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Evaluation of fatigue strength on shot peened pure titanium

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Introduction

Ti-6Al-4V has high static strength and superior corrosion resistance, so it is a material that is widely used, not only for aerospace parts and medical instruments but also in areas such as sports equipment. Prof. Masaki and others investigated the fatigue strength of Ti-6Al-4V processed under various shot peening conditions, and it has been confirmed that the fatigue strength is not able to improve the fatigue strength of Ti-6Al-4V that has not been processed with shot peening. [1] Thus, it can be understood that for Ti-6Al-4V materials, the application of shot peening is difficult.

On the other hand, pure titanium has low static strength, so there are few instances where it has been used. However, compared to Ti-6Al-4V it has higher productivity and its material price is lower. If, through shot peening, it is possible to obtain fatigue strength that is equal to or better than that of Ti-6Al-4V, it may be possible to increase the use cases of pure titanium.

In this study, a plate-bending fatigue test was performed to investigate the effects of various shot peening conditions on the fatigue strength of pure titanium. For comparison, the fatigue strength results for Ti-6Al-4V that were measured in the previous study will also be noted here. [2]

Experiment

Specimen

For the fatigue test, a plate-bending fatigue test was chosen. Fig. 1 shows the shape of the test piece. This test piece was cut out using electrical discharge machining.

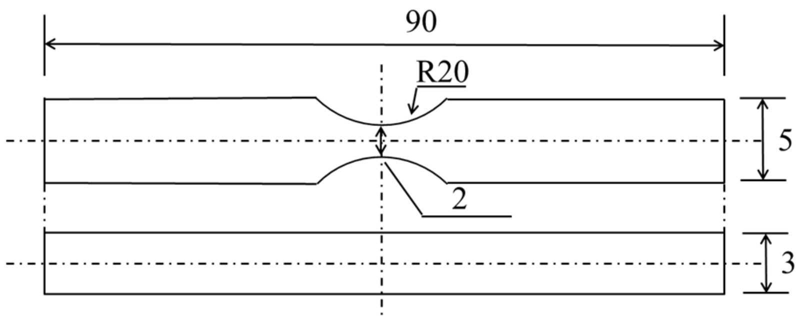

Fig. 1 Shape of specimen

The chemical composition of the pure titanium prepared for the study is shown in Table 1. Table 2 shows the chemical composition of the Ti-6Al-4V material.

Table 1 Chemical composition of pure titanium (mass %)

N	C	H	Fe	O	Ti
0.03	0.08	0.013	0.25	0.2	Bal

Table 2 Chemical composition of Ti-6Al-4V ELI alloy

Al	V	O	Fe	C	N	H	Y	Ti
6.14	4.06	0.17	0.15	0.01	<0.01	H	<0.01	Bal

After shot peening, in addition to the plate-bending fatigue test, surface roughness measurement, surface observation, cross section hardness distribution measurement, and SEM fracture surface observation were performed.

Table 3 shows the conditions for shot peening.

Table 3 Mechanical properties of pure titanium

Density (g/cm[3])	4.51
Proof strength (MPa)	277
Yield strength (MPa)	393
Vickers hardness (HV)	140

Table 3 Conditions for shot peening

	SUS150B	SBM44T(0.2MPa)	SBM44T(0.5MPa)	SBM100T
Diameter (μ m)	150	44		100
Vickers hardness (HV)	240-350	390-510		
Air pressure (MPa)	0.2	0.2	0.5	0.2
Intensity (mmN)	0.046	0.06	0.102	0.08
Density (g/cm3)	7.6	7.45		
Processing time (sec)	12			

Fig. 2 shows the surface roughness after shot peening. With the conditions for the shot peening performed in this study, use of SUS150B showed the least surface roughness, about equal to that of the unprocessed test piece. On the other hand, processing using SBM44T with 0.5MPa air pressure exhibited the greatest surface roughness. For the most part, surface roughness does not have a clear correlation with intensity. With SBM44T (0.5MPa) conditions, surface roughness was the greatest. Fig. 3 shows photographs of surface observation done by SEM after shot peening. With SUS150B conditions, it can be seen that there is largely no change in the surface form. However, with SBM44T (0.5MPa), it can be observed that there are thin raised edges caused by the impact of the shot.

