CHAPTER 1

INTRODUCTION

1.1 GENERAL

Offshore production forms a major portion of the total crude oil produced in many countries. In India, the offshore production is mainly in the Bombay High region on the west coast, while efforts are being made for production in the east coast also.

Offshore drilling and production of oil are made possible with the help of special structures called platforms. They are mainly of the following types: a) Jacket platform b) Gravity platform c) Tension leg platform d) Jack-up platform e) Semi-submersible platform f) Buoy-type platform g) Steel tripod h) Articulated tower i) Guyed tower. Figure 1.1 shows selected types of offshore platforms. All these structures are made of steel, except the gravity platform (Figure 1.1 e) which is a concrete structure with a steel deck.

Jacket type of steel platforms (Figure 1.1 f) are widely used for offshore production and processing of oil. The jacket or "template" platform is a truss-work tower consisting of tubular members with a deck on the top and piles driven into the sea bed. The jacket is fabricated on shore, towed and erected at site. After upending, the jacket is fixed by driving steel tubular piles into the sea bed through the legs of the jacket. Hence these platforms are also referred to as fixed platforms. Then the deck section, also fabricated on shore, is erected over the jacket and welded to it. The deck loads (self weight and weight of machinery) and the environmental loads (due to wave, current and wind) are transferred to the foundation through 4 to 16 legs. The legs are
a) Semi-submersible platform  b) Tension leg platform  
c) Buoy-type platform  d) Jack-up  e) Gravity platform  
f) Jacket  g) Steel tripod  h) Articulated tower  
i) Guyed tower

Fig. 1.1  Selected offshore platforms
stiffened by the bracings, which also transmit the resultant horizontal forces due to environmental loads. Smaller jackets are transported to the field location on a barge and lifted into position by a crane. Heavier jackets are towed in a self-floating condition and positioned by a weight-buoyancy system. There are presently about 6,000 fixed offshore platforms standing in the world's outer continental site [Rawat 1992].

With the confidence gained in the fabrication and installation of a large number of fixed platforms, the technology is being extended to deeper waters in recent times. There are presently five jacket platforms standing in water depths greater than 300 m. Two of them are in the Gulf of Mexico, both designed by Shell Oil. Cognac was the first one to be completed and stands in a 313 m depth of water. The other platform, Bull Winkle is a record holder for its height standing in 412 m of water depth. Another pair of platforms are located off California coast, the Exxon's Harmony and Heritage, installed in 1989 in 366 m and 328 m respectively. The fifth giant is at the centre of BP Explorations Mississippi Canyon Block 109 project in the Gulf of Mexico at 314 m water depth. While Cognac, weighing 33,500 T was built in three pieces, all others have been built in one piece [Offshore Engineer 1990].

In India, offshore oil exploration and production started in the early 70's. A major oil field was discovered in the Bombay High region in 1974. The first offshore oil production system was commissioned in May 1976 and commercial production of crude started in the same year. There are presently about 120 offshore platforms in the Bombay High in water depths of up to 80 m located at a distance of about 170 km NNW of Bombay. All the platforms are of steel jacket type of 4, 6, or 8 main legs. Figure 1.2 shows a typical (schematic) 4-legged jacket platform used in Bombay High.

Tubular members are commonly used for steel offshore structures because their closed sections provide buoyancy and high torsional rigidity, minimum surface area for painting and corrosion attack, simplicity of shape
Fig. 1.2 Typical Bombay High platform
and pleasing appearance. In submerged parts of the structure, circular tubes are preferred because they result in smaller hydrodynamic forces than members with square cross sections even though fabrication is easier for the latter type. Above the splash-zone, hollow rectangular sections or other sectional shapes may be used.

The intersections of the various tubular members of the structure (called tubular joints) are welded connections with the main members or legs of the structure (called chord members) running straight and other members (called brace members) cut to profiles to match the chord members. The joints represent structural discontinuities which give rise to very high stress concentrations in the intersection area. Maximum stresses occur at the joints either in the chord or in the brace depending on the type of joint, its geometry and loading. Referring to type of joints, they can be simple plane (uni-planar) joints or multi-plane joints (Figure 1.3). Uni-planar joints are classified as T, Y, K, DT or X joints depending on how the members intersect. The geometry of a joint is defined by a few non-dimensional parameters like the ratios of brace and chord diameters, brace and chord thicknesses and, chord radius and chord thickness, and the angle between brace and chord members. The loading on a joint can be an axial force on the brace member(s), or bending moment acting on the brace member either in the plane of the joint or out of plane (Figure 1.4). The maximum stresses that occur at the joints are characterised by stress concentration factors. Stress concentration factor (SCF) is defined as the ratio of the maximum stress at the joint to the nominal stress in the brace away from the joint. The locations, or points at which the maximum stresses occur, are called hot spots. Generally, in welded tubular joints, two different hot spots are found, one at the weld toe on the brace side, and the other at the weld toe on the chord side. The maximum stress value may be on the chord or brace depending on the geometry and loading.
a) SIMPLE PLANE JOINTS

b) MULTIPLANE JOINTS

Source: Torgeir Moan (1985)

