CREEP LIFE PREDICTION IN TURBINE COMPONENTS: LECTURE NOTES

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1 Introduction

1.1 Hot Gas Path Components

Turbine components most susceptible to creep live in the hot gas path of the turbine. These components live behind the combustor, and consist of several stages of nozzle guide vanes and rotor blades with accompanying overtip seal segments above the rotor blades. The nozzle guide vanes turn and accelerate the flow, the rotor blades extract work from the gas flow and drive the compressors, and the seal segments provide control of the overtip leakage of the rotor blades. The civil engine in the picture is typical of a high fan bypass ratio engine such as those in the Trent family. The turbine cross section in figure 1 shows the high pressure, intermediate pressure and low pressure turbines of a three shaft engine, and those components of the hot gas path circled.

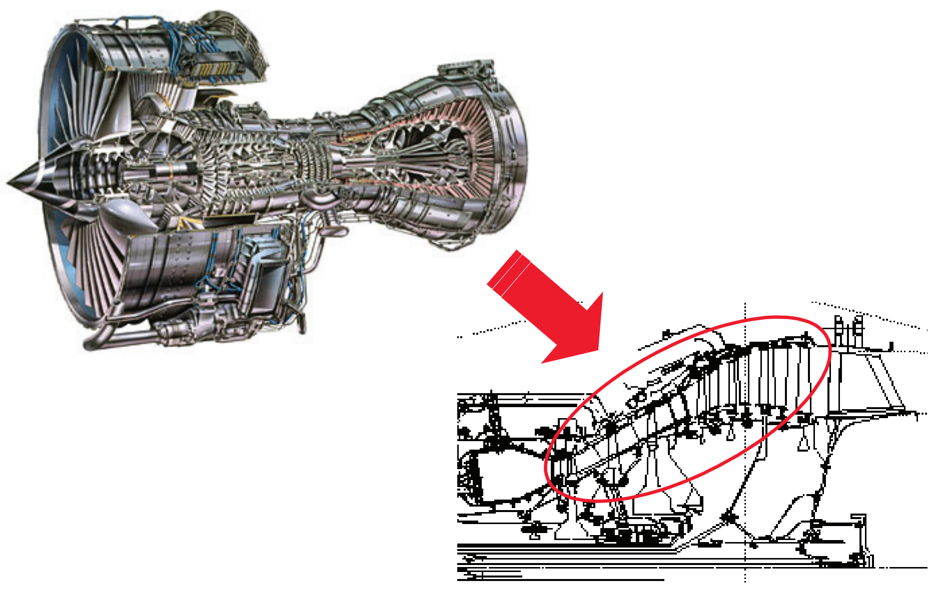

Figure 1 Hot Gas Path Components

1.2 Failure modes on uncoated components

Before progressing into the main presentation on creep, there are other failure modes that can affect turbine components that will be outlined, figure 2. This will show that although creep is a fundamental mode for design, there are many other areas to be considered. The other fundamental mode for design is fatigue which results in cracking. Fatigue can either be of high stress amplitude and low frequency known as low cycle fatigue, or of low stress amplitude and high frequency known as high cycle fatigue. Another key mode is surface attack due to the operation at high temperature in the presence of oxygen and other corrosive elements. Oxidation will lead to spallation and loss of useful load carrying section and corrosion will lead to loss of load carrying section and corrosion cracking. The use of protective coatings to minimise oxidation and corrosion, and the use of thermal barrier coating systems to reduce substrate operating temperatures bring further modes of failure that need to be considered.

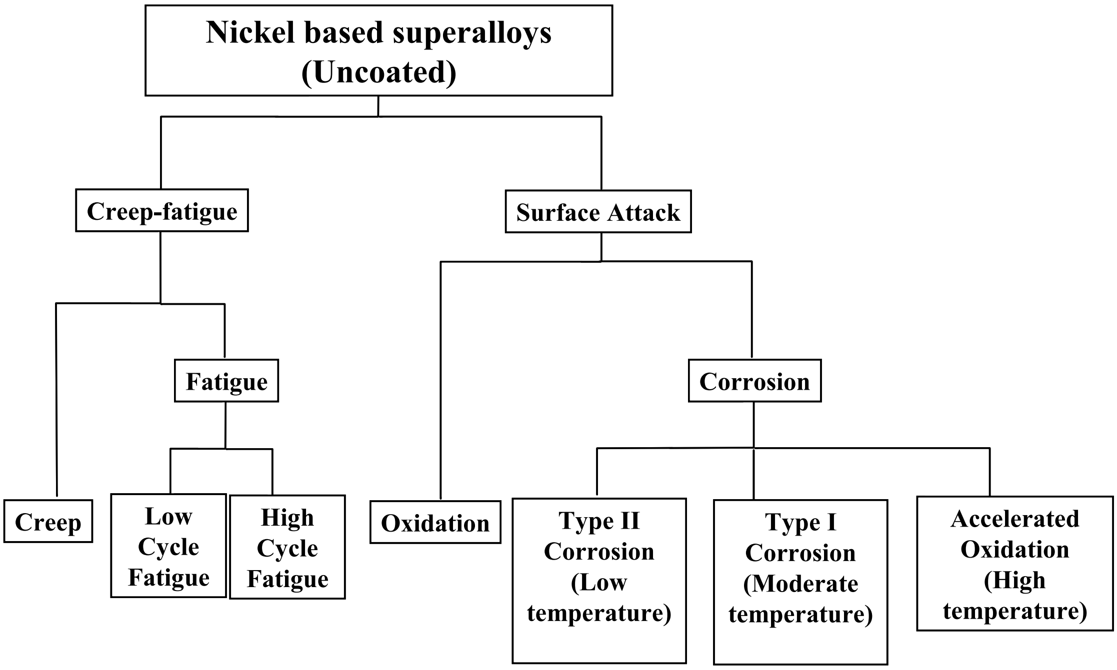

Figure 2 Failure Modes of Uncoated Components

1.3 Description of Creep

Creep can be described as the progressive deformation of a material under a constant stress, where this stress is less than the stress to cause yield. The deformation is time dependent, and has varying rates of accumulation with time at a given stress and temperature. The deformation that occurs is made up of an elastic deformation and an inelastic or permanent deformation which is not recoverable. Typically creep occurs at temperatures above 40% of the absolute melting temperature for turbine materials, and the creep behaviour is highly dependent on the metal operating temperature and stress. The stresses can result from either thermal or mechanical loading or a combination of the two. Creep results in permanent deformation of the component, either in a bulk sense or in a local region, and leads to cracking and in some cases rupture.

2 Characteristics of Creep

The characteristics of creep are shown in figure 3 of strain versus time typical of high temperature creep. The strain axis in this case shows the total strain being the sum of the