APPLICATION OF RESIDUAL STRESS USING POLISHED IMPACT MEDIA

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1. Introduction

Shot peening is a surface modification process that uses blunt-shaped particles as the impact media to apply residual stress fields near the surface, and it has been widely used to improve the fatigue properties of structural and mechanical components. Recent progress in the projection systems and fine particle production methods has made it possible to apply fine particles of less than 100 μm as the impact media, and a micro shot peening process has been proposed as a further effective peening treatment.

On the other hand, shot blasting is a grinding and cleaning process that uses polygonal particles such as abrasive media, and it has also been widely applied as a means of descaling cast bodies. The mechanism for the surface removal in shot blasting is mainly erosive wear, and it results in an increase in the surface roughness accompanied by a degradation of the residual stress field near the surface. As the impact particles' diameter decreases, their geometry becomes much sharper and they act as abrasive media. Therefore, it is possible for erosive wear to occur in micro shot peening.

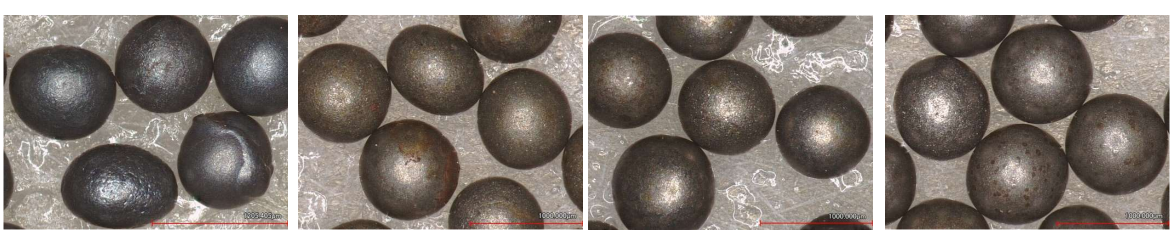
Steel beads are frequently used as the impact media, since their geometry and hardness can be controlled. The surface of the steel beads becomes covered with a thick oxide scale because of the rapid cooling during the atomization process, and becomes rough and contains irregularities. Some beads have a distorted shape and there are concerns about their increasing the erosive wear. Therefore, improvement in the particle roughness, which will affect the reduction of the occurrence of erosive wear, is anticipated.

The present study describes the effects of additional polishing of the steel beads on the mechanical properties, including the hardness, roughness and residual stress, of the shot peened surface, and the applicability of the additional polishing to the improvement of the effectiveness of the shot peening process.

2. Experimental Methods

2.1 Impact media

Steel beads with a nominal diameter of 800 μm were used as the impact media. Polishing of the impact media was carried out using a mass finishing process. The steel beads were put into a polymer vessel with white alumina abrasive media of 12 μm in size and water, and were then agitated using a rubber stirrer. The polishing time varied from 0 to 10 hours. Optical microscope images of the steel beads are shown in Fig. 1. The non-polished beads were covered with a dark oxide layer and their roundness appeared to be inferior. As the polishing time increased, the steel beads became brighter and smoother.