Fig. 1.3 Types of tubular joints

Fig. 1.4 Basic tubular joint load cases
Considering the large investment in offshore structures and the hostile environment in which they are located, additional precautions have to be taken in the design, construction and maintenance of these structures compared to normal structures on shore. The environmental loads acting on offshore structures, particularly the wave loads, are repetitive in nature causing cyclic variation of stresses and fatigue in the structural members and joints. Fatigue is a complex failure mechanism which is characterized by gradual reduction in the capacity of structural members to withstand cyclic loading. In general, offshore platforms have a life span of 20 years during which they are subjected to about 100 million cycles of wave loading. Therefore, ensuring safety against premature failure due to fatigue is one of the stringent requirements for offshore structures. In addition to cyclic loading, the marine environment in which these structures are located causes corrosion of the structures. In fact, there is a combined action of corrosion and fatigue due to seawater environment which is called corrosion fatigue. Offshore structures have to be designed for corrosion fatigue conditions. Inadequate design or detailing may lead to premature failure. There are several case histories of failures of platforms, details of which are presented in the Section 1.2.

1.2 FATIGUE FAILURES OF OFFSHORE PLATFORMS

At this stage, it may be of interest to look at some case histories of platform failure that resulted due to inadequacies in the design for fatigue and under estimation of the fatigue hazard [Torgeir Moan 1985].

An early example of fatigue damage is that of "Sedco 135", a triangular semi-submersible drilling rig which began functioning in the Gulf of Mexico in 1965. By the end of 1967, fatigue failures were experienced in an aft horizontal brace in similar type of rigs that were operating in the North Sea, the South China Sea, the Canadian Pacific Ocean and offshore Australia. High stress concentration, and presence of abnormal weld defects seem to
have contributed to the failure. The failure occurred at a time when fatigue design checks were not routine, and the severity of the fatigue loading was not fully recognised [Marshall 1974].

In May 1979, the jack-up drilling rig "Ranger I" collapsed in the Gulf of Mexico. The collapse occurred because a fatigue crack initiated and propagated in the aft leg/stiffener weld and stiffener/mat fillet weld. The cracks were coincident with the leg/mat bulkhead and structural bulkheads suggesting considerable rigidity in this region resulting in stress concentration. The approximately 500 mm long fatigue crack that developed in the course of the life-time of the structure led to the collapse of the leg, with the subsequent falling down of the aft deck, and bending and separation of the forward legs. The fatigue crack had existed when the platform was taken to a shipyard for repairs three months before the collapse, but remained undetected. Subsequent to this collapse, non-destructive testing of critical connections of support legs at periodic intervals was included as a part of the inspection procedure [USCG 1981].

In March 1980, the accommodation platform "Alexander L.Kielland" with 212 men onboard capsized in the North Sea. The primary reason for the accident was the failure of a brace mainly due to a fatigue crack initiating from a hydrophone support, followed by a rapid, unstable fracture. The fillet welds between the hydrophone support and the brace had a poor shape. Inspections had been performed during fabrication as well as during operation without noticing the 70 mm long cracks present already at the time of fabrication. The failure of this brace was rapidly followed by the failure of other braces connected to the same column. The subsequent loss of this column led to flooding and capsizing of the platform within 20 minutes. No fatigue checks had been made for this platform [Moan 1981].
Besides the above cases, where members actually parted, there are several cases where fatigue cracks have been detected in semi-submersibles and jack-up platforms and these cracks have been repaired.

A case of partial failure of a fixed (jacket) offshore platform with four legs joined by sundry tubular bracing members, in the North Sea, has been reported. This involved the complete failure of three joints between the diagonal bracing and the main legs situated at a level approximately 0.6 m below the lowest astronomical tide level. The failures occurred through the bracing tubes and initiated at the toes of the tube-to-leg welds. Observation of the fracture surfaces revealed that the fractures were initiated at the outside circumference at the weld toe, by low stress-high cycle bending in the vertical plane. Underestimation of the vertical wave loads seemed to be a cause of the failure. Large amount of marine growth surrounding the members, which had not been accounted for, was the main underlying cause. The marine growth amounted to 200 mm at the time of failure, so that the original 300 mm diameter steel brace tubes were supporting increased marine growth of 700 mm outer diameter, surrounding the steel tube [Harrison 1973].

