Comparative Stress Analysis of Gasketed and Non- Gasketed Flange Joints under Preloading Condition-FEA Approach

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Abstract – Flange joints are very common in piping system and pressure vessels. Basically flange joints are used to connect the piping system, where the long pipes are restricted to use. These joints can include pipe to fittings, valves, equipment, or any integral part of the piping system. Flanges are available in different classes of working range and are designed as per ASME standards. These joints are assembled and disassembled using nut and bolts; typically used in industries. In this paper a Gasketed and Non-Gasketed bolted flange (4"-900# CLASS) is considered for pre-stress analysis. The results of a parametric study of the behavior of flanges and stresses in bolts are analyzed by varying the flange thickness, bolt preload, number of bolts, by considering constant flange profile taper angle of 45^0 for both Gasket and Non-gasket joints. Hence comparative stress analysis is carried out using Finite element analysis.

Keywords: Gasket Flange Joint, Non-Gasket Flange Joint, Nut-Bolt, FEM Analysis, Bolt Preload.

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INTRODUCTION

A pipe flange connection is an important part of a piping system. In Conventional gasket-flanged pipe joints are widely used in process industries for connecting pipes to pipes, and pipes to equipment's **[1].** The pipe flanges can be available in different dimensions as per ASME specifications. Because of different loading conditions, especially high loads, bolted connections can separate. To minimize this effect, a pretension is applied to the bolt. This ensures that the connection will not separate, provided the applied load remains less than the pretension **[1].**

For the present study A Gasket and Non-Gasket flanged joint is used for Pre-loading conditions for the analysis of pre-stresses in the bolt and flange connections and results are compared, with change of flange geometry taper profile angle of 45^0 instead of flat faced flange geometry with variation of parameters like flange thickness, preloading conditions, Number of bolts.**[1].**

Analyzed the pre-stresses in bolts and flange during bolt-up conditions by change of flange geometry instead of flat face, considering as male and female joint by varying profile taper angle, flange thickness, preload and number of bolts.**[2].**

Carried out experimental study on Gasketed flanged joint and verified the stress variation on flange and attached pipe during preloading and operating(Pressure)loading conditions.**[3].**

Analyzed the contact pressure distribution on sealing ring during bolt up and operating pressure conditions for 3" and 10"ANSI RF flange tapered sealing ring with RF Gasket. Hydrostatic tests were carried out. **[4].**

Proposed the Modal analysis of Gasketed and Non-Gasketed Flange Joint with and without raised face under Bolt-Up conditions. Frequencies and Mode shapes of both joints were compared.**[5].**

Studied the behavior of flange and stress in bolts by varying the flange thickness, bolt preload and number of bolts by keeping flange dimensions constant, results obtained by ASME design approach were compared with analytically.

2. FLANGE JOINT CONFIGURATION

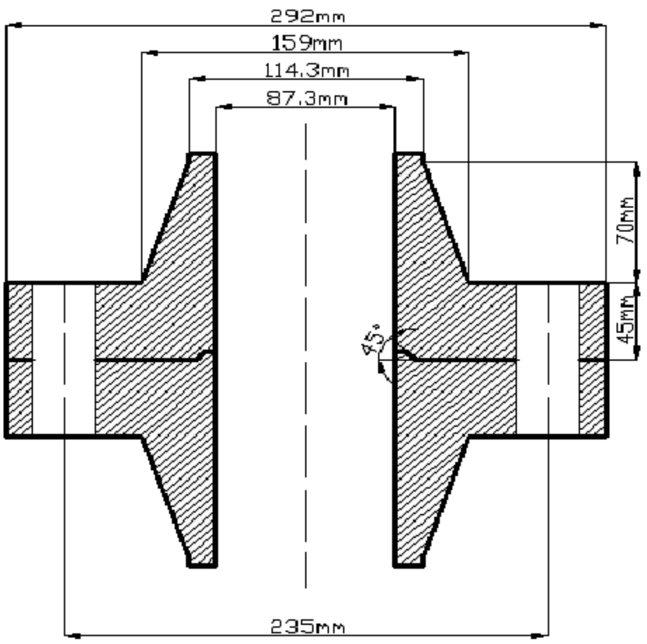

Figure: 1. 2D Geometry of flange

A Common two dimensional geometry model for Gasket and Non-Gasket flange joint with nominal dimensions as per ASME boiler and pressure vessel code with change of profile taper angle is considered for stress analysis as shown in figure: 1.Analysis of three dimensional model flange joint require more space and time to solve the problem, hence 1/8th part of the model is used to study the whole behavior of flange joint as shown in figure: 2 and 3. A three dimensional model of flange joint is done using CAE software by using key points of two dimensional geometry.

