# Static Analysis of Tubular Testrig KT Joint

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***Abstract*:. The test rig consists of a steel framed structure designed to support the engine and actuator. Tubular steel components are gaining popularity in because greater strength-to-weight, greater design properties such as moment of inertia, section modulus and radius of gyration and high resistance to torsional loading, excellent properties of the circular hollow section as a structural element in resisting compression, tension, bending and torsion. Circular hollow section has proved to be the best shape for elements subjected to wind, water or wave loading. The circular hollow section combines these characteristics with an architecturally attractive shape. Structures made of hollow sections have a smaller surface area than comparable structures of open sections. This in combination with the absence of sharp corners, results in better corrosion protection. Typical KT joint in the test rig column is analyzed by using Finite Element Methods by ANSYS software. The design of the typical joint was done according to European Standard EN 1993-1-8;2005.***

**Keywords:** Tubular sections, KT joint, ANSYS, Chord, Braces, Stress

## 1. Introduction

A test rig is a large structure used for the testing of the engine actuators used in the launch vehicles. Few of the parameters of actuators tested in the rig are frequency response, step response and flight profile. Tubular steel sections are used in the testrig structure because of their excellent properties. Typical test rig structures are composed of three dimensional frame fabricated from steel tubes. The connections between the different tubular members are denoted tubular joints. A tubular joint is made up of a chord (element of largest diameter) and one or more braces. In the design of tubular joints one generally considers each brace in turn in association with the chord. The following non-dimensional parameters are used for the analysis and design of joint.

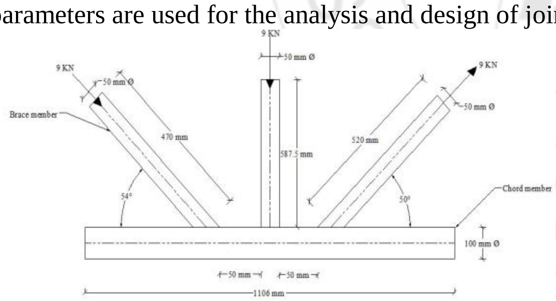


Figure **1:** Geometric parameters of tubular KT joint

Simple welded joints are those that are formed by welding two or more tubular members in a single plane without overlapping of brace members and without the use of gussets or stiffeners. As for the member geometries, a tubular joint may have different numbers of brace members meeting the chord at various angles and positions. Tubular joints come in many shapes**.** Joint classification is the process whereby the axial force in a given brace is subdivided into K, X and Y components of actions. Such subdivision normally considers all of the members in one plane at a joint. These varying configurations are commonly referred by an alphabetic letter corresponding to the shape of the joint.

## 2. Literature Review

**Libin Wang *et al.* (2013)** examined the balance fatigue design of cast steel nodes in tubular steel structures. This paper focuses on the balance fatigue design of these two parts in a cast steel node joint using fracture mechanics and FEM. This kind of joints improves the structural anti fatigue capability and is expected to be widely used in the structures with fatigue loadings. Cast steel node joint consists of two parts: casting itself and the welds between the node and the steel member. The fatigue resistances of these two parts are very different; the experiment results showed very clearly that the fatigue behavior was governed by the welds in all tested configurations.

**K.Satyanarayana *et al*. (2011)** studied about the static strength analysis of tubular T-Joints for offshore structures using finite element software Ansys. The finite element model of the T-joint, created using ANSYS pre-processor. They investigated the strength of T-tubular joints with circular cross section tube chord with circular cross section tube brace. To determine the joint strength of these T-joint subjected to tension, compression, in -plane bending and out-of-plane bending loading cases have been carried out. Finite element ANSYS results have been validated with the experiment results. In experimental study, the chord ends are usually bolted. Reasonable agreement was obtained between the plastic finite element analysis results and the experimental values for all loading cases.

## 3. Failure modes for Tubularjoints

Tubular joints have a number of different failure modes depending on the joint type, the geometric parameters of the joint and the type of loading.

a) **Chord face failure** -This is the most common failure mode for joints with a single bracing, and for K- and N-joints with a gap between the bracings if the bracing to chord diameter ratio (β) is less than 0.85.

b) **Chord side wall failure** -This is the yielding, crushing or instability (crippling or buckling) of the chord sidewall or web under the compression brace member. Also includes sidewall yielding if the bracing is in tension. Usually only occurs when the bracing to chord width ratio (β) ratio is greater than about 0.85, especially for joints with a single bracing

c) **Chord shear failure -** Is found typically in the gap of a Kjoint. The opposite vertical bracing force causes the chord to shear. It does not often become critical, but can if you use rectangular chords with the width greater than the depth.

d) **Punching shear** – Can be caused by a crack initiation in the chord face leading to rupture failure of the chord. It is not usually critical, but can occur when the chord width to thickness ratio (2 γ) is small.

e) **Brace failure -** This is non-uniform stress distribution in the brace causing a reduced effective brace width. This reduces the effective area carrying the bracing force leads to cracking in the welds or in the brace members.

f) **Local buckling -** Failure of a brace member or of a hollow section chord member due to the non-uniform stress distribution at the joint location.

## 4. Finite Element Analysis of Tubular KT Joint

The finite element model of the typical KT joint is created in ANSYS workbench. The chord and braces were modeled according to the geometric details specified. The welded joint was modeled by using mesh connection tool with weld thickness of 5mm for all the three braces. The boundary condition for chord ends is fixity and loads are applied at the brace ends. Axial loading conditions are only considered in the present research to study the stress variations in the KT joint. Compressive loading for the first outer brace and central vertical brace and tensile loading for the second outer brace.

