Effect of Shot Peening on Temper Hardness

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ABSTRACT

Shot peening improves contact fatigue strength of mechanical components due to work hardening. However, in the case of components used under high pressure such as gears of automotive transmission, temperature of the contact part elevated over 200℃ due to frictional heat. Therefore, it was expected that the part cause reduction of beneficial effect of shot peening via temper softening. In this research, softening behavior of shot peened carburized steel due to elevated temperature was investigated, and then the effect of shot peening in high temperature was considered.

KEY WORDS

Carburized steel, Temper, Softening, Vickers hardness, Auto motive gear

INTRODUCTION

Shot peening is popularly applied for improving the fatigue strength of carburized parts such as gears and shafts used as the integral part of automotive transmission. Gears undergone shot peening treatment are used for almost all Japanese cars, and shot peening technology, needless to say, is indispensable for the manufacturing of highly dependable cars.

As commonly known, the strength required for gear is consisted of two elements; one is the bending fatigue strength on dedendum and another is the surface pressure fatigue strength on tooth flank. It is also a common understanding that the residual stress and hardness imparted by shot peening contributes to the improvement of fatigue strength. On the other hand, there is a keen demand for downsizing of transmission unit in automotive industries aiming at the lighter weight of cars for fuel economy. Besides, the standardization of transmission unit is the latest trend in automotive industries aiming at the cost reduction. The compact transmission units must cope with the high output requirement of larger size cars. This tendency is critically worsening the thermal environment inside the transmission unit.

On the other hand, a report tells that the surface pressure fatigue strength is regulable by the hardness of carburized parts after tempering at 300℃. Accordingly, the materials having the composition design of a higher resistibility for softening by tempering have been introduced, and the carburizing technology matching to the material has been developed. However, the study on the effect of shot peening for the material making use of the new technology is hardly adequate.

In this study, therefore, the shot peening is conducted on the test pieces of base material and heat treated material for the purpose of increasing the resistibility against temper softening. The results of investigation on the hardness variation by tempering temperature are reported.[1) 2) 3)]

METHODS

As the basal condition of the material used for the experiments, SCM420H (ISO: 18CrMo4) was selected. In addition, 2 other kinds of steel material with the composition of increased resistibility against temper softening were used. These steel materials retained the hardness after 300℃ tempering presumptive in Formula 1 by adjusting the content of Si, Cr and Mo, the elements involved closely in the softening resistibility. The materials and heat treatment conditions are summarized in Table 1.

Steel type C undergone vacuum high density carburization, and the saturated carbon is precipitated in the matrix of martensite in the form of carbide. The numerical figures in the Table are showing the surface ratio of each carbide. Fig. 1 shows the microstructure of surface proximity of steel type C. Surface hardness in the Table is the result of measuring the surface of material by Vickers hardness tester. The measuring load is 2.94N.
The formation of internal oxidation layer is recognized at the surface proximity of gas carburizing material, and accordingly, the hardness is quite low.

Table 1

Steel Type	Presumed hardness after 300℃ Tempering (HV)	Method of Carburization	Special Remark	Symbol	Surface Carbon Concentration %	Top Surface Hardness (HV)
A	645	Gas carburizing	——	A	0.82	415
		Vacuum carburizing	——	AV	0.76	706
B	678	High temperature vacuum carburizing	——	B	0.78	698
			Return to Low-temperature	BL	0.80	831
			Sub-zero	BS	0.78	936
C	708	Vacuum high density carburizing	Carbide 0%	C0	0.72	768
			Carbide 5%	C5	1.06	805
			Carbide 20%	C20	1.93	842
			Carbide 20% Sub-zero	C20S	1.93	951

Formula 1：(0.75%C)=593+56.1Si+23.3Cr+74.4Mo [7)]