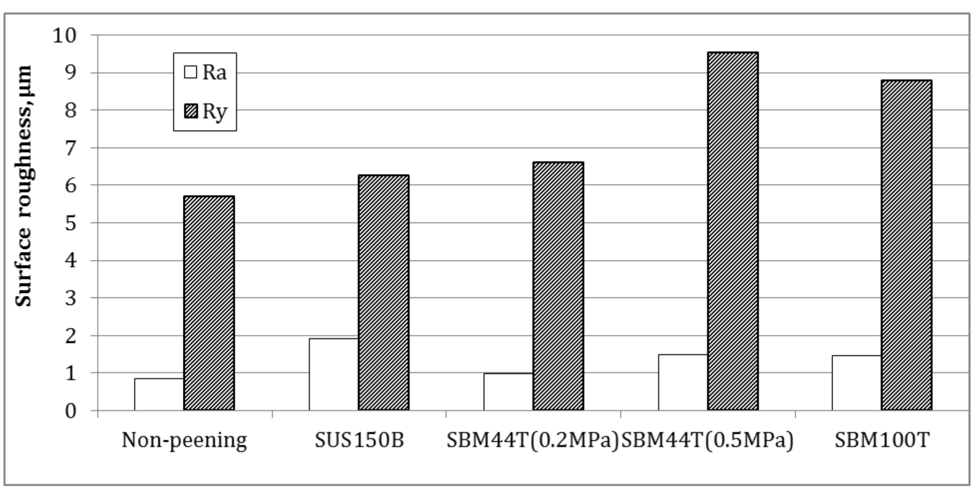

Fig. 2 Surface roughness

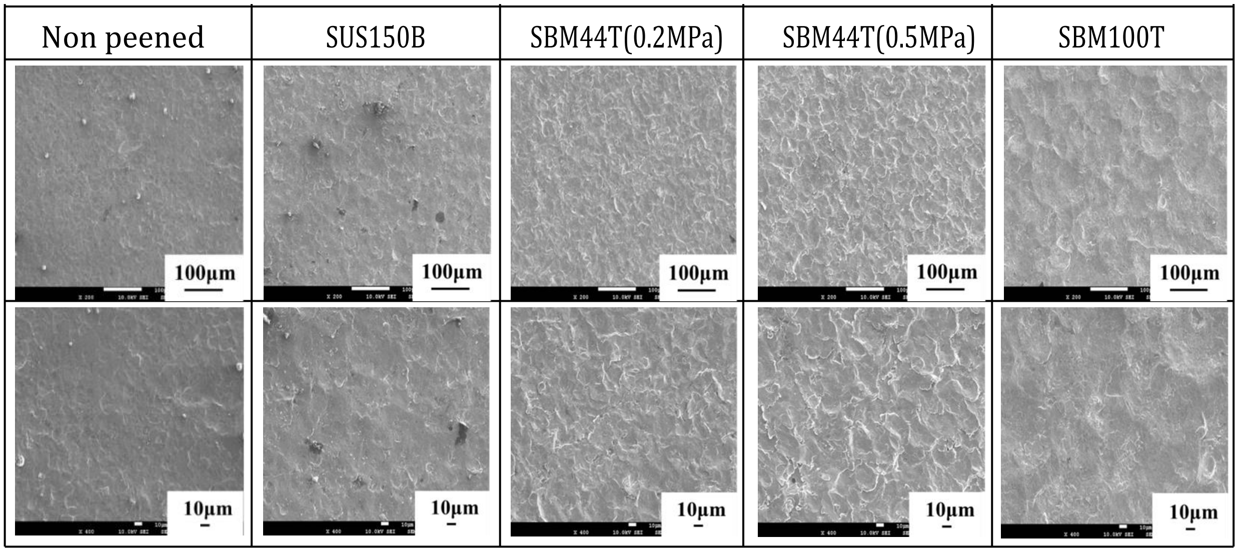

Fig. 3 Surface observation by SEM

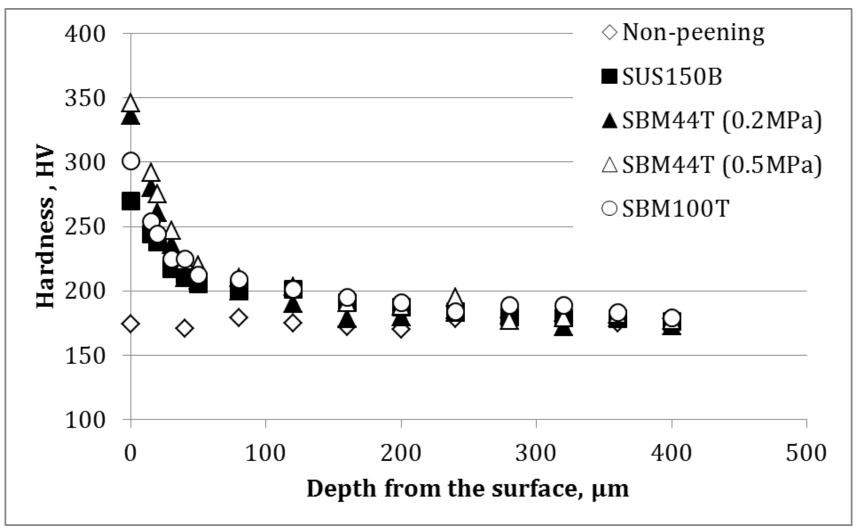

Fig. 4 Hardness distribution

Fig. 4 shows the hardness distribution. The greatest surface hardness was obtained when using SBM44T, and while slight, the SBM44T (0.5MPa) conditions with higher air pressure exhibited greater surface hardness.

Fatigue strength

