SHOT PEENING AND GRIT BLASTING - EFFECTS ON SURFACE INTEGRITY-

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ABSTRACT
This paper describes influence of factors such as particle size (0.55-2.2 mm), particle velocity (15-35 m/s) and work hardness on surface integrity. Hardness, residual stress and crystal transformation of areas affected by shot peening or grit blasting are examined. In order to clarify the influences of those factors on the surface integrity, a medium carbon steel (C:0.45%, 180HV) and an austenitic stainless steel (SUS304, 210HV) were peened by a centrifugal type peening machine using cast steel particles (650-800HV). The following results were obtained: (1) Shot peening maximum hardness is lower while depth of work-hardened layer is thicker. (2) Compressive residual stresses on the peened surface are larger than that of grit blasting. (3) Critical thickness of shot peening is about 50% thicker than that of grit blasting. (4)Strain-induced transformation happens with shot peening and grit blasting.

SUBJECT INDEX
Surface integrity, hardness distribution, residual stress, critical thickness, strain induced transformation

INTRODUCTION
Shot peening and grit blasting are cold working processes where the worked material is peened with spherical shots or non-spherical grits to introduce compressive residual stresses and work hardening or alternatively to remove surface layers. Shot peening improves the mechanical properties such as fatigue (Drechsler et al, 1999), stress corrosion cracking (Kirk, Render, 1999) and so on (Watanabe et al, 1999). Shot peening is therefore widely used in many industries such as aircraft, automobile and machines. Grit blasting produces stock removal and affected layer simultaneously by impact of the grit on work material (Kock et al, 1984).

Surface integrity is a concept including hardness alternations, residual stresses, plastic deformations, heat-affected zone, recrystallization and so on. It influences strength of work materials for fatigue, stress corrosion cracking, wear and so on (Takazawa, 1989). Although shot peening and grit blasting techniques are widely used in many industries, systematic studies on surface integrity are very few.

In order to clarify the influences of those factors on surface integrity, a medium carbon steel (C:0.45%, 180HV) and an austenitic stainless steel (SUS304, 210HV) were peened by a centrifugal type peening machine using 4 different cast steel

METHODS

Experimental conditions on shot peening (SP), grit blasting (GB), work material and residual stress measurement are shown in Table1. Hardness was measured on the perpendicular section using a micro Vickers hardness tester. Hardness distributions were obtained from averaging data measured on the three positions in the same depth from the peened surface. Stock removal which is the important factor in grit blasting was measured using a digital balance whose sensitivity is 0.1 mg. Half-width values are the average obtained from six different inlet angle of X-ray on the residual stress measurement.

Table 1 Experimental conditions

Equipment	Centrifugal type: 15 – 35 [m/s]
Shot and grit: Material, size	Steel : 0.55, 0.92, 1.1, 1.6, 2.2 [mm] Hardness: 650~800 [HV]
Blasting time	1 [s] ~T_f, T_f: Full coverage time
Blasting angle	0, 30, 45, 60, 90 [_] *) *)90[_]: Normal to the peening surface
Work: Material	Medium carbon steel (0.45%C) Hardness: 180 [HV] Size: 25_25_t, t: 1~11.5 [mm]
	Austenitic stainless steel (SUS304) Hardness: 210 HV Size: _20_H20 [mm]
X-Ray diffraction	Cr-k_, (2 1 1) plane
Residual stress measurement	FWHM middle point method

RESULTS

Hardness distribution

Figure 1 shows hardness distributions of cross section after blasting to medium carbon steel. Shot peening maximum hardness is lower while depth of work-hardened layer is thicker. This, therefore, means that the deformation in the hardened layer of grit blasted material is different from that of shot peened one as illustrated in Fig. 2.

