Constant and Variable Amplitude Corrosion Fatigue Performance of a High Strength Jack-up Steel

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Abstract

Jack-up rigs have traditionally been used for short term drilling and maintenance operations. However, they are now being used increasingly as production platforms for marginal field development. The deployment of jack-up platforms for extended periods increases the risk of long term problems such as fatigue due to the reduced frequency of dry dock inspections and the enhanced susceptibility to fatigue crack initiation and propagation. Furthermore, there is less data available on high strength steels used in the fabrication of jack-ups when compared with conventional offshore structural steels such as BS 4360 and BS 7191 and there is no existing fatigue guidance: current fatigue guidance is limited to steels with yield strengths up to 500MPa.

There is need to establish the fatigue behaviour of high strength steels used in jack-up construction and this paper presents results from a major large scale fatigue testing programme on the fatigue performance of a typical high strength jack-up steel, SE 702, which investigated (a) the effects of cathodic protection on the corrosion fatigue behaviour of large-scale high strength welded tubular joints tested under constant amplitude loading, and (b) the corrosion fatigue behaviour of the same steel under simulated service loading and environmental conditions. The effects of cathodic protection and variable amplitude loading on the fatigue performance of SE 702 high strength steel are assessed and compared with results from conventional offshore structural steels.

Introduction

High strength steels have been used in the fabrication of jack-ups for many years. Steels with nominal yield strengths in the range 450 - 700MPa have commonly been used for the fabrication of the leg structure (see figure 1), rack and pinions and spud cans. Recently there has been a significant increase in the size of these rigs enabling them to work in greater water depths and during harsher weather conditions than earlier designs. Several jack-ups are now being used for production, thus limiting the opportunity for inspection and repair. As such there is a higher risk of fatigue crack growth and subsequent structural failure.

A considerable amount of research on fatigue performance of tubular welded joints has been performed by the Offshore industry such as UKOSRP [1, 2]. However, the vast majority of this research has been focused on tubular joint specimens made from conventional offshore structural steels such as BS 4360:50D [3] and BS 7191 [4] with typical yield strengths of 350 MPa. The data for higher strength steel tubular joints is therefore very limited, as indicated in a recent review of the available data presented in [5]. Consequently the fatigue design guidance that has been developed to date is not applicable to high strength steels.

New guidance on fatigue was published in 1995 [6]. In this the basic design S-N curves are restricted to steels with minimum guaranteed yield strengths of up to 400 MPa for nodal joints and 500 MPa for welded plate details. This restriction is due to the limited test data available for both joints and plates fabricated from high strength steels [5], particularly under cathodic protection (CP) and free corrosion conditions, although crack growth data from fracture mechanics type tests are available. As a result, it is recommended that, for higher yield strength steels, data from an approved test programme or associated fracture mechanics analyses are used to determine appropriate S-N curves.

There is a general acceptance that high strength steels have a higher susceptibility to corrosion fatigue compared with conventional structural steels. This susceptibility is known to increase with increasing yield strength and increasingly negative cathodic potential. The generation of hydrogen from the cathodic protection process is recognised as enhancing crack growth rates at the crack tip and it is therefore important that the fatigue performance of selected high strength steels is understood and that appropriate levels of cathodic protection are applied. There is also a need to consider the effects of variable amplitude loading and the presence of sulphate reducing bacteria (SRB) in seabed muds.

The long term fatigue performance of high strength steels is subject to uncertainty and there is a need to investigate their performance further. This paper presents results from an investigation with the aim of