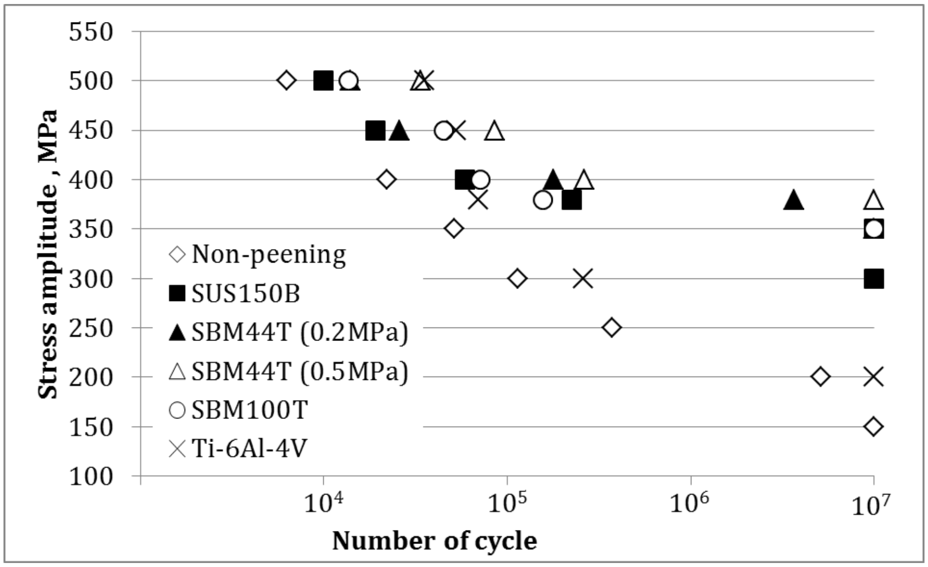

Fig. 5 S-N Curve

Fig. 5 shows the results of the plate-bending fatigue test. For fatigue strength comparison, results from the previous study of Ti-6Al-4V fatigue strength have also been included. It can be seen that the fatigue limit for Ti-6Al-4V is higher than that of pure titanium before peening. This is only natural, as the mechanical properties of Ti-6Al-4V are better than those of pure titanium.

