EFFECTS OF CHROMIUM ADDITION ON FATIGUE CRACK GROWTH BEHAVIOR OF TITANIUM ALUMINIDES

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ABSTRACT

The microstructure and fatigue crack growth behavior of various compositions of Ti-Al based intermatellics, Ti-48Al (at%), and the ternary alloys, Ti-48Al-2Cr, Ti-48Al-4Cr and Ti-48Al-8Cr (at%) have been studied. The fatigue crack growth tests were performed on center-cracked-tension M(T) specimens at room temperature in laboratory air, subjected to a constant applied stress range 100MPa with a load ratio of minimum to maximum level, R = 0.1. It was found that the threshold of stress intensity factor range of Ti-48Al, Ti-48Al-2Cr, Ti-48Al-4Cr and Ti-48Al-8Cr are 12.0MPa √ m, 9.0MPa √ m, 8.0MPa √ m and 4.5MPa √ m respectively. The threshold of stress intensity factor range decreased with the increasing percentage of chromium added to Ti-48Al. The results also show that Ti-48Al-2Cr has the highest fatigue crack resistance followed by Ti-48Al, Ti-48Al-4Cr and Ti48Al-8Cr. Field Emission Scanning Electron Microscopy (FESEM) technique was employed to investigate the fractography of each specimen after fatigue crack growth test. Micro-indentation tests results showed increasing hardness value of Ti-48Al alloys when the chromium content increased. The microstructures of each type of Ti-48Al alloys were examined using optical and Scanning Electron Microscope (SEM). Finer laths of and plates in lamellar structure have been observed when the amount of chromium added in Ti-48Al increased. The effects of microstructure on fatigue crack growth of Ti-48Al alloys are discussed.

ABSTRAK

Mikrostruktur dan kelakuan perambatan retak lesu sebatian antara logam berasaskan Ti-Al, iaitu Ti-48Al, Ti-48Al-2Cr, Ti-48Al-4Cr and Ti-48Al-8Cr (at.%) telah dikaji. Ujian perambatan retak lesu telah dijalankan ke atas spesimen tegangan retak tengah M(T) dalam keadaan suhu bilik dan udara makmal, dengan julat amplitud tegasan malar sebanyak 100MPa serta nisbah beban tahap minimum kepada maksimum malar, R = 0.1 dikenakan. Didapati bahawa nilai ambang julat keamatan tegasan Ti-48Al, Ti-48Al-2Cr, Ti-48Al-4Cr dan Ti-48Al-8Cr ialah 12.0MPa √ m, 9.0MPa √ m, 8.0MPa √ m and 4.5MPa √ m masing-masing. Nilai ambang julat keamatan tegasan menurun dengan peningkatan peratusan kromium yang ditambahkan ke dalam Ti-48Al. Keputusan ujian juga menunjukkan Ti-48Al-2Cr mempunyai ketahanan retak lesu yang tertinggi diikuti dengan Ti-48Al, Ti-48Al-4Cr dan Ti-48Al-8Cr. Kaedah mikroskopi elektron imbasan (FESEM) telah digunakan untuk mengkaji fraktografi setiap spesimen selepas ujian perambatan retak lesu dijalankan. Keputusan ujian kekerasan berskala mikro menunjukkan nilai kekerasan aloi Ti-48Al meningkat apabila kandungan kromium dalamnya meningkat. Mikrostruktur setiap jenis aloi Ti-48Al juga dikaji menggunakan kaedah mikroskop cahaya dan mikroskop elektron imbasan (SEM). Plat dan lapisan dalam struktur lamellar yang lebih halus diperhatikan apabila kandungan kromium yang ditmbahkan dalam Ti-48Al meningkat. Kesan mikrostruktur ke atas kelakuan perambatan retak lesu Ti-48Al telah dibincangkan.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Since it was first discovered over 200 years ago, major advances have been made in the development of titanium, from the understanding of basic metallurgy to the continued development of improved alloys. These developments are more related to the increasing demands of the aerospace and automotive engine component manufacturing industry.

Titanium aluminides are among the most famous titanium alloys that have been newly developed over the late few decades. These are intermetallic compounds consisting of Ti_3Al (α_2) and TiAl (γ) with high strength-to-weight ratio, exceptional resistance to corrosion, excellent fatigue crack growth resistance and good creep property. Although the fatigue performance of titanium aluminides is unsatisfactory at near ambient temperatures, their enhanced fatigue crack growth behavior at high temperature provides the gas turbine designer with an opportunity to exploit the strength-to-weight advantages of titanium based systems at temperatures approaching 1000^oC (Duncan et al., 1989). The fatigue crack growth resistance of titanium aluminides, relative to their tensile strengths, is as good as or better than steels, many showing an endurance ratio above half, is superior to most other structural metals (Kim et al., 1991). It is this high strength-low density characteristic, which has made titanium aluminides attractive candidates for applications in aerospace engines components. The future of titanium aluminides is bright and influenced by developments in new products which enable the optimization of microstructure and mechanical properties in order to meet the demands from aerospace and automotive industries (Kim et al., 1991).

Fatigue crack growth resistance is one of the most important mechanical properties for γ-TiAl applications as structural materials, which have been studied by several researchers. Previous studies have indicated that the mechanical properties of gamma titanium aluminides strongly depend on the microstructure of the alloys. There are three typical microstructures of gamma titanium aluminides: lamellar microstructure, equiaxed γ microstructure and duplex microstructure. Of these microstructures, previous studies reported that lamellar microstructure displayed excellent fatigue crack growth resistance (Gnanamoorthy et al., 1996). The microstructures in TiAl can be varied by heat treatment or by addition of β-stabilizing elements such as chromium, niobium, and vanadium. The addition of Cr to the binary TiAl has been reported not only to improve the room temperature ductility, but also to improve the high temperature oxidation resistance and some mechanical properties of the alloys (Takeyama et al., 1998). These excellent alloying effects make chromium a unique element among other β-stabilizing elements.

The objective of present study is to investigate the effects of chromium on the microstructures, mechanical characterizations, fatigue crack growth behavior at room temperature and fractography of Ti-48Al alloys and to better understand the mechanism of fatigue crack growth in the alloys. Microstructural studies, hardness tests, tensile tests and fatigue crack growth tests at room temperature have been carried out using as-cast Ti-48Al, Ti-48Al-2Cr, Ti-48Al-4Cr and Ti-48Al-8Cr with near fully lamellar microstructure.

1.2 Objectives of the Study

The objective of this study is to evaluate the effects of chromium additions on the fatigue crack growth behavior of as-cast gamma titanium aluminides (Ti-48Al) at room temperature (27^{o}C).

1.3 Scope of the Study

The scope of this study include the following:

(a) Investigation on the effects of addition of chromium on microstructure, mechanical properties and particularly fatigue crack growth behavior of as-cast Ti-48Al-xCr alloys (where x = 0, 2, 4, 8 at %).

(b) Establish the relationship between microstructure and fatigue crack growth properties of Ti-48Al-xCr alloys.

(c) Identify dominant fatigue fracture mechanism of Ti-48Al-xCr alloys.

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