A STUDY ON SEALING PERFORMANCE OF FLANGED JOINT WITH GASKETS USING FINITE ELEMENT ANALYSIS WITH FINAL RESULT

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ABSTRACT

Bolted Flanged Joints are used to join two elements with each other in various applications. Sealing is the very important criteria for these joints. Gaskets play an important role in the sealing performance of bolted flange joints, and their behavior is complex due to nonlinear material properties combined with permanent deformation. The variation of contact stresses due to the pressure of the flange and the material properties of the gasket play important roles in achieving a leak proof joint.

In this project, a three-dimensional finite element analysis (FEA) of bolted flange joints has been carried out by taking experimentally obtained loading and unloading characteristics of the gaskets. Analysis shows that the distribution of contact stress has a more dominant effect on sealing performance than the limit on flange rotation specified by ASME.

In this project, we study about the stresses generated and deflection in the Gasket at various load that is applied on joint and thicknesses of gaskets.

The detailed finite element analysis (FEA) will carried out with various load and thicknesses of gaskets and the results will verify experimentally.

1. Keyword

- To investigate the strength of the gasket in flange joint for various different thicknesses.
- To investigate the strength of the gasket in flange joint for various loads.
- Validate the result of experiment by FEA software with different thicknesses & loads.
- Recommend the proper thickness of gasket for bolted flanged joints through experimentation and validation.

2. INTRODUCTION

Coupling:

A coupling is a device used to connect two shafts together at their ends for the purpose of transmitting power. Couplings do not normally allow disconnection of shafts during operation, however there are torque limiting couplings which can slip or disconnect when some torque limit is exceeded. The primary purpose of couplings is to join two pieces of rotating equipment while permitting some degree of misalignment or end movement or both. By careful selection, installation and maintenance of couplings, substantial savings can be made in reduced maintenance costs and downtime.

Shaft couplings are used in machinery for several purposes, the most common of which are the following.

1. To provide for the connection of shafts of units that are manufactured separately such as a motor and generator and to provide for disconnection for repairs or alterations.
2. To provide for misalignment of the shafts or to introduce mechanical flexibility.
3. To reduce the transmission of shock loads from one shaft to another.
4. To introduce protection against overloads.
5. To alter the vibration characteristics of rotating units.
6. To connect driving and the driven part

Types of Coupling:

Clamped or compression rigid couplings come in two parts and fit together around the shafts to form a sleeve. They offer more flexibility than sleeved models, and can be used on shafts that are fixed in place. They generally are large enough so that screws can pass all the way through the coupling and into the second half to ensure a secure hold. Flanged rigid couplings are designed for heavy loads or industrial equipment. They consist of short sleeves surrounded by a perpendicular flange. One coupling is placed on each shaft so the two flanges line up face to face. A series of screws or bolts can then be installed in the flanges to hold them together. Because of their size and durability, flanged units can be used to bring shafts into alignment before they are joined together. Rigid couplings are used when precise shaft alignment is required; shaft misalignment will affect the coupling's performance as well as its life.

Sleeve Coupling:

A sleeve coupling consists of a pipe whose bore is finished to the required tolerance based on the shaft size. Based on the usage of the coupling a keyway is made in the bore in order to transmit the torque by means of the key. Two threaded holes are provided in order to lock the coupling in position.

Sleeve couplings are also known as Box Couplings. In this case shaft ends are coupled together and abutted against each other which are enveloped by muff or sleeve. A gib head sunk keys hold the two shafts and sleeve together. in other words, this is the simplest type of the coupling. It is made from the cast iron and very simple to design and manufacture. It consists of a hollow pipe whose inner diameter is same as diameter of the shafts. The hollow pipe is fitted over a two or more ends of the shafts with the help of the taper sunk key. A key and sleeve are useful to transmit power from one shaft to another shaft.

Clamp or Split-muff Coupling:

In this coupling, the muff or sleeve is made into two halves parts of the cast iron and they are joined together by means of mild steel studs or bolts. The advantages of this coupling are that assembling or disassembling of the coupling is possible without changing the position of the shaft. This coupling is used for heavy power transmission at moderate speed.

Tapered Shaft Lock:

A tapered lock is a form of keyless shaft locking device that does not require any material to be removed from the shaft. The basic idea is similar to a clamp coupling but the moment of rotation is closer to the center of the shaft. An alternative coupling device to the traditional parallel key, the tapered lock removes the possibility of play due to worn keyways. It is more robust than using a key because maintenance only requires one tool and the self- centering balanced rotation means it is that it costs more

Flexible Coupling:

Flexible couplings are used to transmit torque from one shaft to another when the two shafts are slightly misaligned. Flexible couplings can accommodate varying degrees of misalignment up to 3° and some parallel misalignment. In addition, they can also be used for vibration damping or noise reduction. This coupling is used to protect the driving and driven shaft members against harmful effects produce due to misalignment of the shafts, sudden shock loads, shaft expansion or vibrations etc.

Bush Pin Type Flange Coupling:

This is used for slightly imperfect alignment of the two shafts.

This is modified form of the protected type flange coupling. This type of coupling has pins and it works with coupling bolts. The rubber or leather bushes are used over the pins. The coupling has two halves dissimilar in construction. The pins are rigidly fastened by nuts to one of the flange and kept loose on the other flange. This coupling is used to connect of shafts which having a small parallel misalignment, angular misalignment or axial misalignment. In this coupling the rubber bushing absorbs shocks and vibration during its operations. This type of coupling is mostly used to couple electric motors and machines.

3. LITERATURE REVIEW

Yu Luan,Zhen-QunGuan, Geng-DongCheng,SongLiu [2012] have suggested “A simplified nonlinear

dynamic model for the analysis of pipe structures with bolted flange joints”. In this they have said that Bolted flange joints are widely used in engineering structures; however, the dynamic behavior of this connection is complex in nature. In this paper, a simplified nonlinear dynamic model with bi-linear springs is proposed and validated for pipe structures with bolted flange joints. First, static mechanical properties of the bolted flange joint are investigated. The analytical solution reveals that the axial stiffness of the bolted flange joint is different in tension and compression. Then, nonlinear springs with different stiffness in tension and compression are employed to represent the bolted flange joint. A special type of dynamic behavior, coupling vibration in the transverse and long- itudinal directions, is observed in analytical derivation. Finally, relevant physical experiments and numerical simulations are performed. The physical experiments confirm the existence of the coupling vibration behavior. The relationship of long- itudinal and transverse vibration frequencies is discussed. The numerical solutions reveal that the simplified nonlinear dynamic model better fits the physical response than conventional reduced linear beam model. They have concluded that Upon the investigation of the static behavior of bolted flange connections, a simplified nonlinear dynamic model is proposed, in which the mechanical properties of the joint are modeled by bi-linear springs. The different tensile and compressive modules of bi-linear springs not only present accurate axial stiffness, but also bring flexibility in axial direction under transverse loads, which is an significant improvement compared with the linear beam model. study on the impact behaviors of the mass–spring system reveals that transverse impact can excite the coupling longitudinal vibrations, while longitudinal impact only excites longitudinal vibrations. Furthermore, the relation between longitudinal and transverse frequencies under transverse impact is predicted: the longitudinal frequency doubles the transverse one. The impact behaviors of a typical bolted flange assembled structure are tested, which confirms the existence of coupling response [1].

G. Mathan, N. Siva Prasad [2011] have studied "Studies on gasketed flange joints under bending with anisotropic Hill plasticity model for gasket" they said that the behavior of a gasketed flange joint under bending loads has been studied by three dimensional finite element analysis (FEA) and experiments. The in-plane and bending stiffness of spiral wound gaskets are considered using anisotropic Hill plasticity material model. The variation in bolt axial force of joints under bending load predicted by the finite element analysis compares well with the experimental results. The contact stress distribution obtained have significant variation in the pattern from the previous material models and consistent with the results of Bouzid[17] regarding flange rotation. They concluded that The flange joint is analyzed under bending loads through FEA considering the nonlinear properties of the gasket by anisotropic Hill plasticity model. The contact stresses predicted using anisotropic Hill plasticity model are in reasonable agreement with the pressure closure model. The inclusion of in-plane and transverse stiffnesses shows significant variation in the distribution along the gasket width. The anisotropic Hill plasticity model could be an alternative model for the pressure closure model with reasonable accuracy in predicting contact stress predictions in applications where the use of pressure closure model is restricted (sliding of gasket interfaces, simulation of fluid flow through the interface, torsion and dynamic loading etc.) [2]

Mohsen Gerami, Hamid Saberi ,Vahid Saberi , Amir Saedi Daryan [2011] have worked on "Cyclic behavior of bolted connections with different arrangement of bolts". They explained that During the 1994 Northridge earthquake, relatively poor performance of the bolted web-welded flange connections (BWWFs) was observed. Thereafter, various types of connections such as end plate and T-stub bolted connections were suggested to be used in moment resisting frames that are often used in industrial and tall buildings. In this paper, finite element simulation is used to study and compare the cyclic behavior of fourteen specimens of the mentioned connection type by changing the horizontal and vertical arrangement of bolts. The results show that the moment capacity and the initial rotational stiffness of T-stub bolted connections are higher than that of end plate bolted connections designed based on AISC considering the total energy dissipation of both groups to be approximately equal. It is also evident that the probability of failure mode change in T-stub connections is higher than that of end plate connections under cyclic loading due to the arrangement variation of bolts [3].

