Effect of Young's Modulus of shot peening media on surface modification behavior by micro shot peening

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Introduction

Micro shot peening that is carried out by using fine peening media is a surface treatment to improve various high strength parts by obtaining compressive residual stress and a nanocrystal layer on a peened surface. It is widely known that higher peening effects can be obtained by using media with higher hardness. For example, it was reported that the large maximum compressive residual stress could be obtained by using harder media [1]. Also, it was reported that a thicker nanocrystal layer was generated by using media with high hardness compared with conventional steel media [2]. On the other hand, there is no report which purely discusses effects of Young's modulus of media on shot peening effects.

One reason why there is no report about Young's modulus is supposed that investigating pure effects of Young's modulus is difficult, because there is no suitable pair of conventional media to investigate them. In other words, there is no pair of media which are similar in hardness, density and shape, but different only in Young's modulus as shown in table 1.

However, in the case of metal media, because of their changeable hardness, it is supposed to be able to adjust their hardness value by heat treatment in an appropriate condition. So, high speed steel media and FeCrB media [3] were chosen as candidates for this work. Young's modulus of the high speed steel media and the FeCrB media, which were measured by P/M materials, were 221 and 290 GPa, respectively. Then, these media after heat treatment for adjusting hardness showed similar hardness, density and particle shape, but only different Young's modulus.

Table 1 Typical properties of conventional shot peening media

	Steel	High speed steel	Amor-phous	FeCrB	Zirconia	WC-Co	Alumina
Hardness (HV)	200 - 800	800	950	1200	1300	1400	1900
Young's modulus (GPa)	200	220	100	290	200	300	360
Density (Mg/m^3)	7.8	8.1	7.4	7.4	6.0	14.0	3.8
Particle shape	Spherical	Spherical	Spherical	Spherical	Spherical	Spherical	Random

Objectives

The purpose of this work is to clarify effects of Young's modulus of shot peening media on surface modification behavior by using these media.

Methodology

Pretest for adjustment of media hardness

First, a pretest to adjust hardness of these media to a same hardness level was carried out. The heat treatment for the pretest was carried out in an argon atmosphere for 4 hours in holding time, followed by furnace cooling. Fig. 1 shows the heat treatment temperature dependence of Vickers

hardness of these media. The hardness of the high speed steel media steeply increased by the heat treatment over 773 K and reached a peak of 1000 HV at 823K shown in Fig. 1(a). In addition, the hardness reached 1014 HV by twice heat treating at 823K.
The hardness of the FeCrB media gradually decreased with the heat treatment temperature. Then, by the heat treatment at 823 K, the media showed 1018 HV in Vickers hardness, which was almost the same value as that of the high speed steel media after the heat treatment as mentioned above.

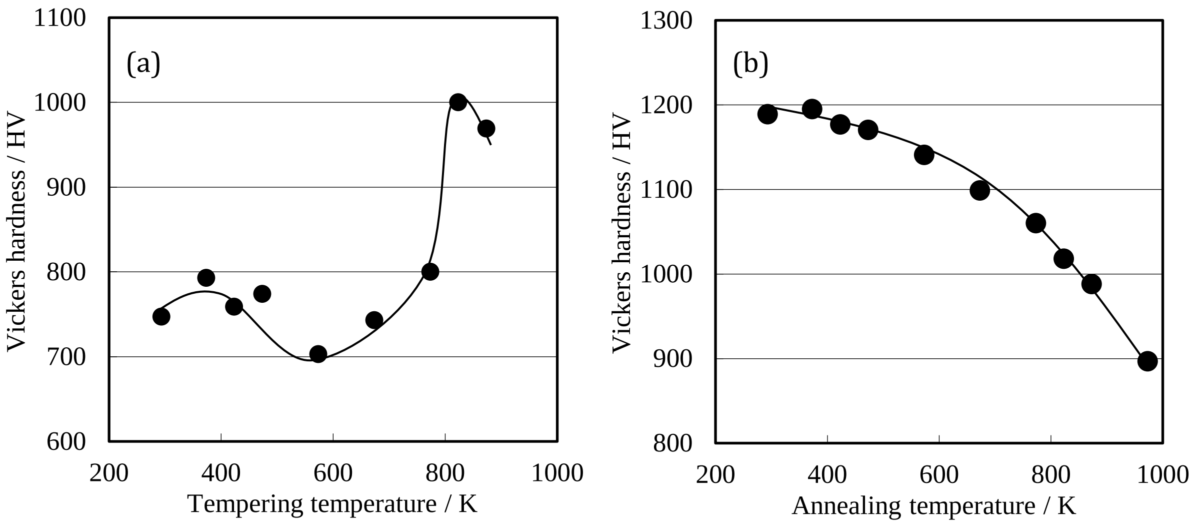

Fig. 1 Variations of Vickers hardness of (a) high speed steel media and (b) FeCrB media with heat treatment temperature.

