Investigation of nano-precipitates in Ti based alloy

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1. Introduction

Commercially titanium alloys are widely used for aircraft as a material having light weight (density being 60% that of steel), high strength, and excellent corrosion resistance. Many studies have been carried out to develop near-α titanium alloys for compressor discs and blades with improved tensile strength, fatigue resistance and creep performance at temperatures. However, it has been reported that solute partitioning in primary α grains causes formation of the α_2, $Ti_3(Al, Sn)$, phase. It is known that the low cycle fatigue resistance is reduced due to promotion of strain localization as a result of the presence of such α_2. This is a significant issue because the resulting lowered fatigue resistance can reduce the lifetime of compressor discs. IMI 834 is a typical near-α Ti-Al-Zr-Sn based alloy where small amounts of Si are added, consequently, the formation of fine ordered precipitates $(Ti,Zr)_6Si_3$ on the lamella boundaries improves the high-temperature strength. As stated here, the precipitates critically affect a combination of creep and low cycle fatigue properties, but the precipitation process is still not well understood. Especially, difference between creep treatments and aging treatments has currently attracted much attention. Hence, it is essential to clarify the nucleation and growth of the precipitates on these processes for further advances in aero-engines.

Our scanning and transmission electron microscopy (SEM, TEM), and three-dimensional atom probe tomography (3DAP) show small α_2 precipitates with size of a few nanometers in equiaxed alpha grains and slightly larger silicide precipitates with sreatmentize of several tens nanometers on the lamella boundaries. However, SEM, TEM, and 3DAP are not suitable for detecting small variation in average size and in precipitate number density during heat treatments. For this reason, we measured small angle X-ray scattering but could not find any structures related to such precipitates in the obtained profiles. The reasons are that the scattering length density of α_2 for X-ray is similar to the matrix and that the scattering from the silicide exists outside the measuring range of our Lab-SAXS. For this reason, we measured wide *q*-range small angle neutron scattering using TAIKAN in J-PARC, to investigate mean size and number density of the nano-precipitates in IMI834 alloys after both the creep treatments and aging treatments.

2. Experiment

The IMI 834 material has a composition of Ti-5.8Al-4.0Sn-80 3.5Zr-0.7Nb-0.5Mo-0.3Si-0.10O, in wt.%. The alloy was forged, then heat treated above the β transus temperature. Finally, some were conventionally aged for various periods of 0, 10, 100, 200, 400, and 1000 hours at 650◦C, and the others were treated in a creep condition periods of 200 and 1100 hours at 650◦C. The samples are stable metal plates with thickness of approximately 0.5 mm. The measurements were performed in an atmospheric pressure at an ambient temperature using the sample auto-changer. The observed *q*-range is from 0.03 nm^{-1} to 3 nm^{-1}.

3. Results

The typical results are shown in Figs. 1 and 2. We can find double shoulder-like anomalies on each profile for the samples after both the treatments. The observations of SEM and TEM indicates that the anomaly in the low *q* region is caused by the precipitation of the silicide, while the anomaly in the higher *q* region is attributed to the α_2 precipitates. The positions of both the anomalies shift toward lower *q* with increasing the aging periods from 200 to 1000 (1100) hours. These shifts can be interpreted as growths of the precipitates. As seen in Figs. 1 and 2, the observed small angle neutron scattering profiles are almost the same between the aging treatments and creep ones, hence, we can say that the growth of the precipitates is not significantly affected by stress from the viewpoint of small angle neutron scattering experiments.

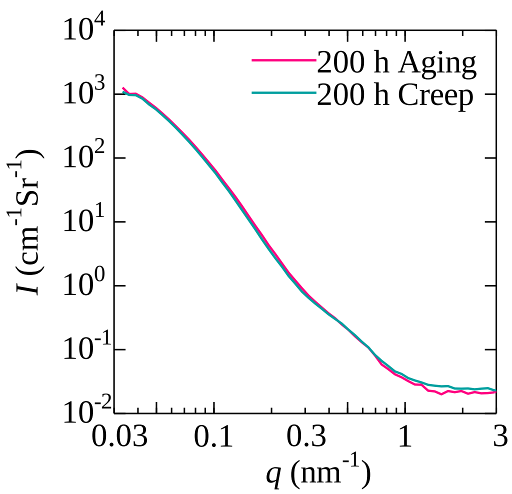

Fig. 1 Small angle neutron scattering profiles of the near-α titanium based alloy aged in the initial growth stage.

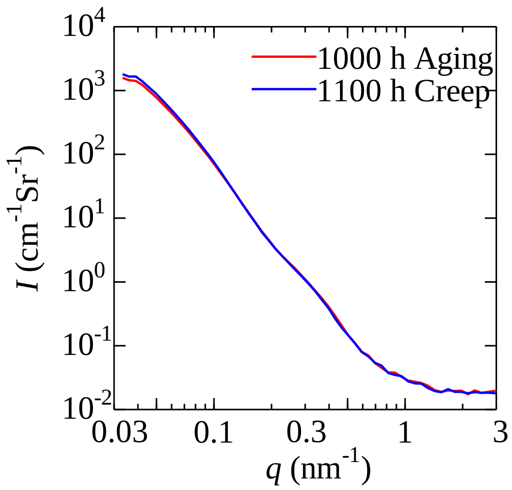

Fig. 2 Small angle neutron scattering profiles of the near-α titanium based alloy aged in the later growth stage

4. Prospective

With the valuable information obtained here, we advance the study on the precipitation in near-α titanium-based alloy from differing points of view.