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# Advantages of High-Formability SP-700 Titanium Alloy and Its Applications†

## 1. Introduction

Titanium alloys are lightweight and have high strength. In particular, many have been used as materials in the aerospace industry. Recently, their fields of application have expanded to automobiles, motorcycles, and sports and leisure goods such as golf clubs. In Japan, wrought titanium alloys account for more than 10% of wrought titanium products.

The SP-700 titanium alloy with a nominal chemical composition of Ti-4.5mass%Al-3mass%V-2mass%Fe-2mass%Mo is categorized as a $\beta$-rich $\alpha + \beta$ type titanium alloy, and has relatively ultra-fine $\alpha$ grains with the grain size of 2–3 $\mu$m[1]. The ultra-fine microstructure of SP-700 alloy significantly improves its fatigue strength, in addition to formability, which is one of the weak points of high-strength titanium alloys. The application of SP-700 alloy to the transportation and other new fields are expected due to its excellent properties.

This report describes the hot and cold formability and fatigue strength of SP-700 alloy, which are favorable mechanical properties of this alloy, and also introduces new fields where the excellent properties of this alloy can be put to practical use.

## 2. Properties of SP-700 Alloy

### 2.1 Hot Formability

The features of SP-700 alloy in hot working processes such as hot rolling and hot forging are as follows:

(1) Wide processing window
(2) Low susceptibility to cracking
(3) Good surface quality after hot working, including reduced oxidation and defects

**Figures 1** and **2**[2] show the flow stress and hot workability of SP-700 alloy when evaluated by the compression test using notched cylindrical specimens in comparison with the Ti-6Al-4V alloy, respectively. The processing window of SP-700 extends to a lower temperature and higher strain rate, indicating that this alloy possesses excellent hot workability.

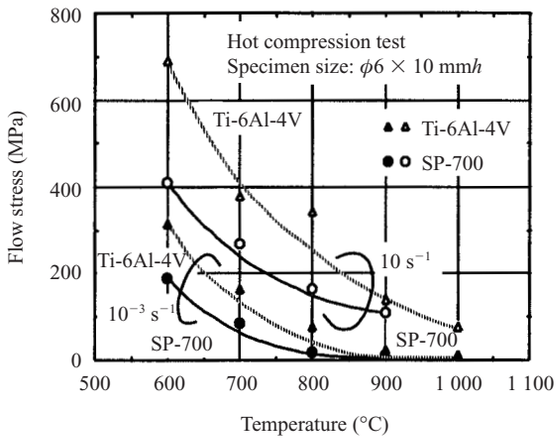


Fig. 1 Comparison in flow stress between SP-700 and Ti-6Al-4V

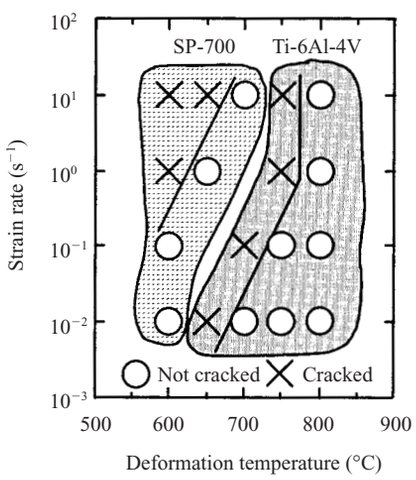


Fig. 2 Susceptibility to hot cracking for SP-700 and Ti-6Al-4V

Oxide and $\alpha$-case tend to form on the titanium surface during hot working because titanium is a very active metal and reacts easily with gaseous elements such as oxygen. A process for removing these layers is indispensable, as their high hardness deteriorates formability, ductility, and fatigue properties. **Figure 3** shows the $\alpha$-case thickness as a function of temperature in air and argon gas (99.9% purity). The thickness of the $\alpha$-case which forms at the optimized hot working temperature for SP-700 alloy is relatively thinner, which can be expected to simplify surface finishing processes such as grinding and polishing, thereby contributing to cost reduction and improved productivity.

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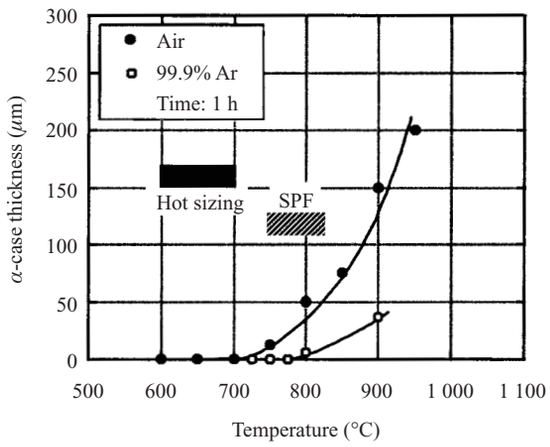


