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Influence of Pre-Annealing on Surface and Surface Layer Characteristics Produced by Shot Peening

Katsuji Tosha
Meiji Univ. Higashimita, Tama-ku, Tawasaki, Japan
Jian Lu, Delphine Retraint, Bruno Guelorget
Universite de Technologie de Troyes, Rue Marie Curie, Troyes, France
Kisuke Iida
Society of Shot Peening Technology of Japan, c/o Meiji Univ. Kawasaki, Japan

1 Introduction

Several effects produced by shot peening for fatigue strength, stress corrossion cracking, wear resistance, heat transfer and flow resistance are reported in many papers. Their factors relative to those effects are surface roughness, residual stresses, hardness and texture. In general, peening effects for fatigue strength are influenced by compressive residual stresses and work hardening [1, 2, 3] , and for heat transfer or radiation is influenced by surface roughness and affected layer [4, 5], but their relations with each factors are not always simple. The most important factor of the effect for fatigue strength is residual stress, and residual stress value changes with the texture of work material and the measuring ways.

In this experiment, in order to clarify the influences of shot peening on the surface roughness, hardness distribution, half width and residual stress, work materials with several different hardness produced by different annealing conditions were peened, and the influence of pre-annealing on surface and surface layer characteristics was studied.

2 Experimental Conditions and Procedures

Experimental conditions on shot peening and residual stress measurement are shown on Table 1 and Table 2 respectively.

Three surface profiles for one specimen were recorded without cut- off and surface roughness R_y was calculated from the records. Hardness distribution was obtained from perpendicular section to the peened surface with Vickers hardness tester, and averaged from the data at the same depth on three positions. Residual stress was measured using X-ray diffractometer.

The pre-annealing temperature and time were changed from 620 degrees to 900 degrees centigrade and from 1 hour to 8 hours respectively.

Table 1. Shot Peening

Equipment	Direct pressure type
Dia. of nozzle	ϕ 6 mm
Air pressure	0.4 MPa
Shot	Cut wire 0.8 mm
Peening time	Tf (5s)
Peening angle	90 °
Work material	Carbon steel (C:0.45%)
Pre-annealing	620, 723, 820, 900 ° C 1, 2, 4, 6, 8 h

Table 2. Residual stress measurement

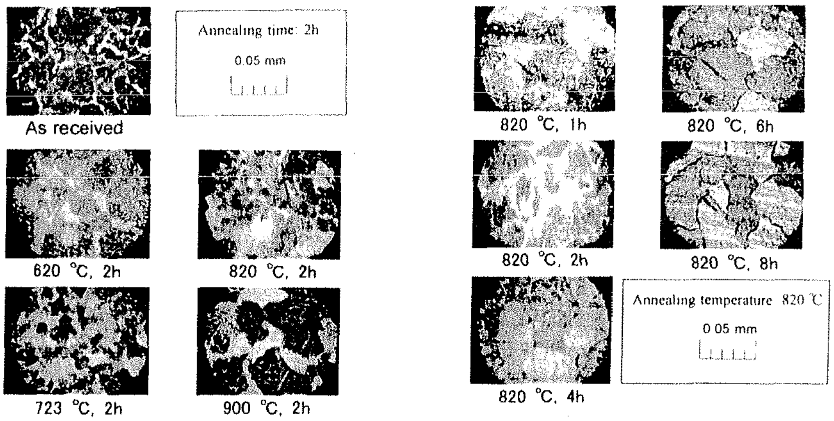
X-ray tube	Cr-K α
Stress constant	-297 MPa
Diffraction plane	(211)
ϕ angle	-12, 6, 15, 21, 27, 33 °
Dia. of projection area	0.15, 0.3, 0.5, 1, 2 mm
Peak angle	$\sin^2\phi$ method

