STOCK REMOVAL AND SURFACE RESIDUAL STRESS OF GRIT BLASTED TITANIUM

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ABSTRACT

Recently titanium became the useful materials for aircraft and automobile industry. But the studies on titanium are not so much as that on steel, especially as to grit blasting. The characteristics of titanium for grit blasting are treated and compared with shot peening experimentally in this paper. Grit blasting is performed for commercially pure titanium (99.6 %) and carbon steel (0.45%C) with steel grit and centrifugal blasting machine. Blasting variables are grit size, grit velocity, blasting time and blasting angle. To clarify the influence of these variables on the work materials, surface roughness, hardness distribution, surface residual stress and stock removal are measured. Surface roughness of titanium is proportion to grit size and velocity as the same to steel. Depth of work hardened layer is proportion to the fourth root of kinetic energy of a grit. The maximum work hardening ratio is larger than that of steel. Stock removal of titanium is proportion to the square of blasting time, to the cube of grit size and to 4.5 power of grit velocity. In grit blasting, titanium induces less surface residual stress from 5 % to 48 % than in shot peening. The more grit size and velocity, the less the surface residual stress owing to stock removal. Surface residual stress decreases to half when blasting angle increases from 0 to 60 degree by the affect of tangential component of grit velocity.

KEYWORDS

Grit blasting, titanium, shot peening, surface roughness, hardness distribution, surface residual stress, stock removal, grit size, grit velocity, blasting time, blasting angle.

INTRODUCTION

Blasting process is divided into two types, shot peening and grit blasting. The media of the former is spherical and the latter is nonspherical. Grit blasting is a process of stock removal and improving of surface quality[1]. Factors influence on stock removal are grit size and velocity, blasting angle and blasting time. Recently, nevertheless use of titanium is increasing for automobile and aircraft industries [2][3], but there is few reports about the influence of grit blasting on surface roughness, stock removal and hardness.

This experiment was run as the first approach on the characteristics of the grit blasted titanium. Grit blasting and shot peening were performed for a commercially pure titanium (Ti: 99.6 %) and a carbon steel (0.45 %C) under several blasting variables. Surface roughness, hardness distribution, surface residual stress and stock removal were measured and then influences of grit blasting on the characteristics of titanium were discussed.

EXPERIMENTAL CONDITIONS AND PROCEDURE

Table 1 shows a blasting machine, grit, shot, blasting variables and specimen. Table 2 shows equipments used in this experiment for measurements of stock removal, hardness, surface roughness and residual stress.

Table 1 Experimental conditions

Blasting machine	Centrifugal type
Grit and shot	Material: Cast steel(HV 510) Size D mm: 0.55 - 2.2, Velocity V m/s: 17.5 - 35
Blasting time	T s: 1 - Tf (full coverage time)
Blasting angle	θ deg: 0 - 60
Specimen	Material St: Annealed carbon steel (0.45 %C), HV: 180 Ti: Annealed pure titanium (99.6 %), HV: 150 Size 25W × 25L × 11.5t

Table 2 Equipments of measurement

Measurement	Equipment		
Stock removal	Balance	Sensitivity	0.1 mg
Hardness	Micro vickers tester	Load	100 gf, 200 gf
Surface roughness	Profile recorder	Magnification	×100, ×50000
Residual stress	X-ray diffractmeter	Target Tube voltage Tube current	Cr(for steel) Cu(for titanium) 30kV 35mA

Surface residual stress was calculated from the following formulae using X-ray diffractmeter.

$$\sigma_R = -\frac{E}{2(1+\nu)} \cot \theta_0 \frac{\partial 2\theta}{\partial \sin^2\psi}$$

where $\nu = 0.32$, E = 113 GPa for titanium, and $\nu = 0.28$, E=206 GPa for steel.

EXPERIMENTAL RESULTS AND DISCUSSION

Surface Roughness Rmax μm

As mentioned above, surface roughness produced by grit blasting is one of the important factors. Blasting variables which influence the surface roughness are geometry, size, velocity of grit and blasting angle.

The influences of size and velocity of grit and shot on surface roughness are shown in Fig.1. Surface roughness produced by grit blasting is proportion to grit size and velocity for titanium (Ti) and steel (St). This relation is the same as that of shot peening. Owing to the geometry of grit, surface roughness produced by grit blasting is larger than shot peening, and surface roughness of titanium is larger than steel.