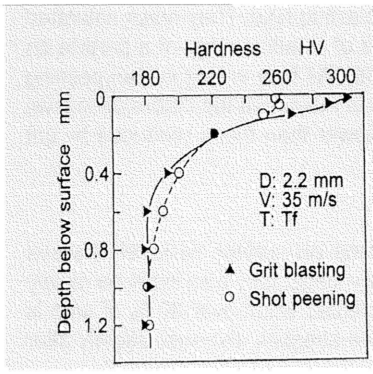

Fig.1 Comparison of hardness distribution Produced by SP and GB

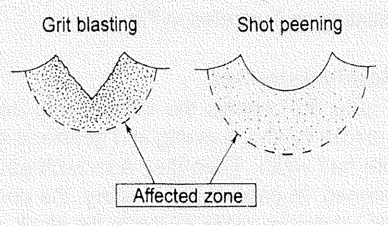

Fig. 2 Difference of affected zone produced by SP and GB

Stock removal

In blasting process, numerous shots or grits are blasted with centrifugal force. The total area of dents increase with blasting time till full coverage. Although stock removal does not appear in shot peened material during the peened time in this experiment, in case of grit blasting, it increases with blasting time as shown in Fig.3.

Stock removal is also influenced significantly by the blasting angle. Figure 4 shows the influences of normal velocity and of tangential component on stock removal. It shows the results obtained from two experiments. In the first one blasting angle is variable with a constant normal velocity. In the second one normal velocity is variable with a normal blasting angle. Nevertheless normal component of grit velocity is the same. Stock removal on the oblique blasting is larger than that on normal blasting.

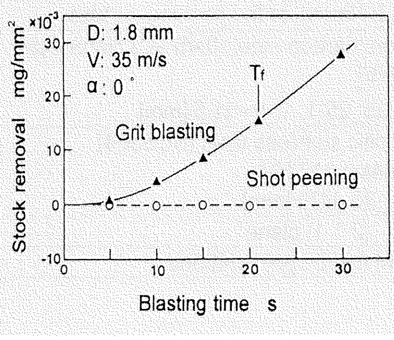

Fig.3 Influence of blasting time on stock removal

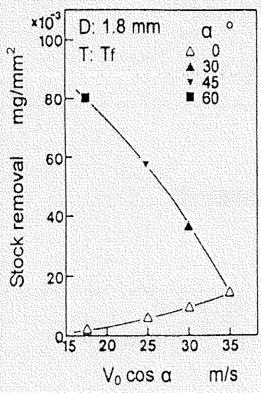

Fig.4 Influence of normal velocity on stock removal

Half width

The broadening of half width means the increase of the scatter of the micro strain in crystal, and its change is similar to the hardness one. Figure 5(a) shows the influence of blasting time on half width. Half width values produced by shot peening and grit blasting increase rapidly with blasting time. They reach saturated values near full coverage times. The influences of kinetic energy of a particle on the half width are very small as shown in Fig. 6(a). As their values in shot peening are always less than in grit blasting. These results mean that the deformation level of surface layer produced by shot peening is lower than those produced by grit blasting as illustrated in Fig. 2.

Residual stresses

Figure 5(b) shows the influence of peening time on surface residual stresses induced by shot peening and grit blasting. In early stage, they also increase rapidly like half width. Then they approach saturated values when over 80 % of area is peened. In case of grit blasting, the compressive stresses decrease slightly after the maximum value, owing to the stock removal.

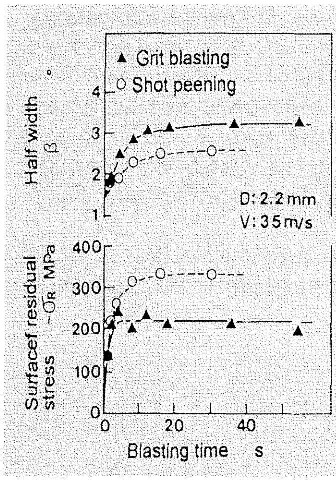

Fig.5 Influence of blasting time on half width and surface residual stress

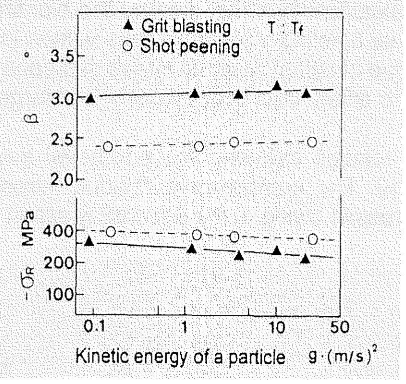

Fig.6 Influence of kinetic energy of a particle on half width and surface residual stress

