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# The Effect of Stress Distribution on Fatigue Behavior of Stiffened Tubular T-Joints: Experimental Investigation

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## ABSTRACT

**Welded tubular joints for offshore structures are often subjected to a combination of axial and bending loads. Fabrication errors may introduce additional bending due to chord-brace misalignments. The combined effect of these loads and fabrication errors may produce chord brace weld toe stress distributions that are more severe under fatigue loading than the constituent single mode loading cases. Most of the earlier fatigue tests, conducted on tubular T-Joints with and without stiffeners, were subjected to either purely axial or bending loads, leading to different stress distributions along the weld toe in the chord section. From these studies it has been found that the initiation and coalescent fatigue lives were approximately the same. Breakthrough lives were quite different for these loading conditions of stiffened and unstiffened joints. It has been observed that there is a beneficial effect due to stiffener in increasing the load-carrying capacity by 3 times when compared to unstiffened joints. Combined loading can, in certain instances, produce a weld toe stress distribution that is relatively constant over more than 50% of the weld length, creating numerous potential sites for crack initiation. In this paper, the effect of combined (axial and bending) loading on a ring-stiffened tubular joint (which produces a more constant stress distribution) has been studied by conducting fatigue test.**


## INTRODUCTION

One of the most important aspects of the offshore structure is the integrity of the welds and the ability of the structure to endure the fatigue loading of the ocean waves during the life of the structure. It is for this reason that the prediction of fatigue performance of welded tubular joints used in the construction of offshore structures has received such attention during the last decade (Steel in Marine Structures, 1981,1987; Salama et al., 1989). Fatigue design of unstiffened tubular joints, in general, is based on the hot-spot-stress concept and a unified S-N design curve that is assumed to be valid for a wide range of joint geometries (U.K. Department of Energy, 1984; API 1982; Norwegian Petroleum Directorate, 1984). Although this method has been used quite successfully for the design of simpler tubular connections, problems may arise when attempting to extend its use beyond the original database of test results. In offshore structures, complex joints are common and internal stiffeners are widely used in large diameter tubulars. For stiffened tubular joints, the situation is more complicated and there appears to be no unified approach to design. The effects of internal ring stiffeners on the fatigue behaviour of large tubular joints have to date been investigated only within Phase II of the U.K. Offshore Steel Research Project (Reynolds, 1987; U.S. Department of Energy, 1987; and the Canadian programme — Thomson and Tyson, 1987; Pates et al., 1989). In the U.K. study, 6 tubular T-joints, each with 2 ring stiffeners (3 with simple stiffening rings, 3 with heavy flanged rings), were tested in air under axial loading; in the Canadian programme, 11 tubular T-joints (9 with ring stiffeners) were tested in axial, in-plane and out-of-plane bending modes in air and seawater with optimum cathodic protection.

A critical review of the data from the Canadian programme suggests that for the same maximum hot-spot-stress range, there is little difference in the initiation life. The number of crack initiation sites and the length of weld toe over which the cracks initiated and coalesced into a single crack seem to depend mainly on the stress distribution along the weld toe. In the axial loading case, the maximum stress at the crown is approximately 70% of the maximum stress at the saddle point. If the axis of the brace is slightly inclined (approximately 5°) or if the axis of the brace has an offset (approximately 1 to 2 in) with respect to the line action of the axial load, the radial stresses at the crown region will approach the maximum stress at the saddle point. The stress distribution in the crown region will also be constant over a certain length as in the case of in-plane loading. Then the cracks may initiate at both saddle and crown regions spanning the entire length of the weld toe from saddle to saddle. The cracks may grow all along the weld toe and the stiffeners may not impede surface crack growth. This may lead to catastrophic failure of the joint.

In general, offshore structural steel joints are subjected to a combination of axial and bending loads, and fabrication errors may introduce an inclination of the brace members. The combined effect of environmental loads and fabrication errors on the nodes may give rise to a constant stress distribution along the weld toe. This paper examines the effect on the integrity of welded tubular joints of the combined loads, which produce long straight fronted cracks.

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