SHOT PEENING FOR TUBULAR WELDED JOINTS OF OFFSHORE STRUCTURES

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ABSTRACT

"Welded steel tubular structures used for offshore plateforms are normally exposed to fatigue due to stress concentration at welded joints and environmental loading. Due to repetitive action of wave forces, fatigue cracks can develop at the welded joints of tubular steel jacket plateforms. This paper presents the possible failure of welded tubular joints and suggests the way of strengthening by shot peening".

1. INTRODUCTION

The stresses in tubular joints are combinations of simple stresses. There are various aspects of failure of tubular joints such as reaching the elastic limit of the material, the material yield strength, detection of first cracking in a tension joint, shear failure of the overall cross section of the chord etc. It is important in the design of a tubular joint that the joint should possess enough deformation capacity to permit the stresses to get redistributed within the joint itself and generally throughout the structure.

In the offshore plateforms the loading by ocean waves has often come into consideration. Here are two important differences from the usual fatigue situation. First, the rate of loading are slow, since ocean waves pass the offshore structures at the rate of about 10 cycles per minute. Second, offshore structures are immersed in corrosive medium. Fatigue cracks grow because of tensile stresses. Corrosion of a metal is accelerated if the metal is subjected to tensile stresses. Thus, the problem of corrosion and fatigue are combined in the case of an offshore plateform.

1.1 Parameters of a Tubular Joint :

The general arrangement of members of an offshore structure are as shown in fig.1. The joints are normally made by round tubes (CHS) and designated as T, Y, K, N etc. depending on the positions of the braces. Fig. 2 shows some of the possible tubular joints.