Fig. 3 $\alpha$-case formation of SP-700 at high temperatures

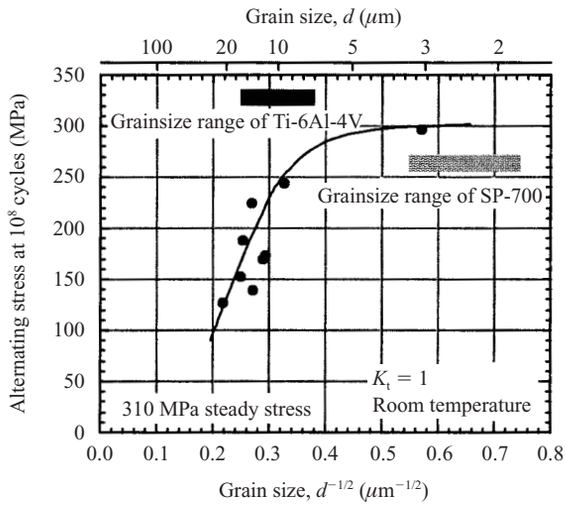


Fig. 4 Effect of grain size on fatigue strength

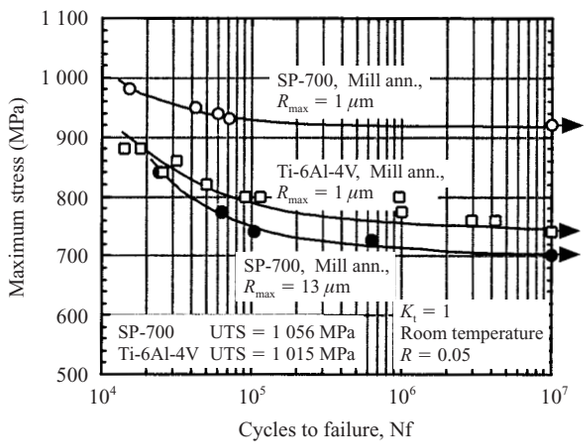


Fig. 5 Comparison in fatigue strength between SP-700 and Ti-6Al-4V

### 2.2 Cold Workability

Because cold forming is not a suitable production process for $\alpha + \beta$ titanium alloys with strengths of approximately 1 000 MPa, a hot working process such as hot sizing is required.

**Table 1**[3] shows a comparison of cold formability for SP-700 and Ti-6Al-4V alloys. In comparison with Ti-6Al-4V alloy, SP-700 alloy has superior formability from the viewpoints of the critical cold rolling ratio and bending factor. Climbing tools and wristwatch cases are already produced commercially from SP-700 alloy by punching and bending at room temperature, taking advantage of its excellent cold formability[4].

### 2.3 Fatigue Properties

Fatigue strength is one of the excellent mechanical properties of the SP-700 alloy. Grain size strongly influences the fatigue strength of titanium alloys, and grain refinement increases fatigue strength, as shown in **Fig. 4**. Because grain growth during hot working of SP-700 alloy is suppressed by its alloy design, an ultra-fine grain microstructure is maintained after hot working. The inherent ultra-fine microstructure and slow grain growth of SP-700 alloy result in superior fatigue strength in comparison with the Ti-6Al-4V alloy, as shown in **Fig. 5**. This alloy has advantageous fatigue properties for use in materials for racing cars, motorcycle engines, and golf club faces.

Table 1 Comparison in cold formability between SP-700 and Ti-6Al-4V

| Alloy | Critical bending factor, $r/t$* | Critical cold rolling ratio (%) |
|---|---|---|
| SP-700 | 2.1 | 60–70 |
| Ti-6Al-4V | 4.0 | 20 |

* $r$ : Radius of test tool, $t$ : Thickness of test sample

## 3. New Applications

In comparison with the conventional lightweight, high strength titanium alloys, the SP-700 alloy has markedly improved mechanical properties, including formability and fatigue strength, and has won an excellent reputation from customers. Based on these features, the outlook for SP-700 alloy in new fields, as shown in **Table 2**, also appears optimistic.

Table 2 Current and potential applications of SP-700

| Field | Application | Required properties |
|---|---|---|
| Transportation | Automobile | Fatigue strength<br>Hot formability |
| | Ship | Errosion |
| | Railway | Fatigue strength<br>Wear resistance |
| Miscellaneous | Sport, Leisure | Fatigue strength<br>Hot forgiability |
| | Ultrasonic | Fatigue strength |

## 4. Conclusion

This report has described the advantageous mechanical properties of SP-700 alloy, including hot and cold formability and fatigue properties, and introduced promising new applications. Although titanium alloys possess desirable properties such as light weight and high strength, the difficulty of forming and working conventional alloys limits their applications. The SP-700 alloy with its excellent mechanical properties is expected to expand the application of titanium alloys in various new fields where formability and fatigue strength are essential.

## References

1) Ishikawa, M. et al. Titanium ’92 Science and Technology. vol. 1, 1993, p. 141.
2) Mechanical Properties Handbook: Titanium Alloys. ASM, 1994, p. 59.
3) Ogawa, A. et al. Beta Titanium Alloys in the 1990s, 1993, p. 513.
4) Fukai, H. Press Gizyutsu. vol. 42, no. 2, 2004, p. 35.

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