Polishing time 0 h 1 h 5 h 10 h

Fig. 1 Optical microscope images of steel beads

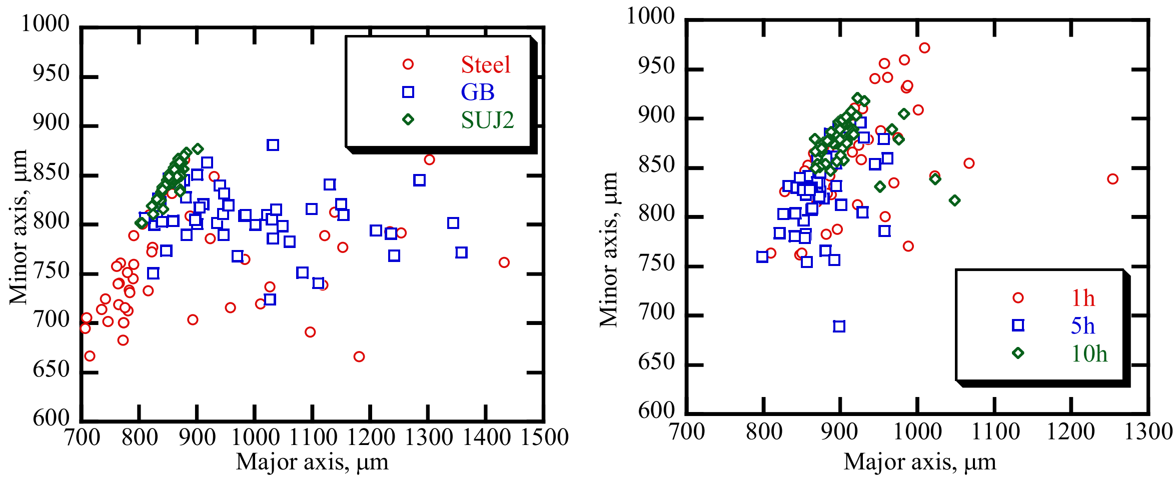
The major and minor axes of the beads measured from the optical microscope images in Fig. 1 are shown in

Fig. 2. Glass beads (550 HV) and hardened chromium alloy steel (SUJ2) balls with a nominal diameter of 800 μm were also used as impact media. The major and minor axes of the non-polished steel beads ranged from 650-800 μm and 700-1450 μm, respectively. A similar tendency was found in the results for the glass beads. As the polishing time increased, the variation in the major and minor axes of the steel beads became smaller. In particular, there was a significant decrease in the range of the major axis.

The roundness, defined as the ratio of the major and minor axes, is listed in Table 4. The roundness was 0.87 for the non-polished steel beads, and increased to 0.94 with the increase in the polishing time. Examination of the optical microscope images and the range of the axis distributions indicates that the polishing was an effective means of improving the smoothness and roundness of the steel beads. In particular, a significant increase in the roundness was found in the 1-hour polished beads.

Table 4 Roundness of polished beads

Bead	Glass	SUJ2 balls	Non-polished	1 h of polishing	5 h of polishing	10 h of polishing
Roundness	0.83	0.99	0.87	0.94	0.94	0.97



A. Conventional beads and balls (with no polishing) B. Polished steel beads

Fig. 2 Distributions of major and minor axes of impact media

2.2 Peening apparatus

The target specimen was a quenched steel disc containing 0.45% carbon (650 HV). The geometry of the specimen was a diameter of 20 mm and a thickness of 8 mm. The end surface was polished with a diamond slurry (size 1 μm) and was used as the target surface. A newly developed peening system consisting of a double-walled nozzle that makes it possible to control the particle flow rate and the projection speed individually was used. The peening conditions are listed in Table 5. After the shot peening, the target surface roughness and the erosive wear loss were evaluated from the surface profile, then the specimen was cut parallel to the peening direction in a way that included the central part in the peening, in order to measure the residual stress and the micro-hardness distribution.

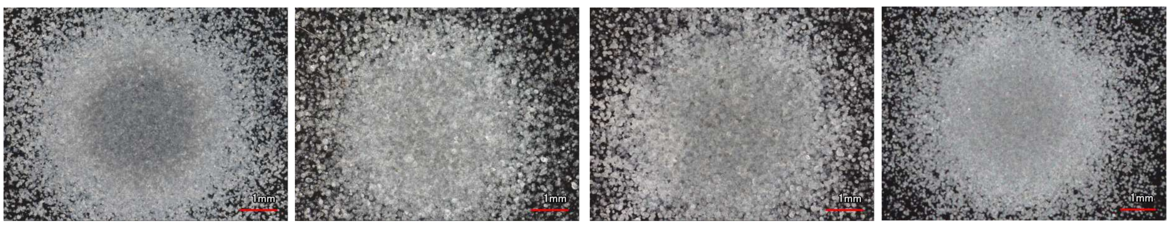
Table 5 Shot peening conditions

Material	S45C
Gas pressure at outer nozzle, MPa	0.6
Gas pressure at inner nozzle, MPa	0.5
Projection angle, deg.	90
Distance between nozzle and target, mm	7
Treatment time, sec	10

