FEA ANALYSIS OF O-RING IN MECHANICAL FACE SEAL

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ABSTRACT

Mechanical face seal is a mechanical device use to join the two static or rotary machines. The only function of mechanical face seal is to prevent the leakage of the fluid. In todays scenario the budding issue is to make the standardise leakage capacity in the industry which is applicable all over world. The impact of pressure applied to the spring housing and then transfer to the rotatory face of mechanical face seal is shown and the deformation occurred in the part of the mechanical seal is analysed in this paper. The simulation is studied on the rotatory o ring and analysis has been done. Material selected for mechanical face seal plays important role in carrying and showing the results. The seal is designed here to withstand the high amount of load and show the failure criteria near the shaft and rotatory face. A number of design change and material changes for the mechanical face seal to withstand the high amount of pressure which is applied on the front face of rotatory face and to fulfil the main function of O ring and that is to maintain the standardise the leakage capacity of fluid. It is very important for the industry to rely on the mechanical seal which has good material property and also the purpose is being fulfilled. Material used in this mechanical seal has lot of merits and easily applicable and also feasible. The FEA analysis carried out in the simulation process is done on COMSOL 5.3 model and the drawing is done in modelling software Solid Work 2017. It is very important to understand the effect of O-ring result with the force applied on it and the design criteria is of immense important criteria in all this.

Keyword: mechanical face seal, COMSOL 5.3, leakage.

1. INTRODUCTION

To prevent leakage from fluid handling equipment such as centrifugal pump, mixer, turbine and compressor mechanical face seal plays a crucial element in industrial machinery. Environment saving is the main focus nowadays for an engineers and keeping this in mind the leakage inside the instrument are not just cut totally out but tried to be in the standard leakage capacity . Mechanical face seal is of two type first the pusher type mechanical seal and the second one is non-pusher type mechanical seal and , in which the current research is going on the rotating O-ring which come under the category of non-pusher type mechanical seal. Mechanical seal is further classified in different segments but for research purpose we are focusing on mechanical face seal. It consist of four working part, one where the analysis are carried out is on the rotating O-ring. Rotational phase is a part in which it rotates in the parallel motion with the shaft and o ring attached in it also rotate with the same dynamic motion as of shaft. In this research the clearance of 0.02micron is given in between the shaft and O-ring but there is no clearance provided in between the O-ring and the rotating face. The main analysis is been done in between the rotating O-ring, shaft and rotating face and also the distortion occurred due to contact analysis of rotating o ring and rotating shaft. The seal faces cannot be permitted to run dry due to frictional heat build-up will be very quick causing severe seal face damage and extensive leakage. They are designed to allow a very thin film of liquid to exist between and migrate across the seal faces. In a centrifugal pump, the mechanical seal (referred to as the “shaft seal assembly”) prevents the water that is being pumped from entering the bearing housing of the pump or simply the area between the motor face and the volute where the shaft passes through. This is not the same seal as the motor lip seal (or wiper seal), a part of the hydraulic motor that seals the motor shaft at the motor face and prevents any liquid from entering the hydraulic motor.

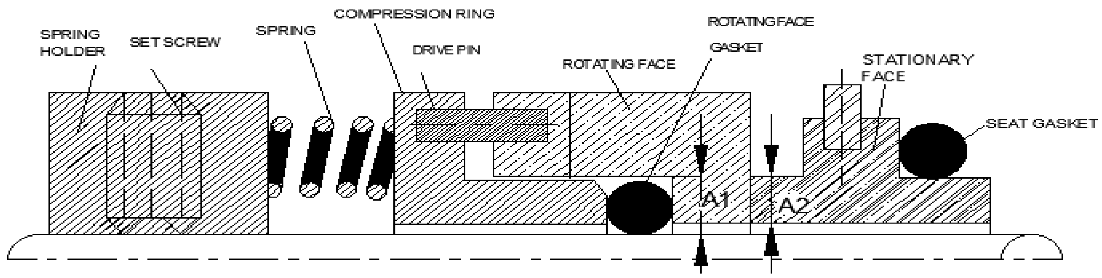
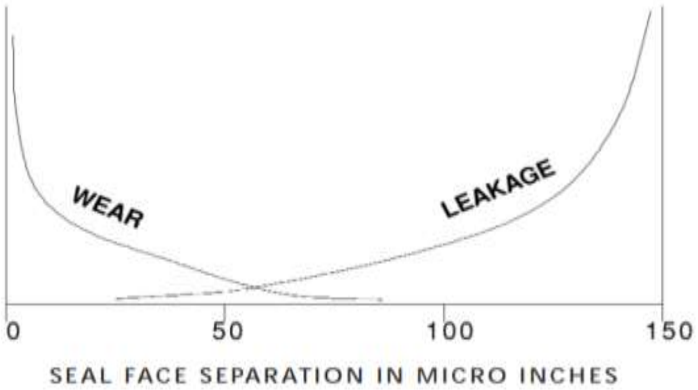