4. RESULT

Stress Distribution in the Gasket for Three Cases:

The effect of loading on the flange was investigated by comparing the stress distributions within the three cases in gasket under the bolt preload and internal pressure. The von-Mises stress contour plots for gasket are shown in the figure below.

case 1 Load = 45 MP (Inner pressure acting on the coupling is 45 MPa)

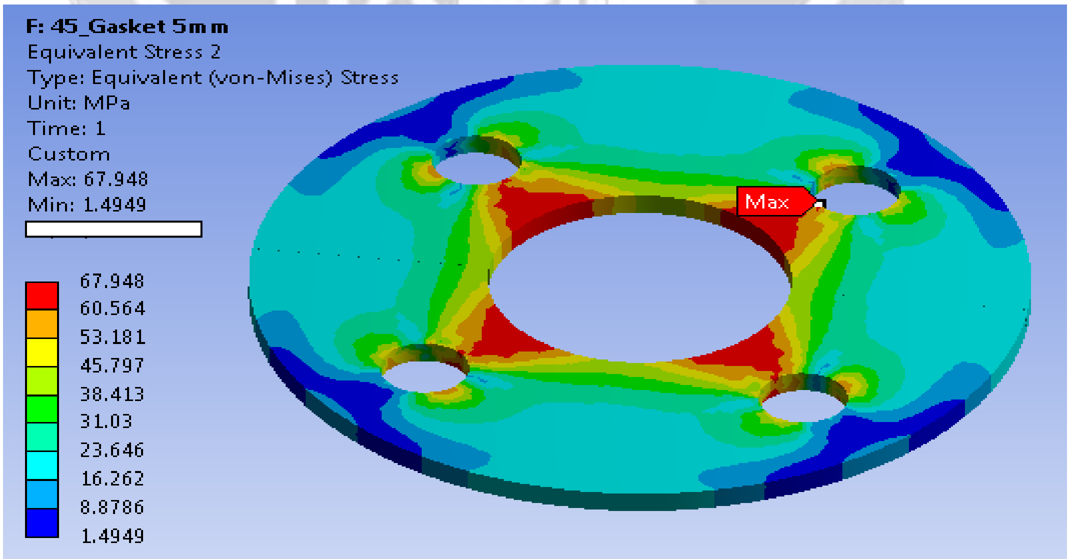


Figure7.1: Von-Mises Stress Contour Plot – Gasket 5mm (45MPa)

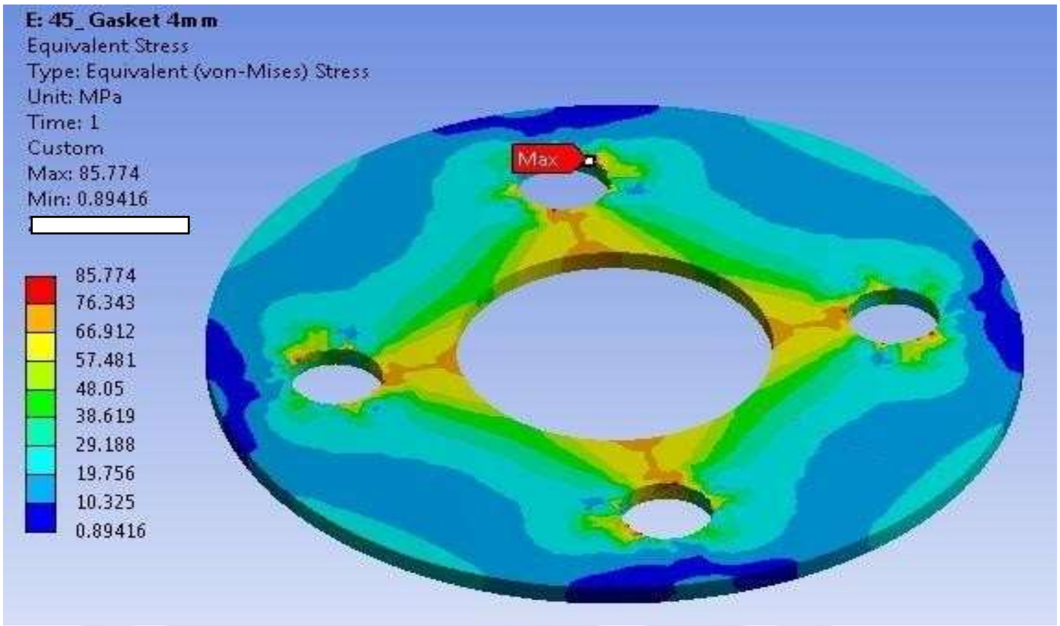


Figure7.2: Von-Mises Stress Contour Plot – Gasket 4mm (45MPa)

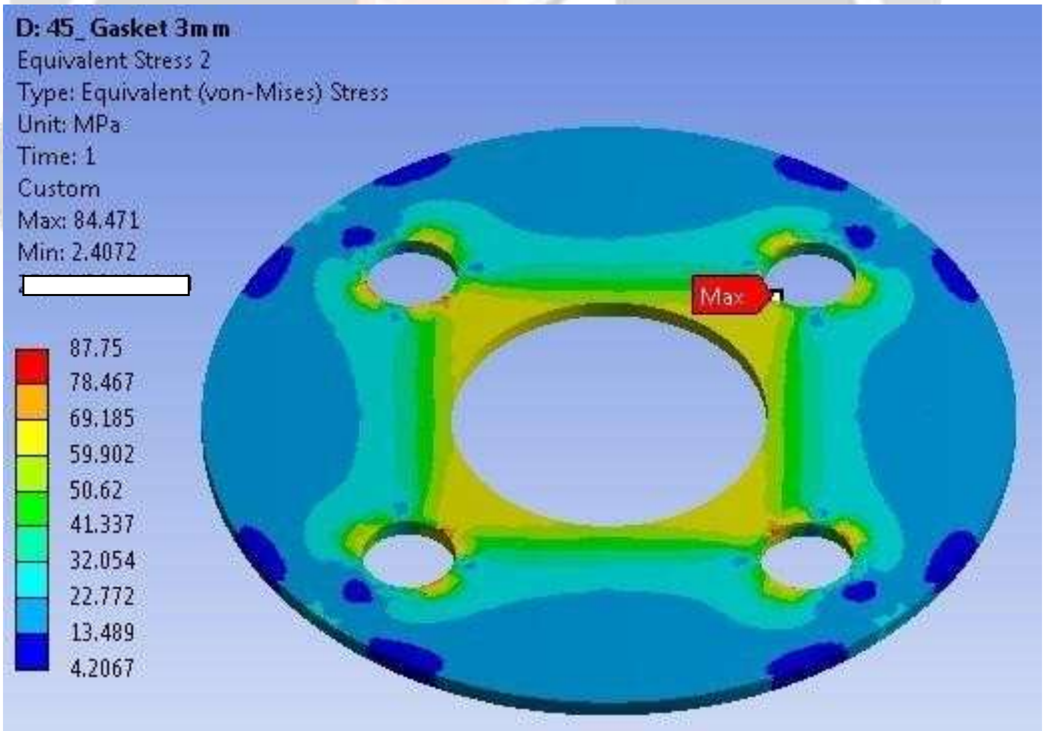


Figure7.3: Von-Mises Stress Contour Plot – Gasket 3mm (45MPa)

case 2 Load = 50 MP (Inner pressure acting on the coupling is 50 MPa)