Comparison of properties of media used in this study
These media that have almost the same hardness of around 1000HV were sieved between 45 and 125 μm in particle size. Then, they were used in this study. Table 2 shows the comparison of the properties of these media. Fig. 2 shows appearance images of these media by SEM. Their hardness, density, particle size and particle shape are similar, but only Young's modulus are largely different. Hereafter, the high speed steel media with 1014 HV and the FeCrB media with 1018HV in Vickers hardness are denoted by LYM(Low Young's modulus Media) and HYM(High Young's modulus Media), respectively.

Workpiece and micro shot peening conditions
Conventional case hardening steel (JIS-SCM420) was used as workpiece for micro shot peening. The workpiece size was 50 mm in diameter and 5 mm in thickness. The surface with 50 mm in diameter was polished into mirror finish. After that, the workpiece was carburized in a vacuum furnace, followed by quenching and tempering. The finished surface showed 0.16 μm in arithmetical mean roughness and 760 HV in Vickers hardness.
Micro shot peening was carried out to the finished surface at 0.2 to 0.6 MPa in projection pressure with a suction type machine. The projection distance was 50 mm. The mass of projected media was 200 g.

Investigation items
SEM observation, arithmetical mean roughness measurement and Vickers hardness measurement on peened surfaces were carried out. Vickers hardness was measured with 0.98 N in test load. Residual stress and retained austenite volume were measured with the X-ray diffraction method and their distributions in the thickness direction were also evaluated by electropolishing.

TEM observation was carried out to clarify microstructure right under the peened surface. The thin film for TEM observation was cut out from the peened surface to the thickness direction by an FIB (Focused Ion Beam) equipment.

Table 2 Comparison of various properties of shot peening media in this study.

Media Code	Heat treatment condition		Vickers hardness (HV)	Density (Mg/m^3)	Average particle size (μm)	Young's modulus (GPa)
LYM	Tempering	823K×2	1014	8.0	70	221
HYM	Annealing	823K	1018	7.4	75	290
Ratio of each property (HYM/LYM)			1.00	0.93	1.07	1.31

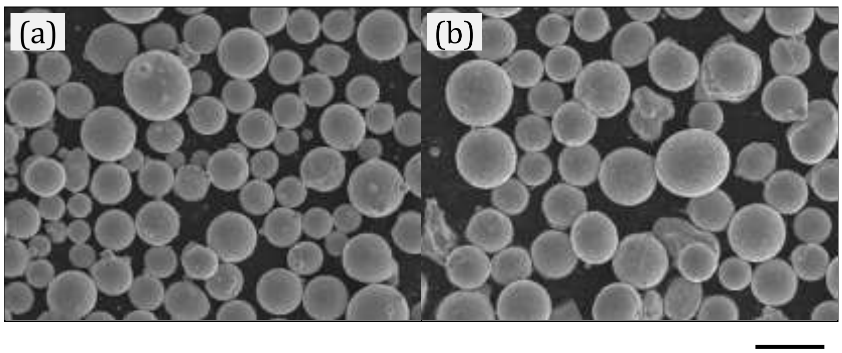

Fig. 2 Appearance images of (a) LYM and (b) HYM.

Results and analysis

Peened surface analyses

Fig. 3 shows SEM images of peened surfaces. Dimples made by the collision of the media are observed on peened surfaces of all workpieces. Arithmetical mean roughness on the peened surfaces increased with increasing projection pressure as shown in Fig. 4. Also, it was clarified that projection with HYM made arithmetical mean roughness of the peened surface higher, compared with projection with LYM. Fig. 5 shows Vickers hardness on the peened surface. In every projection pressure, higher Vickers hardness was obtained by using HYM.

Compressive residual stress and retained austenite volume

Fig. 6 shows compressive residual stress distributions on and right under the peened surfaces. The maximum compressive residual stress in every test condition was observed at around 10 μm in depth from the peened surfaces. The positions where the maximum compressive residual stresses were observed became deep with increase of projection pressure.

Fig. 7 shows the effects of projection pressure and Young's modulus of media on the maximum compressive residual stress. The maximum compressive residual stress increased with increase of projection pressure. In addition, it was clarified that higher maximum compressive residual stress was obtained by using the media with higher Young's modulus.

