INFLUNCE OF MICROSHOT PEENING ON SURFACE CHARACTERISTICS OF HIGH-SPEED TOOL STEEL

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ABSTRACT
The influence of microshot peening on the surface characteristics of the high-speed tool steel was investigated. In general, shot media used for peening consists of small spheres. More recently, new media have been developed to enhance the peening effect. They are made of cemented carbide or amorphous alloy, and the diameter is in the range from 0.02 to 0.20 mm. The use of new media is effective for the hard material such as tool steels. In the experiment, a compressed air-type microshot peening apparatus with a heating furnace was produced experimentally. The peening microshots were 0.1 mm in diameter, and the workpiece was made of high-speed tool steel. Surface roughness, compressive residual stress, and hardness of the peened workpieces were measured. The influences of processing temperature on the surface characteristics by warm peening were also examined. The use of hard microshot was shown to cause a significantly enhanced peening effect for high-speed tool steel.

KEY WORDS
Microshot peening, high-speed tool steel, residual stress, hardness

INTRODUCTION
To enhance fatigue life and the surface characteristics of machine parts, the shot peening process is widely used in automotive industry. The surface characteristics of mechanical parts such as gear and spring can be greatly improved by shot peening. These actions are called the peening effect. In a conventional shot peening process, the peening media consists of small spheres. In general, it is made of high carbon cast steel and the diameter is in the range from 0.3 to 2.0 mm. More recently, new media have been developed to enhance the peening effect. Such the peening media are smaller and harder than the conventional one. They are made of cemented carbide, amorphous alloy, and high-speed tool steel. The diameter is in the range from 0.02 to 0.20 mm. The use of new media is effective for the hard material such as tool steels. In the case of the tool steels in metal forming such as forging and rolling, high wear resistance and high fatigue characteristics are required. Although many new alloys are under development in order to enhance wear resistance and fatigue strength of the tools such as die and punch, at the same time several surface treatment technologies have been developed for improving the surface characteristics. Therefore, many studies have been carried out to investigate the effects of new media on the surface characteristics of the tool steels (H. Akamatsu et al., 2001 ; L. Lu et al., 2003). However, little is known about the relation between the

surface characteristics of high-speed tool steel and shot peening (Y. Harada et al., 2007).

In the present study, the influence of microshot peening on the surface characteristics of the high-speed tool steel were investigated. Surface roughness, hardness and residual stress near the surface were measured after microshot peening.

EXPERIMENTAL PROCEDURE

The apparatus with a heating furnace was fabricated to examine the effect of the working temperature in the warm shot peening operation. The workpiece was set on the holder with the heater. The microshots made of cemented carbide were used. Air pressure was in the range from 0.4 to 0.8 MPa and coverage was from 200 to 800 %. The experiment was performed between room temperature and 300 ^{o}C in air. The conditions used for the shot peening experiment are summarized in Table 1.

The workpiece was the commercial high-speed tool steel JIS-SKH51 quenched and tempered. The dimensions of the workpieces are 25 mm in diameter, 10 mm in thickness. The surface of the workpieces was hand polished on the abrasive papers, and the workpieces were normal heat treated prior to microshot peening. The heat treatment conditions of the workpieces used for the experiment are summarized in Table 1.

The distributions of Vickers hardness, residual stress, and surface roughness in the peened workpieces were measured. The workpiece was cut, and then the distribution of the hardness at the side surface was measured as a distribution in the thickness direction. Vickers hardness test and the determination of residual stress were carried out with a microhardness tester and X-ray diffractometer. The hardness was tested under constant load of 9.80 N. The distribution of residual stress in the thickness direction was obtained from the X-ray diffraction method by removing the surface layer of the workpiece using electrochemical polishing.

Table 1 Conditions of microshot peening

Shot material	Cemented carbide (1400 HV); *d*=0.1 mm
Air pressure / *p*	0.4, 0.6, 0.8 MPa
Coverage / *C*	200, 400, 800 %
Workpiece	High-speed tool steel SKH51 tempered at 550 ^{o}C (930 HV)
Working temperature / *T*	RT, 100, 200, 300 ^{o}C

Table 2 Conditions of warm double peening

Stage	1st	2nd
Shot material	High carbon cast steel (700 HV); *d* =1.0 mm	Cemented carbide (1400 HV); *d* =0.1 mm
Air pressure / *p*	0.8 MPa	0.6 MPa
Coverage / *C*	200 %	200 %
Working temperature / *T*	RT, 100, 200, 300 ^{o}C	RT

The surface conditions were observed by SEM. The microstructures of both the unpeened and the peened workpieces were observed by the optical microscope.

