FATIGUE LIFE PREDECTION OF THE AA2024-T351 ALUMINUM ALLOY

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Abstract
The purpose of this styudy is to investigate the cyclic behaviour of the AA2024-T351 aluminum alloy widely used in the aircraft industry. This alloy shows a relatively low ductility at room temperature and is generally heat treated in various conditions to suit particular applications. Monotonic and cyclic tests have been conducted in order to characterize the fatigue behaviour and determine the fatigue life of aluminum alloy. Cyclic tests in the Low Cycle Fatigue (LCF) regime were performed under fully reversed total strain amplitudes ranging between 0.6% and 1.2%. The elastoplastic behaviour was analysed through the stress-strain hysteresis loops leading to evaluate kinematic and isotropic hardenings. The AA2024-T351 was also shown to be prone to cyclic strain hardening. Besides, symmetric High Cycle Fatigue (HCF) tests were also performed and the Stress-Number of cycles (S-N) curve until 10^7 cycles was plotted. A fatigue limit of about 150 MPa was found. Based on all LCF and HCF tests, the fatigue life could be represented in a strain approach by the Manson-Coffin-Basquin law. Moreover, observations of the fracture surfaces were carried out using a Scanning Electron Microscope (SEM) in order to detect the crack initiation and follow the propagation for the two fatigue regimes.

1. Introduction

The aeronautical industries always demand innovative in particular in materials domain, by designing alloys with improved mechanical properties. Aluminum-Copper alloys and specially the AA2024-T351 aluminum alloy are used in aircraft components such as the wings and fuselage skins for more than 80 years, thanks to their good properties. Fatigue of materials is the process of accumulated damage and then failure due to cyclic loading. Engineering efforts over more than 150 years, aimed at preventing fatigue failure, led first to the development of a stress-based approach. This approach emphasizes stress versus life curves. More sophisticated approache, namely the strain-based approach have arisen in recent years. Stress versus life (*S*-*N*) curves are commonly plotted in terms of stress amplitude versus cycles to failure. To understand the fatigue evolution, the Wohler curve will be studied. The microstructural analyzes with SEM of the fracture facies of certain specimens, allowed us first to conclude that the type of fracture in our material is ductile and to confirm the cracking modes obtained during cyclic loading.

2. Results

This work on the cyclic behaviour of the aeronautical AA2024-T351 aluminum alloy, tempered, hardened and aged, allowed us to:

a. Fig.1 displays the stress amplitude versus the number of cycles at different strain amplitudes ranging from 0.6% to 1.2% with a semi-logarithmic scale along the X-axis. It is clearly seen that the cyclic stress amplitude increases with the strain amplitude, whereas the fatigue life of AA2024-T351 decreases.
b. Determinate the fatigue endurance limit under constant amplitude loading and stress ratio R -1 which is near 150 MPa (see Fig 2)
c. Examine the fracture surfaces of the tested material by scanning electron microscopy (see Fig 3 and Fig 4). The results show that the fatigue damage originates from the surface. With the increasing strain amplitude, the material fatigue life obviously decreases; the microstructural analyzes of the fracture facies allowed us to confirm the cracking modes obtained during cyclic loading and to conclude that the type of fracture in our material is ductile.

d. Study the elastoplastic behaviour by monitoring the evolution of strain hardening variables of isotropic and kinematic nature. Both variables vary almost linearly with the number of cycles. However, the kinematic variable decreases while the isotropic variable increases during the fatigue tests. Also, their evolution is shown to depend on the strain amplitude.

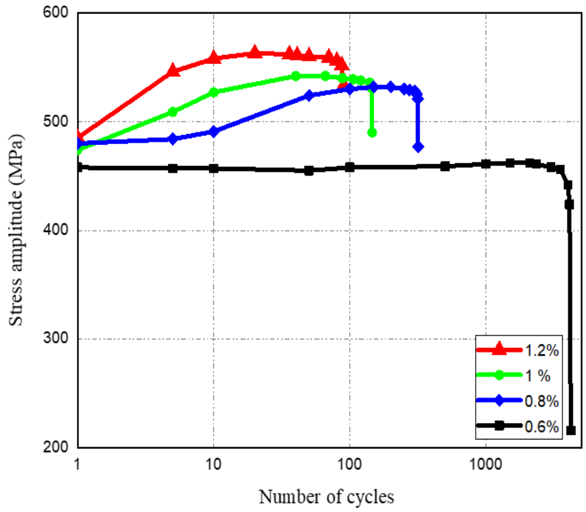

Fig.1- Cyclic stress amplitude versus number of cycles at different strain amplitudes.