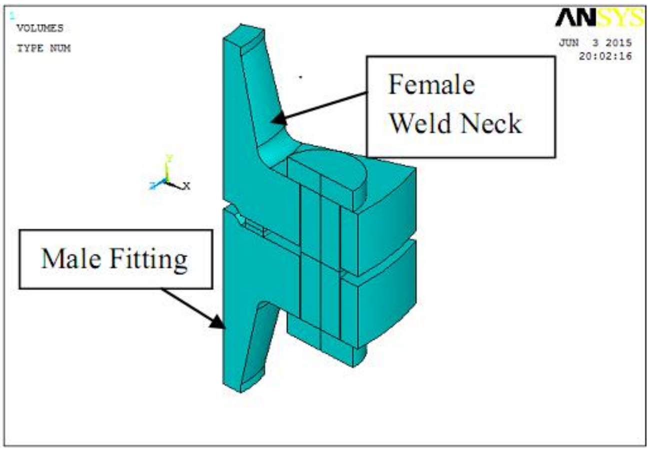

Figure: 2. 1/8th part model of Flange joint (Gasketed)

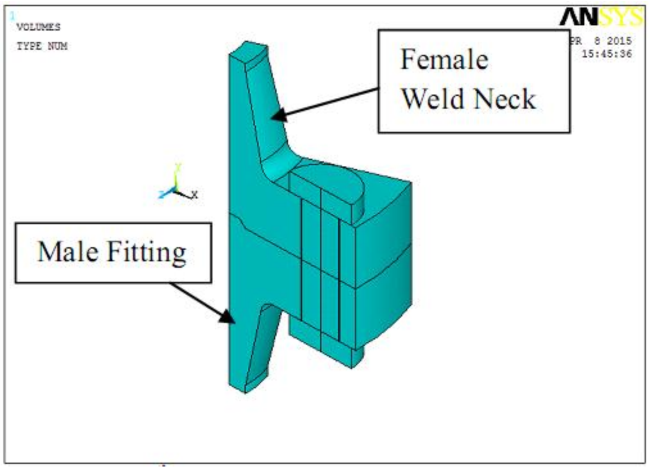

Figure: 3. 1/8th part model of Flange joint (Non-Gasketed)

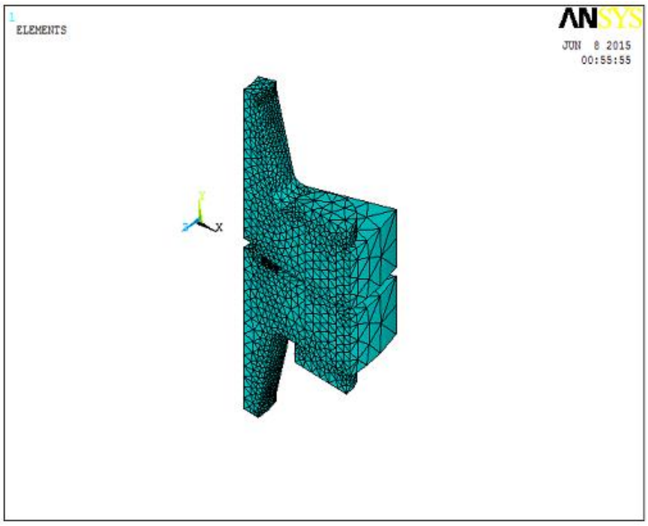

Figure: 4. Finite Element mesh for the flange joint (Gasketed)