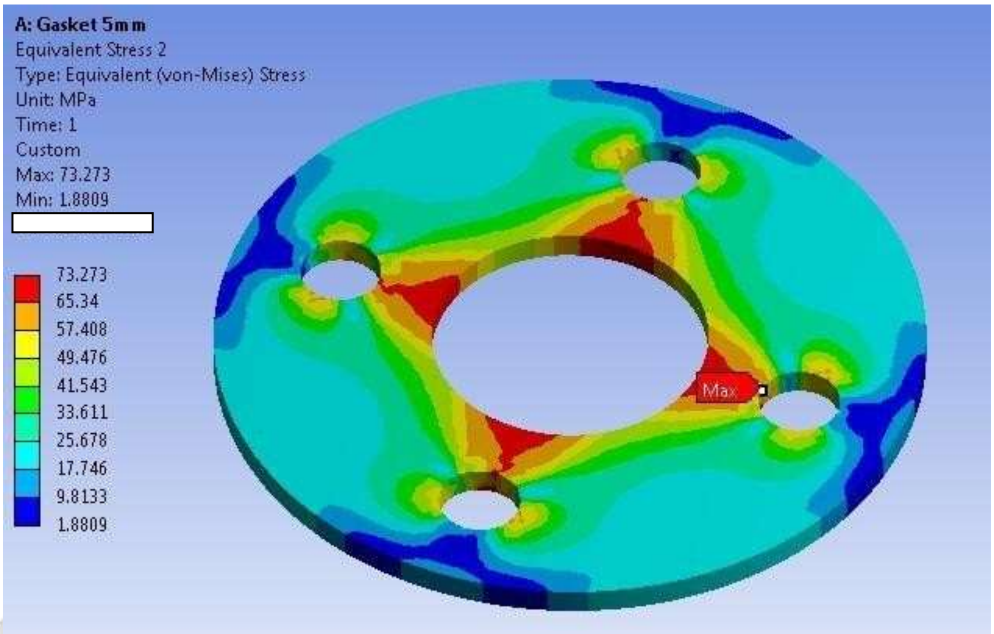


Figure7.4: Von-Mises Stress Contour Plot – Gasket 5mm (50MPa)

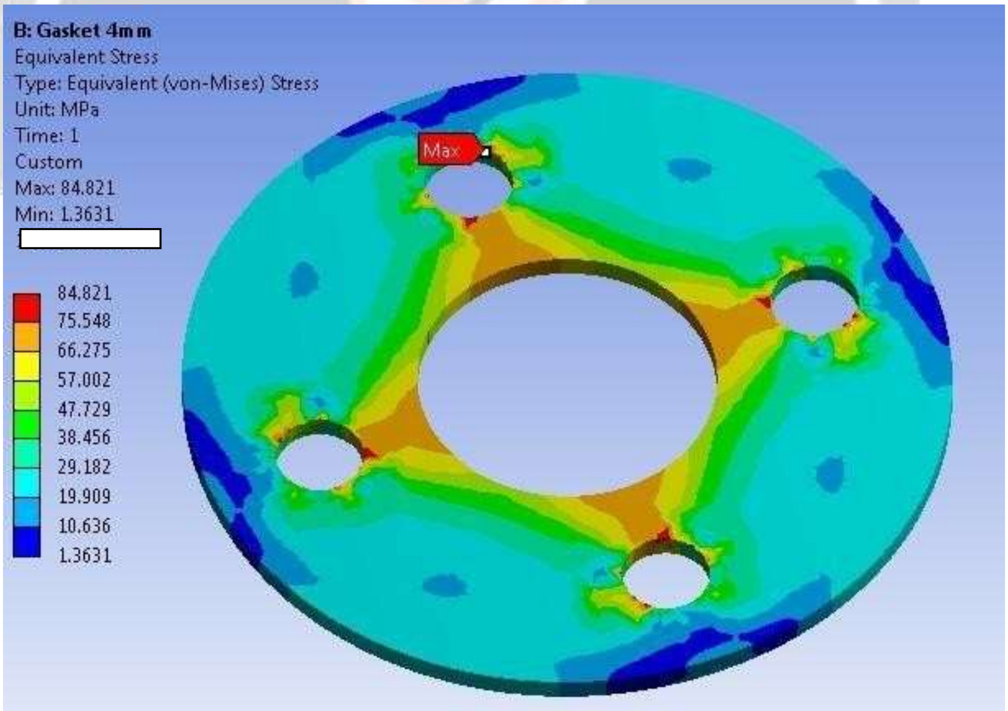


Figure7.5: Von-Mises Stress Contour Plot – Gasket 4mm (50MPa)

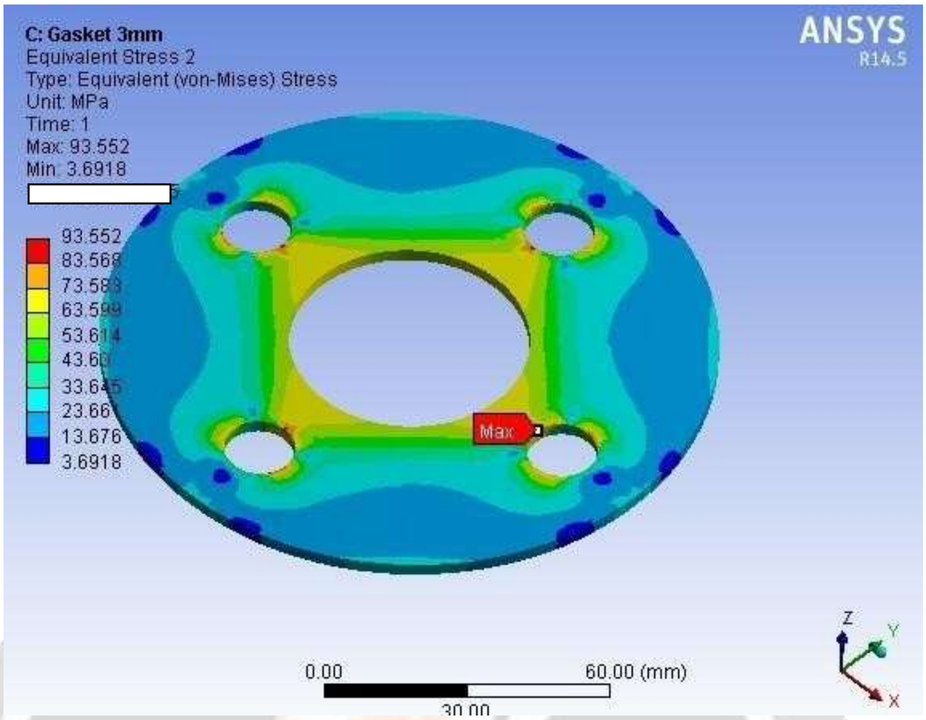


Figure7.6: Von-Mises Stress Contour Plot – Gasket 3mm (50MPa) case 3 Load = 55 MP (Inner pressure acting on the coupling is 55 MPa)

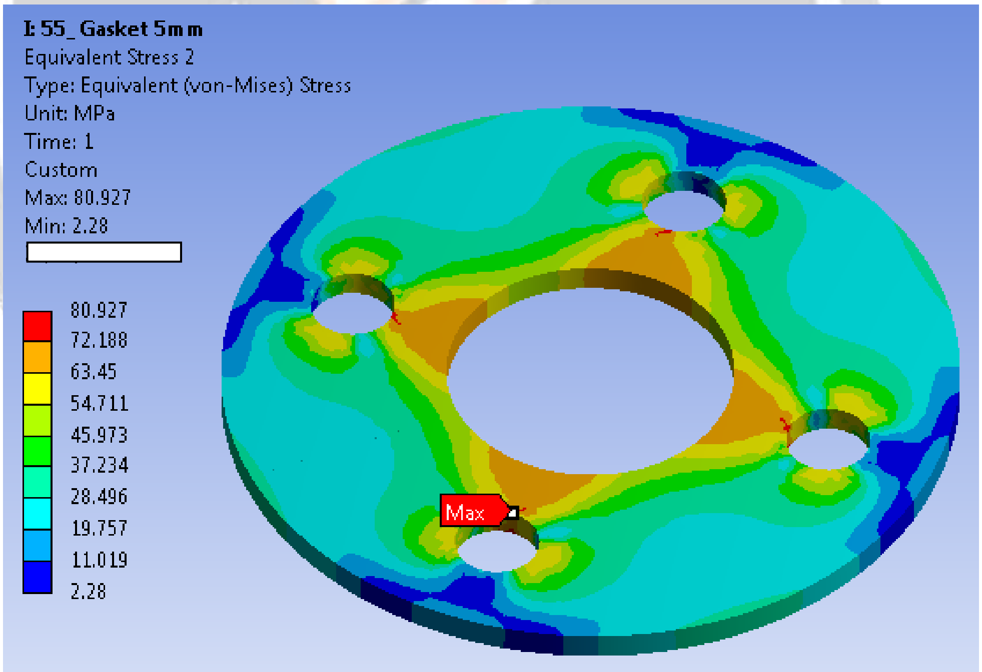


Figure7.7: Von-Mises Stress Contour Plot – Gasket 5mm (55MPa)

