FATIGUE LIFE PREDICTION IN TURBINE COMPONENTS: LECTURE NOTES

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1 Introduction

1.1 Hot Gas Path Components

Turbine components are susceptible to fatigue as a result of the cyclic behaviour experienced by a gas turbine in addition to the high operating temperatures and stresses. 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 the three shaft engine, and those components of the hot gas path.

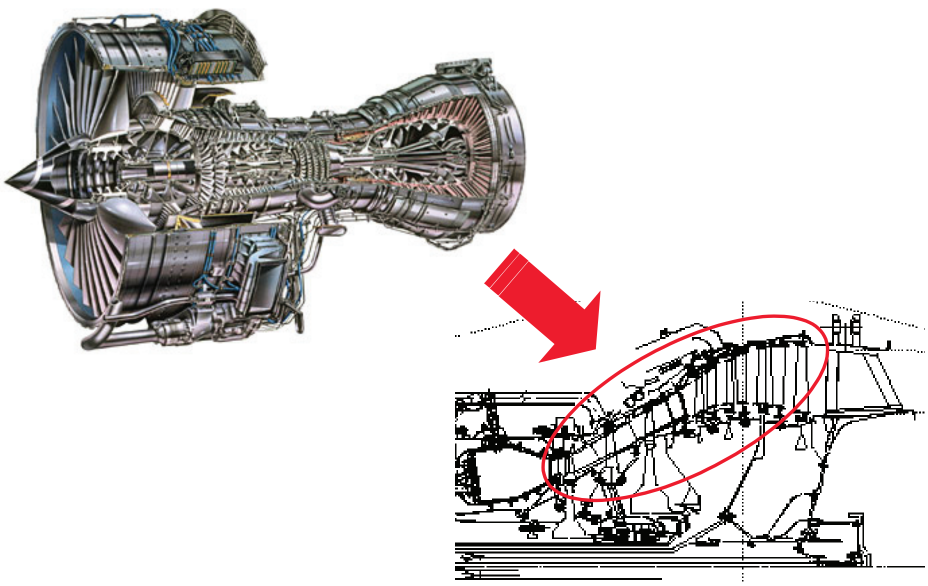

Figure 1 Hot Gas Path Components

1.2 Failure modes on uncoated components

Before progressing into the main presentation on fatigue, there are other failure modes that can affect turbine components that will be outlined, figure 2. This will show that although low cycle fatigue is a fundamental mode for design, as it results in cracking that can propagate to the point of component failure, there are many other areas to be considered. Low cycle fatigue is by nature of high stress amplitude and low frequency (<1Hz) whereas high cycle fatigue is of low stress amplitude and high frequency. High cycle fatigue will not be covered in this presentation, although some aspects of the influence on fatigue behaviour described herein will naturally relate to high cycle fatigue as well. The other fundamental mode for design is creep which results in deformation and cracking. 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.

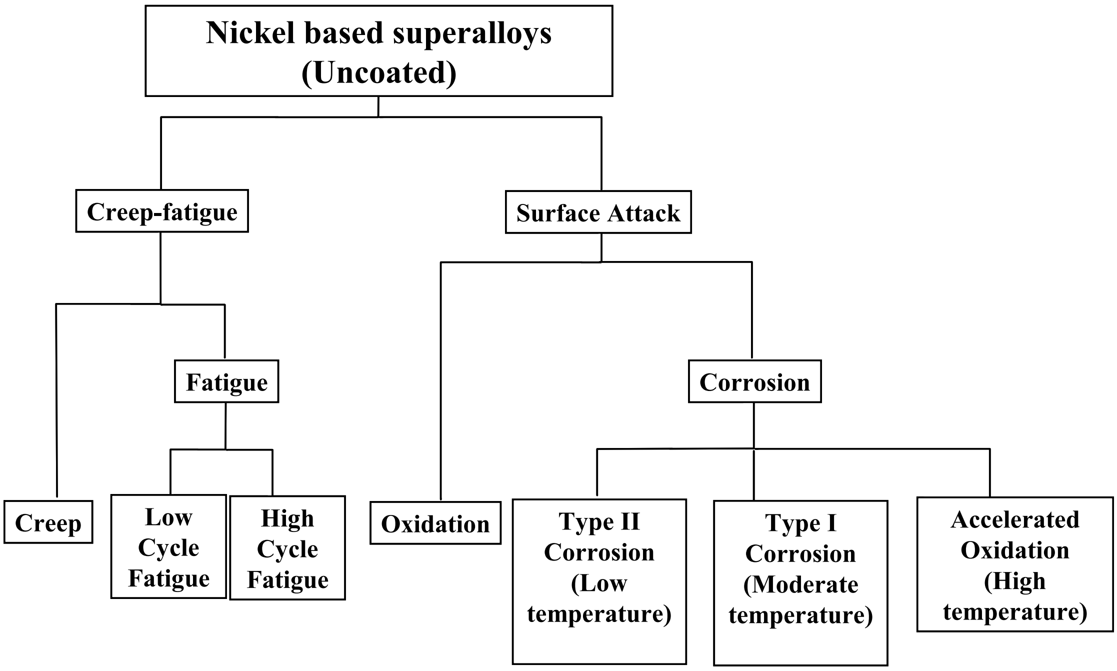

Figure 2 Failure Modes of Uncoated Components

1.3 Description of Fatigue

Fatigue is the progressive accumulation of damage in a material under a repeated cycling of stress and strain at temperature. Low cycle fatigue (LCF) damage tends to result in a life of less than 100,000 cycles in comparison to high cycle fatigue (HCF) which is in the region from 100,000 cycles and above. The driving stresses in turbine components can result from either thermal or mechanical loads or a combination of the two. Mechanical loads on turbine blades include the forces due to rotation, the gas bending moments and the offset bending moments due to the blade radial section alignment. Low cycle fatigue results in fatigue cracks that can propagate in length under some loading conditions until component failure occurs.