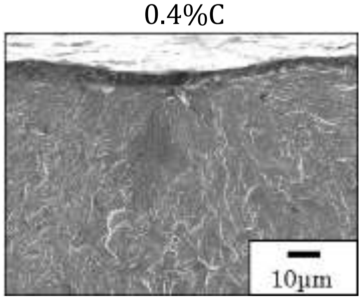
0.4%C



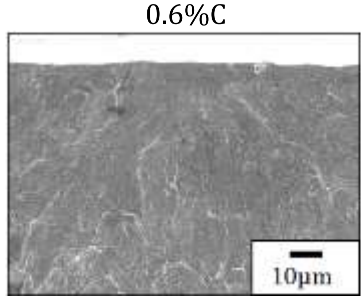
0.6%C



0.8%C



0.4%C+SP



0.6%C+SP

Fig.8 Fracture surface

Summary

1. Shot peened specimen was higher hardness than unpeened specimen due to work hardening and deformation induced martensite.
2. 0.6%C+SP was higher compressive residual stress than 0.4%C+SP. This is because 0.6%C was higher hardness than 0.4%C.

3. In unpeened specimens, fatigue strength increased with decreasing carbon content. This is because high carbon carburized steel such as 0.8%C was easy to break at low cycles due to occur quickly brittle fracture by applied stress.
4. Shot peened specimen were higher fatigue strength than unpeened specimen. This is because fatigue crack of shot peened specimen was inhibited by compressive residual stress.

References

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