3 Experimental Results

3.1 Influence of Annealing

3.1.1 Number of Grains

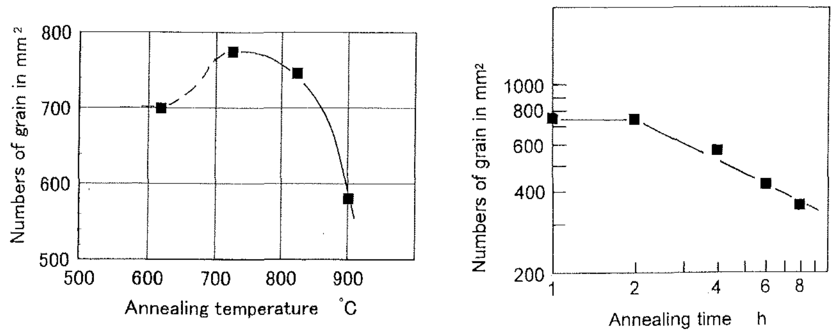
Figure 1 shows microstructures etched by 3% aqueous solution of nitric acid. Ferrite and cementite become much clear after annealing, and in the case of 900 °C, 6h and 8h of 800 °C annealing, grain growth were observed clearly.



(a) Influence of annealing temperature (b) Influence of annealing time

Figure 1: Microstructures

Figure 2 shows the influence of annealing temperature and time on the numbers of grains per unit area. As shown in Fig. 2(a), the grain numbers is the most in the case of 720 °C, because the grain size of as-received material is relatively large. Figure 2 (b) shows the influence of annealing time in the case of 820 °C, and the number is inversely proportional to the time over 2 hours annealing.



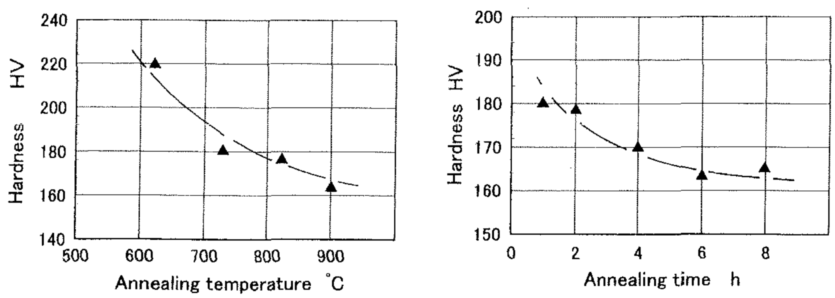
(a) Influence of annealing temperature (Annealing time: 2 hours)

(b) Influence of annealing time (Temperature: 820 ° C)

Figure 2: Influence of annealing on the numbers of grains per unit area

3.1.2 Hardness of Work Material

Figure 3 shows the influence of annealing on the hardness of the work material. As the hardness is 290HV, the hardness after annealing of 620 °C decreases largely, but annealing is not complete. After 723 °C annealing, those hardnesses are almost similar to each other. As shown in Fig. 3(b), the hardness decreases gradually with the annealing time.



(a) **Influence of pre-annealing temperature (Annealing time: 2 hours)**

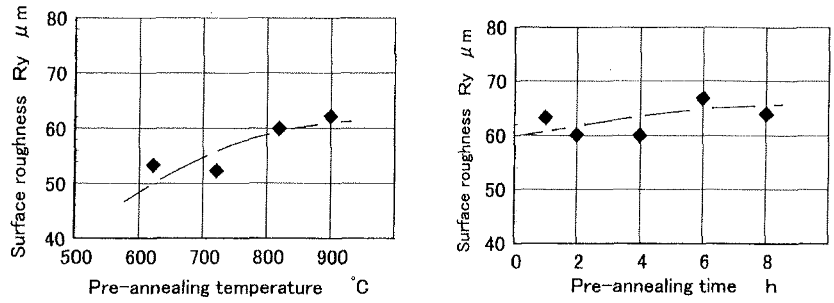
(b) **Influence of pre-annealing time (Temperature: 820 ° C)**

Figure 3: Influence of pre-annealing on the hardness

3.2 Shot Peened Material

3.2.1 Surface Roughness

Surface roughness produced by shot peening is shown in Fig. 4(a), (b). Surface roughness increases slightly with the pre-annealing temperature and time.