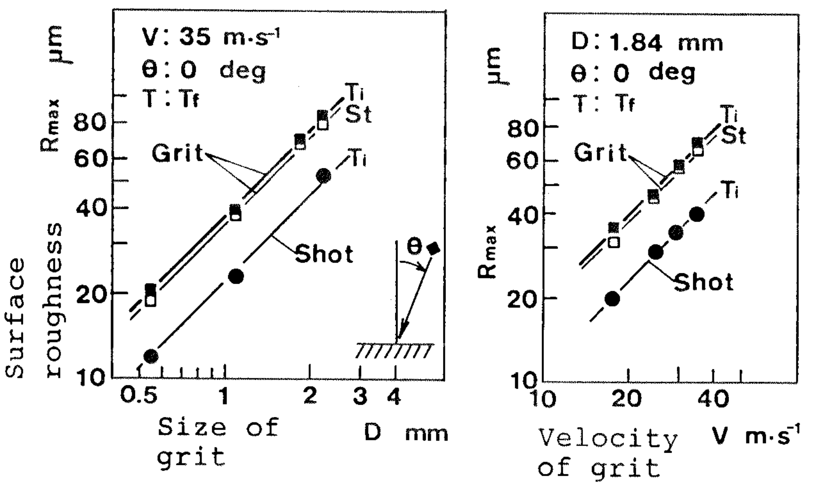
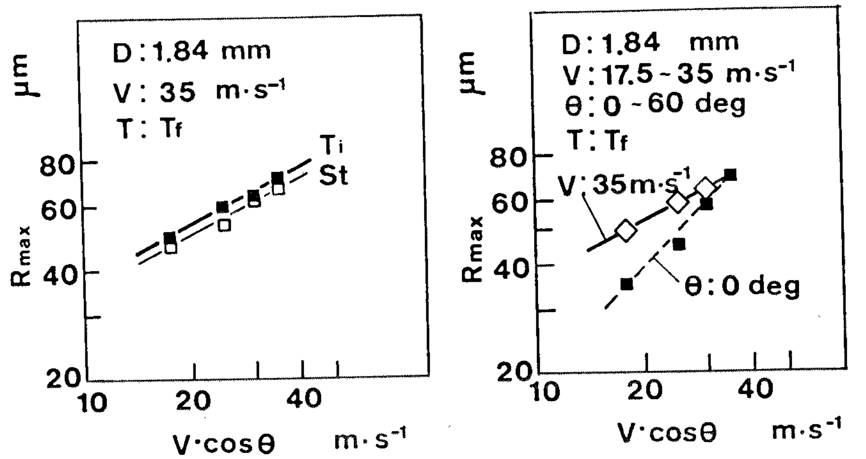


Fig.1 Relation between size and velocity of grit and surface roughness.

Blasting angle varies not only the normal or tangential components of velocity but also the density of dents. The density of dents is closely related with working efficiency as to blasting time but don't influence surface roughness, affected layer and surface residual stress[4]. Fig.2 shows influences of the normal grit velocity to surface roughness. As shown in Fig.2(a), the relation between the normal velocity and the surface roughness on titanium is similar to that on steel. Fig.2(b) shows that even if the normal velocity is the same, surface roughness of the oblique blasting is different from that of the normal blasting owing to the influence of tangential component of velocity.