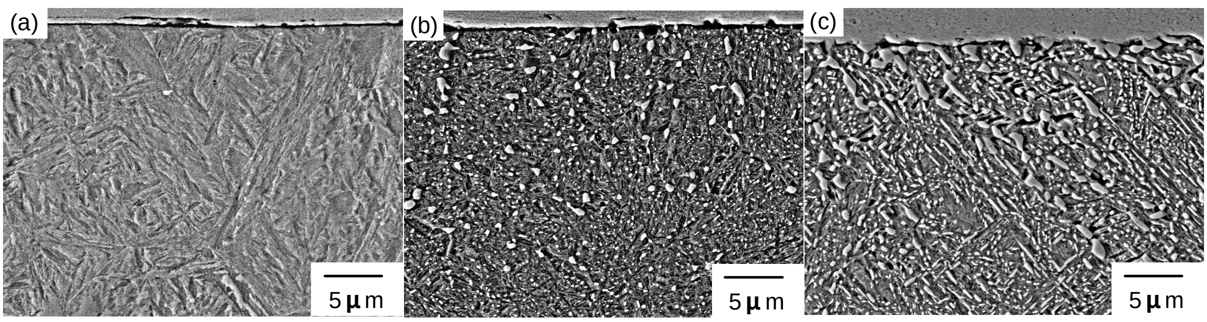

Figure 1 SEM micrographs of carbide containing steel type C
(a) Carbide 0% (b) Carbide 5% (c) Carbide 20%

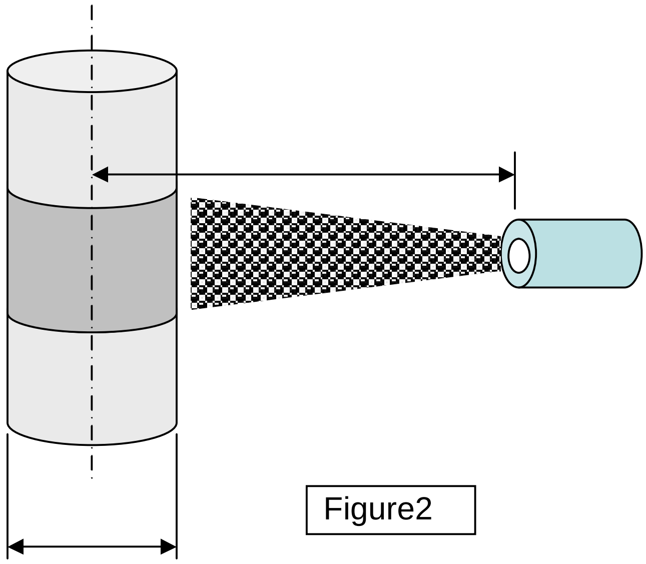

Figure2

Shot peening was conducted as per the experiment conditions shown in Table 2. Method of processing is illustrated in Fig. 2.

After shot peening, tempering at the temperature of 200℃, 300℃ and 400℃ was carried out for 180 minutes using salt furnace.

The hardness before and after shot peening was evaluated by measurement at the position of 25 μ m and 50 μ m from the surface of cross section using micro-Vickers hardness tester. The measuring load is 2.94N.[4) 5) 6)]

Table 2

	Hardness of Shot	Fineness of Shot	Projection Pressure	Coverage	Arc Height
SP1	HV950	0.3mm	0.5MPa	300%	0.372mmA
SP2	HV900	0.05mm	0.5MPa	300%	0.262mmN