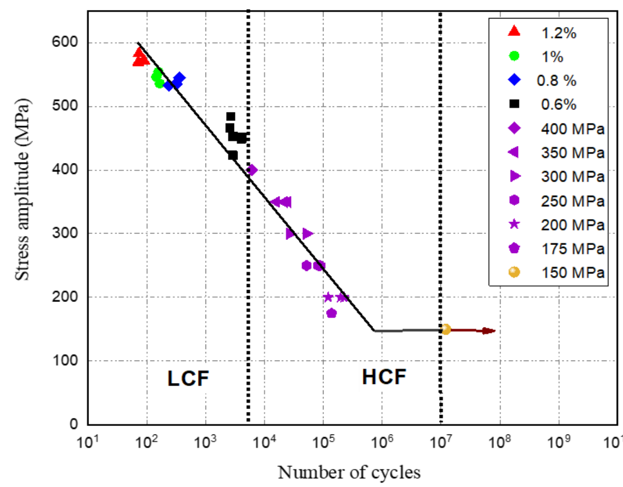

Fig.2- S-N curve of the AA2024-T351.

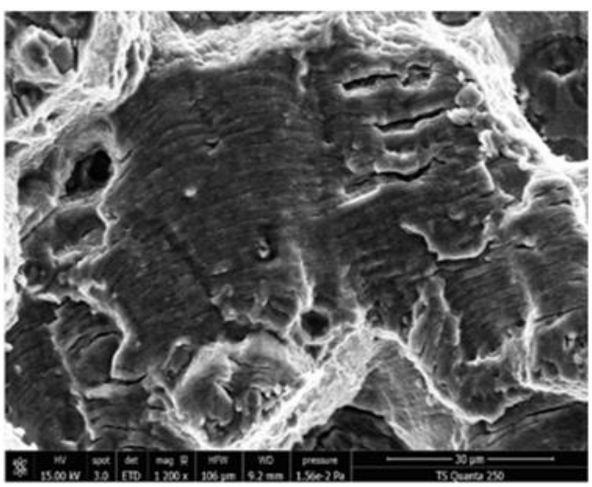

Fig.3- Fatigue striations created during crack propagation in HCF (at a stress amplitude of 250 MPa).

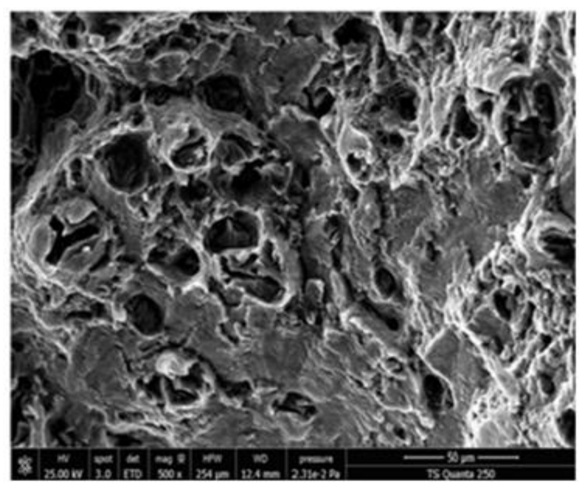

Fig 4- SEM fractographies: Dimples with clearly spherical form in LCF (at a strain amplitude of 0.8%).

3. Conclusions

This work allows us to investigate the fatigue behaviour of the AA2024-T351 aluminum alloy by estimate the fatigue life using stress approachs, cyclic tests in the Low Cycle Fatigue (LCF) and High Cycle Fatigue (HCF) regime were studied, fatigue limite endurance was determinated which is near 150 MPa. .Indeed, as depicted on Fig.2, a fatigue limit does appear on the S-N curve from about 10^7 cycles. It is also well known that aluminum alloys hardened by strain aging clearly exhibit a fatigue limit Finally, microstructural analyzes of the fracture facies allowed us to confirm that the fatigue damage originates from the surface, and the type of fracture is ductile.