1.2 Geometrical Joints

β,ratio = brace diameter / chord diameter

γ, ratio = chord radius / chord wall thickness

τ, ratio = wall thickness of brace / wall thickness of chord

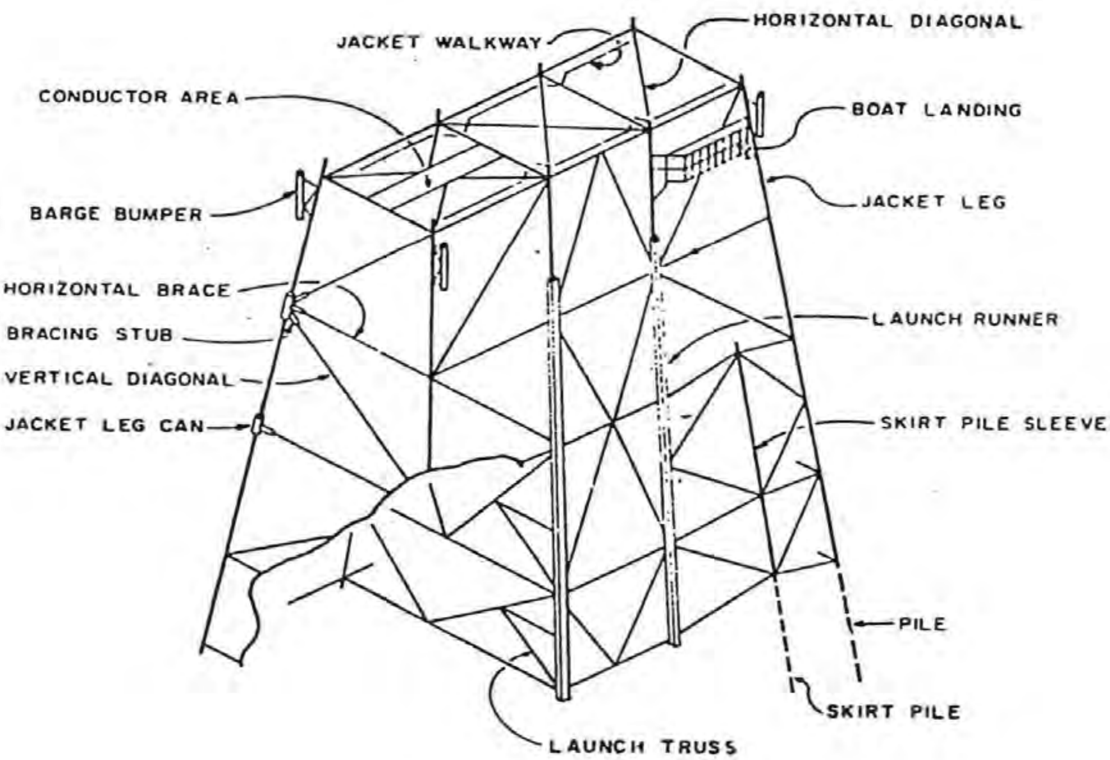

Fig. 1. Major Components of an offshore plateform

For tubular joints, with β < 0.3 failure occurs by punching shear and when β > 0.8, chord fails by collapse.

When β is in between o.3 and 0.8 the failure is due to interaction of punching shear and general chord collapse. Many investegators propose tubular joints in the γ (range) of 7 to 15 and a β (range) of 0.4 to 0.7 connections with larger τ (ratios). For τ > 0.5, the stresses in the brace being critical are compared to the stresses in the chord.

As a thumb rule, if ratio of τ over β does not exceed unity is considered to be a well proportioned design.When the load in the brace is in tension, compression or bending circumferentially about the chord axis the hot spot stress is at point 2 or 5 as shown in fig. 3. For bending of the brace in the plane of the axis of the chord and brace, the hot spot lies at one of the points 1,3,4 or 6.

1.3 Stress Concentration and Fatigue

Stress concentration referes to the condition in which high localised stresses are produced as a result of the geometry of the structural element. Fatigue failures occur at nominal stress levels lower than the yield stress of a material in areas of high local stress and the fatigue cracks propagate perpendicular to the direction of maximum applied tensile stress into areas of low local stress and the very location is called the hot spot. Three basic stresses contribute to the development of hot spots :