Fig: 1 Mechanical seal

2. PURPOSE & OBJECTIVE

Colfax is a production based company which is famous and master in production of mechanical seal and other mechanical parts. the major problem was noticed by the company that as the clearance between rotatory and stationary face increases the leakage increases and as the clearance decreases between the two faces the heat generation increases as we can see in the figure given by the company itself. So there are two objective of doing the research the first one is to standardise the leakage capacity of fluid by maintaining the proper clearance between the two faces and the second is to prevent the disaster on the environment which occur due to the leakage of harmful fluid. In the research the main objective was to select the material for the 0-ring and rotating face so that first it should be easily available and second it should be long life sustainability. The boundary condition for the analysis is also the bottleneck of this research as for example of selecting the fixed constraint and to the load applied. As an engineer we have to consider in mind that the environment prevention and safeguard them is the first and foremost important task we have to do. In this research the main focus was on the first segment of the mechanical seal that is the rotatory O-ring, shaft and the rotatory mechanical face seal.



The aim of the research is to analyse and suggest the material for the mechanical face seal for first segment on applying the mechanical pressure that is uniform load on the front surface of the rotatory face.

3. MATERIAL PROPERTY

Mechanical seal are used continuously in the industrial sector on daily basis. It is highly important for the device to fulfil its purpose of designing that is to prevent the leakage and for long lasting which will enhance the performance of the centrifugal pump and also will not hamper the environment which nowadays are the main concern of study. To design the mechanical face seal we have to mainly focus on the dimensions and also the uniform pressure applied on the upper surface of rotatory face. Mechanical seal has a wide range of its own dimension based on different material selection including ceramic, elastomer and ceramic. In the research, the material of the shaft, O-ring, rotating and stationary face are selected on the given materials. Material of the shaft selected is structural steel which carries the density of 7850 kg/m^3 in basic. The mass per volume ratio of the material should be kept in balanced so that it can withstand the mechanical pressure. Young modulus for the material taken is 200e9 pa, in this the resisting force per deformation should be minimum range so that it does not form any deformation in shaft when the application of fluid or mechanical pressure. Poisson's ratio is taken as 0.3 and the rest of the property of structural steel for shaft was provided by the software itself. To absorb the high pressure in rotating face it is necessary to study the material and then analyse the simulation, so for this the material which was taken for rotating face was same as the shaft. The O-ring plays a major role in the mechanical seal and firstly the project research has been focused in this part on it . The material selected was PTFE (Polytetrafluorethylene) for both the rotating and stationary face also. Point to be ponder here is the material is creep resistant, it has resistant to corrosion and also it repeal water and oil. Density taken for this material is 2200 kg/m^3. Young modulus is 0.4e9 pa and the Poisson ratio is 0.46. The O-ring is attached to shaft leaving no clearance but with the rotating face it has clearance of 0.02mm so, the property given to the material is moderate not so highly resistive and not too flexible. The other property of the material was provided by the software itself. While selecting the material of the shaft, rotatory and stationary face and O-ring, mechanical properties are always kept in mind such as

1) Strength
2) Elastic property
3) Thermal Property
4) Surface energy
5) Tribological Property

With all the consideration of the property as an engineer we must think about the consequences or the mode of failure by considering the required material. The mode of failure could be

1) Fracture
2) Surface Crazing
3) Face Pitting and scoring
4) Face blistering
5) Squeal.

For getting an efficient result the material selection is very important and for this the above mentioned things must be kept in mind.

- Material Property of Shaft.