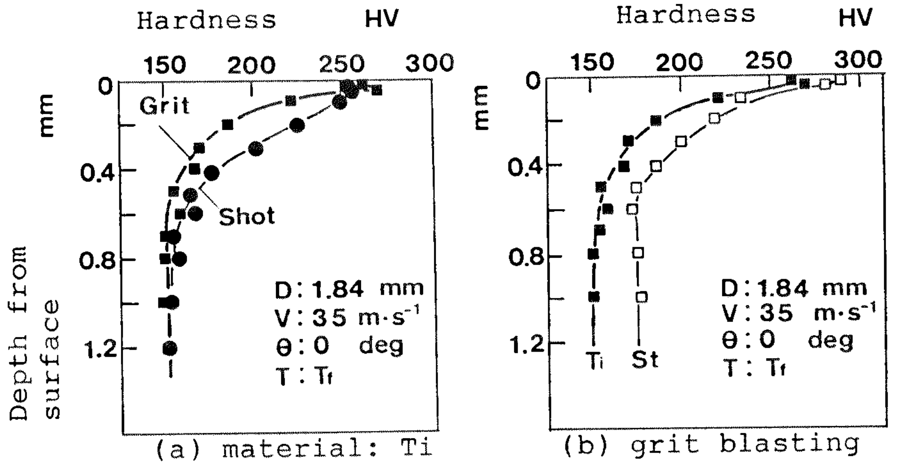


(a) Grit blasting (b) Material: Ti

Fig.2 Influence of normal component of velocity on surface roughness.

Hardness Distribution

In order to discuss the influence on the hardness of grit blasting, the hardness of cross section should be measured. Hardness distribution is also influenced with geometry, diameter and velocity of grit. Fig.3(a) shows hardness distribution produced by grit blasting different from by shot peening, the depth of work-hardened layer produced by grit blasting is shallower than that of shot peening but the surface hardness with grit is larger than with shot. Fig.3 (b) shows hardness distributions produced by grit blasting on titanium and steel and these are similar.



(a) material: Ti (b) grit blasting

Fig.3 Hardness distributions produced by shot peening.

The influence of kinetic energy of a grit on the maximum hardness and the depth of work-hardened layer are shown in Fig.4. The more the kinetic energy of a grit, the more the hardness increasing ratio and the depth of work-hardened layer, but the influences on the depth is larger than that on the hardness increasing ratio. The influences of blasting angle on the hardness distributions are shown in Fig.5 and the increase of blasting angle decreases the affected zone.

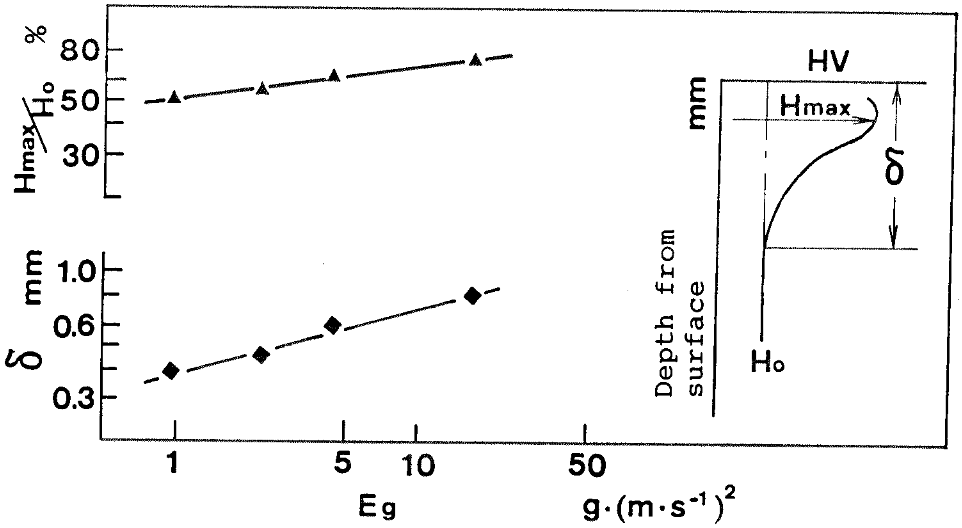


Fig.4 Influence of kinetic energy of a grit on depth of work-hardened layer and maximum hardness.
(Grit blasting. Material: Ti)

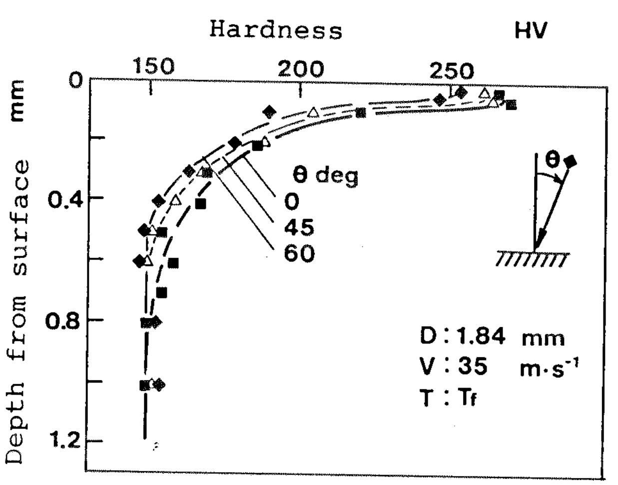


Fig.5 Influence of blasting angle on hardness distribution.
(Grit blasting. Material: Ti)