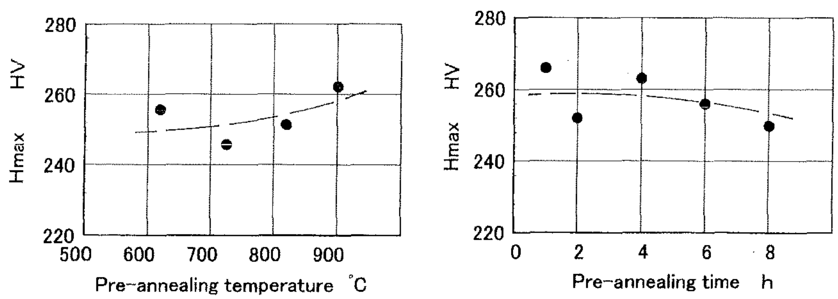
(a) Influence of pre-annealing temperature (Annealing time: 2 hours)

(b) Influence of pre-annealing time (Temperature: 820 °C)

Figure 4: Influence of pre-annealing on the surface roughness

3.2.2 Hardness Distribution

In this experiment, hardness distribution are all work hardening types. The influences of pre-annealing on the maximum hardness (Hmax) and the depth of work hardened layer (δ) are shown in Fig. 5 and Fig. 6 respectively. Their influence of the temperature are relatively small, but the depth of the work hardened layer increases gradually with pre-annealing temperature and time.



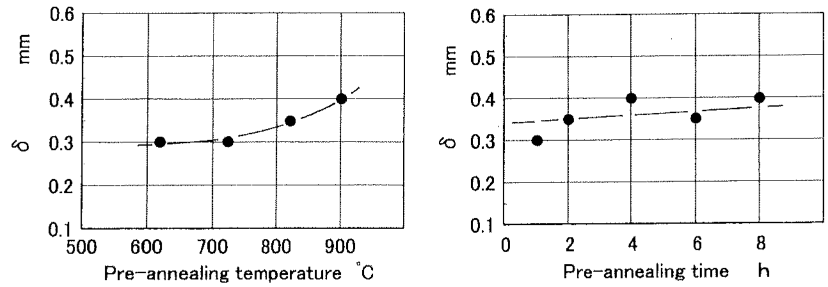
(a) Influence of annealing temperature (Annealing time: 2 hours)

(b) Influence of annealing time (Temperature: 820 °C)

Figure 5: Influence of pre-annealing on the maximum hardness (Hmax)

3.2.3 Half Width

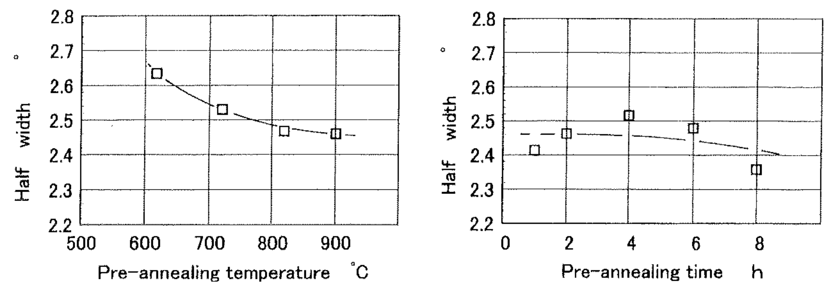
Half width means the micro strain of crystals and the change is similar to the hardness one. As shown in Fig. 7, the half width of 600 and 723 °C annealed materials are larger than those of other cases and this means that the micro strain before shot peening affects the values after shot peening. In the case of 820 °C pre-annealing, the influence of the time is shown in Fig. 7(b).



(a) Influence of annealing temperature (Annealing time: 2 hours)

(b) Influence of annealing time (Temperature: 820 ℃)

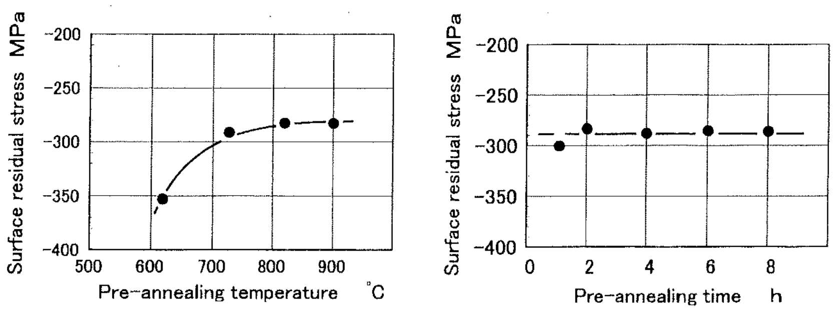
Figure 6: Influence of pre-annealing on the depth of work hardened layer



