Analysis of tubular joint of offshore structure

Sanket Santosh Sawant\textsuperscript{1} Dr. Muthumani K.\textsuperscript{1,2},

\textsuperscript{1}School of Civil Engineering, Vellore Institute of Technology, Chennai, India.

\textsuperscript{2} E-mail: muthumani.k@vit.ac.in

Abstract— The Jacket of an offshore structure is made up of tubular members. These tubular members are made up of steel and designed to resist yield and buckling loads. The tubular sections form various types of joints like K joint, KT joint, Y joint, etc. These joints are subjected to various types of cyclic loading conditions, due to which fatigue failure starts and increases as the time passes. As a result, the most critical section of the jacket fails first epically joint. The excessive strains due to axial forces, in-plane, and out plane bending moment accelerate the failure mechanism. In this paper, the comparative study is made between K joint and KT joint for the same loading conditions is made by selecting a finite method approach. By referring to API RP 2A and DNV RP C203. The observations are made on the behavior of joints for the same loading conditions, to the made conclusion of this project.

Keywords: K Joint, KT joint, Axial force, in plane bending moment, out plane Bending moment, API RP 2A, DNV RP C203

1. Introduction

In designing of any Platform in the marine environment, the stability of the jacket plays an important role as this is a structure that is installed to sustain the deck along with other necessary loads. Thus, these jackets should be designed for extreme load conditions. These jackets are constructed by using tubular sections, usually made up of anti corrosive material \cite{1}. These sections are connected by using proper joints to form a whole structure. The main member of the joint is known as a chord, and secondary members are known as brace. The joints are classified according to the position of braces and chords. These joints are indicated by alphabets due to resemblance to the particular alphabet. The T joint, K joint, Y joint, KT joint, DT joint, X joint, DKDT joint, DYDT joint, DY joint, etc. \cite{1}.

These joints are subjected to various types of loading conditions like wave load, marine growth loading, etc. According to a superposition of stresses in tubular joints, the loading is classified in axial force, in-plane bending moment, and out plane bending moment. These loading conditions can cause the failure of a joint in a short time. Thus, the joint is designed to resist these loads \cite{2}. In this project, the comparison of K joint and KT joint is carried out for the same loading conditions to obtain the conclusion of selecting the joint for joint fabrication. So, the lifespan of the jacket can increase. This analysis is done by using international standards like API-RP-2A and DNV-RP- C203.

2. Scope

The scope of this project is to compare different joints under marine conditions; this will give a better view of the fatigue strength of joints. Thus, results that are obtained will help to identify to choose the type of joint which can provide better strength against sea loading, which can consider while...
constructing the jacket. It also helps in the designing phase of the structure, giving opportunities to make a structure more economical and durable, which is beneficial for an organization.

3. Objective
The primary objective is to analyze the tubular KT joint under the axial force and in-plane and out-plane bending moment and comparing the results with similar loading conditions for K joint. Thus, to identify the best joint for the jacket under sea wave conditions.

4. Methodology
The analysis of the CHS K and KT joint is done by taking a finite element approach. The whole process is explained in (fig.5). The methodology is carried out as follows.

4.1. Modeling of joint
Modeling of K and KT joint is done in “ANSYS R19.3”. The model was created in the “space-claim” module [3]. The dimensions and size of the joint are given in Table 1 below. The selection of these sizes depends on pile size, which is going to be installed with a jacket. As per design standards, the c/c distance between two braces is kept as 75mm. [1]

| K/KT JOINT   | Diameter | Thickness | Length   |
|--------------|----------|-----------|----------|
| Chord        | 1876     | 50        | K = 2915 |
| Diagonal brace | 762     | 20        | KT=4600  |
| Horizontal brace | 610     | 20        |          |

4.2. Assigning material properties
The determination of material is done by using DNV-RP-C208, section 4. The material which is used in the joint is S355. The material properties are given in Table 2. [4]

| Engineering Properties | Specifications   |
|------------------------|------------------|
| Material Used          | S355             |
| Density                | 7850 kg/m³       |
| Young’s Modulus        | 2*105 MPa        |
| Poisson’s Ratio        | 0.3              |
| Bulk Modulus           | 1.67*10¹¹ Pa     |
| Shear Modulus          | 7.69*10¹⁰ Pa     |
Figure 1. Typical View KT joint.

Figure 2. Typical View of K joint.
4.3. **Welding**

The weld of suitable size is provided at the intersection at the chord and brace. This is complicated because the weld profile is a function of the dihedral angle, which depends on the position of interaction [5]. In this paper, the arc welding is provided. Arc welding is one of the methods in which electric arc is used to create and join the metals. The current can be direct or alternating. The power supply produces an electric arc between the electrode and the base material. [6] In this project, the arc weld is used to create a weld of a thickness of 15mm.

