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# Analysis of Bolt Subjected to Temperature Using Different Materials

**Neha Andrews[1], Muneera B.[2]**

*[1]M.TECH. (Structural Engineering) Student, Dept. of civil Engineering, Younus College of Engineering and Technology, Kollam, Kerala, India*
*[2] Assistant Professor, Dept. of civil Engineering, Younus College of Engineering and Technology, Kollam, Kerala, India*

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**Abstract -** *Steel structures are one of the most important part of a construction industry. Connections are structural elements which joins the members of streel frames. Bolted connections are mostly preferred among any other connections. It is because, while using bolted connections the structure can be dissembled whenever needed and it is low cost. There are certain factors that affects the serviceability of bolts that may cause failure of the entire structure. Bolted connections under cyclic loads must be protected against self-loosening. Especially cranes and their secondary construction, mast constructions, smokestacks and bridges are at risk. To avoid self-loosening several safety elements are on the market. Unfortunately, recent results showed the malfunctioning of most of these devices. Loosening also takes place due to temperature. When bolts are subjected to elevated temperature, thermal stress is induced in it thereby increasing in thermal expansion which causes loosening of bolts and thereby failure of the structure. Failure may be also due to differential thermal expansion. So here in this paper the effect of preload and temperature to the bolt is analysed. The percentage reduction in preload due to temperature is found out. Different methods like changing bolt material, bolt hole shape and adding insulation are adopted inorder to find out whether the stress reduces.*

***Key Words***: ANSYS, XPS extruded polystyrene, ASTM 307,ASTM 354, ASTM 193

## 1.INTRODUCTION

Bolt is a metal pin with a head at one end and a shank threaded at another end to receive the nut. Steel washers are usually provided under the bolt head and nuts to prevent the treaded portion of the bolt from bearing on the connecting pieces and to distribute the clamping pressure on the bolted member. Thermal cycling generates thermally induced fatigue since not all areas expand simultaneously with the same amplitude. The boundaries between “hotter” and “colder” areas undergo extra stress, which can lead to local fatigue of the material.

Increase in temperature can cause the increase in thermal stress in the bolts thereby increasing in thermal expansion. This causes the bolts to loosen and hence it causes failure. Due to difference in material used in brackets and bolts differential thermal stressis induced.

### 1.1 Objectives

- To evaluate the effect of bolt preload while connected members aresubjected to axial and transverse load.
- To evaluate the strength of preloaded bolt subjected to cyclic thermal loads.
- To find out the percentage reduction in preload due to expansion.
- To find the best material combination of bracket and bolt.

### 1.2 Scope

- Effect of axial load, preload and temperature are only considered.
- Axial load on the bolt is calculated using numerical method.
- Optimum combination of bracket and bolt material is analysed.
- Earthquake load, wind loads, and flood loads are not considered.

## 2. MODELLING

Different element of bolted connection in truss is modelled using ANSYS software. The joint is modelled same as that of a joint in truss member of a thermal powerplant. Single column and beam members connected with bracket and bolt is taken for modelling.

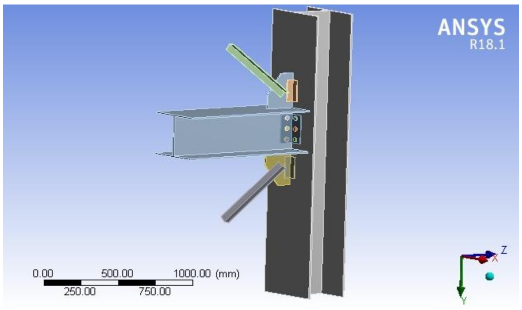


Fig.1 Connection modelled in ANSYS

### 2.1 Calculation of load

A static structural load can be performed using the ANSYS. A static structural analysis can be either linear or non-linear. Linear procedures are applicable when the structure is expected to remain nearly elastic for the level of ground motion or when the design results in nearly uniform distribution of non-linear response throughout the structure. The truss is modelled in ANSYS. Truss with a span of 23 m, Wind pressure of 1.5 kN/m$^2$ and Variable load of 0.75 kN/m$^2$ was taken for modelling.

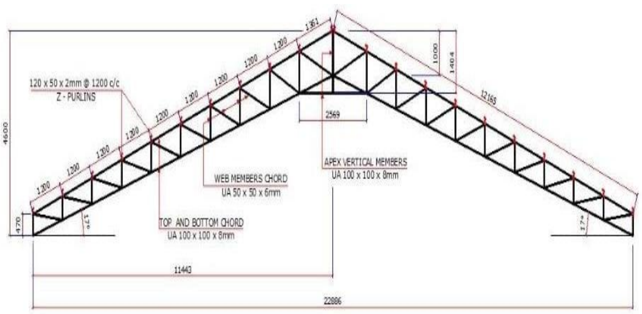


Fig 2 Schematic representation of truss

After analysing the model total load on joint was found to be 6774.9N

For the calculation of bolt preload the model is assembled using column, beam, brackets and bolt. The below table 1 shows the material used for bracket, bolt, column and beam.