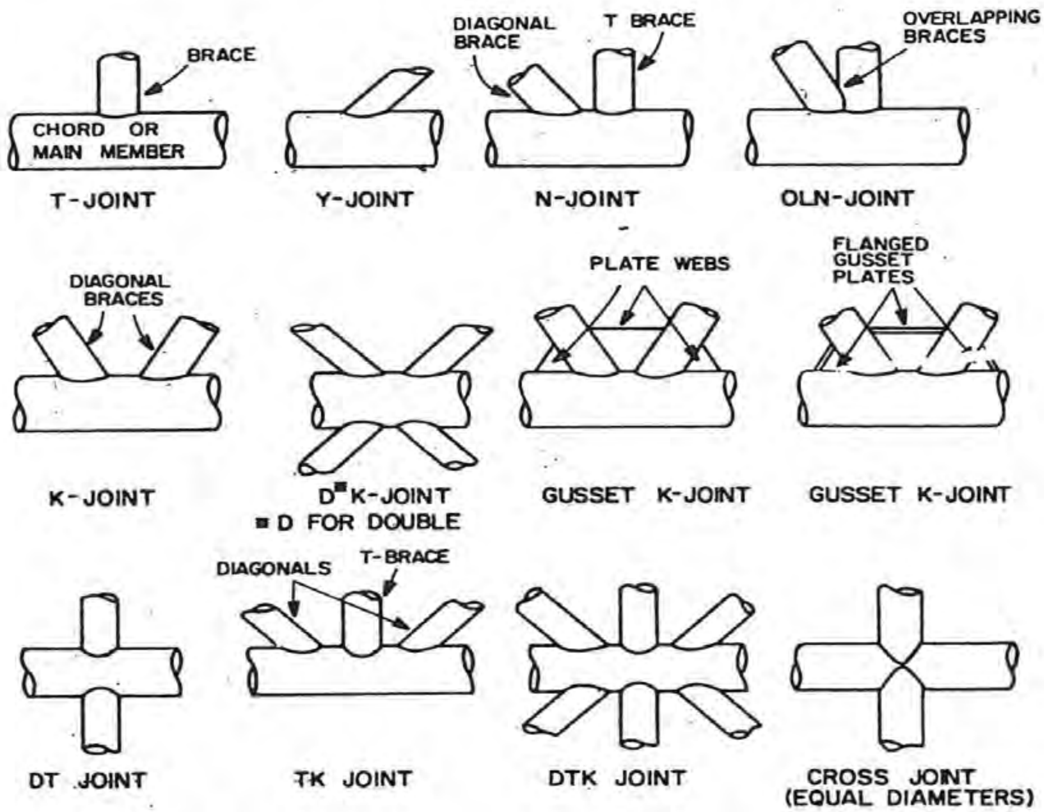

Fig. 2. Typical possible tubular connections

i. Primary (type A) stresses are caused by axial forces and moments resulting from the combined truss and frame action of the jacket. In Fig.3 stress at hot spot locations 1,3,4 and 6 are most affected by axial forces and in-plane bending moments in the braces. The regions around hot spots 2 and 5 are most affected by axial forces and circumferential moments in the braces.

ii. Secondary (type B) stresses are caused by the structural details of the connection such as poor joint geometry, poor fit - up, restraint of braces caused by circumferential welds etc.

iii. Secondary (type C) stresses are caused by metallurgical factors that results from faulty welding such as insufficient weld penetration, under cutting, weld porosity, varying cooling rates etc.