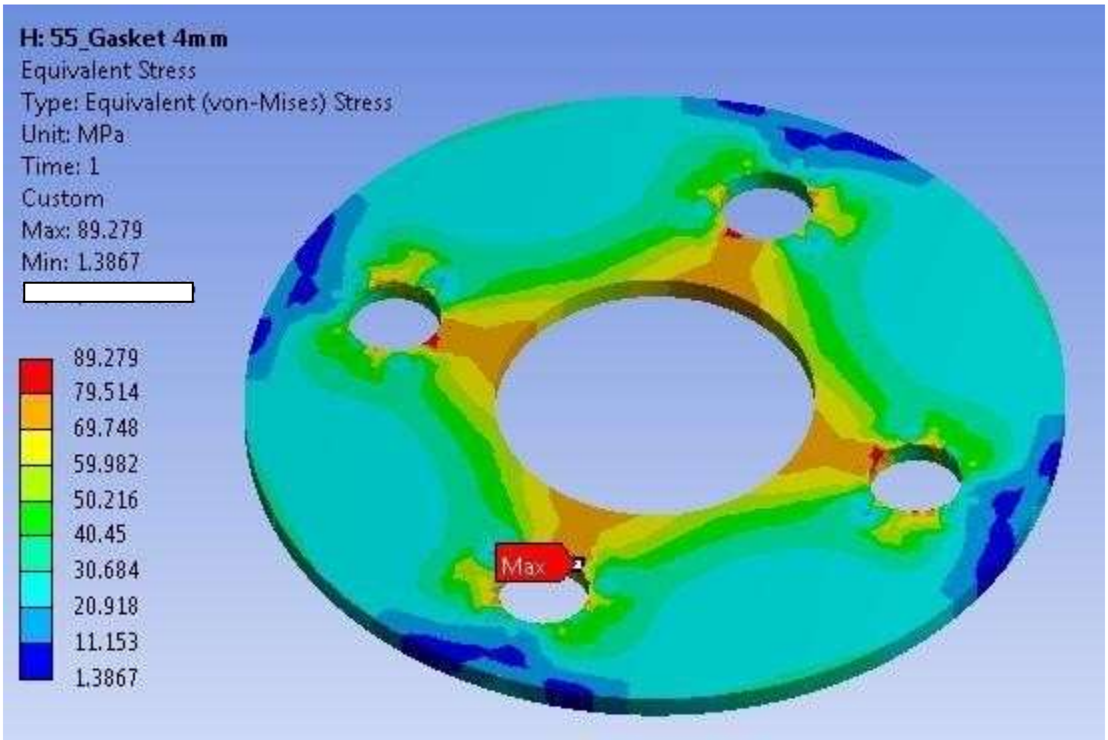


Figure7.8: Von-Mises Stress Contour Plot – Gasket 4mm (55MPa)

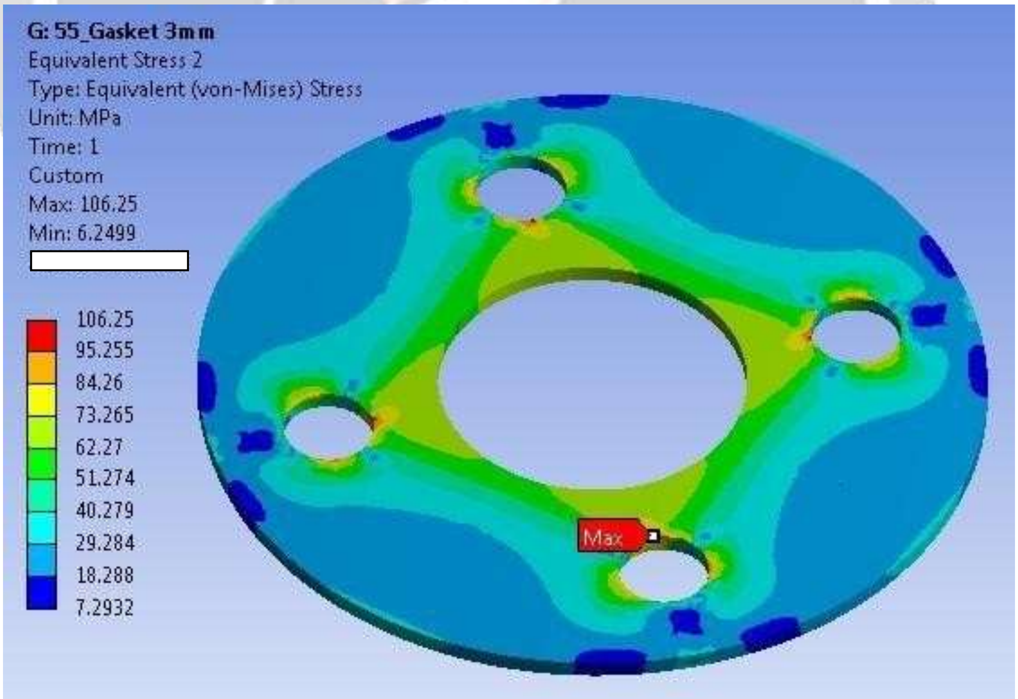


Figure7.9: Von-Mises Stress Contour Plot – Gasket 3mm (55MPa)

The 5mm gasket shows maximum von-mises stress upto 73.27 MPa which is under the limit of maximum allowable stress of 80 MPa. The 5 mm gasket is not yielding beyond allowable stress for applied loading scenario. The 4 mm gasket shows maximum von-mises stress upto 84.82 MPa which is slightly greater than yield strength of the material. The 3 mm gasket shows maximum von-mises stress more than 93.55 MPa which is more than the yield strength of the material. Therefore, the gasket is safe for first case (for 5 mm in size) in applied structural loading conditions. The stresses at flanges, bolt and nut where within limit. Therefore, 5mm thickness gasket is most suitable for the application.

Maximum Displacement of Gasket:

The maximum displacement of the gasket observed due to compressive load of the flange upper and lower housing. The displacement contour plots are shown in the below figure. The gasket shows displacement up to 0.4 mm for 5 mm thickness. The 4 mm thickness gasket shows displacement of 0.46 mm. The maximum displacement shown by the 3 mm thickness gasket up to 0.48 mm.

case 1 Load = 45 MP (Inner pressure acting on the coupling is 45 MPa)

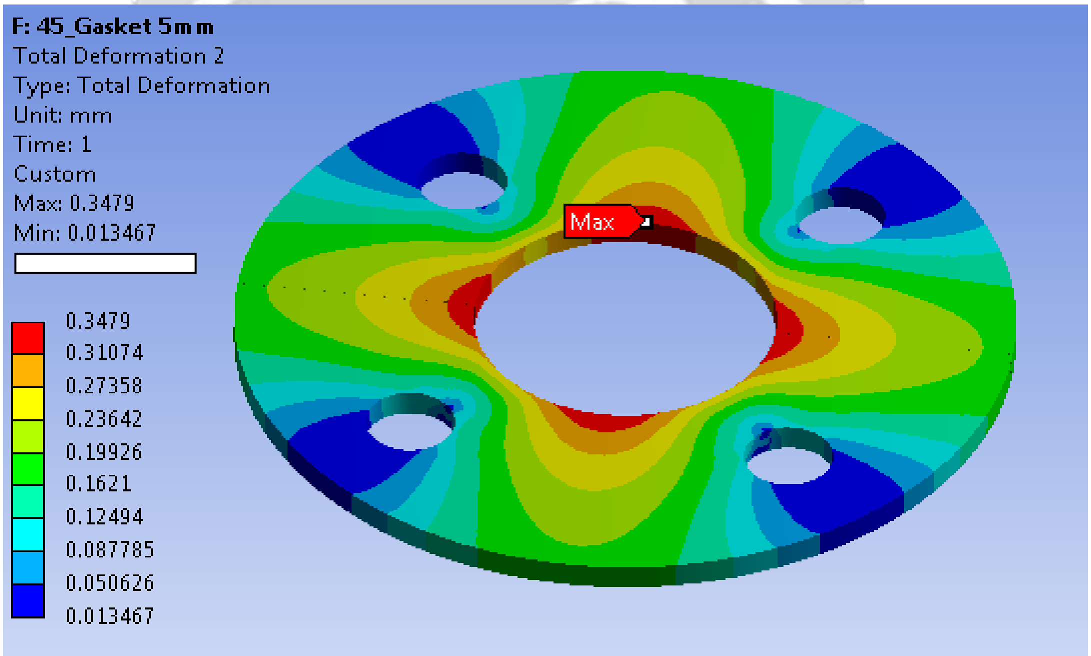


Figure 7.10: Maximum Displacement contour plot – 5mm gasket (45MPa)