**Table 1:** Geometric properties of the joint

| Geometric Property | Chord (mm) | Brace 1 (mm) | Brace 2 (mm) | Brace 3 (mm) |
|---|---|---|---|---|
| Outer Diameter | 100 | 50 | 50 | 50 |
| Thickness | 14.5 | 11.5 | 11.5 | 11.5 |
| Length | 1106 | 470 | 520 | 587.5 |

**Table 2:** Material properties

| | |
|---|---|
| Materials used | Mild steel |
| Modulus of elasticity | $2\times 10^5$ N/mm$^2$ |
| Poisson's ratio | 0.3 |
| Yield stress | 250 N/mm$^2$ |

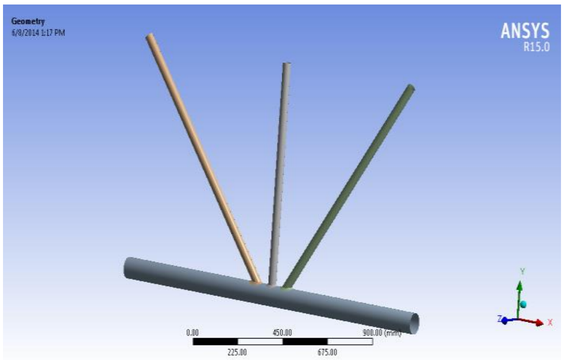


**Figure 2:** ANSYS model of the joint

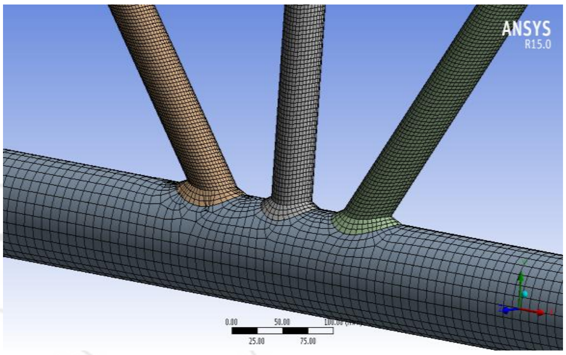


**Figure 3:** Meshed view of the joint

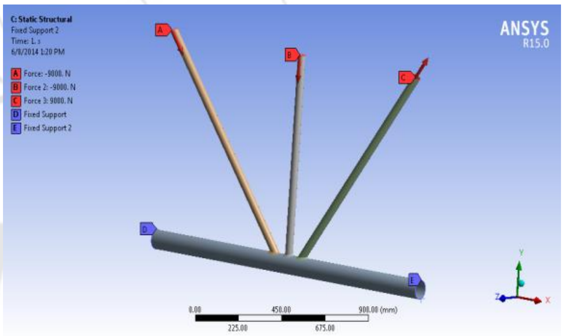


**Figure 4:** Boundary and loading conditions

## 5. Results and Discussion

The finite element analysis of the tubular KT joint was done in ANSYS Workbench15. The results of static structural analysis was obtained in terms of deflections at each node, Von Mises stress in each elements. Fig. 7.1 shows the deflected shape of the joint and Fig. 7.2 shows the Von Mises stress variations in the joint.

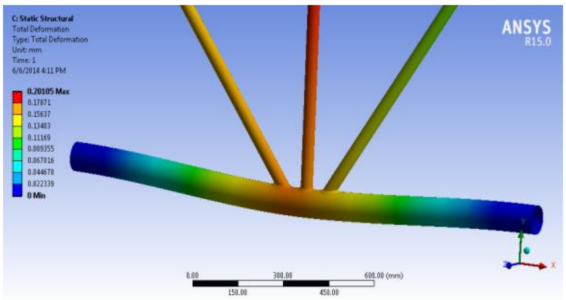


**Figure 5:** Deflected shape of the joint

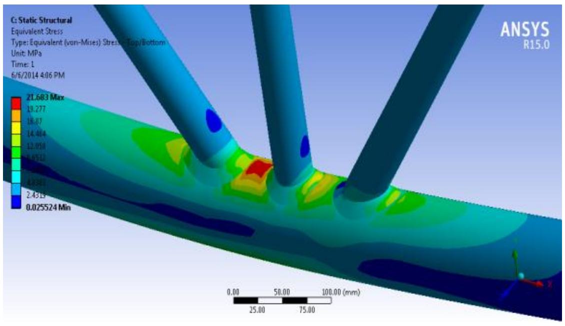

**Figure 6:** Variation of Von Mises stress

From the finite element analysis of the joint study it is clear that the maximum stress occurred near the chord brace intersection. For the typical joint for the axial load case the maximum stress value is very much less than the material yield stress. For the length of chord nearly three times the chord diameter the displacements and stresses are found to be high. As expected the displacements are greatest at the intersection of brace and chord.

## 6. Conclusions

Typical tubular joint in the rig is analyzed by hand computation based on relevant design standards to ensure that the joint had adequate joint resistance for the given loading conditions. Welded joints are provided for all the structural members with 5mm thickness based on the thickness of the connecting members as per Indian standards. Tubular joint in the rig is analyzed by finite element method to ensure that Von Mises stress criterion is satisfied. The maximum Von Mises stress in the joint was obtained as 21.683MPa and the maximum deflection of the joint as 0.20105mm. For the tubular joint Von Mises stress obtained is very much less than that of the material yield strength. Hence the joint in the test rig structure is safe enough.

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