1. INTRODUCTION

Fatigue is the most common cause of failure in welded structures and components, accounting for around 90% of failures, and usually design stresses in repeatedly loaded structures are limited by the fatigue strength of weld details, which can be very low (Fig. 1). Fatigue failures can prove to be expensive, in terms of lost production, repair cost and even loss of life, and companies have been known to close down as a result of fatigue problems. A survey of published fatigue failures (1) reveals that most failures can be attributed to poor design. Much is known about the fatigue behaviour of welded joints (2) and reasonably comprehensive design rules exist for many structures. However, to make
effective use of such rules, or to be in a position to deal with problems not covered in rules, it is important to have a good understanding of the fatigue behaviour of welded joints and, in particular, to appreciate what are the most significant factors to affect fatigue strength. This lecture considers these points in a general introduction to fatigue design rules and fatigue life prediction methods for welded joints.

2. EFFECT OF WELD GEOMETRY

The geometry of a weld, and hence its effect as a stress concentration, is the most significant feature from the fatigue point of view. Two sources of stress concentration are important:

2.1. Stress concentration due to weld shape

Stress concentrations arise as a result of either a decrease or an increase in section, the latter being the most significant in welded joints (Fig. 2). Welds do not need to be load-carrying to introduce stress concentrations and, in practice, welded attachments to stressed members are common sites for fatigue failure. The weld toe is the most likely site for fatigue cracking in transversely loaded welds and short or discontinuous longitudinal welds. The surface irregularities in continuous longitudinal welds (Fig. 2b)) represent less severe stress concentrations. Sub-surface stress concentrations include the weld root in transverse load-carrying fillet welds (Fig. 2c)) and buried defects in either longitudinal or transverse welds.

2.2. Stress concentration due to weld flaws

The stress concentration due to the profile of a weld is not a true reflection of its fatigue strength, the fillet welded attachment and the hole in Fig. 1 being equivalent in this respect. Locally the weld toe is more severe because of the presence of minute (0.05–0.4mm, but typically 0.1–0.2mm deep) crack-like flaws (3,4,5) from which fatigue cracks propagate. These flaws appear to be unavoidable in steel welds made using normal arc welding processes and are, therefore, an inherent part of the joint. The combined effect of such flaws situated in fields of stress concentration is that fatigue cracks readily initiate and most of the life is spent propagating a crack.

The weld root in transverse load-carrying fillet welds also constitutes a crack-like flaw, as do planar features like lack of penetration and lack of fusion in butt welds, and again the fatigue life consists mainly of crack growth.

Thus, the fatigue behaviour of welded joints contrasts significantly with that of most unwelded components where crack initiation may occupy the majority of the life. Hence, the large difference between the S-N curves for plain or notched plate and a plate with a welded attachment shown in Fig. 1 is not surprising. However, in addition, the fact that the fatigue life of the welded joint is dominated by crack growth while the fatigue life of the unwelded part is normally dominated by crack initiation has a number of other consequences relating to the influence of various factors on fatigue life. These arise because the factors have different effects on fatigue crack initiation and on fatigue crack propagation.

In view of the significance of crack growth, fracture mechanics can be used to calculate the fatigue lives of those welded joints in which fatigue cracks propagate from pre-existing crack-like flaws. The method is to integrate the crack growth relationship, e.g.

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\frac{da}{dN} = C(\Delta K)^m
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[1]