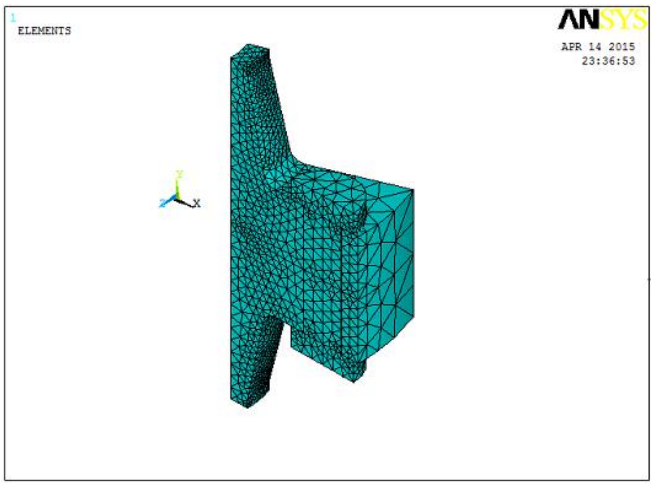

Figure: 5. Finite Element mesh for the flange joint (Non-Gasketed)

3. MATERIAL PROPERTIES:

Components of pipe flange joints are isotropic, elastic, and homogenous in nature different material properties of Gasket and Non-Gasket bolted flange are listed below in table: 1, 2 respectively as per ASTM standards and these properties are used for the finite element analysis.

Table: 1. Material properties of Gasket flange joint

Components	Young's Modulus , E (MPa)	(υ)	Allowable stress (MPa)	Material
Flange	173,058	0.3	248.2	ASTM A350 LF2 or A105
Bolt	168,922	0.3	723.9	ASTM SA193 B7
Gasket	164,095	0.3	206.8	ASTM A182 F316

Table: 2. Material properties of Non-Gasket flange joint

Components	Young's Modulus , E (MPa)	(υ)	Allowable stress (MPa)	Material
Flange	173,058	0.3	248.2	ASTM A350 LF2 or A105
Bolt	168,922	0.3	723.9	ASTM SA193 B7

4. FINITE ELEMENT ANALYSIS AND MODEL GEOMETRY:

A three dimensional finite element model has been developed for bolted joint connections with and without gaskets. For flange, bolts and Gaskets SOLID187 a higher order 3-D, 10-node element is used. Figure 4 show finite element mesh for the joint. The geometric three dimensional model can be done using any modeling software and meshing, definition of boundary conditions, preloading can be given using CAE package, in this study modeling, meshing, preloading, Boundary conditions is done using ANSYS11.0 APDL. For this model there is a contact between top of the flange and bottom of the bolt surface to predict the exact physical behavior, and Contact between male fitting and female weld neck is given for both joints and along with this there is a contact between flange and gasket for Gasketed joint as a 3D surface-to-surface CONTA174 and TARGE170 elements are used to simulate contact.

5. BOUNDARY CONDITIONS AND LOADING

Fallowing boundary Conditions and loadings are used to perform Finite element analysis. The Pretension feature was used in ANSYS11.0.For this analysis, bolts were given a pre-load values in percentage like 30%, 35%, 40%, 45%, which are yield strength of the bolt material with variation of flange thickness, flange profile taper angles, and for number of bolts.

- Symmetry conditions are applied on both sides of the bolt cross-sectional area, both sides of the flange ring, Gasket (Gasketed) and attached pipe.
- A nominal preload i.e.35% of the yield strength of the bolt was chosen to perform stress analysis.