To enhance the peening effect, it is known that double peening and warm peening are effective. In this study, the warm double peening process was performed to enhance the peening effect. This process is a combination of double peening and warm peening. First, to decrease the flow stress of the high-speed tool steel, a first peening was carried out in the warm state using the hard shot media (700 HV). Then, to cause the high compressive residual stress in the top surface, the second peening was carried out using cemented carbide media (1400 HV). The conditions used for the warm double peening experiment are summarized in Table 2.

RESULTS AND DICUSSIONS

Microshot peening

The microshot peening using the cemented carbide media was performed at room temperature. Vickers hardness of the peened workpiece was examined. The distribution of the measured hardness in the thickness direction is given in Figure 1. In all workpieces, the hardness of peened workpiece has peaks near the surface, and the hardness at p =0.8 MPa is the highest. However, inside the workpiece, the difference between the residual stress at p =0.6 and p =0.8 MPa is not large. The plastic deformation induces work hardening to a depth of about 70 % of the shot diameter. On the other hand, Vickers hardness increased as the coverage increased. This is due to the increase of the amount of plastic deformation near the surface.

The residual stress of the workpiece peened at room temperature was examined. The distribution of the measured residual stress in the thickness direction from the surface is illustrated in Figure 2. The residual stress of the peened workpieces has peaks near the surface, and the maximum appears about 2000MPa near 0.01 mm in depth from the surface. As the air pressure increases, the residual stress increases. The surface layer is higher in the mount of plastic deformation than the inside material. However, there is only a slight difference between the residual stress at p =0.6 and p =0.8 MPa. This may be because the surface layer is sufficiently deformed under the air pressure of p=0.6 MPa. The plastic deformation induces compressive stresses to a depth of about 70 % of the shot diameter. On the other hand, the increase of coverage had no effect on the residual stress near the surface.

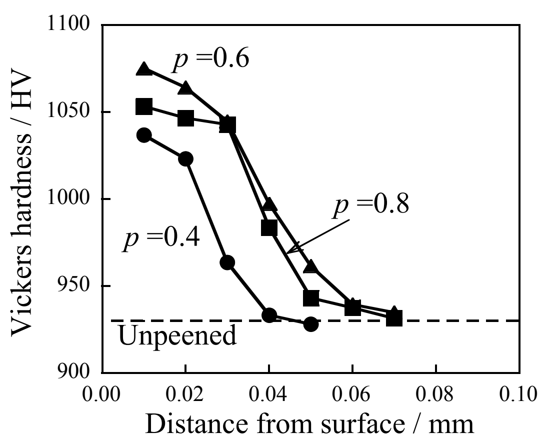

Figure 1 Distribution of Vickers hardness in thickness direction in microshot peening

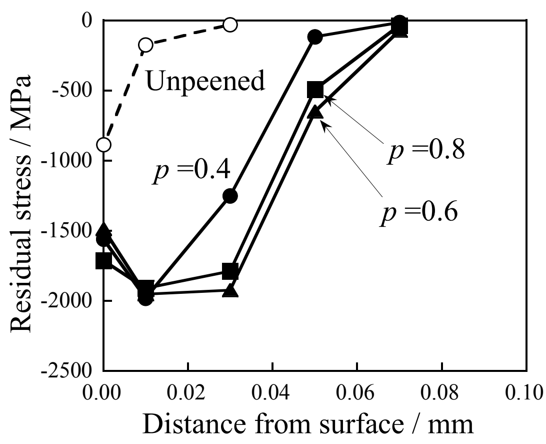

Figure 2 Distribution of residual stress in thickness direction in microshot peening

