CHAPTER 4

FATIGUE, FRACTURE MECHANICS AND DEFECT ASSESSMENT
OF TUBULAR STRUCTURES

M.M.K. Lee
University of Wales, Swansea, UK

ABSTRACT

This chapter introduces the methodologies used in the fatigue design and defect assessment of offshore tubular structures. The topics covered include

- Introduction to fatigue design of tubular structures
- Fatigue assessment using fracture mechanics
- Calculations of stress concentration factors and stress intensity factors using finite elements
- Parametric equations for stress concentration factors
- Stress intensity factor solutions
- Fatigue and fracture assessment in practice

The contents are aimed at giving readers state-of-the-art information on fatigue design and fracture assessment of offshore tubular structures.
4.1 INTRODUCTION TO FATIGUE DESIGN OF TUBULAR STRUCTURES

Steel jacket structures, Fig. 4.1, are used extensively for oil and gas extraction in the North Sea and in many parts of the world. Jackets are fixed, bottom supported structures and their main function is to provide a safe working environment for the equipment and personnel who operate the platform. A steel jacket is a large three-dimensional welded braced frame constructed from circular hollow sections. Apart from permanent, operational and live loads, jacket structures located in hostile waters, such as the North Sea, are also subjected to dynamic forces from wind and waves, which generate fatigue loading.

Figure 4.1 A typical North Sea platform

Figure 4.2 Causes of damage to North Sea structures (1974-1992)

4.1.1 Fatigue cracking of tubular joints

Fatigue damage from cyclic wave loading is a major cause of damage to offshore tubular structures. A recent review of offshore structures in the UK sector of the North Sea shows that fatigue accounts for about a quarter of the damage, Fig. 4.2. Undetected fatigue cracking can result in the catastrophic failure.

Fatigue is characterised by the gradual reduction in the capacity of structural elements to withstand cyclic loads. The amplitude of the applied load or stress cycle may only be relatively low (less than the yield stress of the metal), but its repeated application causes fracture of the metal. Fatigue cracks generally occur on the chord in the region of high local stresses near to the intersection. The weld toe is a prime site for fatigue cracking because of the presence of weld toe undercuts and other defects caused by the welding process. Fatigue failure is normally caused by the coalescence of a number of small fatigue cracks into one dominant crack.