PROGRESS REPORT FOR AINGRA09107

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<th>PROJECT TITLE</th>
<th>Thermomechanical properties of multifunctional titanium alloys</th>
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SCIENTIFIC OBJECTIVES

The aim is to investigate a new route for producing Multi-Functional Titanium Alloys (MFTA) involving hot isostatic pressing (HIP) followed by equal channel angular pressing (ECAP) and to examine the optimal conditions for producing these alloys. ECAP will allow large components to be consolidated without the need for forging and hot rolling, as used by the Japanese pioneers of these alloys. Through the modification of composition or manufacturing parameters, we aim to further reduce the elastic modulus and increase the strength of MFTA for applications in the medical and aerospace industries.

PROGRESS REPORT and RESEARCH OUTCOMES

We carried out one HIP run of MFTA in 2006, but the vacuum level was unsatisfactory which resulted in pores in the samples. Although we obtained the correct composition and phases, the microstructure of the sample after forging was inappropriate. In 2007, we carried out two sintering runs of MFTA and achieved the correct composition, phases and microstructure after forging, but vacuum did not reach $1 \times 10^{-3}$ Pa. In 2008, we carried out four sintering experiments and the vacuum level met our requirements, reaching $1 \times 10^{-3}$ Pa. The samples were successfully forged and solution treated. In 2009 we cold swaged one sample from a diameter of 15 mm to 3 mm or with a 96% area reduction.

We measured the hardness of the sample and found that the alloy shows a very low work hardening rate. The optical analysis shows that the pores existing in the sintered sample were eliminated through forging and swaging and a consolidated microstructure was formed. The alloy was composed of grains of 50-150 micrometer in size after solution treatment. After 96% cold swaging, a highly distorted microstructure was formed. TEM analysis revealed that the alloy contains beta phase and omega phase in the cold swaged conditions.

Positron Annihilation Lifetime Spectroscopy (PALS) analysis revealed that the mean lifetime increased after cold swaging compared with the alloy in solution treated condition, which implies that the total amount of defects (vacancies and dislocations) in the alloy increased after cold swaging.

DATA

1. Microhardness

The hardness was 284.4 HVN for the sample after solution treatment and 308.4 HVN for the sample after cold swaging by 96% area reduction. Hence, the work hardening rate is only 8.4%.

2. Optical microscopy

2.1 Un-etched samples

Fig 1 shows that the pores existed in sintered samples are eliminated by forging and solution treatment.
Fig 1 Optical micrographs of MFTA after: (a) sintering; (b) solution treatment; (c) swaged by 69%, and (d) swaged by 96%.

2.2 Etched samples

Fig 2 shows that the alloy consists of grains of 50-150 µm in the solution treatment condition, and a highly distorted microstructure was generated after cold swaging by 96% area reduction.
3. TEM analysis

The TEM analysis shows that the alloy contains beta phase and omega phase after cold swaged by 69% and 96%.

Fig 3 TEM bright image of sample cold swaged by 69% (A), TEM diffraction pattern, showing omega phase (B).

Fig 4. TEM bright image of sample cold swaged by 96% (A), TEM diffraction pattern, showing omega phase (B).
4. Positron annihilation lifetime spectroscopy (PALS)

The result of PALS analysis of the alloy Ti-36Nb-2Ta-3Zr-0.4O is shown in Fig 5. It can be seen that the mean lifetime of positron increases from 150 ps to 184 ps and 195 ps for samples cold swaged by 69% and 96% area reduction, respectively. This means that the amount of defects in the alloy increases considerably after cold swaging, despite the low work hardening rate.

Fig 5 The mean lifetime (PALS) of the alloy Ti-36Nb-3Zr-2Ta-0.4O.