Fig. 8 shows retained austenite volume distributions on and right under the peened surfaces. Retained austenite volume on the peened surface with every shot peening condition was almost 0 vol. %. So, it was clarified that the retained austenite on the surface before shot peening transformed to the martensite by the intensive collision with the media. In addition, the drop of the retained austenite volume by shot peening was observed until deeper position from the surface, in the case of using HYM, with higher projection pressure.

Microstructure consisting of nanoclystal grain right under peened surface by TEM observation

Fig. 9 shows cross-sectional dark field images with TEM near the peened surfaces. Peening media collided from right upper direction in Fig. 8. Nanocrystal layers were observed on all workpieces' surfaces. White dotted lines in Fig. 8 mean boundaries of a nanocrystal layer and an ordinal crystal area. The thickness of the nanocrystal layer increased with increase of projection pressure. Furthermore, it was clarified that the thicker nanocrystal layer was obtained by using the media with higher Young's modulus.

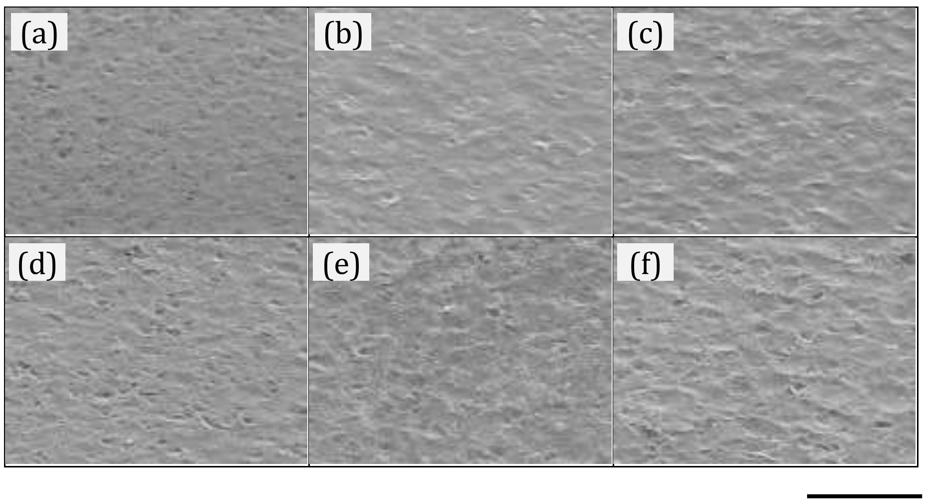

Fig. 3 SEM images of peened surface. (a), (b) and (c) show those peened by LYM at 0.2, 0.4 and 0.6 MPa of projection pressure, respectively. (d), (e) and (f) show those peened by HYM at 0.2, 0.4 and 0.6 MPa of projection pressure, respectively.

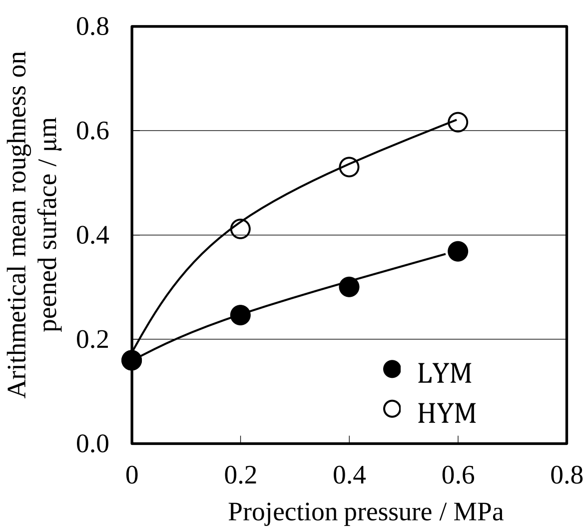

Fig. 4 Effects of Young's modulus of shot peening media and projection pressure on arithmetical mean roughness on peened surface.