However, with every shot peening condition, the fatigue limit for pure titanium after shot peening exceeded not only that of the unprocessed material but also the fatigue limit for Ti-6Al-4V. SBM44T (0.5MPa) conditions showed the best fatigue characteristics. In this case, these were the conditions with the highest intensity, but surface roughness was also the worst.

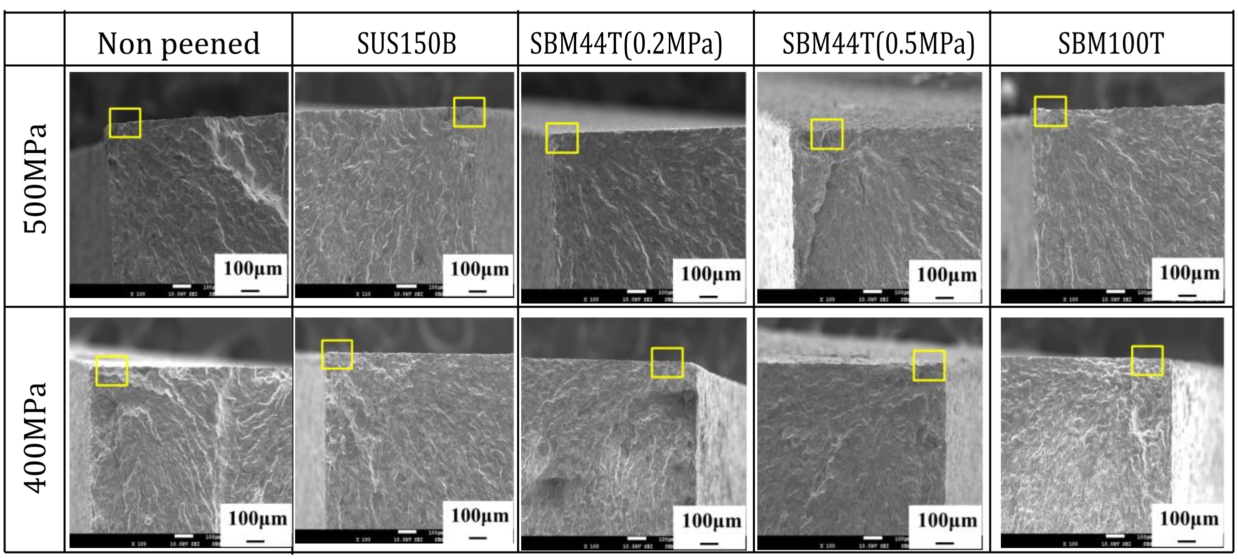

Fig. 6 Surface observation by SEM

Fig. 6 shows the fracture surface observation results with additional stress of 400MPa and 500MPa. It can be seen that for all conditions, cracks began adjacent to the corners of the test pieces.

Conclusion

Compared to the fatigue strength of unprocessed pure titanium, the fatigue strength after shot peening was up to 2.5 times greater. The fatigue strength of shot peened pure titanium also exceeded that of Ti-6Al-4V.

Reference

[1]J. Soc. Mater. Sci., Jpn. Vol. 65 (2016) No. 9 p. 679-686

[2]Yuichiro Suga， 2013， Evaluation of Fatigue Properties of Shot-Peened Titanium Alloy, Sophia University Graduate School of Science and Engineering Science and Engineering Mechanical Engineering Area, Master's thesis