Stock Removal W mg

Stock removal is the important factor in grit blasting and don't appear in shot peening. In grit blasting process, as numerous grit are blasted with air or a centrifugal force, the total area of dents increases with blasting time. Therefore, stock removal also increases with blasting time as shown in Fig.6. Fig.6(a) is expressed on ordinary coordinates and (b) on the logarithmic coordinates. The influence of blasting time on stock removal is small at early blasting time and after it is proportion to the square of blasting time. Stock removal of titanium is proportion to 4.5 power of grit velocity and the cube of grit size as shown in Fig.7(a). The influence of velocity on titanium is larger than that on steel as shown in Fig.7(b) owing to the difference of the work-hardening ratio.

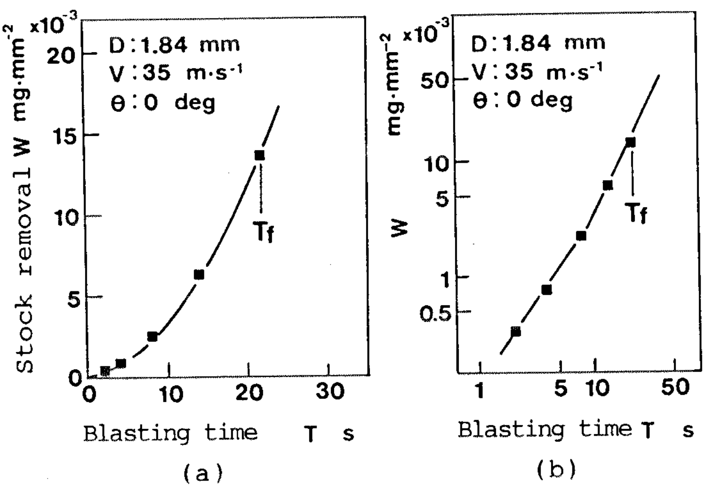


Fig.6 Influence of blasting time on stock removal. (Grit blasting. Material: Ti)

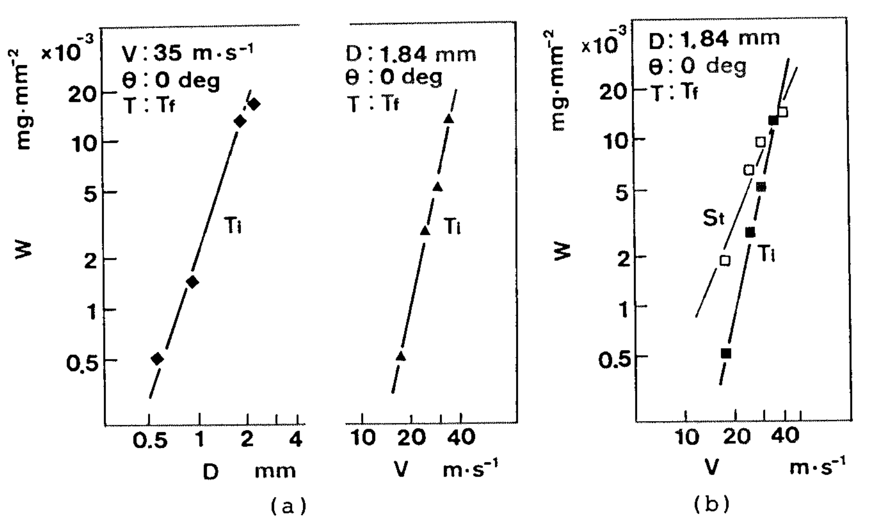


Fig.7 Relation between size and velocity of grit and stock removal. (Grit blasting)

On the oblique blasting, as shown in Fig.8 ,stock removal appears at early time of blasting but the influence of blasting time is less than the normal blasting. Stock removal on the oblique blasting is proportion to 1.4 power of blasting time. Fig.9 shows the influences of normal and of tangential component on stock removal and Fig.9(a) shows the results obtained from two experiments; one is that blasting angle is variable with constant velocity, and the other is that velocity is variable with constant blasting angle 0 deg. Nevertheless normal component of grit velocity is the same, stock removal on the oblique blasting is larger than that on normal blasting. The influence of tangential component of velocity on stock removal is shown in Fig.9(b) and the more the tangential velocity, the more the stock removal.