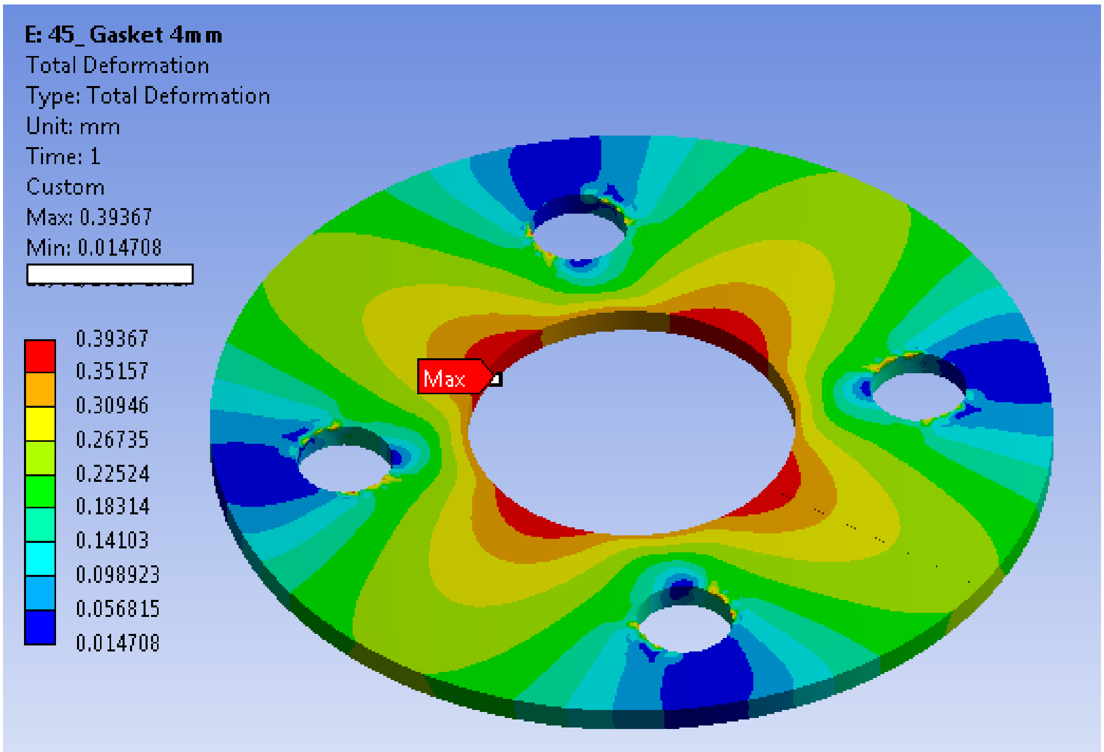


Figure 7.11: Maximum Displacement contour plot – 4mm gasket (45MPa)

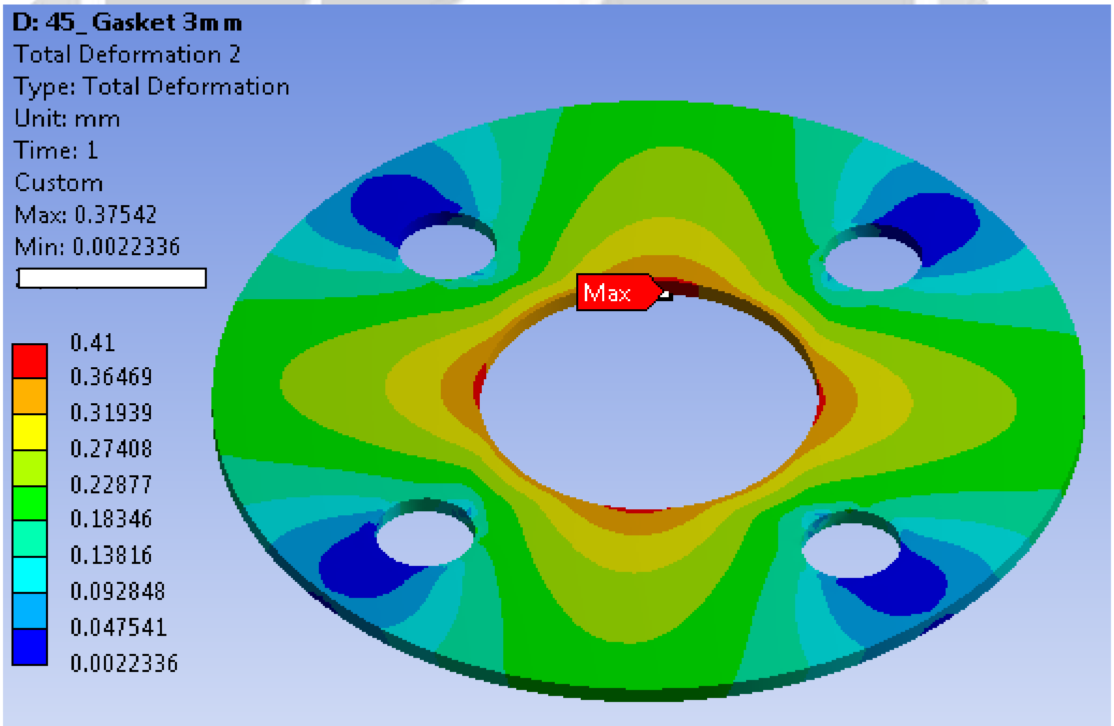


Figure 7.12: Maximum Displacement contour plot – 3mm gasket (45MPa)

case 2 Load= 50 MPa (Inner pressure acting on the coupling is 50 MPa)

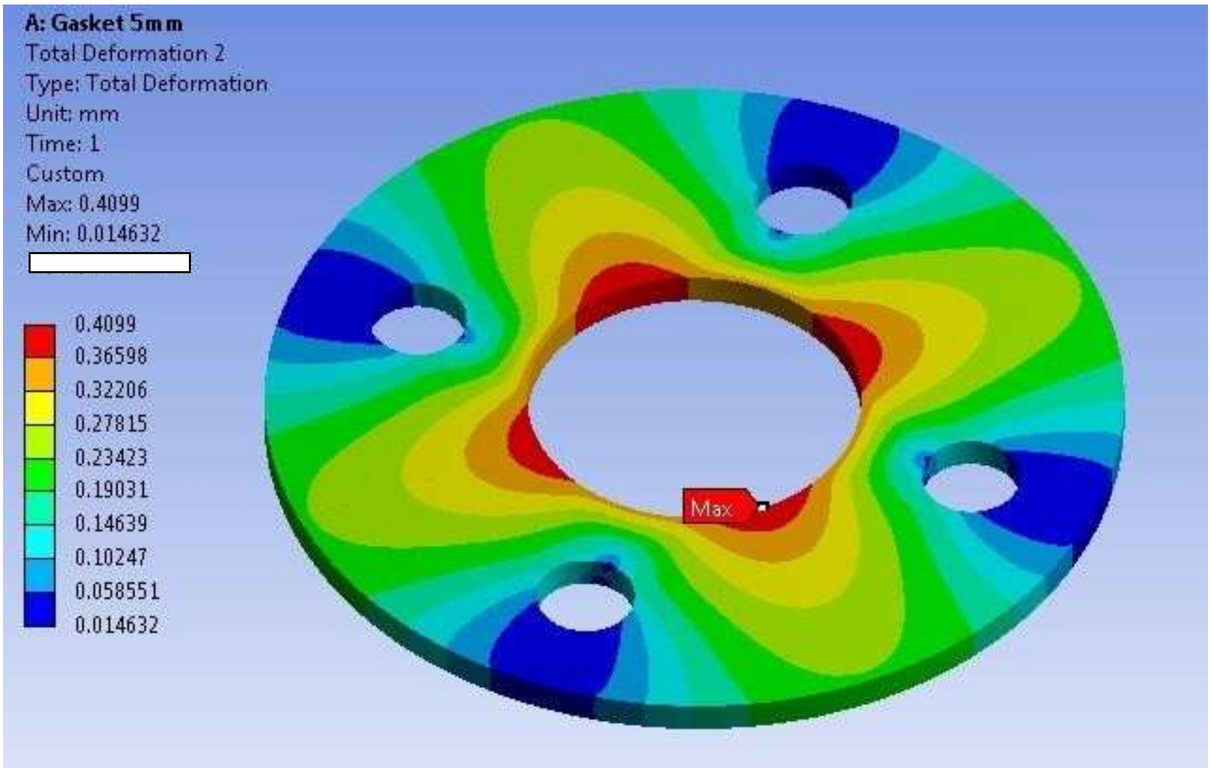


Figure 7.13: Maximum Displacement contour plot – 5mm gasket (50MPa)

