CHAPTER 1

INTRODUCTION

Since second World War, there were high demands of new materials for using in turbine engines. These materials improved a higher performance for military and commercial aircraft, industrial turbines as well as in chemical and petrochemical applications. These materials would prolong life time service at high temperatures and stresses in severe environments. During this war period, the material technologists and scientists tried to find a solution which were superalloys. Superalloys provide good heat resistance, high strength, good corrosion resistance, good creep and fatigue resistance. Superalloys can be divided in three main groups: cobalt base, iron base, and nickel base. In this current work nickel base superalloy will be investigated.

In pressent, nickel base superalloys are used in aircraft, marine, industrial, vehicular gas turbines, space vehicles, rocket engines, experimental aircraft, nuclear reactors, submarines, steam power plants, petrochemical equipment, and other high temperature applications. But the main use of superalloys is in gas turbine industry. Thus gas turbine will be considered for its operation, component, and materials requirements [1].

Nickel base superalloys were applied for high temperature service. In most cases, they provided their good hot strength by precipitation of finely dispersed second phase particles. The precipitates improve the creep strength by increasing the flow stress and/or the work hardening and by decreasing the recovery rate [2]. The close-packed face-centered-cubic (FCC) lattice of these austenitic compositions has very high capability to provide good tensile, good rupture, and good creep properties to high temperature, much higher than for equivalent body-centered-cubic (BCC) systems, because of many factors, including the excellent modulus and diffusivity of the FCC lattice for secondary elements since its high solubility of many other elements in the austenetic matrix and the ability to control the precipitation of intermetallic compounds such as gamma prime for the strength. In nickel base superalloys, strengthening can also obtained by solid solution hardening and carbide precipitation [1]

High temperature operating components in aircraft turbine engines are supposed to resist on complex stresses including thermal stress, stress originating from centrifugal force and frequency vibration and temperature changes. Several previous works have been studies to understand the mechanism of high temperature pure creep and fatigue deformation in dispersion strengthened nickel base alloys [3,4,5,6,7]. For components like turbine blades the loading can be idealized as sationary or pure creep over time service, and therefore the design engineers widely approximate the response of the component through the application of constant load (or stress) creep data of alloys [8]. However, in actual service, the components are subjected to varying loads and temperature such as creep-fatigue interaction and conditions of thermomechanical fatigue (TMF).

Thus only stationary creep and conventional fatigue tests at high constant temperature represented poor simulation to actual service conditions where timedependent deformation can occur under load and temperature various. Especially in cyclic creep with thermomechanical fatigue loadings, during the transient regimes of start-up and shut-down operations where components are subjected to low cycle thermomechanical fatigue (TMF) due to the temperature gradients generating by temperature variations, or internal air cooling.

Therefore, recently several tests about effect of load cycling have been studied to understand the mechanism of creep-fatigue interaction in different either isothermal or anisothermal thermomechanical fatigue conditions **[9,10,11,12,13,14]**. At present, many studies express results that the creep-fatigue interaction appears to be an important factor affected to lifetime prediction of components. It is believed that combinating action between creep and fatigue stress components should be considered to approach the deformation mechanism in stressed parts. An additive cyclic stress component to stationary creep stress can either accelerate or decelerate the creep rate depending on alloys structural characteristics and employed materials testing conditions **[10]**.

EI 698 VD is a trade mark alloy assigned to a one of the wrought Ni-base superalloys using mainly for the rotor parts of turbine engines of Russian and former Eastern European jet aircrafts. It provides a high strength, good ductility material with excelent fabrication characteristics. It has high resistance to overaging in long term exposured. Employing aging heat treatment, the adequate gamma prime precipitation strengthening and carbide grain boundary strengthening can be achieved providing good creep properties. Due to these beneficial properties, EI 698 VD wrought alloy has been widely used as high temperature material in the aircraft and power generating industry for variety of applications such as shafts and discs.

In this present investigation, the attention was paid to study the creep behaviour and creep-fatigue interactions for both isothermal cyclic creep (ICC) and cyclic creep with thermomechanical fatigue loadings (TMF) of wrought nickel base superalloy EI 698 VD in load control for both cyclic creep loadings. However, up to the present, there is no study in the effect of cyclic creep at a constant temperature and cyclic creep with thermomechanical fatigue stress component in EI 698 VD to simulate from the working steps of flying operations. This is a reason for the author to carry out in this research program.