Fatigue cracks were reported at two levels (-6 m, -20 m) in the horizontal conductor frame of an eight-leg jacket platform in 110 m water depth. The reasons for premature appearance of these cracks were attributed to the underestimation of vertical component of the wave forces and stress concentration effects [Green 1983].

There have also been several other cases where fatigue cracks were detected. For example, 163 cracks, fairly evenly distributed over the water depth, were detected in 27 North Sea jackets in the four year period 1980-83. The actual number of cracks might be greater, as only 5-10% of the nodes are reported to have been inspected in a four to five year cycle [Sollie 1982].
Finally it has also been observed that malfunction of the corrosion protection system may lead to reduced plate thicknesses, and hence increased crack growth due to corrosion fatigue. Such malfunctions of impressed current corrosion protection systems have been experienced [Sollie 1982].

An analysis of the fatigue failures of offshore structures would reveal that fatigue crack growth especially occurs when the loading is predominantly dynamic, the local stresses are relatively high, the strength of steels used are high and when crack-type fabrication defects are likely. Crack may grow even in areas where the stresses due to the external loading are predominantly compressive, due to the presence of tensile residual stresses. The need for proper inspection both during fabrication and in-service cannot be underestimated.

During operation, the main aspect of fracture control involves reliable detection of cracks, judgement of their significance and the decision to repair. Repaired welds, particularly when made underwater or in other difficult circumstances, are unlikely to be better than those that have failed. They often fail again after a relatively short period.

1.3 TUBULAR JOINTS

The most critical parts of a steel offshore platform are the welded tubular joints and its fatigue life is governed by the fatigue lives of the tubular joints. As explained before, the welded joints of tubular structures represent structural discontinuities which give rise to very high stress concentrations in the intersection area. The reduced fatigue strength due to high stress concentrations at the weld toes of the connecting welds is a major problem in welded tubular joints. Proper design of tubular joints against fatigue failures must therefore be based upon a detailed knowledge of the magnitudes of the stress concentration factors and the corresponding values of the peak stresses at the weld toes of the connections.
In principle, the design procedure to verify that tubular joints have adequate fatigue strength is to ensure that the sum of fractional fatigue damage arising from the expected number and magnitude of dynamic peak stresses is less than one. This is familiarly known as Palmgren-Miner rule. The fractional damage refers to the ratio of the number of cycles applied at a given stress level to the number of cycles to failure at the same stress level. The latter is obtained empirically based on fatigue tests conducted on similar joints in the laboratory. Tubular joints must also be designed to sustain the ultimate static design loads (ie. 100-year storm conditions). Furthermore, the joints must have adequate weldability and toughness to prevent brittle fractures [Gibstein et al 1985]. Regular inspection of offshore platforms is necessary for making decisions affecting safety, integrity and efficient operation.

Fatigue life of tubular joints is mainly dependent on the applied stress range besides other factors. Since the maximum stresses in tubular joints will be much higher than the nominal stresses due to stress concentration effects, any effort in reducing the stress concentration factor can be expected to improve their fatigue lives and in turn that of the structure itself. Stress concentration may be reduced by strengthening the chord wall. This can be done either by thickening the chord member at the joint or by providing external or internal ring stiffeners or gussets. Figure 1.5 shows the main methods of strengthening of tubular joints. At present, thickening of chords is resorted to for reducing stress concentration in Bombay High platform structures. This involves procurement of different tubulars for the chord members, welding and fabrication problems associated with thicker plates, and the so-called thickness effect, whereby an increased tube thickness can result in a shorter fatigue life for the same stress range. Internal ring stiffeners are found to be efficient in reducing stress concentration, improving fatigue life and increasing ultimate strength [Ramachandra Murthy et al 1992a]. Internal ring stiffeners do not attract additional wave forces and they are less prone
PASS-THROUGH GUSSET PLATE

EXTERNAL RING STIFFENERS

INTERNAL RING STIFFENERS

Source: Graff W.J. (1981)

Fig. 1.5 Strengthening of tubular joints
to corrosion attack. Hence, internally ring stiffened tubular joints are preferred in offshore construction, wherever feasible.