**Table -1:** Specimen details

| Elements | Material |
|---|---|
| Bracket | SA 350 LF2.CL.1 |
| Bolt | SA 193 Gr. B7M |
| Beam | HN 400X200 |
| Column | HN 700X300 |

For the calculation of preload, the below equation is used

$$P = \frac{1}{FOS} \times \left(\sigma y \times \frac{\pi}{4} \times D \times D\right) - F$$

Hence the preload is obtained as 6774.725N

## 3. ANALYSIS

For the analysis of the model different loads (structural load, preload, and thermal load) are applied on the model one by one. This helps to identify the effect of each loads on the model. After the analysis using one-inch diameter A193 bolt, it is found that temperature induces stress on bolt which cause failure. The percentage reduction in preload after application of temperature was found to be 39.%. So inorder to reduce the stress the diameter of bolt was reduced to half inch and analysed in which it is clear that reduction in diameter reduces stress. After that to reduce the stress further the bolt material was changed and analysed. The specimen details of different bolt material is tabulated below in table 2.

**Table -2:** Specimen details

| Material | Youngs modulus (GPa) | Poisons ratio | Density (kg/mm$^3$) |
|---|---|---|---|
| SA 193 Gr.B7M | 200.373 | 0.3 | 7750 |
| A 307 | 190 | 0.27-0.3 | 7800 |
| A 354 | 190 | 0.27-0.3 | 7800 |
| SS | 193 | 0.27 | 8030 |