6. RESULTS AND DISCUSSION

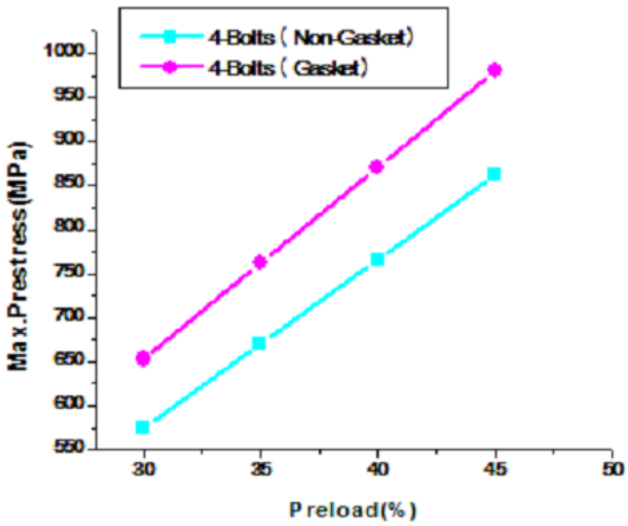

Figure: 5 Y-Component of Stress

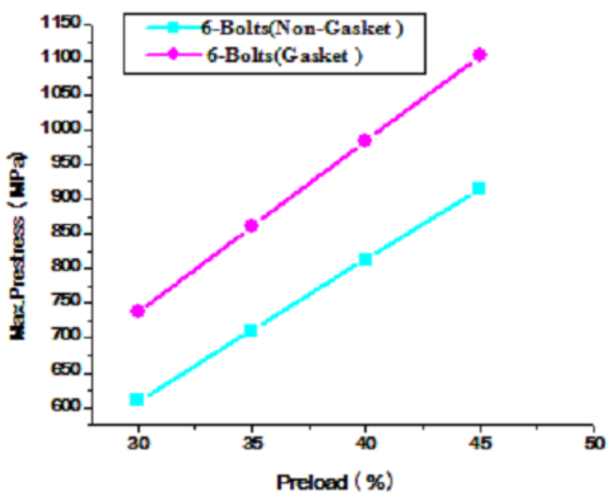

Figure: 6 Y-Component of Stress

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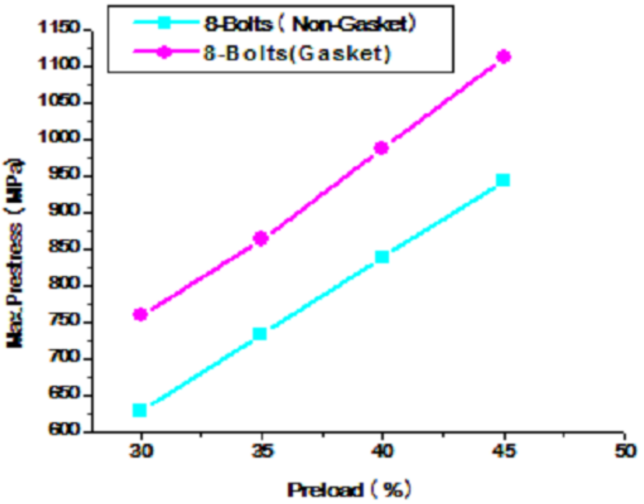

Figure: 7 Y-Component of Stress

Figure: 5, 6, 7 Indicates the comparison of effect of Pre-stress by varying Preload and number of bolts for Gasket and Non-Gasket flange joint by keeping constant flange profile taper angle of 45^0 and flange thickness of 45mm,Y direction of stress.

