ABSTRACT

Steel jacket platforms consisting of welded tubular members are the most extensively used structural facilities for offshore production and processing of oil and gas. Because of the repetitive sea wave loading, fatigue is an important consideration in the design of these steel jacket platforms. Fatigue failure normally occurs or initiates at the joints of these structures, where many tubular members are welded together, resulting in locations of high stress concentration. The problem of fatigue in steel offshore structures is further compounded due to the continuous exposure of these structures to the corrosive sea water environment. The phenomena of fatigue and corrosion complement each other and the resulting synergistic effect is referred to as 'corrosion fatigue'. Generally, nearly one-third of the total reported failures in offshore installations is accounted as due to fatigue/corrosion fatigue.

Fairly good amount of fatigue (in air) and corrosion fatigue (in sea water) experimental investigations on small scale plate specimens have been reported in literature. But the results of tests on small scale plate specimens are inadequate to understand the complex fatigue/corrosion fatigue behaviour of large size tubular joints of offshore structures. At best, the plate specimen test results are only qualitative or indicative in nature to understand the tubular joint behaviour. Many variables – mechanical, metallurgical, environmental etc. are involved in the process of fatigue/corrosion fatigue. The complexity of the process of corrosion fatigue, too many variables contributing to the process, and the difficulties involved in modelling such a complex process have made it necessary to conduct tests on large size steel tubular joints in order to have a better understanding of the behaviour of steel jacket structures which are
constantly exposed to sea water environment and continuously subjected to repetitive sea wave loading. Experimental investigations on fatigue behaviour of large size steel tubular joints are expensive and time-consuming. Corrosion fatigue studies are even more so since the tests have to be conducted at the sea wave frequency of 0.2 Hz. The time and expense involved in these investigations severely restrict the number and duration of tests.

The immersed zone of an offshore jacket structure is protected against corrosion by Cathodic Protection (CP). Sacrificial anodes are normally used to provide CP. The fatigue behaviour of cathodically protected joints in sea water is yet to be understood properly. Does CP provided to the tubular joints help in regaining fully the in-air fatigue strength of the joints – a firm answer to the question is still evading.

In the light of the above, the present investigations on stiffened steel tubular T joints to study the effect of CP on the fatigue life of the joints were taken up. The joints tested were approximately quarter scale models of a typical joint in the Bombay High jacket platforms in India. Totally five fatigue tests were conducted, two in air and three in sea water with CP. The main aim was to study the fatigue behaviour of cathodically protected joints and examine whether adequate CP would help in regaining the in-air fatigue life. The air tests were conducted to get the fatigue life values for comparison. During the fatigue tests, crack depth measurements were made at regular intervals of load cycles by using Alternating Current Potential Difference technique. The tests were conducted at different levels of hot spot stress range so that the behaviour over a large range of stress range could be studied. Results of three air fatigue and four free corrosion fatigue tests on similar joints, based on earlier investigations, were also considered for comparison of fatigue life values and making conclusions.
Before conducting fatigue tests on the tubular joints, static test was conducted on a T joint specimen to know the values of maximum Stress Concentration Factor (SCF) in the chord and brace members. Recommendations of the European Steel and Coal Community (ECSC) were followed in determining the hot spot stresses. The experimental SCF values were compared with analytical values and values obtained from parametric equations. To have an idea about the improvement in the joint behaviour due to the provision of ring stiffeners, the experimental SCF values for the stiffened T joint were compared with the SCF values for an unstiffened T joint with similar geometry and material. Ring stiffeners give considerable relief to the SCF at the saddle location, while the SCF may increase at the crown.

It is observed that the fatigue life of joints freely corroding in sea water is reduced by a factor ranging between two and three. The existing Guidance of the United Kingdom Department of Energy (UKDoE) recommends a penalty factor of two for joints subjected to free corrosion in sea water. The proposed Guidance of the UKDoE that a penalty factor of three be applied to unprotected joints in sea water environment seems appropriate.

Crack initiation was not observed in any of the cathodically protected joints tested in sea water. All the three CP tests were runout tests. The tests were terminated after exceeding the mean S-N curve or the mean+2SD curve of the UKDoE.

It is very clearly established from the investigations that cathodic protection helps in completely regaining the in-air fatigue life of the joints.