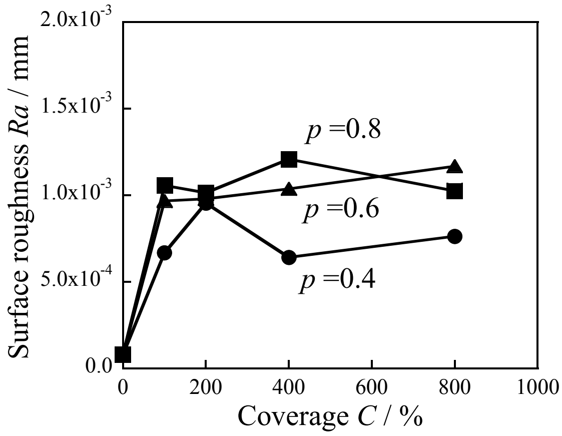

Figure 3 Variation of surface roughness with coverage in microshot peening

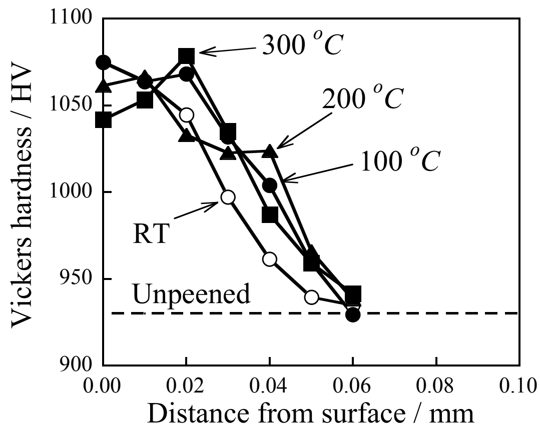

Figure 4 Distribution of Vickers hardness in thickness direction in warm peening

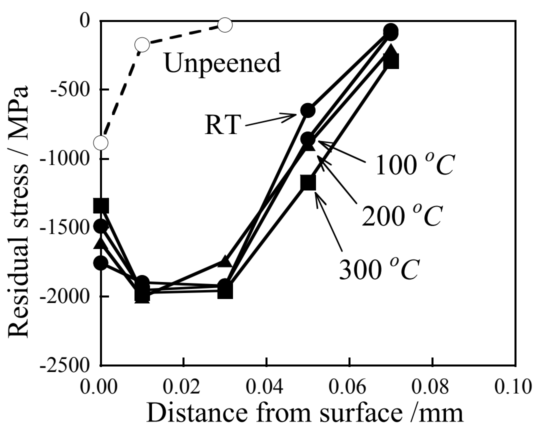

Figure 5 Distribution of residual stress in thickness direction in warm peening

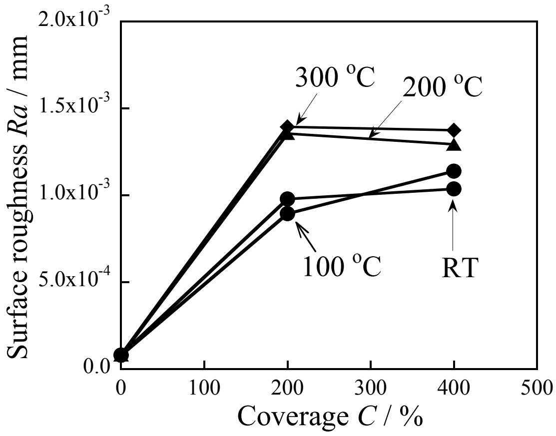

Figure 6 Variation of surface roughness with coverage in warm peening

In order to examine the effects of the air pressure and coverage on surface roughness, the microshot peening experiment was carried out at room temperature. The relationship between surface roughness and the coverage is shown in Figure 3. As the diagram indicates, at initial stage (C =0 - 100 %), there is an immediate sharp increase of surface roughness. However, it is steady over C =200 %. As the shot media used is very small, the surface condition may not change over time. Microshot peening is a very effective means of reducing surface defect.

Warm peening

The microshot peening was performed to investigate the effect of working temperature on the peening effect. Vickers hardness of the peened workpiece was examined over the temperature range room temperature to T =300 °C. The distribution of the measured hardness in the thickness direction is given in Figure 4.

The air pressure is p =0.6 MPa. The hardness of peened workpieces has peaks near the surface. As the working temperature increases, hardness increases owing to the flow stress of workpiece lowers. The distributions of hardness in the workpieces peened by warm shot peening were almost unchanged by varying the coverage.