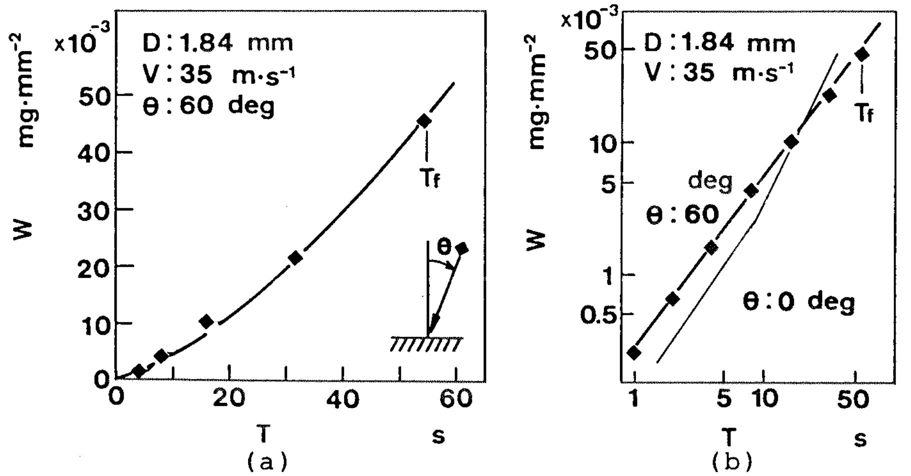


Fig.8 Influence of blasting angle on stock removal. (Grit blasting. Material: Ti)

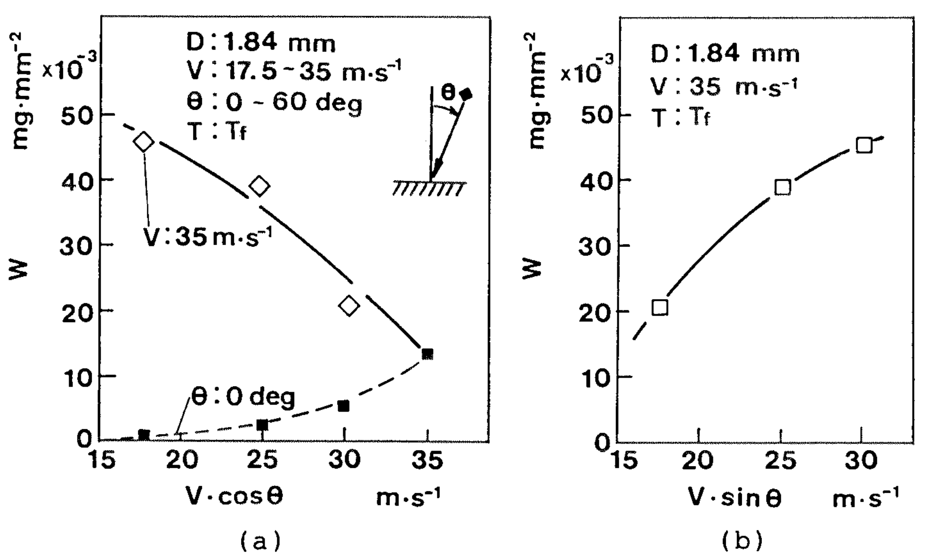


Fig.9 Influence of component of velocity on stock removal. (Grit blasting. Material: Ti)

Surface Residual Stress

Surface residual stress also increases rapidly in early blasting time and then approach saturated values. Fig.10 shows the results on grit blasting and shot peening. In early time, residual stress induced by grit blasting is similar to by shot peening, but when stock removal begins, surface residual stress decreases.