4.4. **Meshing**

The meshing is a phenomenon in which the whole geometry is divided into smaller units to get accurate results for given loading conditions [7]. The size of meshing can be changed according to requirements. In this experiment, the meshing is done on both joints with a size of 0.15m for K joint and 0.7m for the KT joint. The physical preference of meshing is mechanical. [8]

![Figure 3. The Meshing of K Joint.](image)

4.5. **Application of Boundary condition and loading condition**

As the ends of the chord are welded in any offshore jacket structure, both ends of chords are kept fix. Total three conditions of loads are applied to these joints as per design criteria as follows: [9]

4.5.1. **Axial Load**

The axial loads are applied in the form of compression force on the surfaces of the braces. This load is distributed through-out the surface equally. This load is gradually increased to determine the variation in parameters and weld surface. [10][11]

4.5.2. **In-plane Bending Moment**

In this load case, the bending moment is applied on the free end of a brace in such a manner that the deflection will be parallel to the chord surface. [8][10]

4.5.3. **Out plane Bending Moment**

The application of out plane bending moment is the same as an in-plane bending moment. The direction of the moment is reversed to that of an in-plane bending moment, which causes the deflection of the joint perpendicular to the chord. [12]
The summarized methodology is given in the form of flow chart given below:

Modeling of K and KT joint

Assigning material Properties to model

meshing the model

Applying Boundary and loading conditions

interpreting the results

**Figure 5.** Flow chart of Methodology.
5. Results and Discussion
From the output of ANSYS, various types of results are obtained. These results are presented in graphical form to compare the K joint and KT joint and interpreting the result.

5.1 For axial compression
In this load case, the axial compressive load is applied on the brace surface and increased in steps.[13] The variation in strain with axial load. The results are shown in the following graph. It is seen that from initial loading to final loading, both braces of K joint counteract the load. But in the case of the KT joint, the diagonal brace didn’t react to initial loading conditions until the loading of 1226.65 tones is applied in the joint, after that loading every brace takes part in resisting the loading condition.

![Figure 6 Variation in strain in K joint under Axial load.](image1)

![Figure 7 Variation in strain in KT joint under Axial load.](image2)
5.2 In-Plane bending moment

The moment is applied at the end of braces in such a way that the deflection is parallel to chord.[12] The change in deflection and strain in the joints with respect to the increasing moment is as follows. The moment is applied in the range of $10^5$ Nm to $15*10^5$ Nm. It has been found that the strain value for the KT joint shows a higher growth rate than for K joint. As well as in the deflection case, the KT joint shows more deflection than K joint.

![Figure 8](image1.png)

**Figure 8** Variation in strain under Axial Load for K and KT joint.

![Figure 9](image2.png)

**Figure 9** Variation in strain in K joint under In-Plane Bending moment.
Figure. 10 Variation in strain in KT joint under In-Plane Bending moment.

Figure. 11 Variation in strain under In-Plane Bending for K and KT joint.

Figure. 12 Variation in deflection under In-Plane Bending for K and KT joint.
5.3 Out Plane bending moment

For this loading condition, the range of moment is taken the same, i.e. from $10^5$ Nm to $15*10^5$ Nm. The direction of the moment is kept opposite to that of an in-plane bending moment.[12] The variation in strain and deflection is recorded. It is seen that the values of strain found out the same as in-plane bending moment conditions, due to the same strain-stress curve. The values of deflection in out plane bending moment are slightly greater than in-plane bending moment conditions. The reason for this result is that, in case of resisting the deflection caused by an in-plane bending moment, the whole assembly of the jacket act as a frame. But to counter the deflection caused by out plane bending moment, every part of the joint acts differently. As a result, the resistance will be less, and deflection will be more.[9]

![Figure 13](image13.png)

**Figure 13** Variation in strain in K joint under Out Plane Bending moment.

![Figure 14](image14.png)

**Figure 14** Variation in strain in KT joint under Out Plane Bending moment.
6. Conclusion
The conclusion which can be made by carrying out this experiment is as follows:
1. The capacity of the KT joint is greater than K joint in terms of axial load along with in-plane and out-plane bending moment.
2. From obtained data and simulations, we can conclude that, in the case of axial compression, in the KT joint, the vertical brace plays an important role in resisting the load until one point. But if the load exceeds that point, all braces take part to counter the load, which makes KT joint vulnerable in this case, if there is a manufacturing error in a vertical brace.
3. So, K joint is suitable in terms of safety as compared to KT joint in terms of axial compression.
4. In the case of an in-plane bending moment as well as out plane bending moment, the maximum stress is seen near the welding section.

5. The KT joint resists more in-plane bending moment than K joint but shows more deflection while resisting than K joint, which makes KT joint less preferable in terms of safety.

6. In the case of out plane bending moment, both K and KT joint shows the same trend as in-plane bending moment case, but have more deflection in this case as compare to in-plane bending moment.

7. The deflection in out plane BM can be reduced by providing external support to joint in terms of the stiffener, to increase framing action.

8. In terms of efficiency, the KT joint shows more efficiency for the applied load cases as compare to K joint.

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