The distribution of the measured residual stress in the thickness direction from the surface for the different working temperature is shown in Figure 5. The air pressure is p =0.6 MPa. The values of residual stress are similar for all working temperature. The maximum appears about 2000 MPa near 0.01 mm in depth from the surface. Compared to the maximum obtained at room temperature, it is unchanged in warm. When the coverage was C =400 %, the increase of coverage had no effect on the residual stress near the surface.

The relationship between the surface roughness and the coverage is shown in Figure 6. As the working temperature increases, surface roughness increases. Surface roughness of the workpiece peened at T =200 ^{o}C or 300 ^{o}C is about Ra =0.0013 mm. The flow stress of the workpiece decreases with an increase in temperature.

Warm double peening

The warm double peening process was applied to enhance the peening effect. The distribution of the measured hardness in the thickness direction is given in Figure 7. The air pressure and the coverage are p =0.6 MPa and C =200 %. The result of the workpiece peened only by the cemented carbide media is added for comparative purposes. In all workpieces, hardness of the peened workpieces has peaks near the surface. However, the hardness near the surface is similar to all working temperature. The effect of the warm double peening on hardness is small. On the other hand, inside the workpieces, hardness increases as the working temperature. This is due to the reduction of flow stress. Hardness inside the workpiece is maximum at T =300 ^{o}C. The depth of hardening layer generated by the warm double peening is roughly twice that obtained from the first step peening.

The distribution of the measured residual stress in the thickness direction from the surface for the different working temperature is shown in Figure 8. The air pressure and the coverage are p=0.6 MPa and C=200 %. The result of the workpiece peened

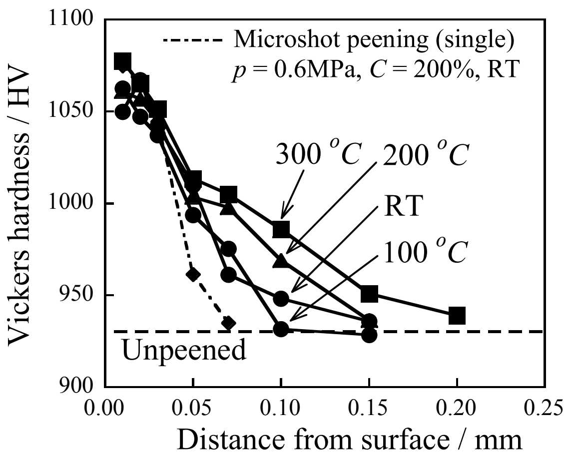

Figure 7 Distribution of Vickers hardness in thickness direction in warm double peening

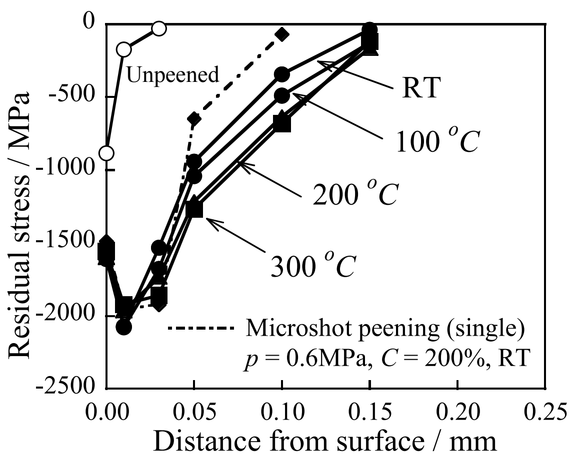

Figure 8 Distribution of residual stress in thickness direction in warm double peening

only by the media of cemented carbide is added for comparative purposes. The values of residual stress near the surface are similar to all workpieces. The maximum appears about 2000 MPa near 0.01 mm in depth from the surface. The results are similar to those found in Figures 2 and 5. On the other hand, warm double peening induces large compressive residual stress inside the workpiece.

CONCLUSIONS

The influence of microshot peening on the surface characteristics of the high-speed tool steel was investigated. The shot peening process using the cemented carbide microshot was very efficient in improving the surface characteristics. Especially, the residual stress near the surface was higher under the low surface roughness. Warm peening and warm double peening using microshots were also carried out to examine the influence of the processing temperature on the surface layer characteristics. The use of microshots in warm shot peening process was found to cause a significantly enhanced peening effect for the high-speed tool steel.

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