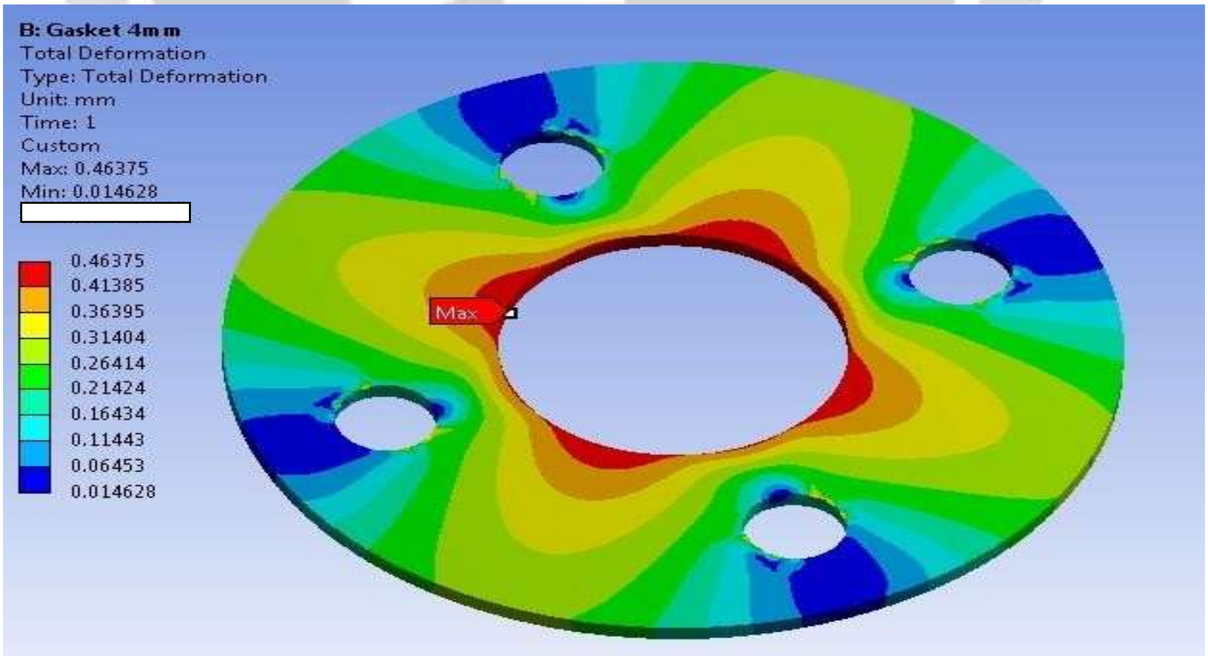


Figure 7.14: Maximum Displacement contour plot – 4mm gasket (50MPa)

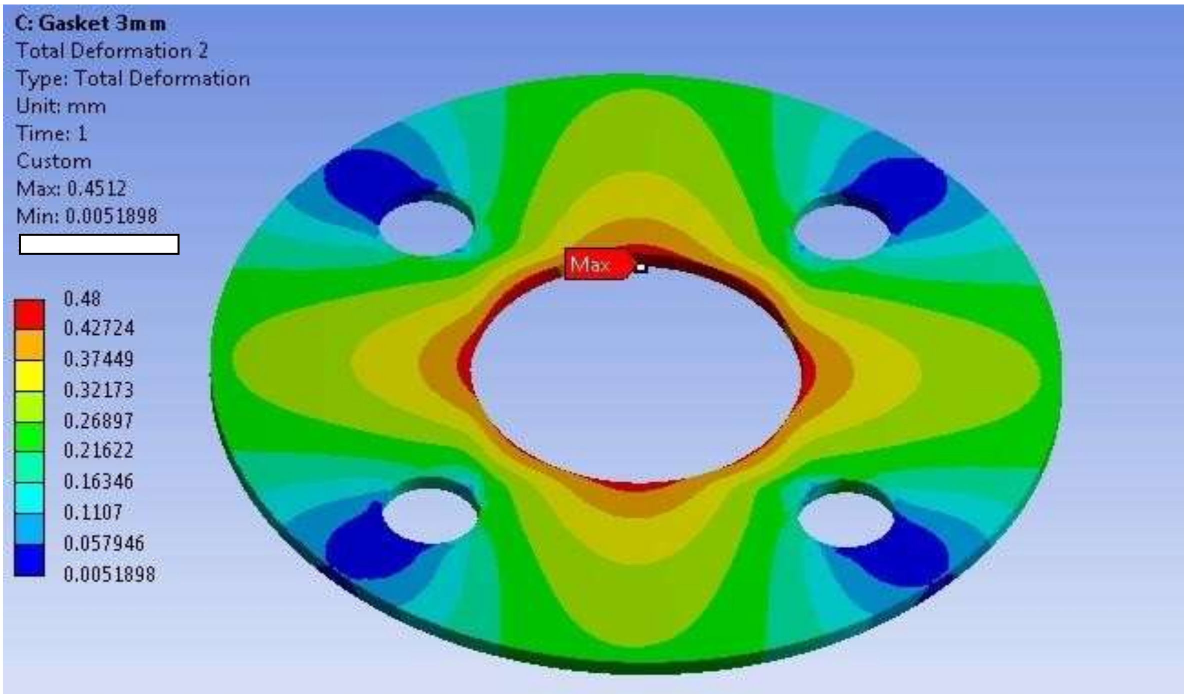
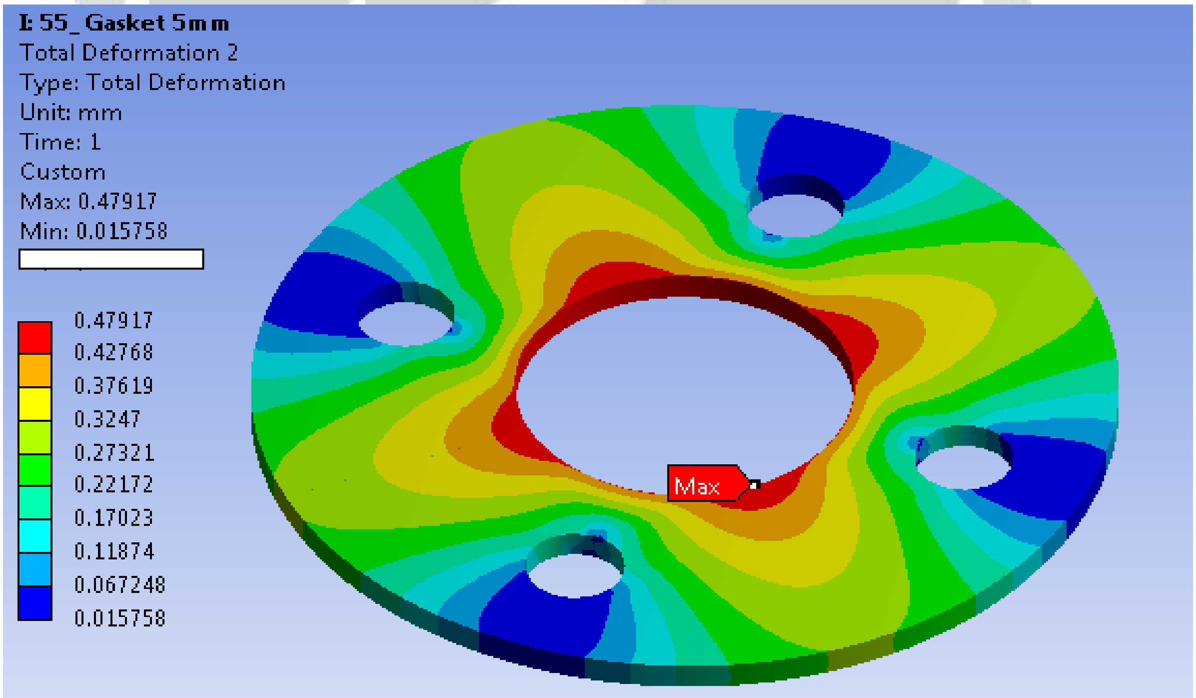


Figure 7.15: Maximum Displacement contour plot – 3mm gasket (50MPa) case 3 Load = 55 MPa (Inner pressure acting on the coupling is 55 MPa)

Figure 7.16: Maximum Displacement contour plot – 5mm gasket (55MPa)