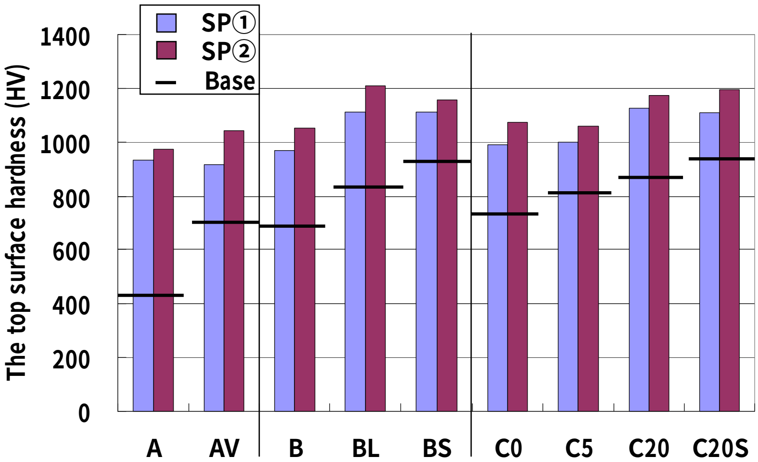

Figure 3 Hardness of top surface after shot

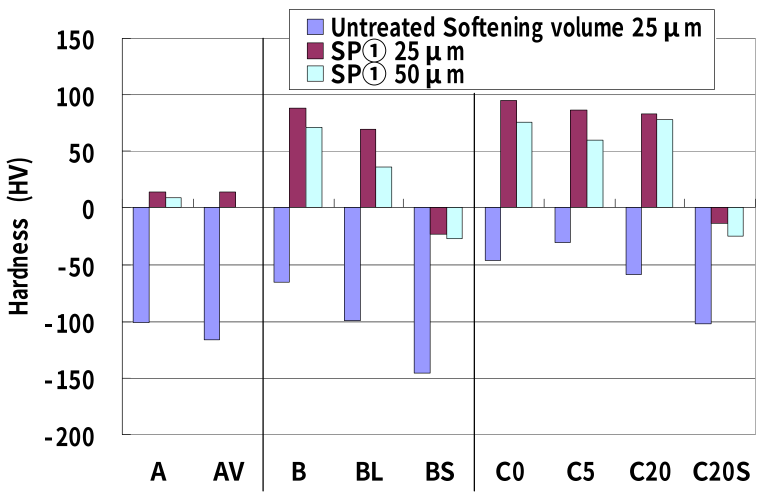

Figure 4 Closs section hardness after SP①

RESULTS

Fig. 3 shows the hardness of top surface after shot peening treatment. It is understood that the hardness attained by SP ② is higher in all test pieces. It is considered that this phenomenon is caused by the smaller particle size of shot. The substantially high hardness as over 1200HV is obtained on the top surface.

Fig. 4 and 5 show the cross section hardness (at the position of 25 μ m and 50 μ m) after tempering and peening by SP① and SP② regulated by the hardness parameter shown in Formula 2. As understood in Fig. 4, all untreated materials show the decrease of hardness after 300℃ tempering. However, it is understood that the hardness imparted by shot peening remains in all steel materials except Steel type A (SCM420H) and the one with sub-zero treatment. The similar result was obtained at the depth of 50 μm where the imparting of hardness should be less.

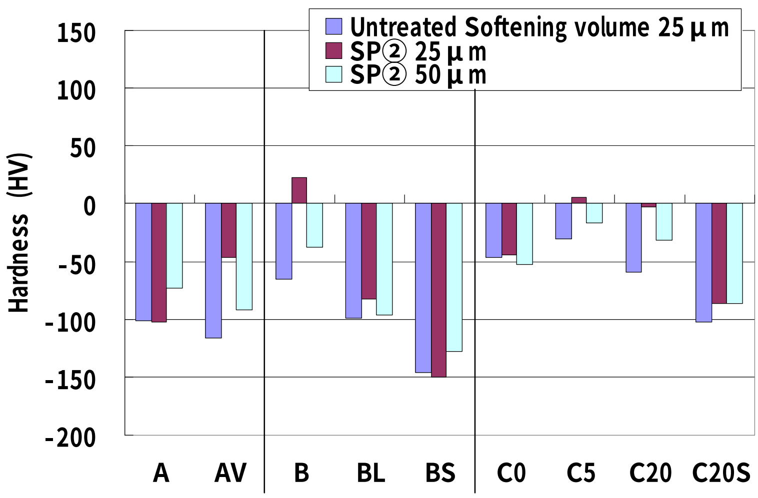

Figure 5 Closs section hardness after SP②

As shown in Fig. 5, in almost all conditions, the materials were softened as they could not sustain the hardness imparted by shot peening after 300℃ tempering. In case of SP②, a quite high hardness was imparted on the top surface because the blasting media of 0.05mm diameter was used. However, on the contrary, it failed to impart high hardness to the deeper section. In this test, the effect did not appear even atthe depth of 25 μ m. Accordingly, the reduction of the following data is conducted mainly on the result obtained by the conditions of SP②.