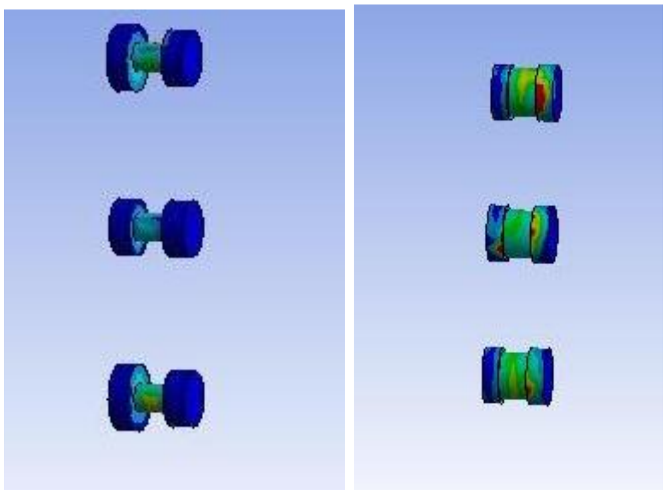

Fig 3 Stress in A307 & A193 bolt

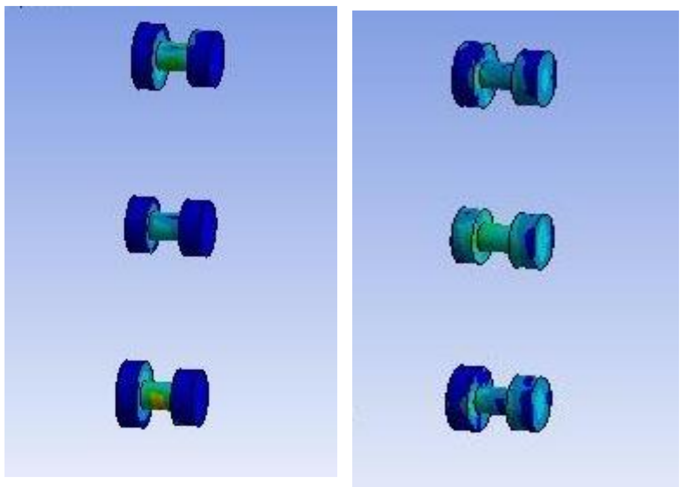

Fig 4 Stress A354 & SS bolt

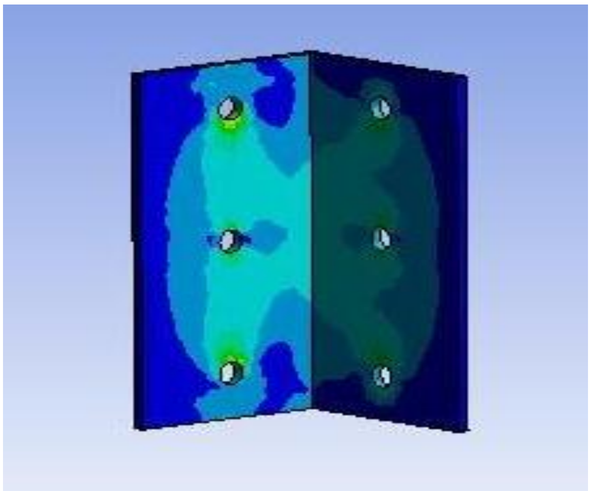

Fig 5 Stress in bracket of A193 bolt

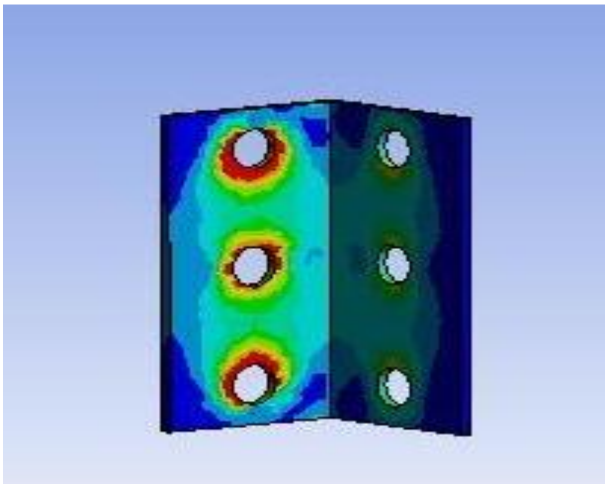

Fig 6 Stress in bracket of ss bolt

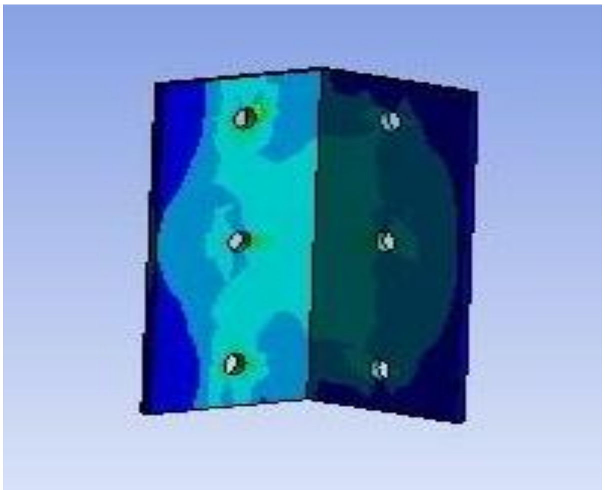

Fig 7 Stress in bracket of A307 bolt

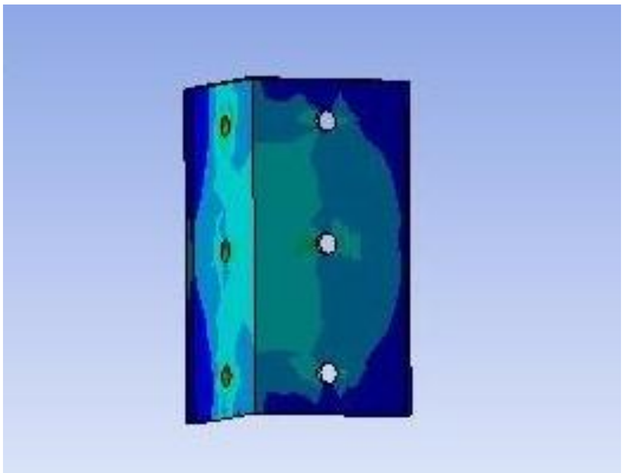

Fig 8 Stress in bracket of A354 bolt

**Table -3**: Re

| **Material** | **Stress in bracket (N/mm²)** | **Stress in bolt (N/mm²)** | **Normal stress in bolt (N/mm²)** | **Shear stress in bolt (N/mm²)** |
|---|---|---|---|---|
| A307 | 847.01 | 823.4 | 422.8 | 370.6 |
| A354 | 847.01 | 823.4 | 422.8 | 354.6 |
| SS | 5369.1 | 3073.5 | 765.09 | 708.5 |
| A 193 | 1987.1 | 1042.7 | 708 | 520.71 |

From the above analysis the we can infer that the stress in each element of the model is high and failure occurs. After changing the bolt material there is no significant change in stress so choosing a good material from them is not possible. So, change in material of bolt does not contribute to stress reduction.

## 4. CONCLUSION

- The percentage reduction in preload was found out, which was about 39.2%
- This reduction in preload in bolted connection due to temperature which cause failure.
- The diameter was changed from 1 inch to half inch. It showed that the change in diameter reduces the stress. By reducing the diameter stress in bolt was reduced upto 46%
- The material of bolt was changed and analysed but stress reduction was not effective.

## 5. FUTURE SCOPE

- Bolt hole shape can be changed and analysed to check whether stress reduction occur.
- Different insulation material can be introduced into the connection to find out best material for stress reduction.

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