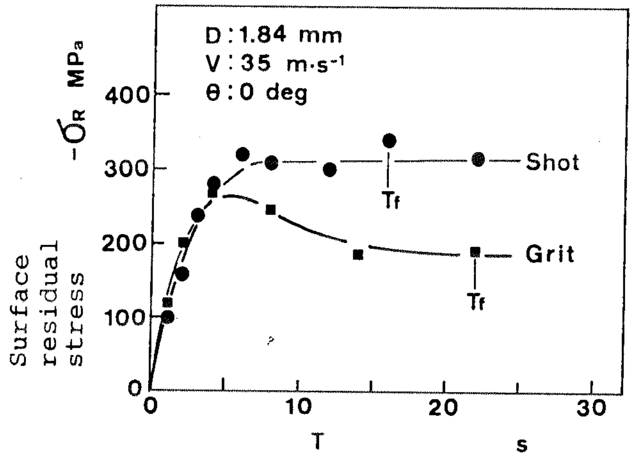


Fig.10 Influence of blasting time on surface residual stress. (Material: Ti)

Fig.11 shows the influences of grit size and velocity on surface residual stress. Surface residual stress induced by grit blasting is less than shot peening owing to stock removal.

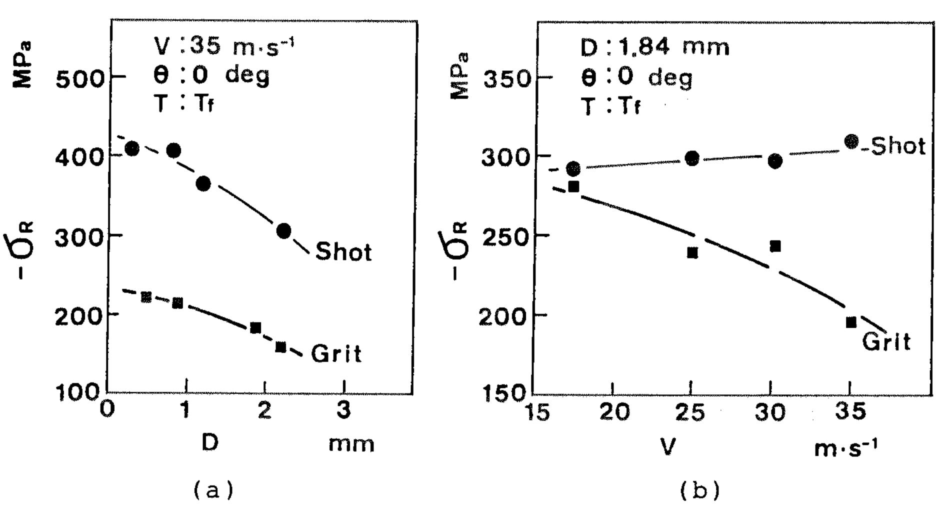


Fig.11 Influence of size and velocity of grit and shot on surface residual stress. (Material: Ti)

Surface residual stress by oblique blasting is less than normal blasting as shown in Fig.12 and the influence of the normal component is shown in Fig.13(a). Fig.13(b) shows the relation between the tangential component of grit velocity and surface residual stress, and as the increase of the tangential component, surface residual stress decreases. Fig.14 shows that the increase of stock removal decreases surface residual stress. Therefore, grit blasting removes the surface in which high residual stress is involved.

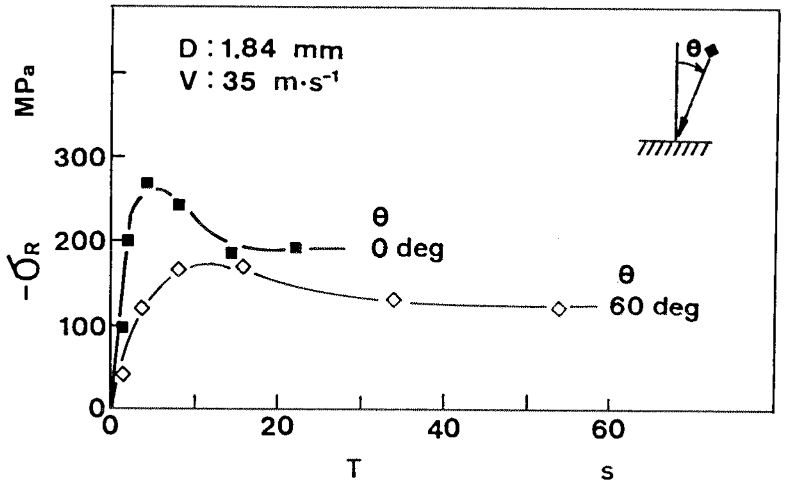


Fig.12 Influence of blasting time on surface residual stress. (Grit blasting. Material: Ti)