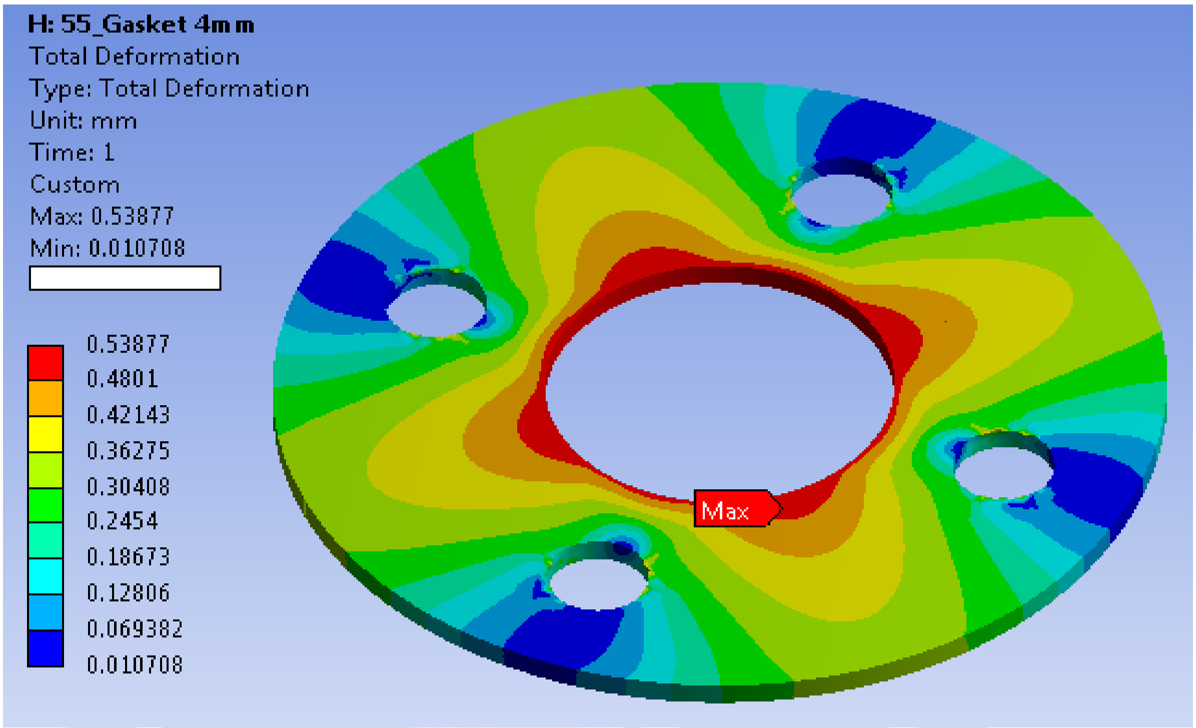


Figure 7.17: Maximum Displacement contour plot – 4mm gasket (55MPa)

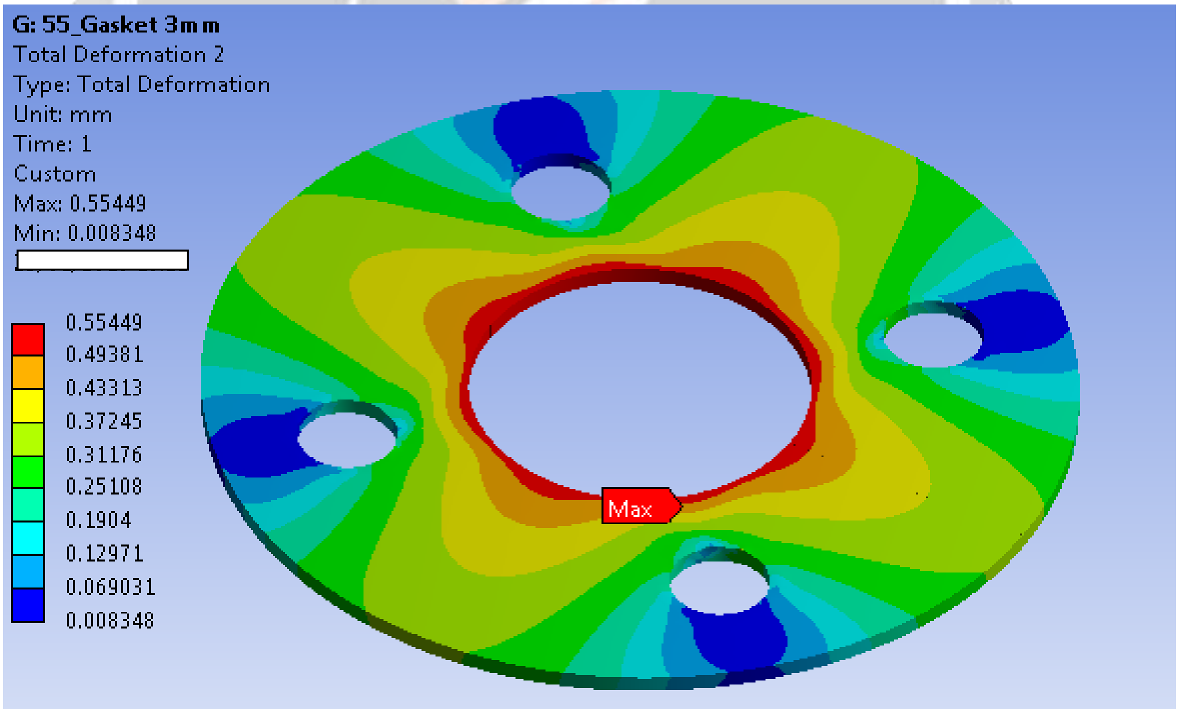
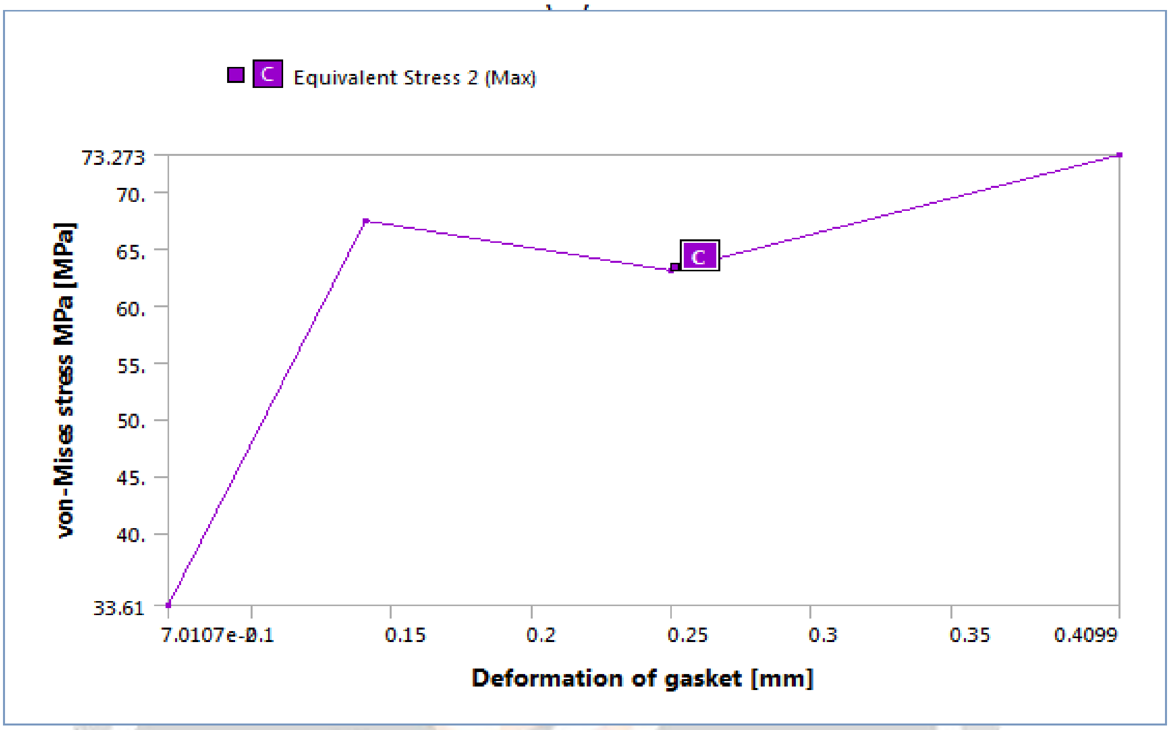
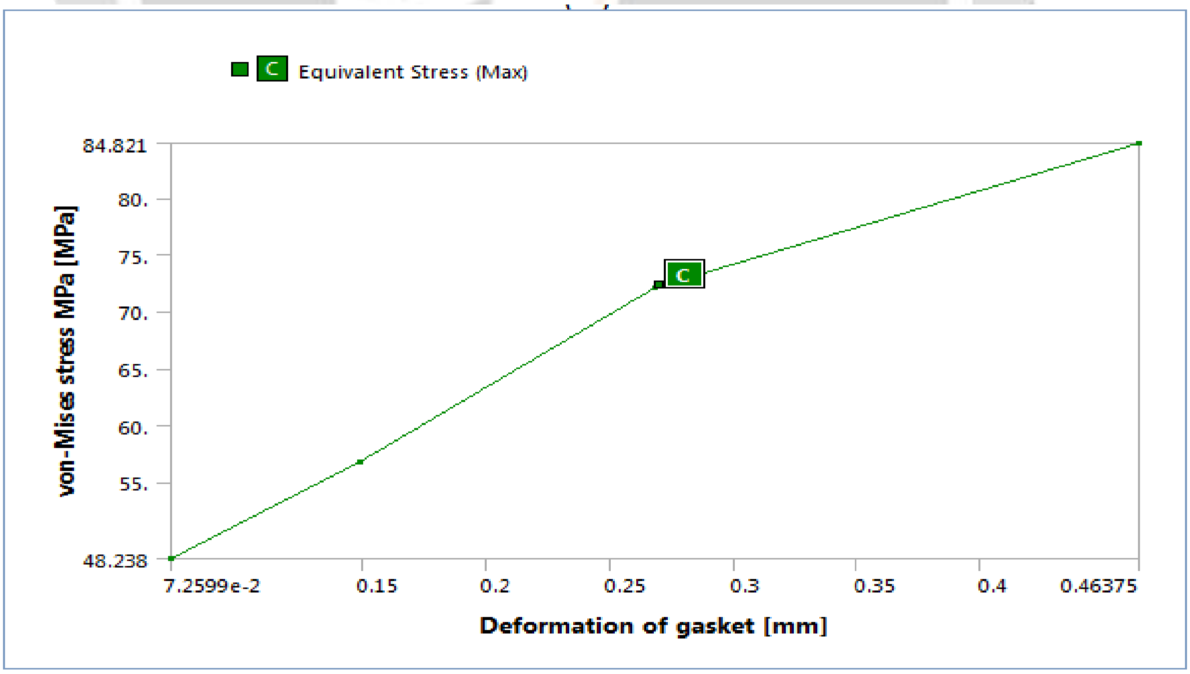


