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Comparative Study of Formed-In-Place Gasketing Anaerobic and Silicone Chemistry Experimental and Finite Element Analysis

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***Abstract* - A gasket is a material located between two flanges which are retained together by fasteners. By completing filling the gap between the surfaces of the flange the leakage is prevented with the help of gasket. Traditional solid gasket may fail due to relaxation, creep, surface irregularities, due to vibration and thermal expansion. This paper proposes the methodology of testing and validation of the flange joints by the use of Finite element analysis in which chemical compounds are used as a gasketing material. Chemical Gasketing also called FIPG (Formed in place gasket) is the latest offering in flange sealing. Due to pre-developed automation and processing technology Silicone FIPG emerged first in the auto industry. Further development Anaerobic gasketing was also introduced which cure in the absence of air, and its ideal for small flange gaps where they cure rapidly. Anaerobic sealants cure into high modulus thermoset plastic films with good shear strength and comparatively high compressive modulus. The further study evaluates these two different chemistries used in FIPG which are Anaerobic and Silicone and its implication towards sealing functionality in loading conditions.**

***Index Terms* - Anaerobic, Finite element analysis, Formed-In-Gasketing, Silicone**

I. INTRODUCTION

A gasket is a material positioned between two flanges which are held together by fasteners. By completing filling the space between the surfaces of the flange the leakage is prevented with the help of gasket. Traditional solid gasket may fail due to relaxation, creep, surface irregularities, due to vibration and thermal expansion.

Flanges were seal historically with thin paper composition gaskets, or O rings in a grooved flange were employed when shimming was critical and compression set could not be tolerated. The disadvantages of traditional gaskets such as Pre-cut, O rings and profile packaging is that the clamping forces required to be readjusted over time to compensate creep effect. It may also require extensive inventory of several shapes and sizes and sometimes there is leak under vibration, thermal expansion and or improper clamping.

Fig.1 Traditional Gaskets

For applying a reusable elastomer seal to plastic housing and metal Formed-In –Place gasket method is a consistent system and more accurate. The level of flexibility obtained through this method is more. Once the gasket is applied it can be cured in ovens or at room temperature, depending on the time required and material respectively.

The major advantage of using Formed in place gasket in place of traditional gasket is metal to metal contact; Metal to metal contact eliminates the need for gasket thickness, so tolerance can be more accurately maintained. It in turns reduced inventory cost and gasket relaxation is reduced to zero [1].

To obtain the required sealing characteristics and performances on wide range of flanges, two types of Formed-In-Place sealants are used –

Anaerobic Chemistry
Room temperature vulcanizing RTV Chemistry

Anaerobic Chemistry

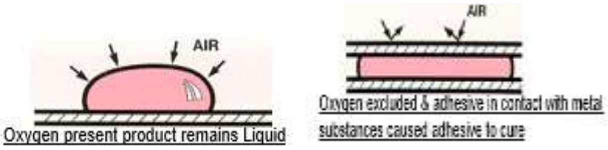

Fig. 2 Anaerobic Gasket

The anaerobic sealants cure in the presence of metal or absence of air and other active surface. Such types of products are well suited for the rigid flange sealing which are made to restrict the movement between two parts and to achieve optimum stiffness between two mating parts.

Silicone Chemistry

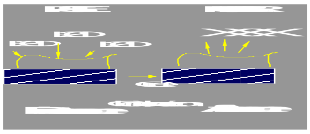

Fig. 3 Silicone Gasket

RTV silicones cure to a rubbery solid by reacting with moisture in the environment. It can be used for stiff as well as flexible joints. Unlike rigid flanges, the function of component is not supported, therefore the optimum clamp load distribution is not necessary and micro movement can be tolerated between the flanges. Silicone sealants are best suitable for flexible flanges because they assure high gap filling and ensures metal to metal contact; with silicone RTV T-joint sealing is also possible it can also create seal on non machined flanges.