3. Results and Discussion

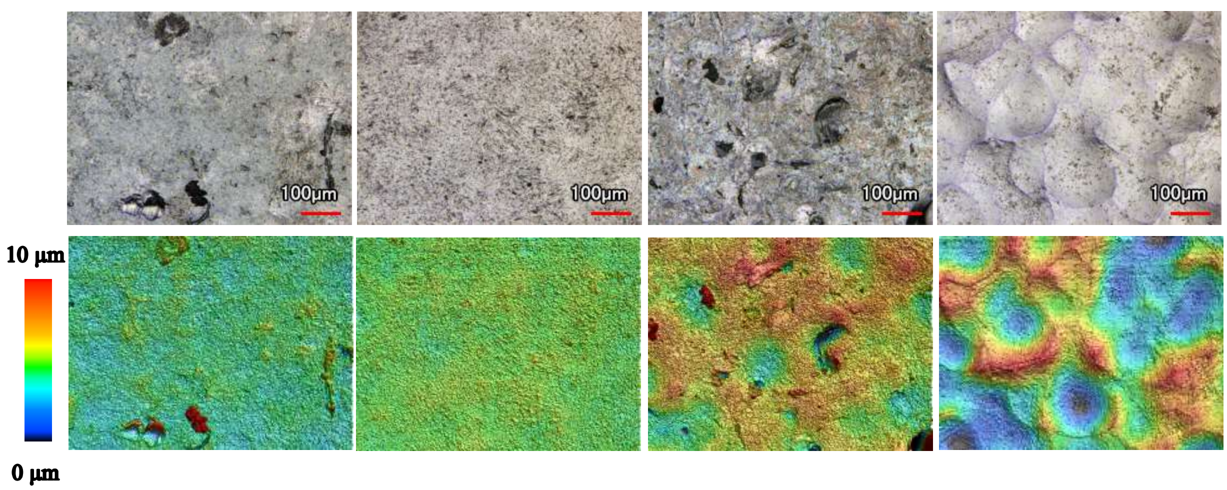
3.1 Target surface roughness

Optical microscope images of the target surface are shown in Fig. 3. The impact marks were concentrated within a diameter of 2.5 mm. A further concentration area less than 2 mm in diameter was also found on the surface peened with the non-polished beads. Enlarged images and surface contour maps of the center of the target surface are shown in Fig. 4. Transfer fragments were found on the surface peened with non-polished beads. In contrast, the surface peened with the 10-hour polished beads was relatively flat and without transfer fragments. An SEM/EDX analysis showed that the transfer fragments were iron oxide. As a result, it was inferred that penetration of iron-oxide fragments resulted in the increase in the target surface roughness. The surface peened with glass beads was relatively rough and had transfer fragments and sweep dents. A larger amount of roughness was also found on the surface peened with SUJ2 balls, and severe plastic deformation near the surface region was suggested, since no fragments were found on the target surface and hemispherical impressions were clearly seen. Therefore, it was found that the increase in the peened surface roughness had been suppressed by using polished steel beads.