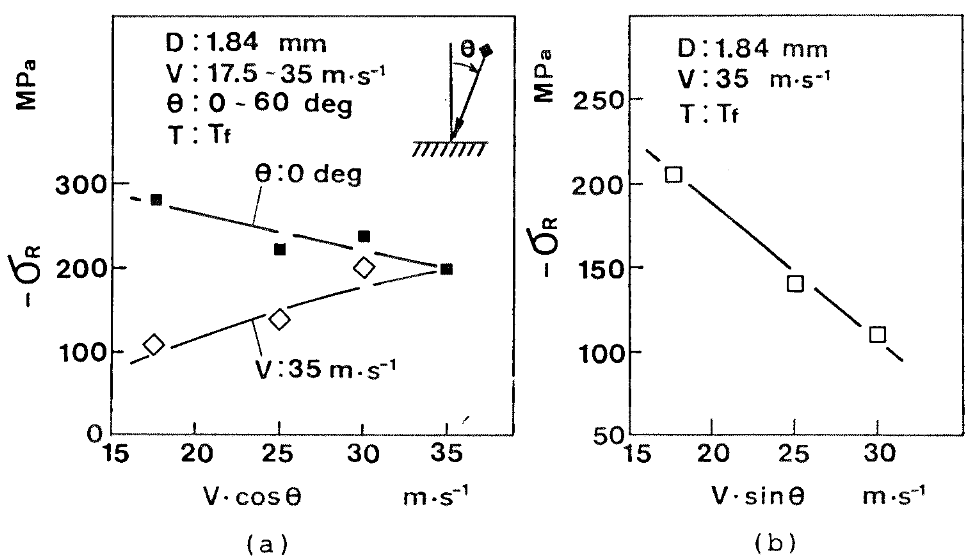


Fig.13 Influence of component of velocity on surface residual stress. (Grit blasting. Material: Ti)

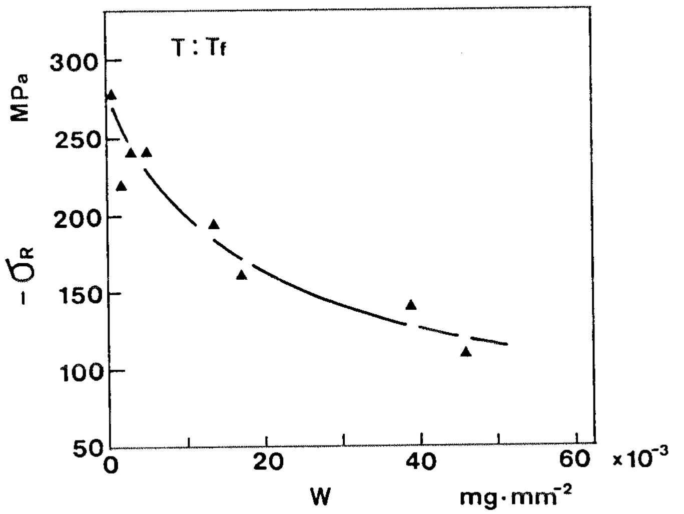


Fig.14 Relation between stock removal and surface residual stress. (Grit blasting. Material: Ti)

CONCLUSIONS

1)Surface roughness produced by grit blasting on titanium is proportion to grit size and velocity as same as steel.
2)Even if the normal component of grit velocity is the same, surface roughness with oblique blasting is larger than that with normal blasting owing to the influence of the tangential component of grit velocity.
3)The depth of work-hardened layer produced by grit blasting on titanium is proportion to 0.25 power of kinetic energy of a grit as same as shot peening.
4)Stock removal on titanium is proportion to the square of blasting time, to the cube of grit size and to 4.5 power of grit velocity.
5)Surface residual stress on titanium induced by grit blasting is 5 % - 48 % less than that by shot peening.
6)Stock removal releases surface residual stress.
7)Tangential component of grit velocity is effective to decrease surface residual stress, and surface residual stress induced by oblique blasting of 60 deg decreases 50 % compared with the normal blasting under the same grit velocity.

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