	Property	Name	Value	Unit	Property group
☑	Density	rho	7850[kg/m^3]	kg/m³	Basic
☑	Young's modulus	E	200e9[Pa]	Pa	Young's modulus and Poisson's ratio
☑	Poisson's ratio	nu	0.30	1	Young's modulus and Poisson's ratio
	Relative permeability	mur	1	1	Basic
	Heat capacity at constant pressure	Cp	475[J/(kg*K)]	J/(kg·K)	Basic
	Thermal conductivity	k	44.5[W/(m*K)]	W/(m·K)	Basic
	Electrical conductivity	sigma	4.032e6[S/m]	S/m	Basic
	Relative permittivity	epsilonr	1	1	Basic
	Coefficient of thermal expansion	alpha	12.3e-6[1/K]	1/K	Basic
	Young's modulus	E	2009	Pa	Basic
	Poisson's ratio	nu	0.3	1	Basic
	Murnaghan third-order elastic moduli	l	-3.0e11[Pa]	N/m²	Murnaghan
	Murnaghan third-order elastic moduli	m	-6.2e11[Pa]	N/m²	Murnaghan
	Murnaghan third-order elastic moduli	n	-7.2e11[Pa]	N/m²	Murnaghan
	Lamé parameter λ	lambLame	1.15e11[Pa]	N/m²	Lamé parameters
	Lamé parameter μ	muLame	7.69e10[Pa]	N/m²	Lamé parameters

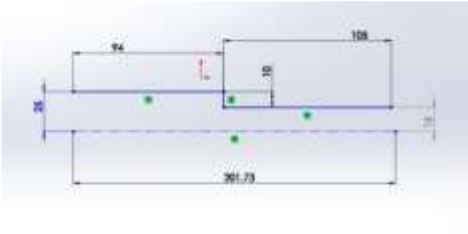
- Material property of Rotatory O-ring, Rotating face, Stationary face.

	Property	Name	Value	Unit	Property group
☑	Density	rho	2200[kg/m^3]	kg/m³	Basic
☑	Young's modulus	E	0.4e9[Pa]	Pa	Young's modulus and Poisson's ratio
☑	Poisson's ratio	nu	0.46	1	Young's modulus and Poisson's ratio
	Coefficient of thermal expansion	alpha	100e-6[1/K]	1/K	Basic
	Heat capacity at constant pressure	Cp	1050[J/(kg*K)]	J/(kg·K)	Basic
	Relative permittivity	epsilonr	2	1	Basic
	Thermal conductivity	k	0.24[W/(m*K)]	W/(m·K)	Basic

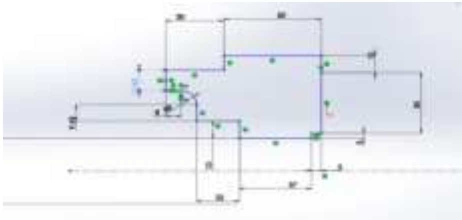
4. Computer Aided Design of Mechanical Seal

As per the work plan presented, firstly it is important to finalize the standard dimension geometry of mechanical seal. The standard geometry was designed in SOLID Work 2017 software part wise and then it was assembled all together.

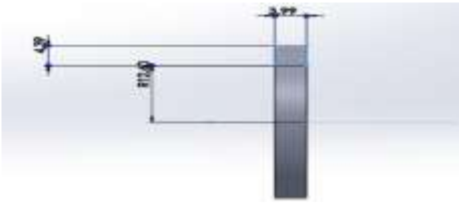
- Rotating Shaft



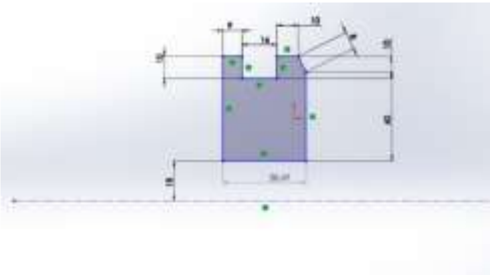
- Rotating Face



- Spring Housing



- Stationary face



- Rotating O-ring

- Stationary O-ring

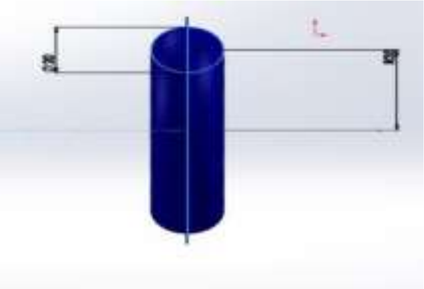


Fig: 2 Face geometry as per standard dimension [EN 12756- Mechanical seal,

ISO 21049 & API 681 – Shaft]

After the successful design of standard dimension of mechanical face seal geometry in SolidWork 2017 software the next process was mounting of the different part with accurate clearance so that the motive of standard leakage in the industry can be fulfilled.