(a) Influence of annealing temperature (Annealing time: 2 hours)

(b) Influence of annealing time (Temperature: 820 ˚C)

Figure 7: Influence of pre-annealing on half width



(a) Influence of annealing temperature (Annealing time: 2 hours)

(b) Influence of annealing time (Temperature: 820 ˚C)

Figure 8: Influence of pre-annealing on surface residual stresses

3.2.4 *Surface Residual Stress*

As shown in Fig. 8, the influences of shot peening on the surface residual stresses is very small except for the case of 620 °C pre-annealing.

3.3 Grain Size and Change of Surface Residual Stresses

As the grain size is relative to the micro residual stresses, at first, the influence of X-ray projection area on the surface residual stresses is discussed.

3.3.1 *Influence of Projection Area*

The projection area is changes with the diameter of a collimator. Figure 9 shows the results on the scattering of surface residual stresses and Figure 10 shows the relation between the projection area and the difference of residual stress. Its difference is inversely proportional to the projection area. These differences suggest that micro residual stresses are also affected by the grain size.

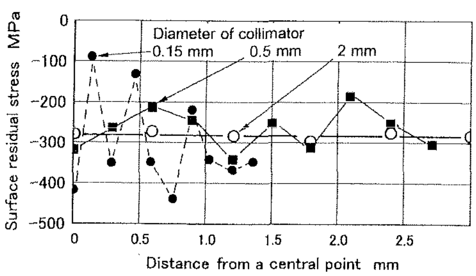


Figure 9: Difference of surface residual stresses by the X-ray projection area

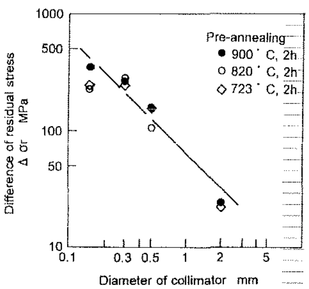


Figure 10: Relation between the projection area and the difference of residual stresses

3.3.2 *Influence of Grain Size on the Difference of Micro Residual Stresses*

Figure 11 shows the difference of residual stresses measured using collimators of ∅ 2 mm and 0.15 mm in diameter. As shown in Fig. 11(b), in the case of small projection area, the differences increases with the grain size.

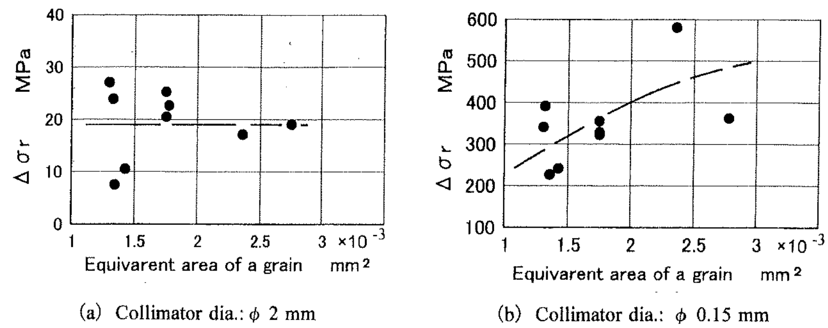


Figure 11: Influence of the grain size on the differences of surface residual stresses

4 Conclusions

In order to clarify the influence of pre-annealing on surface characteristics produced by shot peening, shot peening was performed for a plain carbon steel (C:0.45%) with conditioned cut wire-shot by an air blasting machine. The influence of grain size and hardness of the work material on the several characteristics such as surface roughness, hardness and residual stresses and half width were discussed, and the following results are obtained.

The grain size increases but the hardness of work material decreases with the increase of pre-annealing temperature.

The depth of work hardened layer and the maximum hardness in the affected layer are affected by the increase of pre-annealing temperature.

The influence of pre-annealing on residual stress values is not very large, but the scattering of residual stress values increase with the pre-annealing temperature.

The maximum difference of surface residual stresses is 584 MPa in this experiment

5 Acknowledgement

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6 References

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