Figure 7.18: Maximum Displacement contour plot – 3mm gasket (55MPa)

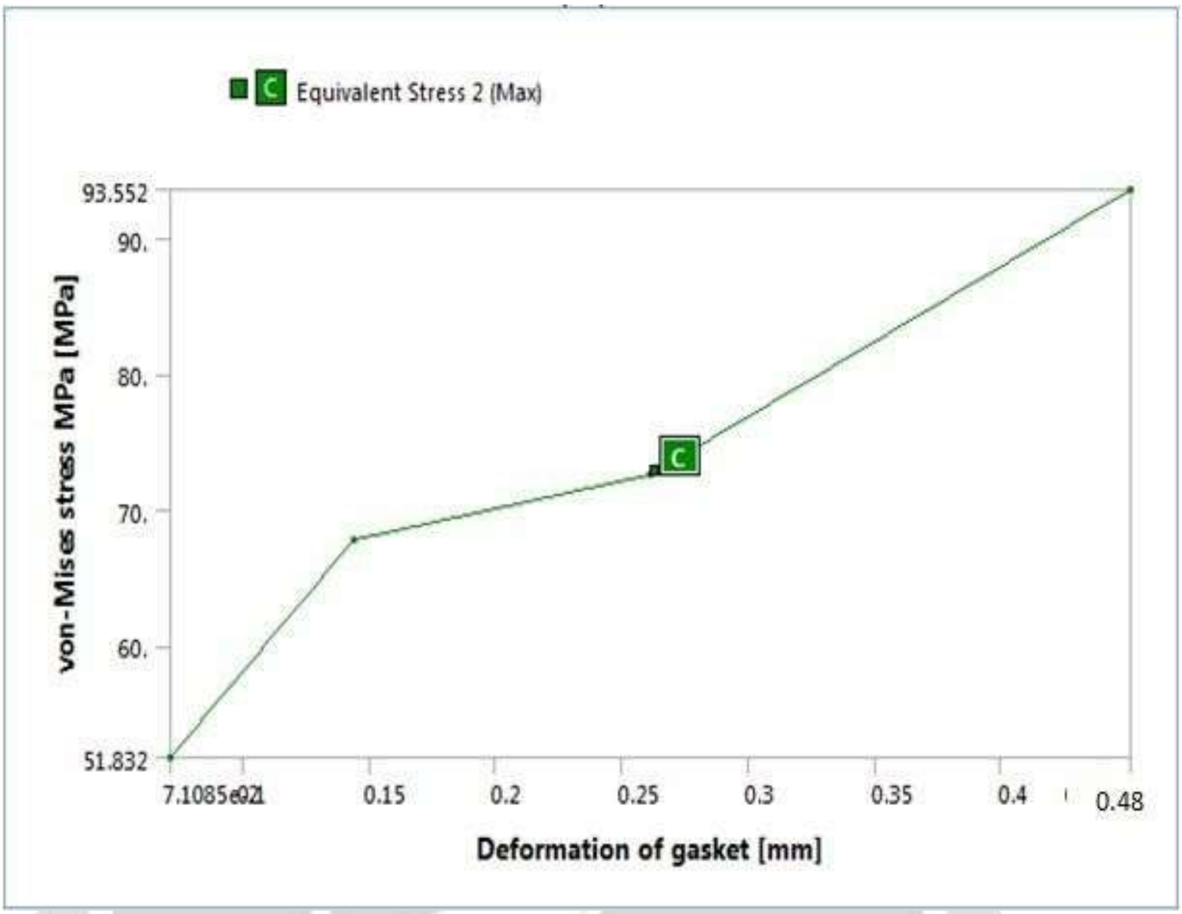
Graphs of The Result:



Graph 7.1: Von-mises Stress Vs Deformation for Gasket 5mm



Graph 7.2: Von-mises Stress Vs Deformation for Gasket 4mm



Graph 7.3: Von-mises Stress Vs Deformation for Gasket 3mm

Result Table:

Table 7.1: Comparison of FEA and Experimental Results

Sr. No.	Load case	Description	FEA Results		Experimental Results	
			Deflection (mm)	Von-Misses stress (MPa)	Deflection (mm)	Von-Misses stress (MPa)
1	Case_1 (Inner pressure _45 MPa)	Gasket – 5mm	0.347	67.94	0.3	64
		Gasket – 4mm	0.39	85.77	0.35	80
		Gasket – 3mm	0.41	87.47	0.4	85
2	Case_2 (Inner pressure _50 MPa)	Gasket – 5mm	0.4	73.27	0.45	70
		Gasket – 4mm	0.46	84.82	0.5	90
		Gasket – 3mm	0.48	93.55	0.55	110

3	Case_3 (Inner pressure_ 55 MPa)	Gasket – 5mm	0.47	80.92	0.45	80
		Gasket – 4mm	0.53	89.27	0.50	85
		Gasket – 3mm	0.55	106.25	0.53	106

It has been observed that the maximum displacement of the gasket observed due to compressive load of the flange upper and lower housing. The displacement contour plots are shown in the table. The gasket shows maximum displacement up to 0.55 mm for 5 mm thickness when load is 55MPa in FEA result and 0.53 in experimentation.

It has been observed that the maximum stress of the gasket observed due to compressive load of the flange upper and lower housing. The stress are shown in the below in table. The gasket shows stress up to 106.25MPa for 5 mm thickness when applied load is 55MPain FEA result and 106 in experimentation.

It has been observed that the minimum displacement of the gasket observed due to compressive load of the flange upper and lower housing. The displacement contour plots are shown in the table. The gasket shows minimum displacement up to 0.347 mm for 3 mm thickness when load is 45MPa in FEA result and 0.30 in experimentation.

It has been observed that the maximum stress of the gasket observed due to compressive load of the flange upper and lower housing. The stress are shown in the below in table. The gasket shows stress up to 67.94MPa for 3 mm thickness when applied load is 45MPain FEA result and 64 in experimentation.

5. CONCLUSIONS

A finite element analysis is carried out performed to investigate the leakage and structural integrity of the bolted flange joint assembly for the design conditions for bolt preload and internal pressure 69 MPa. The deformation of the flange and bolt was studied when subjected to these external loads. This deformation is responsible to induce the stresses in the gasket so that it may get compressed. It was also determined that, the difference between FEA and experimental values are less than 10%. So, it is concluded that, the 5 mm thickness of the gasket is structurally safe to use in the flange and the bolt. The experimental and FEA results are reported in the table. The other parts in the assembly like flanges, nut and bolt exerts minimum stresses that are within yield strength (350 MPa) of the material.

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At last I am thankful to my Father, Mother and Sisters for their valuable support to me for completion of project.

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