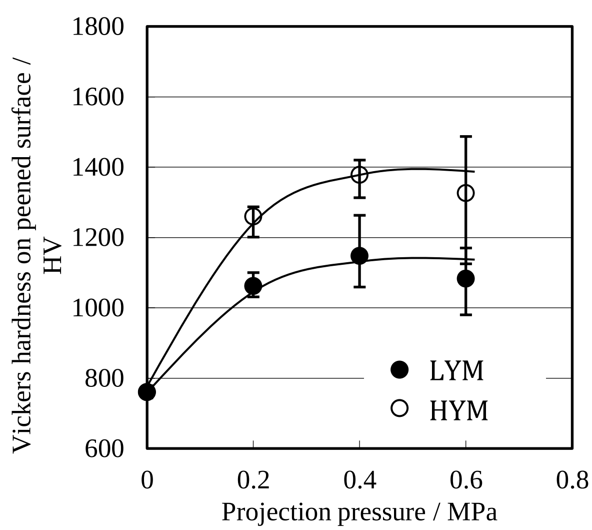

Fig. 5 Effects of Young's modulus of shot peening media and projection pressure on Vickers hardness on peened surface.

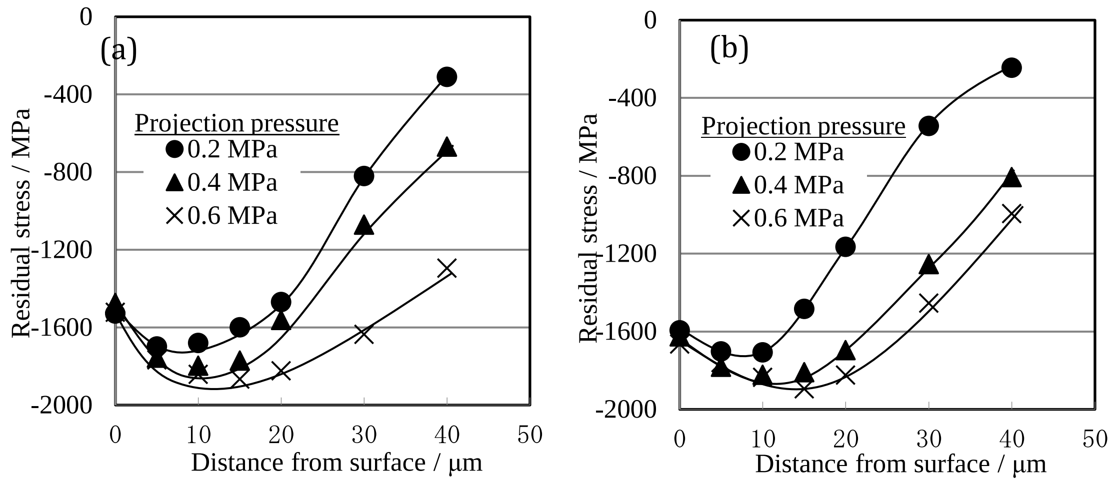

Fig. 6 Residual stress distributions on peened surfaces by (a) LYM and (b) HYM.

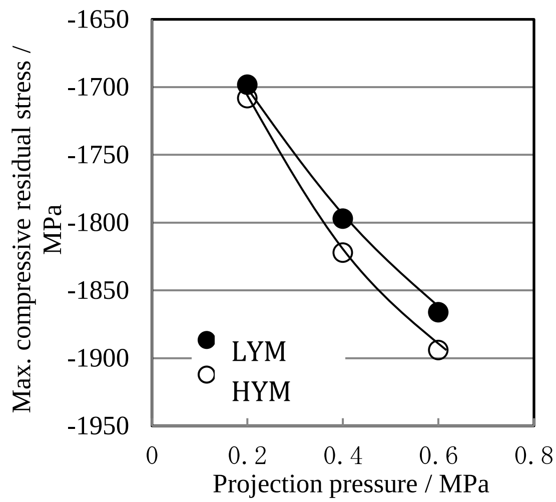

Fig. 7 Effects of Young's modulus of shot peening media and projection pressure on the maximum compressive residual stress on peened surface.

