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OXYGEN EFFECTS ON INTERNAL FRICTION AND MODULUS OF A TITANIUM ALLOY

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Resume - Les effets de l'oxygene sur la friction interne, le module et la vitesse du son d'un alliage alpha/beta de titane disponible commercialement ont été étudiés dans un intervalle de température de 80 à 290 Kelvin. L'atténuation générale décroît avec la concentration d'oxygene et un pic de friction interne observe entre 110 et 130 degrés K a présenté un accroissement lorsque la concentration d'oxygene augmentait. A température ambiante, les vitesses du son et par conséquent les modules dependent du montant d'oxygene et peuvent croître ou décroître, suivant la direction de propagation, indiquant que la texture peut avoir un effet important. Les indications sont que le pic de friction interne est due à une transformation $\beta \rightleftharpoons \omega$ dans la phase beta de l'alliage et que l'atténuation générale est causée par la solution solide d'oxygene dans la phase alpha. Ces résultats sont consistants avec les résultats de la littérature rapportés pour les phases individuelles.

Abstract - The effects of oxygen on the internal friction, modulus and sound velocity of a commercially available alpha/beta titanium alloy were investigated over a temperature range of 80 to 290°K. The overall background damping decreases with oxygen concentration and an internal friction peak observed between 110 and 130°K was found to increase with increasing oxygen concentration. At room temperature, the sound velocities and therefore the moduli depend on the amount of oxygen and can either increase or decrease, depending upon the propagation direction, indicating that texture can have a strong effect. Indications are that the internal friction peak is due to a $\beta \rightleftharpoons \omega$ transformation in the beta phase of the alloy and that the background damping is caused by the solid solution oxygen in the alpha phase. These data are consistent with literature data reported for the individual phases.

I - INTRODUCTION

The effects of the presence of interstitial oxygen on the mechanical properties of Ti and Ti alloys have been a subject of interest for some time. Most of the previous work has been done on pure beta phase alloys of Ti. Lately, there has been considerable interest in Ti-6211 because of its toughness and weldability [1]. Ti-6211 is primarily an α -phase material with the β -phase embedded in the matrix. The purpose of these experiments is to determine the effects of interstitial oxygen on alpha/beta phase Ti alloys.

II - EXPERIMENTAL PROCEDURES

Internal friction and modulus measurements were performed on five Ti-6211 samples having from 0.075% to 0.29% oxygen. The 0.075% sample is typical of commercially available material. The temperature for the internal friction and corresponding Young's modulus measurements ranged from 80 to 290K. Further modulus results were obtained at room temperature using ultrasonic velocity measurements.

The samples were cut from pieces that were rolled, annealed for 1 h at 925°C, then air-cooled. Reference 1 gives a detailed description of the material. The internal friction samples were rectangular pieces 4.6 cm long, 0.5 cm wide and 0.2 cm thick, which resonated in a free-free flexural mode with a frequency of about 5 KHz /2/. The sample was placed in the inner chamber of a double Dewar system, evacuated, then 2 mm Hg of He added as a thermal exchange gas. The sample was cooled at a rate of 0.5 K/min, with data taken at 10 min intervals. The room temperature moduli were obtained from ultrasonic velocity measurements on cubes, 1.5 cm on a side, oriented with the three principal directions in the rolled plate material (L,T,S).

III - EXPERIMENTAL RESULTS

The internal friction in Ti-6211 as a function of temperature and oxygen content is shown in Fig. 1. The data exhibit a substantial peak centered at about 120K with a half-width of about 40K. A similar peak has been seen and studied in other Ti alloys by Sommer et al /3/ and Buck et al /4/. The peak is thought to arise as a result of a thermally activated relaxation process involving $\beta \rightleftharpoons \omega$ phase transformation having an activation energy of 0.22 eV and a relaxation time of $\tau_0 = 2 \times 10^{-14}$ s.

Fig. 1 Internal friction in Ti-6211 as a function of temperature and oxygen content.

The width of the peak is about a factor of two, too broad for a single relaxation process. This is probably due to the presence of nuclei metastable ω -phase in the β -phase. Reference 3 shows that the height of the internal friction peak is a function of alloy content and first increases with alloy addition, goes through a maximum, and then decreases with further additions. The data of Fig. 1 show that the addition of oxygen increases the peak height. This is consistent with the effect of alloy composition on peak height, i.e., when oxygen is added, the β -phase material reacts as if the alloying is increased /4/. Thus, it appears that the β -phase is a low concentration alloy. Verification of this using STEM microanalysis of the β -phase has been started.

The high temperature background in the 0.075% oxygen data (180 to 290K portion) was found to strongly decrease with increasing oxygen. This effect has been observed by earlier investigators /1/, and was shown to be due to pinning of the α -phase by oxygen /1/. The β -phase does not show this effect /3/.

Fig. 2 Young's modulus in Ti-6211 as a function of temperature and oxygen content.

The results of the corresponding Young's modulus data from the internal friction measurements are shown in Fig. 2. The data show little small or no modulus defect, which is consistent with previous observations /4/ in other Ti alloys. The modulus is seen to increase with oxygen content, as expected, because the associated increase of the volume fraction of α -phase material which has a higher modulus than the β -phase /1/.

To determine the directional dependence of the effects of oxygen on the modulus, shear and longitudinal measurements were made at ultrasonic frequencies in the principal propagation and polarization directions on a cube from each sample. The results of the shear data are shown in Fig. 3, and demonstrate that texture is playing an important role and may overshadow the effect of oxygen on the modulus.

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Fig. 3 Shear modulus in Ti-6211 as a function of oxygen content.

IV - CONCLUSION

Internal friction peaks have been found in an α/β Ti alloy. The results are consistent with the behavior expected for a β -phase of the material with low alloy concentration. Furthermore, the addition of oxygen acts as if there is a composition change to the alloy. The overall background damping decreases with increasing oxygen content.

The ultrasonic velocity measurements reveal that both texture and oxygen affect the modulus.

V - ACKNOWLEDGEMENTS

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