Investigation of nano-precipitates in Ti-Al-Zr-Sn based alloy

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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, Ti3(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)6Si3 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. Hence, it is essential to clarify the nucleation and growth of the precipitates 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 size 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 QUAKKA in ANSTO, to investigate mean size and number density of the nano-precipitates in variously aged IMI834, near-α Ti-Al-Zr-Sn based alloy.

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 beta transus temperature. Finally, some were aged for various periods of 0, 10, 100, 200, or 400 hours at 650?C and of 0, 10, 100, 1300, or 2000 hours at 700 ?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 autochanger. The observed q-range is from 6 x 10^-3 ^-1 to 0.6 ^-1.

The obtained results are shown in Figure. We can find double shoulder-like anomalies on each profile for the samples with the aging 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. This behavior is consistent with the results of microscopy. We are able to discuss their size distributions strictly when the compositions of these precipitates are determined by our on-going 3DAP measurements, then we can clarify nature of the precipitation in near-α titanium based alloy from differing points of view.