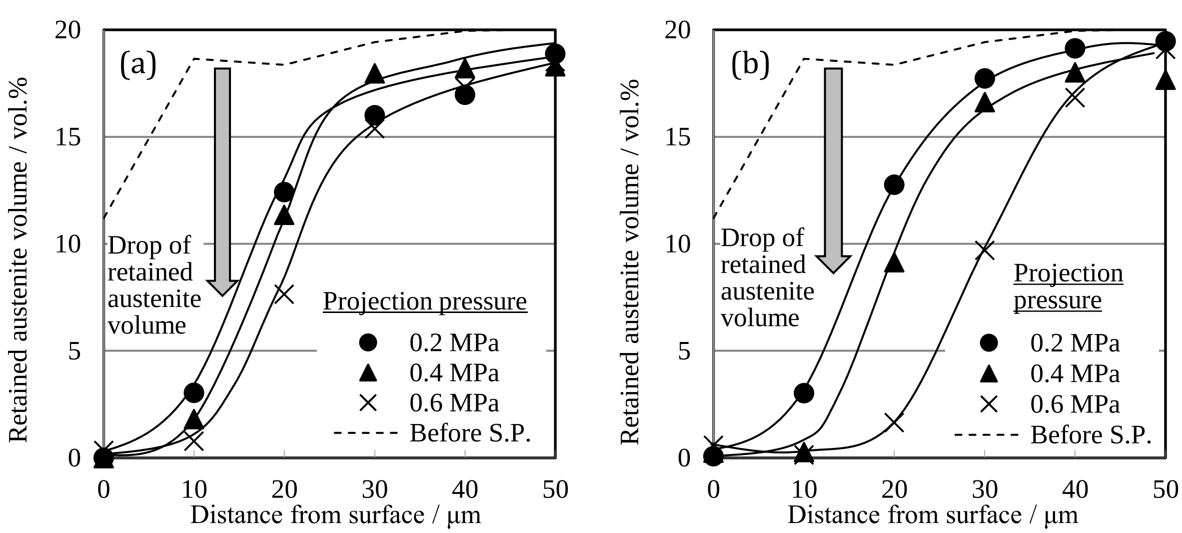

Fig. 8 Retained austenite volume distributions on peened surfaces by (a) LYM and (b) HYM.

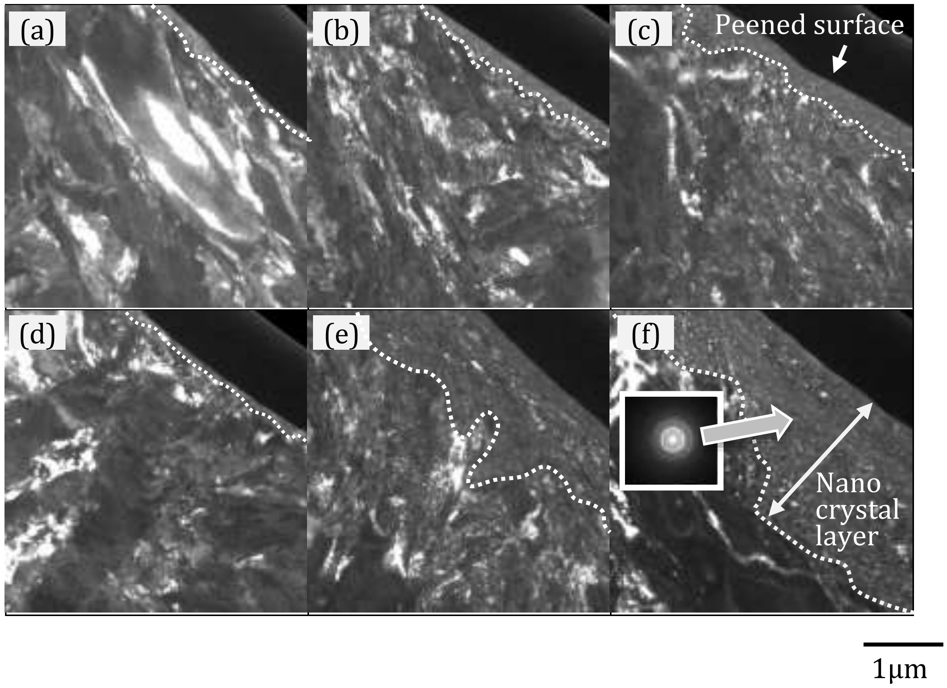

Fig. 9 Dark field images of peened surface with TEM. (a), (b) and (c) show those peened by LYM at 0.2, 0.4 and 0.6 MPa with projection pressure, respectively. (d), (e) and (f) show those peened by HYM at 0.2, 0.4 and 0.6 MPa with projection pressure, respectively.

Conclusions

The effect of Young's modulus of peening media on micro shot peening effects was investigated. Also, as a pretest, the condition setting to manufacture two kinds of peening media that show almost the same hardness, density, particle size and particle shape, but only different Young's modulus was carried out.

(1) It was possible to obtain two kinds of media that had almost the same hardness, density, particle size and particle shape, but only different Young's modulus by adjusting hardness of high speed steel media and FeCrB media by the appropriate heat treatments.

(2) By using the peening media with higher Young's modulus, higher arithmetical mean roughness and higher Vickers hardness on the peened surface were obtained. Also, it was clarified that higher maximum compressive residual stress, drop of retained austenite volume until deeper position and thicker nanocrystal layer could be obtained by using the media with higher Young's modulus.

References

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