The influence of kinetic energy of a particle on surface residual stresses is very small and decrease slightly with the energy as shown in Fig. 6(b). The influence of blasting conditions such as particle size and its velocity on surface residual stresses are shown in Fig.7. In the case of shot peening, the influences of both factors are negligible. In the case of grit blasting, the influence of grit size is small, but the influence of velocity of grit is larger than that of shot peening.

Figure 8 shows the effect of the specimen thickness on the surface residual stresses. Critical thickness (Tc) means the minimum thickness for efficient introduction of compressive residual stresses. Compressive residual stresses induced by grit blasting are lower than those of shot peening wherever the thickness is over the critical thickness. Surface residual stresses fall to zero wherever the thickness of work material and those depths of work hardened layer are overlapped.

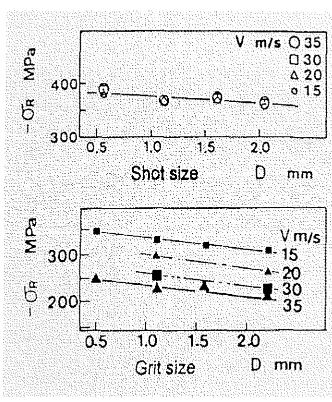

Fig.7 Influence of particle size on surface residual stresses

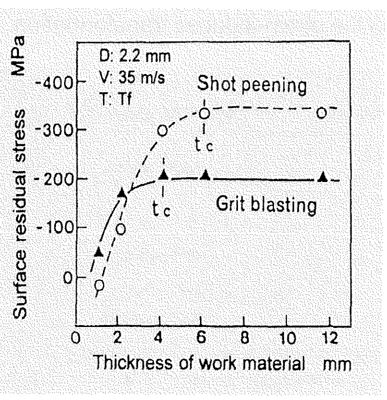

Fig.8 Influence of thickness of specimen on surface residual stresses

Figure 9 shows combinated influence of angle and particle normal velocity on surface residual stresses for shot peening and grit blasting. Residual stresses induced by shot peening are approximately constant while values for grit blasting are significantly influenced by the blasting angle and normal velocity. In case of normal blasting, residual stress values increases with normal velocity. In case of oblique blasting, residual stress decreases while normal velocity increases. This is due to differences in grit velocity and large cutting action as mentioned in Fig. 4.

The relation between stock removal and surface residual stresses is shown in Fig.10. The compressive residual stresses decrease while the stock removal inscreases owing to the grit cutting action.