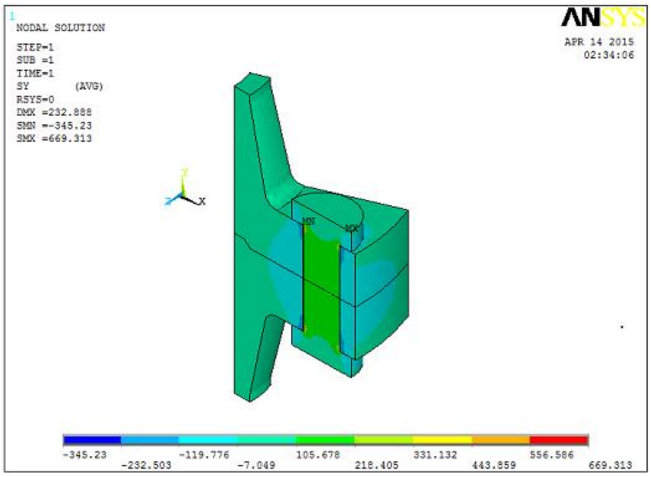

Figure: 8 Flange thickness of 45mm

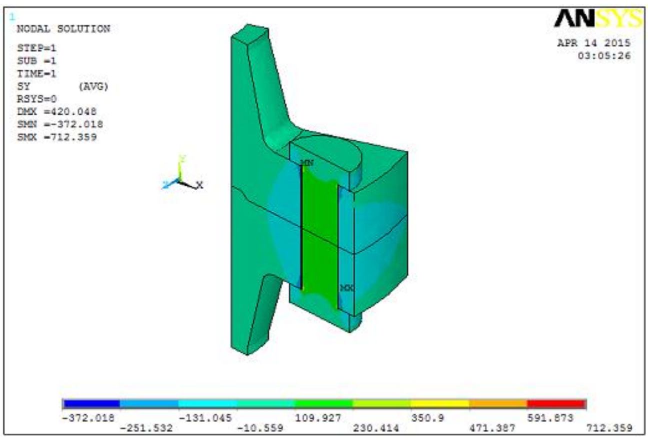

Figure: 9 Flange thicknesses of 55mm

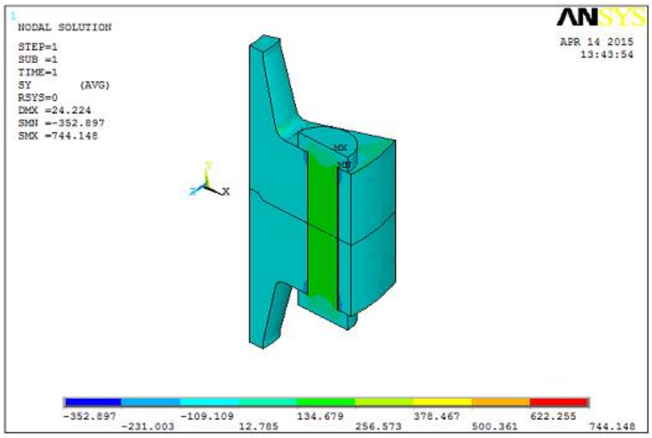

Figure: 10 Flange thicknesses of 65 mm

Figure: 8, 9 and 10: Stress distribution in Y-Component of stress for variation of flange thickness for 35% Preload and 45^0 taper angle. (Non-Gasketed with 8-Bolts)

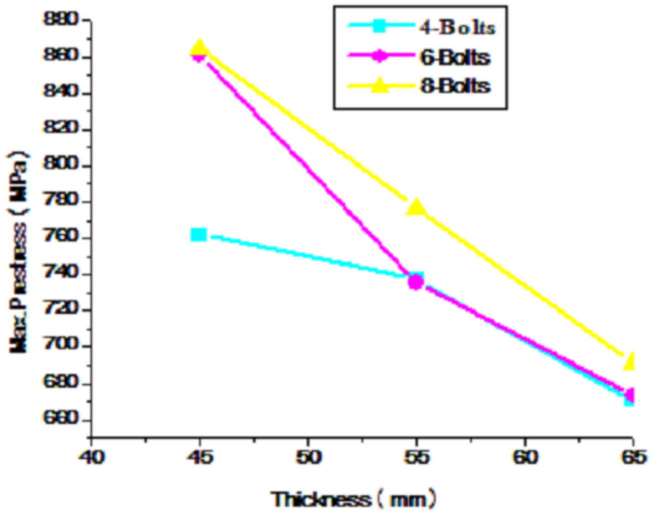

Figure: 11 Effect of Pre-Stress by varying flange thickness and Number of bolts with 35% of Preload and 45^0 taper angle for Gasketed Joint. (Y-Component Stress)

7. CONCLUSIONS:

For present study a Gasketed and Non-Gasketed weld –neck flange is considered for comparative stress analysis with change of taper geometry and analysis is carried out, for different loading values for the bolt, as pretension. By, considering the Female weld neck and Male fitting there may a proper lock between the two parts of flanges and may protect from leakage due to gasket provided, for comparison the parameters like taper angle, flange thickness, Number of bolts and preload are varied.

- Figure: 5, 6, 7 Indicates the comparison of effect of Pre-stress by varying Preload and number of bolts for Gasket and Non-Gasket flange joint. Which shows by the change of geometry with gasket provision due to preloading the stresses in the bolt and flanges are higher as compared to Non-Gasketed flange.

- Figure 8,9,10 stress distribution for flange thickness of 45mm, 55mm and 65mm which shows, as increase of flange thickness will increase the stresses in the flange and Bolt.

- Figure: 11 stress distribution for flange thickness of 45mm, 55mm and 65mm which shows, as increase of flange thickness will decrease the stresses in the flange and Bolt.

8. REFERENCES:

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