II. PROCEDURE OR WORK METHODOLOGY

Material Parameters:

Table 1 Material Parameters for Anaerobic [3] and Silicone Sealant [4]

Anaerobic	Silicone RTV
Young's modulus: 6.0 Mpa Shear modulus: 2.1 Mpa Poisson's ratio: 0.47	Young's modulus: 2.37 Mpa Shear modulus: Poisson's ratio: 0.497

Table 2 Aluminum Properties [5]

Aluminum Alloy
Young's modulus: 71000 Mpa Shear modulus: 26692 Mpa Poisson's ratio: 0.33

Table 3 Silicone Sealant Hyperelastic Properties [4].

Material model(for Silicone RTV)	Approximated coefficients(Mpa)
Ogden 2-terms	μ_1=0.9331; a_1=2.1388 μ_2=5360.1; a_2=0.15971
	d_1=0.770143

Lap Shear Test

This test method is used to determine the shear strengths of the adhesives for bonding metals which are tested on a standard lap-joint specimen under specified conditions of preparation and test. [2]

The lap joint used here is single lap joint. Standard test method for apparent shear strength of single lap joint adhesively bonded metal specimens under tension loading (ASTMD 1002-05). The machine used for the testing purpose of lap shear test is Universal testing machine name "UTM-SHIMADZU MODEL AGI-100KN"

Practical Lap Shear Test

The main objective of the lap shear test according to the ASTMD1002-05 is to calculate load at the failure and nature of failure for each specimen; calculating the shear strength of the adhesive sealant mathematically with the load value obtained from the UTM and the bond area which can be find out manually.

Finite Element Analysis (Lap Shear)

Here in this particular study ANSYS 14.5 is used for the analysis purpose and for modeling CAD, PRO-E is used. The approach used for lap shear modeling is CZM method; the results obtained from CAE are then validated with the practical lap shear test.

The CAE is performed for the both chemistry with different substrate materials and thus comparing silicone and anaerobic adhesive on the basis of the strength of the end application after the bonding. The specimen dimensions used as per standard are 100mm×25mm and thickness of 1.6mm; the overlap area is 12.5mm and the thickness of sealant/adhesive between two specimens is kept to be 60µm.

The approach used for analysis is cohesive zone model, here it has to be understood that the thickness of the adhesive/sealant is very small thus calculating force values from the lap shear model which can be validated with the practical shear test. Total 6 sample test are performed and evaluated in this study.

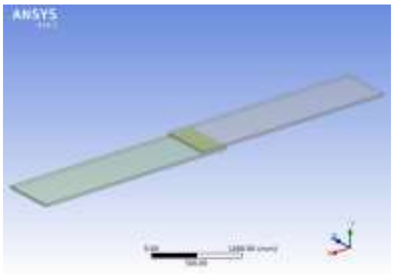

Fig.4 Lap Shear Model

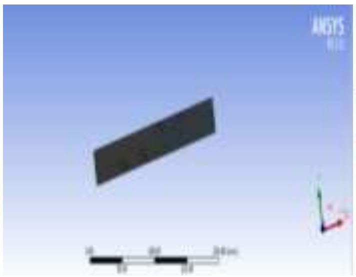

Fig.5 Mesh Model

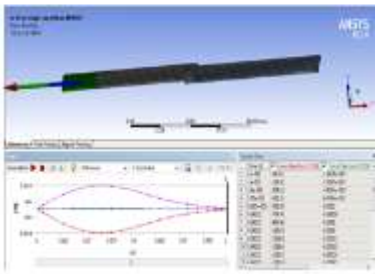

Fig.6 CZM Results

Results and Validation of Lap Shear Test

From the load values obtained in lap shear experimental test the average shear strength of anaerobic sealant is found out to be 4.07Mpa and for the Silicone RTV sealant it is recorded near to 1.48Mpa.