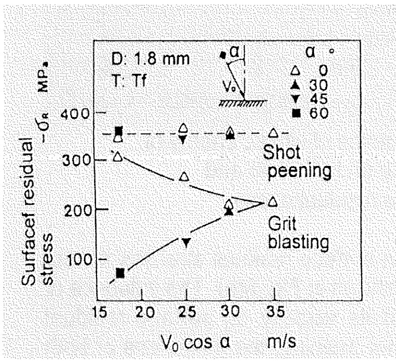

Fig. 9 Influence of normal velocity on surface residual stresses

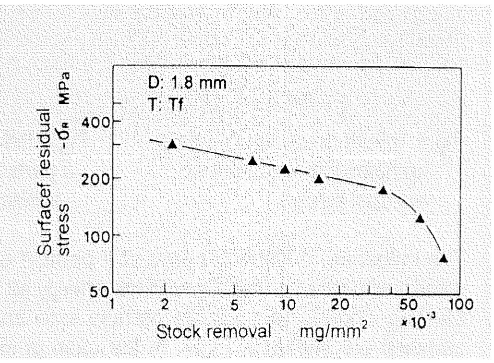

Fig.10 Relation between stock removal and surface residual stress

Transformation of crystal

Figure 11 shows the X-ray diffraction patterns on as-annealed, grit blasted and shot peened. The peak neighbored on 149 degree shows that the structure of the annealed material is clearly austenite. After blasting, the height of the peak decreases and another peak arises neighbored on 156 degree, which is the peak of (211) plain of alpha-Fe. This result suggests that strain-induced transformation happened due to blasting. Figure 12 shows the austenite volume distribution changed by shot peening, and also the volume in the affected layer decrease owing to the strain-induced transformation.

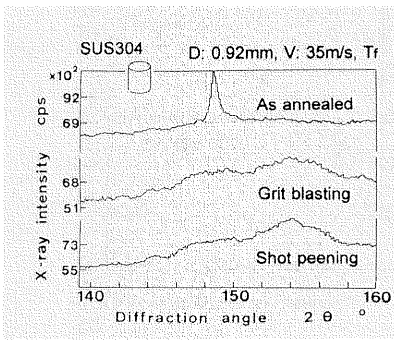

Fig. 11 X-ray diffraction patterns

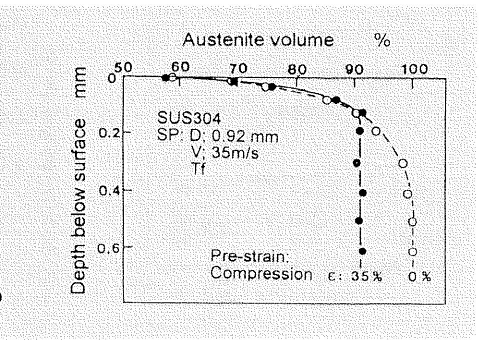

Fig.12 Austenite volume distributions after shot peening

Fatigue strength of shot peened material

The important factors closely relating to the fatigue strength are residual stresses, work hardening or forging effect and surface roughness. Figure 13 shows the effect of thickness of specimen and peening effect for 3 different thickness of specimen. The fatigue strengths increases while the thickness decreases with the exception of one result.

Figure 14 shows the influence of affected-layer ratio (ratio of the depth of work-hardened layer to the thickness of material) on the increase of fatigue strength. The sweet zone is from 0.3 to 0.4 of the ratio.

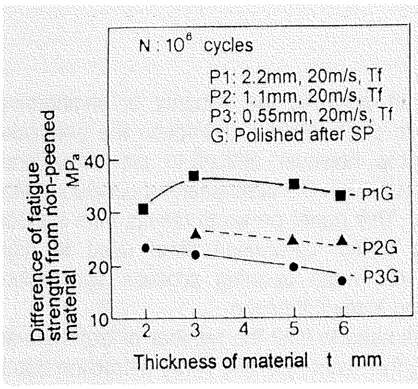

Fig. 13 Influence of thickness of specimen on fatigue strength

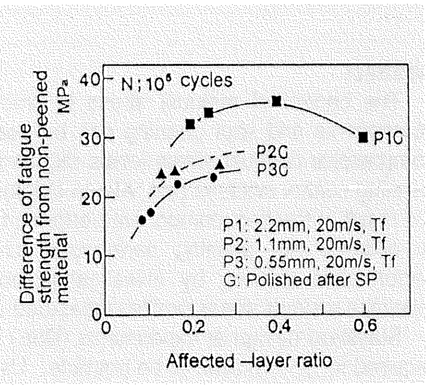

Fig.14 Influence of affected-layer ratio on fatigue strength

CONCLUSIONS

Hardness distribution produced by blasting is different for those points:

(1) Shot peening maximum hardness is lower while depth of work-hardened layer is thicker.
(2) Compressive residual stresses induced by shot peening is larger than the one induced by grit blasting owing to stock removal.
(3) Critical thickness produced by shot peening is about 50% thicker than those c grit blasting.
(4) Strain-induced transformation happens by shot peening and grit blasting.

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