Formula 2：hardness increase - hardness decrease (300℃)
＝(hardness after SP - hardness before SP) - (hardness after SP - hrdnes after 300℃ tempering)

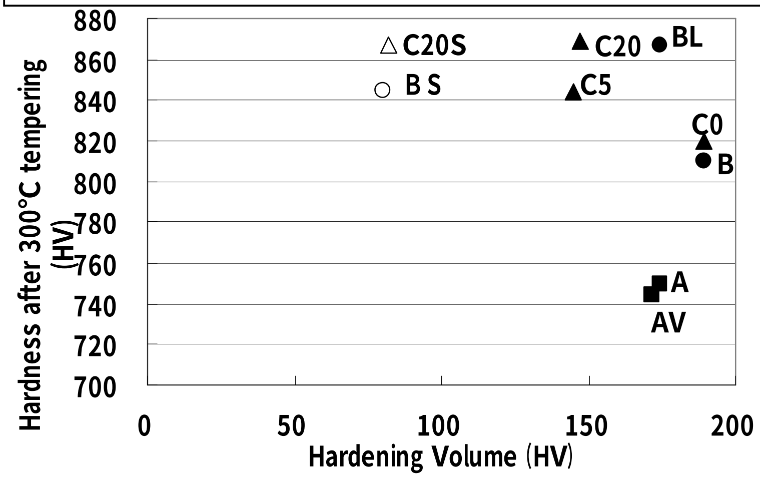

Figure 6 Compare hardening volume to hardness after 300℃ tempering

Fig. 6 shows the graph of the hardness attained by SP ② after 300℃ tempering reduced by the hardening volume after shot peening. As the basal condition, no consideration was paid for SCM420H for its resistibility of temper softening. Therefore, even if the hardness equal to other steel materials was imparted by shot peening, its hardness after 300℃ tempering was lowered substantially. As the similar results were obtained either in gas or vacuum carburization, it is understood that changing of carburization method will not make any difference. The hardness volume of sub-zero treated steel material is lower than other steel materials, but the hardness after tempering is higher. Besides, in low temperature tempered Steel type B and carbide precipitated Steel type C, the hardness amount as well as the temper hardness are high. On the other hand, in Steel type B and C0, for which no particular heat treatment was conducted at all, exhibited lower temper hardness compared to other steel materials undergone special heat treatment.

CONCLUSION AND IMPLICATIONS

- In the blasting media (shot) having the same chemical composition and physical property, the shot of smaller diameter imparted high hardness to the surface of test piece, while the shot of larger diameter imparted hardness to interior sections of specimen.
- By the shot peening with the shot having diameter of 0.3mm, the hardness was improved to the depth of 50μm of test piece, and the hardness imparted by shotpeening remains even after 300℃ tempering.
- Quality governed test piece B, C proved that they can maintain higher hardness compared to SCM420H even after tempering, and also proved that the resistibility for temper softening was improved.
- In Steel type B, the hardness after shot peening was improved by low temperature tempering.

REFERENCES

1) Y. Watanabe, N. Narita, Y. Matsushima and K. Iwasaki, 20th ASM Heat Treating Society Conference Proceedings, 9-12 October 2000, St. Louis, MO, ASM International, 2000.

2) T.Shimomura, T.Morita, K.Inoue, T.Hanyuda: Electric furnace steel, Vol.77(2006 Feb.), No.1, 11-18.

3) K.Matsui, H.Eto, K.Yukitake, Y.Misaka, K.Ando: The Japan Society Mechanical Engineers, Vol.66(2000 Oct.), No.650, 1878-1885.

4) Y.Watanabe. N,Hasegawa. Y.Matsumura: J.Soc.Mat.Sci.Japan Moter., Vol.44(1995 Jan.), No.496, 110-115.

5) M.Mitsubayashi, T.Miyata, H.Aihara: The Japan Society Mechanical Engineers, Vol.61(1995 jun.), No.586, 28-34.

6) K.Ohji, S.Kubo, M.Tsuji, H.Ogawa, K.Sakurada: The Japan Society Mechanical Engineers, Vol.53(1987 Aug.),No.492, 1516-1524.

7) T.Nakamura, T.Hanyuda, M.Yoshida, Y.Murakami: SAE Technical Paper Series, (2001), No.2001-01-0827