Polishing time：0 h 1 h 5 h 10 h

Fig. 3 Optical microscope images of surface peened with polished steel beads



Nominal steel beads 10-h polished steel beads Glass beads SUJ2 balls

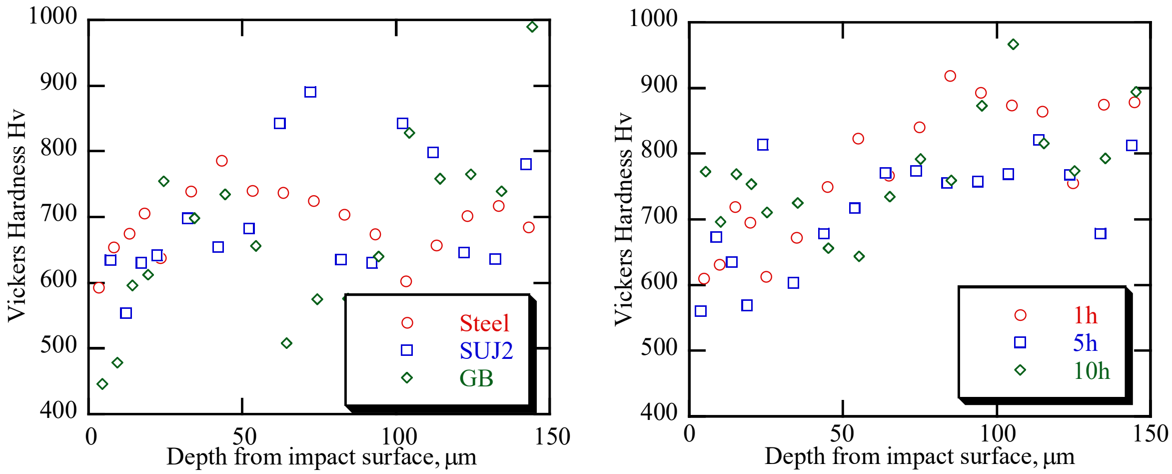
Fig. 4 Optical microscope images (upper) and surface profiles (lower) of peened surfaces

3.2 Hardness distribution

The depth profile of the hardness of the peened surfaces is shown in Fig. 5. The results ranged from 450 to 950 HV. The hardness of the surface peened with glass beads showed a larger amount of scattering. A higher hardness was found for the surface peened with SUJ2 balls. The hardness of the surface peened with polished beads increased with increasing measurement depth, and the range appeared to be smaller than that of the results for the non-polished beads.

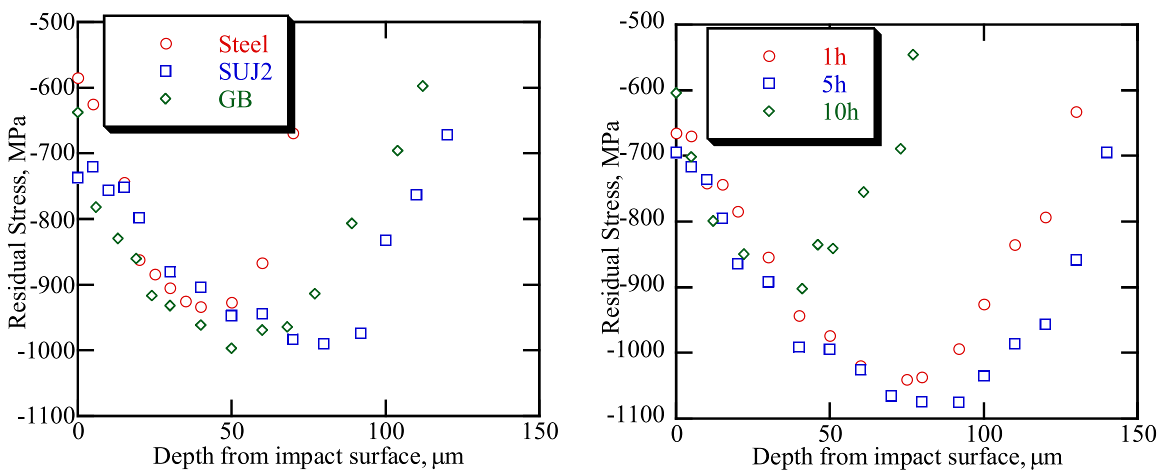
3.3 Residual stress distribution

Residual stress profiles are shown in Fig. 6. The residual stress profile showed that its maximum value was located at a specific depth and the stress and the depth depended on the peening media: For the surface peened with the non-polished steel beads, it was -950 MPa and 40 μm. For the polished steel beads, there was a larger stress of -1050 MPa at a depth of 80 μm. By examining the surface profiles and hardness distributions, it was concluded that the additional polishing of the steel beads is an effective means of improving shot peening effectiveness.



A: Non-polished beads B: Polished steel beads

Fig. 5 Vickers hardness distributions for peened surfaces



A: Non polished beads B: Polished steel beads

Fig. 6 Residual stress distributions for peened surfaces

4. Summary

The applicability of steel bead polishing to the improvement of shot peening effectiveness was examined. As a result, the thick oxide scale was eliminated and the roughness of the beads was improved. The roughness of the target surface decreased and the hardness and residual stress profiles were improved.