The load results observed in the test are in between 1200N to 1400N for anaerobic sealant which are more as compared to RTV silicone sealant which shows around 400N to 500N. From the results obtained from CAE software the experimental results are validated with minimum error percentage.

Flange Opening Test

From the output of lap shear test next step is to study the gap opening phenomenon on the circular flange application. Testing for such parameter needs high end machinery which in turns measures the displacement and gap opening with help of sensors. Further study involves CAE for the desired displacement, gap opening and comparing both the chemistries.

Fig.7 Circular Flange

Finite Element Analysis (Flange Displacment for Gap Open Behavior)

The model used for the analysis has been modeled in CREO parametric and the particular FEA has been performed at static condition in Ansys 15.0. The objective of this case under the study is to establish comparison between two different chemistries and implicating results obtained from the study on actual application. The analysis is carried out for different loads from 1000N – 10000N for both anaerobic and silicone sealants/adhesive.

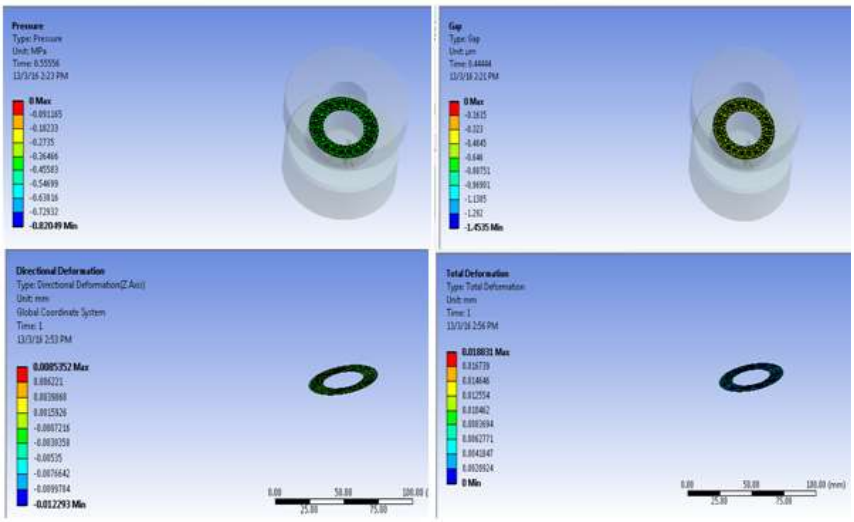

Fig.8 Gap Opening and Displacement of Circular Flange

Results for Flange Displacement and Gap Open

The specimens were tested on Ansys at various load conditions from 1000N to 10000N on both Anaerobic and Silicone Chemistries. The results obtained from the above study are satisfactory; the gap opening and deflection with Anaerobic being a structural sealant is low as compared to RTV silicone. The maximum gap opening at 1000N is observed to be 5.5µm in case of Anaerobic and 14.5µm in case of RTV silicone chemistry or sealant.

III. CONCLUSION

The above study confirms that anaerobic being a structural sealant significantly reduces the deflection across the flange; gap opening under applied load condition is less than silicone and other conventional sealing methods. The future of this research study lies in value engineering or reverse engineering changing the parameter study, design of experiments & optimization of method.

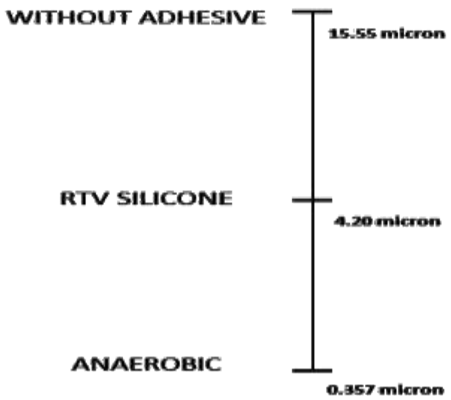

Fig.9 Relative Gap Opening and Deformation in Sealing Application

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