1.4 ENVIRONMENTAL EFFECTS ON OFFSHORE STRUCTURES

In addition to the cyclic forces due to sea wave action causing fatigue stresses, the integrity and consequently the life span of offshore structures are unfavourably affected by the various processes of deterioration due to seawater environment by corrosion and fouling. The degree of deterioration depends on the climate, properties of seawater and its seasonal variations, tidal range and the behaviour of material under given climatic conditions and with respect to its relative immersion (i.e., splash zone, tidal zone, or continually immersed) in seawater.

Corrosion, in general, is due to an electrochemical process whereby atoms of a given metal loose electrons (oxidation) thus becoming positively charged. The free electrons then combine (reduction) with atoms of an adjacent area or surrounding substance. The migration of electrons (an electronic current) from an anodic area to a cathodic area may be caused and even accelerated by various conditions. Corrosion can be classified as pitting corrosion, crevice corrosion, stress corrosion, corrosion fatigue and galvanic corrosion according to the conditions or type of electrochemical process. Under corrosion fatigue conditions, pitting acts as stress raisers and contributes significantly towards fatigue crack initiation. Structural steel corrodes at an average rate of around 0.13 mm per year in quite seawater, but pit growth may be up to ten times as great [Gaythwaite 1981]. Under marine environment, the fatigue life is found to reduce significantly by a factor of 2 to 3 [Vosikovsky et al 1986].

Corrosion of structures is usually controlled by giving a protective coating to the metal surface or by cathodic protection. In an offshore structure, maximum corrosion occurs in the splash zone which constitutes an
area from the high water level to the upper levels attained by spray. This zone is subjected to intermittent wetting and drying as waves run up or break on the structure. Also, the protective film of corrosion is continuously washed away in this zone. The rate of corrosion is the greatest in this region, perhaps 3 to 5 times as great as that for normal exposure to the marine atmosphere (Figure 1.6). Just below the high tide mark, corrosion often decreases to a near minimum, as this zone is somewhat protected by oxygen concentration cell effect. The rate again increases in the continuously immersed portion, especially in the upper layers where there is plenty of dissolved oxygen or where there are strong currents to accelerate the galvanic effect. Below the mudline, corrosion becomes minimal, as there is little or no oxygen present and protective films remain intact. Above the splash zone, the structure is subjected to atmospheric rate of corrosion which, nevertheless, is still more than that experienced by land structures due to the presence of salt in the marine atmosphere [Gaythwaite 1981]. Therefore sufficient precautionary measures have to be taken in the design stage as well as during maintenance of offshore structures to ensure the integrity of the structure against corrosion.

At present, different regions of an offshore platform are protected by different methods considering the severity of corrosion and practical limitations. The regions above the splash zone are usually painted by a protective coating. In the splash zone (including tidal zone), a combination of extra steel (usually 12 mm) and painting is used. In regions below the tidal zone, suitable cathodic protection system is provided. Cathodic protection can be provided by either sacrificial anode system or impressed current system or by a combination of both. The commonly used sacrificial anodes are anodes of zinc or aluminium alloys. The number of sacrificial anodes used on a typical large platform in 100 m water depth may exceed 800, each weighing (in air) upto 500 kg. The weight of sacrificial anodes is usually about 10% of the weight of the jacket itself.
Typical corrosion rate of steel (mils per year)

1 mpy = 0.0254 mm/year

Source: Gaythwaite J. (1981)
Fouling is another environmental effect to be considered while designing offshore structures. Fouling is the accumulation of various plant growths and animal organisms on immersed and partially immersed surfaces. Depending upon the type and severity of fouling at a site, its effects should be considered in the design. Some of the effects that fouling has on offshore structures are: increased drag, inertial and gravity loads due to increased surface roughness, projected area and mass; possible increase in corrosion rates due to destruction of protective coatings and oxygen concentration cell effects at the point of attachment of certain organisms such as barnacles; difficulty for inspection and maintenance caused by the presence of prolific and tenacious plant or animal growths.

The prevention of fouling is a difficult problem. Anti-fouling paints and inhibitors must be re-applied frequently and thus are not of much use on fixed offshore structures. Electric currents and resistive claddings have been used with limited success. Offshore platforms are usually cleaned by divers though it is a costly exercise.

Marine organisms can reduce the anode efficiency. The organisms most likely to reduce anode operational efficiency, were found to be the barnacle. This is because it has a calcareous base plate which can act as an insulator between seawater and the anode surface. Zinc anodes have been found to be less affected by biofouling than aluminium anodes. Biofouled anodes should be cleaned at proper intervals to ensure that full current output capacity is achieved [Swain et al 1987].