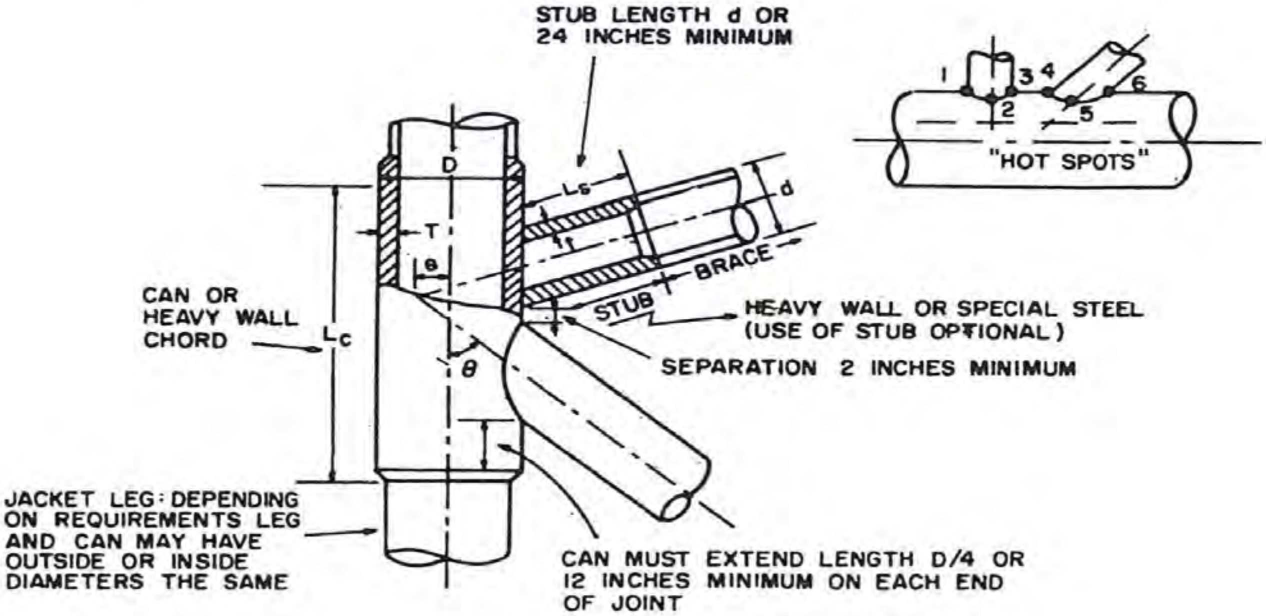

Fig. 3. Details of an inplane tubublar joint

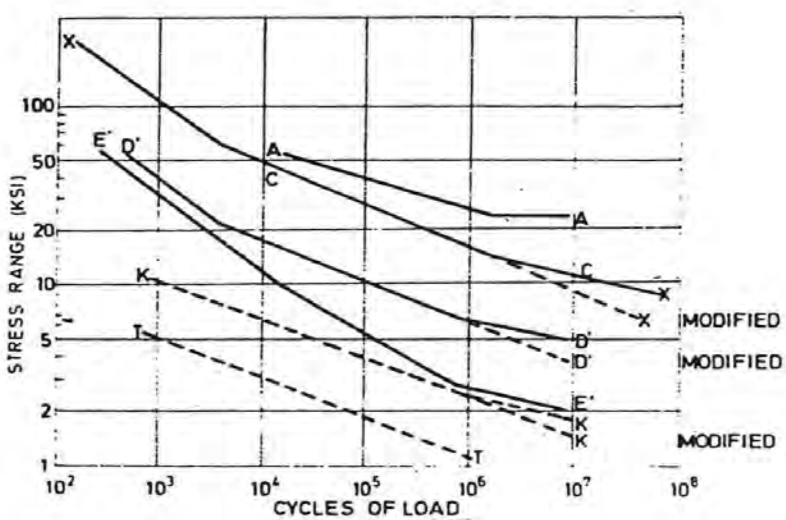

Fig. 4. AWS, S-N curves

1.4 AWS Fatigue Curves

S-N Curves for tubular connections were first published in 1972 by the American Welding Society (AWS) and are presented here in Fig. 4 and Table 1.

Table 1. AWS Fatigue categories

Stress category	Situation	Kinds of stress
A	Plain unwelded tube	Tension,comp,bending, reversal
B	Butt splices, no change in section, full penetration groove welds,ground flush and inspeced by X-ray or ultrasonics	Tension,Comp,Bending,reversal
C	Butt splices,full penetration groove welds as welded	Tension,Comp,Bending,reversal
D'	Simple T,Y and K connections with full penetration tubular groove	Tension,Comp,Bending,reversal in branch member
E'	Simple T,Y and K type with partial penetration groove welds, complex tubular connections etc.	Tension,Comp,Bending,reversal in branch member
X	Main member at simple T,Y and K connection	Hot spot stress or strain on the outside surface of the main member at the toe of the weld joining branch member - measured in model of prototype connection
X	Unreinforced cone-cylinder intersection	Hot-spot stress at angle change
X	Connections whose adequacy is determined by testing an accurately scaled model	Worst measured hot spot strain, after shake down.
K	Simple K type tubular connections in which gamma ratio R/T of main member does not exceed 24.	Punching shear on shear area of main member
T	Simple T and Y tubular connections in which gamma ratio R/T of main member does not exceed 24.	Punching shear on shear area of main member

The fatigue life of a welded connection depends on many factors ie. number and occurence of waves causing local yielding, metallurgical behaviour of the steel, surface appearance of weld, geometrical shape of the weld etc. Over the span of its design life the offshore structure is subject to a spectrum of cyclic waves which produce cumulative damage and it may be estimated by Palmgran-Miner cumulative damage rule.

$$D = \sum_{i=1}^{k} \frac{ni}{Ni} \leq 1$$

where, ni = number of cycles within stress range interval i of the long-term stress range distribution.

Ni = number of cycles to failure at the same stress range, derived from the S-N curve.

K = Total number of stress range intervals

D = Cumulative damage ratio

2. DISCUSSION

It may be advantageous to induce compressive residual stress in critical areas located as hot spots in Fig. 3. of the weldments where cyclic applied tensile stresses are expected. Further welding sequence that controls residual stresses from welding also needs due consideration. The localised shot peening treatment will place these surfaces in compression. The controlled shotpeening is the fact that a harder, embrittled heat affected zone will also be visually obvious after peening. There will be shallower dimpling in the harder areas. These areas need properly controlled shot peening. This will offer the most effective post weld stress relief method to solve the problem of fatigue in steel sea shore structures. Shot peening as reported by many investigators may reduce stress corrosion and corrosion fatigue under sea water.

3. REFERENCES

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