In order to examine the influence of the additional fatigue stress component superimposed onto the creep stress and the specific loading schedules representing continuous higher tension-lower tension cycling were performed. The isothermal cyclic creep loading was defined by different tensile hold periods at the maximum level of creep load. The thermemechanical fatigue stress component was the result of a forced temperature reduction between the individual hold periods when the load was applied. The parameters in this investigation are time, stress and temperature, according to simulating various thermomechanical creep fatigue regimes. Loading schedule will be used to simulate the working schedule of the engines including heating up, idle run, cruising and relaxing. Thus the effect of different time intervals for cruising to the endurance of material in cyclic creep conditions will be investigated. The simulated loading regime will be run till failure.

The microstructural characteristics of fracture specimens which were cut parallel to the applied loading axis from both types of cyclic creep loading tests were studied by means of optical microscope and transmission electron microscope (TEM). These observations revealed the changes in the microstructure including size and shape of gamma prime precipitates and the development of dislocation substructure under deformation of different types of cyclic creep loading.

The fracture surfaces were investigated by scanning electron microscope (SEM) with the purpose to study and determine effects of tensile loading hold time periods and the superimposed effect of the isothermal and thermomechanical fatigue loading onto stationary creep on the fracture nucleation and propagation process comparing to those in pure creep and fatigue.

1.1 Objectives

The main goals of the work can be generally summarized into the followings:

1. Study tensile behaviour of EI 698 VD alloy at elevated temperatures.

2. Evaluate the effects of various stress levels at a constant testing temperature on creep characteristics of the alloy on life time, strain rate, and fracture.

3. Analyze the deformation mechanism of creep process on primary, secondary and tertiary creep using optical microscope and TEM.

4. Investigate the effects of superimposed cyclic stress on cyclic creep tests at a constant temperature and cyclic creep tests with thermomechanical fatigue stress component as well as the effects of holding time on life time of the alloy.

5. Investigate the additional effects of fatigue component at constant and various temperatures together with the effects of holding time on fracture characteristics of the alloy by using SEM.

6. Investigate the effects of stress relaxing on the deformation mechanism under a constant temperature and the various temperature conditions for different holding times.

7. Consider the creep exposure time as a detrimental factor to influence the stability of the alloy at testing conditions as stated above.

1.2 Scope of Studying

To study and analyze the experimental obtained results from the following tests:

1. Tensile test at room temperature (T≅25°C) and high temperature (T=650° C).

2. Creep tests at high temperature (T=650°C) with different stresses (612, 706, 740, 760, and 850 MPa).

3. Cyclic creep tests of various holding times (1, 3, 5, and 10hrs.) at a constant high temperature (T=650°C). Maximum stress and minimum stress are 740 and 20 MPa, respectively.

4. Cyclic creep tests of varying holding times (1, 3, 5, and 10hrs.) with thermomechanical fatigue stress component. Maximum stress is 740 MPa. and minimum stress is 20 MPa. Maximum temperature is 650°C and minimum temperatures 50°C.

5. Fatigue test at constant high temperature (T=650°C) with maximum stress (R=740 MPa.) and minimum stress (R=20 MPa.)

These specimens were investigated using optical microscope for all mentioned tests. Transmission electron microscope was used to study dislocation substructure under different testing conditions which are as follows: 1) three stages of creep at stress level R=740 MPa and temperature T=650°C. 2) both selected cyclic creep at constant temperature and cyclic creep with thermomechanical fatigue stress component. 3) high temperature fatigue test. Furthermore,scaning electron microscope (SEM) was used to investigate fracture surface.

1.3 Expected Usefulness

1. Understanding of substructure development of the alloy for primary, secondary and tertiary stages of creep process.

2. Understanding the effects of holding time on mechanical properties, fracture characteristic and final substructure of the alloy in both cyclic creep at constant temperature and cyclic creep with thermomechanical fatigue stress component.

3. Knowing the holding time suitable for obtaining the maximum prolong life time.