1.5 CORROSION FATIGUE

As per ASTM E 742 (1981), "Corrosion fatigue" is defined as the synergistic effect of fatigue and aggressive environment acting simultaneously, which leads to a degradation in fatigue behaviour. In relatively mild environments or in short time corrosion fatigue, fatigue cracks initiate at
corrosion pits. On the other hand, in severe corrosive environments such as seawater or in long-time corrosion fatigue, general attacks and surface roughening proceed at a remarkably fast pace and fatigue cracks form on surfaces roughened by severe corrosion. Corrosion fatigue strength of carbon steels in seawater has been shown to be almost independent of tensile strength, while fatigue strength in air increases with the increase in tensile strength [Kawahara et al. 1988].

The effects of marine environment and cathodic protection (CP) on S-N (Stress range - Number of cycles) and crack growth diagrams are schematically shown in Figure 1.7. The S-N curves show that free corrosion in marine environment reduces markedly the fatigue life of plain specimens, whereas the reduction is less for welded joints. The fatigue limit is eliminated or at least drastically reduced by corrosion. The main mechanisms acting on structural steels in seawater and the typical conditions favouring each mechanism are briefly reviewed below [Einar Bardal 1985].

a) Corrosion pits and grooves act as stress raisers and thus contribute to crack initiation at an earlier stage and at a lower nominal stress than initiation in air (Figure 1.7 a). For ordinary welded joints this mechanism is probably less important because weld defects may be more effective stress raisers than corrosion defects. In the case of improved welds, however, corrosion defects on the surface are more significant.

b) Corrosion fatigue is governed by a synergistic mechanism. Local plastic flow and the creation of new active surfaces at the initiation site or at the crack front accelerate anodic dissolution, and vice versa, local anodic dissolution promotes plastic flow. This mechanism is responsible for easier and accelerated initiation as compared to fatigue in air, with a marked effect on the S-N curves for plain specimens (Figure 1.7 a). It also favours the conditions of crack
Fig. 1.7 Effects of seawater corrosion and cathodic protection on a) S-N curves and b) crack growth rate curves

Source: Einer Berdal (1986)
growth. The reduction in the threshold value of stress intensity factor range, $\Delta K_{th}$ in corrosive environment (Figure 1.7 b) may be explained by this mechanism.

c) Particularly during stress-free periods, corrosion may blunt the crack front and retard crack growth for some time after the stress-free period, and thus counteract mechanism explained in para b above. Under variable load amplitudes, the resulting effect of mechanisms b and c are difficult to assess.

d) Seawater corrosion at or near the crack front may make the crack environment acidic. This allows hydrogen development to take place inside the crack, and the development is further stimulated by the enhanced anodic dissolution mentioned in para b. At medium to high load levels the crack growth may be aggravated by hydrogen embrittlement (Figure 1.7 b).

e) Full cathodic protection eliminates the mechanisms discussed in paragraphs a, b and c. In deep cracks, however, the effects discussed in paras b and c and the cathodic polarization to prevent them, may not be 100% effective.

f) At medium to high load levels, hydrogen embrittlement due to cathodic protection may increase crack growth (Figure 1.7 b).

g) Under cathodic protection, calcareous deposits may be produced on the crack surfaces and thus lead to closure of cracks. Consequently lower crack growth rates and a higher threshold value of $\Delta K$ will result (Figure 1.7 b).

h) Mass and charge transport within the crack affect both corrosion and cathodic protection at the crack front. Supply of reactants to and
removal of products from the crack tip region are restricted, and there will be a potential drop between the crack front and the free surface.

There are several factors that have a bearing on corrosion fatigue. When test data are adopted for practical purposes such as design, evaluation of damage tolerances etc., it is essential that these factors and their effects are known. Load frequency, type of environment, stress level and electrochemical potential are among the most important factors. The effect of environment also depends on temperature, stress ratio, material strength and weld quality. High pressure and low rates of water flow may also have some significance. These details are further discussed in Chapter 2.

The above mentioned mechanisms acting on structural steels in seawater and the various factors affecting corrosion fatigue behaviour bring out clearly the complexities involved in the corrosion fatigue process. Due to the absence of a fully developed theory encompassing all the above complexities, experimental data from corrosion fatigue tests are relied upon in the fatigue life estimation of offshore structures under freely corroding conditions. However, adequate care should be taken in interpreting the experimental results; the results obtained from one set of specimens (for example unwelded or plain plate specimens) cannot be applied directly to another set of specimens (for welded/notched specimens or tubular joints). Most of the available results are only for plate specimens and very little experimental data are available for tubular joints.

