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Jian Li [a, b], Peng Zhang [a, b], Lei Lu [a, b], Fei Lv [a, b], Xin-Ting Miao [a, b], Le Chang [a, b], Bin-Bin Zhou [a, b], Xiao-Hua He [a, b], Chang-Yu Zhou [a, b, *]

[a] School of Mechanical and Power Engineering, Nanjing Tech University, Nanjing 211816, China

[b] Jiangsu Key Lab of Design and Manufacture of Extreme Pressure Equipment, Nanjing 211816, China

* Corresponding author. Prof., Ph.D.; Tel.: +86-25-58139951; Fax: +86-25-58139951.

E-mail address: changyu_zhou@163.com (C.Y. Zhou).

Abstract

In this paper, the effects of pre-strain on fatigue crack growth rate are investigated considering wide ranges of load amplitudes and load ratios for commercial titanium alloy (CP-Ti). Considering the influences of load ratio and load amplitude, the effect of pre-strain on the strain energy and crack tip plastic zone size, and on the fatigue fracture mechanism have been clearly demonstrated. Besides these, how the pre-strain affects fatigue crack propagation, and therefore affects whole fatigue life have also been clearly stated. Results demonstrate that pre-strain may be more sensitive to the enhancement of fatigue crack growth resistance under high load ratio and high peak load conditions. Fatigue lives increase with increasing in the pre-strain level. With the increase of load ratio and load amplitude, pre-strain has more and more significant influence on the plastic strain energy of specimen. A high pre-strain level of 8% and a high load ratio of R=0.8 are more sensitive to the fatigue life. Static load or static damage has the most significant contribution to the crack tip plastic deformation than fatigue load. The production of twin crystal and dislocation structure after pre-strain process will greatly ensure the enhancement of fatigue crack resistance under all loading conditions. This research will provide support to the insight of pre-strain effect on fatigue crack growth behavior of CP-Ti.

Key words: pre-strain; fatigue crack growth; load ratio; load amplitude

1. Introduction

Over the past 40 years, titanium alloys have proven themselves to be technically superior materials for a wide spread of applications across the industries of aerospace, marine, industrial, and even the commercial products [1]. This is due to the good combination of mechanical properties [2]. Plastic deformation in titanium alloys is usually known to have important relation to the crystal orientation. The hexagonal close-packed (HCP) materials show complex modes of deformation because of the low symmetry. The plastic deformation by slipping in the hexagonal metals is greatly anisotropic due to the different deformation resistances in the crystals slip systems [3]. The decisive factor for cyclic plastic deformation of crack tip in ductile metals is fatigue crack growth. The adaptability of a parameter derived from the linear elastic fracture theory to describe highly non-linear phenomena is limited. Various observed phenomena of fatigue crack growth cannot be explained without considering cyclic plasticity [4]. It is well known that the accumulation of plastic strain near crack tip is generated under cyclic loading [5, 6]. Even when the applied overall stress field is elastic, fatigue crack grows in a local elastic-plastic field and their macroscopic mechanical behavior is local plastic surrounded by the outside elastic stress field [7]. It was proposed by Kapoor [8] that the choice of failure mode might depend on the material constitutive behavior. Two modes of failure under cyclic loading, low-cycle fatigue (LCF) and ratchetting, may be determined in ductile fracture. Failure occurs under low cycle fatigue with a strain cycle closed. While failure by ratchetting occurs and