Variable Amplitude Corrosion Fatigue Behaviour and Hydrogen Embrittlement of High Strength Steels for Off-Shore Applications

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ABSTRACT

Jack-up platforms are made from high strength steels and the offshore oil and gas industry is now proposing to use these platforms for production and exploration. The possibility of deterioration from long term problems such as fatigue has been heightened due to this change in use. However, there is very little information available for designers on how these high strength steels behave under corrosion fatigue conditions and, up to now, they were suspected to be more susceptible to the environment assisted cracking than the medium strength type steels used for fixed platforms. Because of the need to establish stress and fracture mechanics analysis to assist the design and use of the platforms, further investigation of the high strength steels for offshore applications is necessary.

In a first stage, corrosion fatigue crack propagation tests have been performed on CT specimens made from Creusot Loire Industrie SE702 (A517 Gde Q Mod.) type high strength steel (790 MPa < UTS < 940 MPa) in order to determine the Paris laws of base metal and Heat Affected Zone (HAZ) under cathodic protection conditions (-850 mV/EC)S. The results were compared to the mean curves obtained on 50D type steel and to the recommendations of codes and standards. SE702 happens to be in good agreement with the recommendations.

Corrosion fatigue tests have then been performed on T and Y tubular joints made from SE702 under constant amplitude or variable amplitude loading, using a North Sea simulated wave load history. Under variable amplitude loading, the fatigue life consists of crack initiation, small crack growth at a low rate, and finally rapid crack growth to through wall penetration. The results, in terms of initiation and total lives, were compared to data available on similar joints made from 50D type steels and gave an indication of the likely stress-life (S/N) curve. Two levels of cathodic protection have been tested (-800 mV and -1000 mV) in order to take into account the role of hydrogen, which had been found to be more detrimental for higher strength steels.

The role of hydrogen has been studied through hydrogen embrittlement tests and review of literature and the particular behaviour of SE702 steel is exposed in this paper in order to understand better the influence of cathodic protection.

Even in the worse cathodic protection conditions, the variable amplitude corrosion fatigue behaviour of SE702 is very encouraging.

In particular, there seems to be a real benefit in using SE702 high strength steel, compared to 50D type steel, when relatively low stresses are met.

Key words: Fatigue, corrosion-fatigue, hydrogen embrittlement, high strength steel, off-shore

1. INTRODUCTION

High strength steels such as A517 Gde Q or F have been widely used for Jack-Up platforms all over the world for a long time. However, some cracks have been detected a few years ago on legs in the North Sea (Davey, 1991). These cracks were mainly associated with leg chords and spudcan, and initiated in HAZ's of welded areas. As a consequence, safety organizations have prepared guidelines for the use of high strength steels in Jack-Up platforms (HSE, 19XX).

The higher yield strengths of the steels used in Jack-Ups typically 590 to 700 MPa are obtained by quenching and tempering, thereby promoting a tempered refined martensite microstructure. These steels are likely to be more susceptible to environmental effects.

Jack-Up rigs are used in a more varied fashion than fixed platforms, giving a more complex service loading history and changes in mode of loading. In the past, Jack-Up rigs have been used extensively for oil exploration. In the future, it is envisaged that Jack-Ups will be increasingly used for production and exploitation of relatively small pockets of oil. This will present new problems of fatigue.

To protect the legs from general corrosion, cathodic protection is used and an optimum level has been set at -830 mV/ECS. Unfortunately, in use, the cathodic protection level often exceeds the value recommended (Davey, 1991). Previous work carried out on medium strength steels (50D type) shows that, under conditions of cathodic over-protection, the fatigue life of tubular joints may be significantly reduced compared to the lives of tubular joints protected at the optimum potential (King, Sharp and Nichols, 1992). Existing fatigue guidelines are restricted to steel welded tubular joints of strength less than 400 MPa and optimum CP levels of -830 mV/ECS. At present, fatigue data is not available for tubular joints constructed from the grade of steels commonly used for Jack-Up legs.