1.6 FATIGUE LIFE PREDICTION OF TUBULAR JOINTS

It is necessary to estimate the fatigue life of offshore structures at the design stage as well as during service when fatigue cracks develop at the joints. There are basically two approaches for fatigue life estimation, namely, the S-N curve approach and the fracture mechanics (FM) approach [Singh
et al 1988]. While S-N curve approach gives only total (or final) fatigue life of tubular joints based on experimental data, FM approach can give remaining fatigue life of joints having sizeable fatigue cracks. This aspect is essential in monitoring the integrity of offshore structures which is a major concern for ensuring economical and safe operation.

For fatigue life estimation based on S-N curve approach, many codal agencies, like the American Petroleum Institute (API), Det Norske Veritas (DnV) and the UK Department of Energy (DEn), have recommended S-N curves which can be used to obtain fatigue damage for a particular hot spot stress from which the cumulative damage and fatigue life can be calculated using Palmgren- Miner rule. A penalty factor of 2 is usually applied to the calculated fatigue life in air to account for corrosive seawater environment.

One of the main impediments in the development of a fracture mechanics model for tubular joints has been the determination of stress intensity factors (SIF) for the defects in tubular joints. Due to the complexities of geometry and loading, difficulties are experienced in determining analytically the SIF which requires stress distribution both around the intersection and through the thickness as the crack advances [Seetharaman 1991]. The crack growth both across the tube thickness and along the weld toe makes analytical modelling more difficult. Therefore attempts have been made to develop empirical models based on crack growth data obtained from fatigue tests on tubular joints.

While fatigue life prediction of tubular joints based on S-N approach is fairly well established with respect to air fatigue, very few experimental data is available for corrosion fatigue conditions. The penalty factor of 2 or a reduction of 50% in fatigue life for freely corroding condition has been arrived based on experimental results mainly on plate specimens and a few tubular joints. No results are available for corrosion fatigue life of internally ring stiffened steel tubular joints. Also, the available recommendations of other
countries have to be verified with respect to Indian conditions of seawater characteristics and fabrication before they are adopted for offshore structures in India. Further, no model is available for prediction of remaining fatigue life of internally ring stiffened tubular joints based on FM approach.

1.7 SUMMARY

Offshore structures are subjected to fatigue loads due to repetitive action of wave forces. As a result, welded tubular joints are susceptible to fatigue failure, aided and abetted by stress concentration and seawater environment. Corrosion fatigue is a complex phenomenon and very few experimental results are available for reviewing the behaviour of tubular joints under corrosion fatigue. The recommendations available are mainly applicable to other countries and hence they have to be verified with respect to seawater characteristics and fabrication techniques in India before they are accepted for design of offshore structures in the subcontinent. Internally ring stiffened tubular joints are found to be structurally efficient in reducing stress concentration and improving static ultimate and fatigue strengths. However, to the best of the knowledge of the author, no data is available on corrosion fatigue behaviour of these joints. For prediction of remaining fatigue life of tubular joints based on FM approach, a realistic model is not available for stiffened tubular joints. Therefore, there is a need for conducting detailed investigations on these vital aspects.

1.8 SCOPE AND OBJECTIVES OF THE INVESTIGATION

1.8.1 Scope

Corrosion fatigue behaviour of steel tubular joints used in offshore structures, particularly jacket platforms widely used for oil exploration and production in many countries including India, is the main subject of this investigation. In this, welded steel tubular T and Y joints have been studied under corrosion fatigue in sea water environment applicable to Indian offshore
conditions. Internally ring stiffened joints have been considered since they are structurally efficient. It is worthwhile to mention that no study has been made on these joints relating to their corrosion fatigue behaviour and fatigue life prediction and hence the available literature on this aspect is inadequate.

1.8.2 Objectives

The objectives of the studies are:

1. To conduct experimental investigations on corrosion fatigue behaviour of internally ring stiffened and unstiffened welded steel tubular T and Y joints under constant amplitude axial brace loading and free corrosion conditions.

2. To suggest a model for estimating corrosion fatigue life of these joints based on S-N approach suitable for Indian conditions.

3. To develop a fracture mechanics model for predicting remaining fatigue life of internally ring stiffened steel tubular joints having sizeable fatigue cracks.