

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

In mechanical industry, the prediction of fatigue life in the high stress/strain field (relatively low number of cycles) is becoming more widespread. This is due to the increasing demand for improved performance in mechanical components. Design is becoming steadily oriented to more complicated shapes, which introduces more stress risers (usually reported as notches), and to lighter geometries, especially in fields such as the aircraft or automotive industries. The prediction of the fatigue life of specimens loaded under variable amplitude conditions is a complex subject. In the early 1960s it was shown that the low-cycle fatigue behaviour of metals is dominated by the strain, rather than by the stress as assumed previously. In fact, when a sharp notch occurs in a component, the effect on the stress field is so heavy that often the material yields locally. In such a case the quantity that must be used to describe the material behaviour is the local strain, so it is necessary to carry out a life prediction based on the strain-fatigue properties. From these considerations a method called the "Local Strain Approach" was proposed. Its main points can be summarised as (i) the actual strain at the notch root is evaluated. The most important method to solve this problem was proposed by Neuber (1961), and is still widely used;(ii) the prediction of the component life is made using strain based fatigue life law. This approach to low-cycle fatigue life was proposed by Manson and Coffin (1954). This methodology studies only the behaviour of the material at the notch root, so that the predicted life is referred to a small part of the resisting section, in the neighbourhood of the notch. The failure is assumed to occur when a relatively small crack appears at the notch root.

Other works on the evaluation of the local strain have been published, mainly because the Neuber's method gave a large conservatism on the predicted life. Furthermore the latter does not have a theoretical basic, but is based only on experimental observations on notched components. With modern computing facilities it is possible to assess the local strain using a numerical method, mainly Finite Element Analysis, when the load history is very simple, such as a sinusoid between two fixed values. Another source of conservatism is the fact that the Local Strain Approach neglects the remaining life of the component needed to extend the crack up to the real failure, which for some geometries can be a large part of the total life. The phenomenon of the crack growth has been studied from the early 1900s, and its analysis is based on the law proposed by Paris (1961). The chief aim of the project is to evaluate the importance of using a combined approach, to predict the two parts of the life. Moreover, a comparison of the methods (Neuber method, Finite Element Analysis, and Energy based method) now available to assess the local strain is carried out in order to find out which of them is more accurate and suitable in different load situations.

The fatigue life until failure has been divided into two periods: (i) the crack initiation period, and (ii) crack growth period. Crack nucleation and microcrack growth in the first period are primarily phenomena occurring at the material surface. The second period starts when the fatigue crack penetrates into the subsurface material away from the material surface. The growth of the fatigue crack is then depending on the crack growth resistance of the material as a bulk property. The fatigue life of an unnotched specimen in the high-cycle fatigue regime is largely covered by the crack initiation period. The crack growth period could almost be disregarded and often is ignored. Under which condition is crack growth in the second period of practical interest? Obviously, the load spectrum should contain stress cycles above the fatigue limit in order to have a problem of fatigue crack growth. Secondly some macrocrack growth must be acceptable ,or, as phrased in a different way, some crack growth might be unavoidable, and it should then be known how fast crack growth occurs. Two well-known examples are: (i) crack growth in sheet material where the crack is growing through the full thickness of the material. An obvious example is fatigue crack growth in aircraft skin structures; (ii) a second example is the growth of part through cracks where a corner crack and a surface crack start at a hole. Another example is the

occurrence of surface cracks starting at the toe of a weld in a welded structure. In many practical cases, part through cracks are associated with either massive components or with thick plate structures.

The prediction of the fatigue life of specimens loaded under variable amplitude conditions is a complex subject. The most widely used theory is the linear damage rule commonly referred to as the Miner rule (Miner, 1945). The $S-N$ curve is the only information needed for the Miner rule. However, in many cases it leads to inaccurate, often non-conservative life predictions. The reason for this is the different load-dependency of the crack initiation and the crack growth phase. A comprehensive review paper providing an overview of cumulative damage theories for metals and alloys has been published recently (Fatemi and Yang, 1998). Most theories wish to gain a high improvement of the life prediction accuracy by only adding little information in excess of the $S-N$ curve. Three of these theories (Subramanyan, 1976; Hashin, 1980; Manson and Halford, 1981) use a power-law damage rule to account for the load sequence effects. In this paper a new exponent for the power-law damage rule has been determined. Load interaction effects such as crack growth retardation after overloads are not taken into account. Instead of calculating the transition point between the crack initiation and the crack propagation phase, a steady change in the damage accumulation speed is considered.

1.2 PROBLEM STATEMENT

Crack can be acceptable for different reasons. It may be that crack does not have significant safety or economic consequences. The more cases arrive if safety, or economy, or both are involved. This occurs in pressure vessels if a leak from a fatigue crack can lead to an explosion. Another category of problems is related to fatigue crack growth monitored by periodic inspections. The purpose of the inspection is to discover fatigue cracks before they become dangerous. It then is necessary to know how fast a crack is growing in order to set timely inspection periods. The keyhole is subjected to cyclic loading. The keyhole, uncertainly is related to loads expected given to the component due to individual usage style and environment conditions. The best design