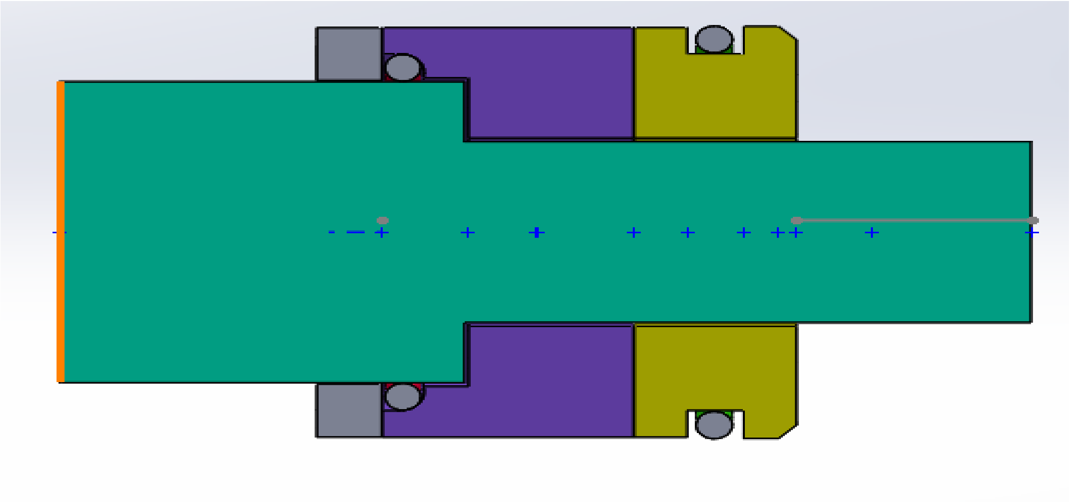


Fig 3: Section view of front plane

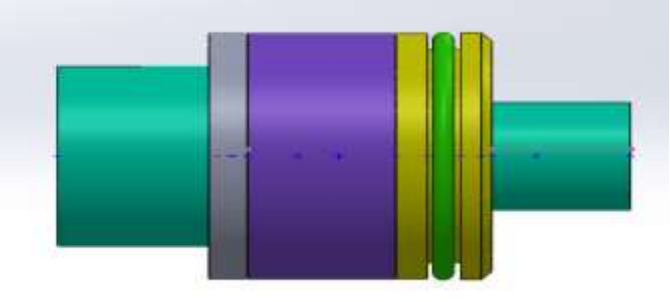
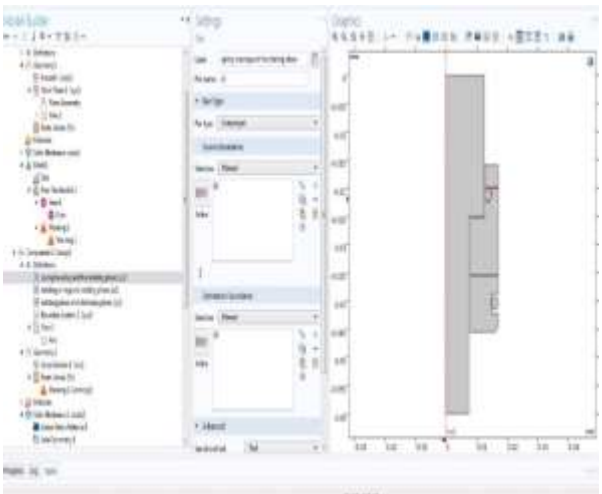


Fig 4: 3D View of front plane

After the design of the mechanical face seal geometry and mounting the second most important thing is the material they are holding. In COMSOL 5.3 software the material are in built and we have to select the material out of all that by getting into all the research of mechanical face seal.

4.2 Finite Element Analysis of Mechanical Seal

COMSOL Multiphysics 5.3 is a finite element analysis and Multiphysics simulation software. COMSOL provide unified workflow for electrical, mechanical, fluid and chemical application. In this research we have used the mechanical base with 2D axisymmetric and structural mechanics. The seal analysis can be performed for steady state conditions where there is continuous operation at constant application condition, by COMSOL 5.3. The engineers using this software input a numerical interpretation of the mechanical seal by providing geometric seal component details, material properties, process fluid details and boundary condition that define the environment of the seal. Based on this input the software calculates service dependent seal performance values such as power loss, face gap, leakage, fluid film stability and condition, asperity contact, if present, etc.



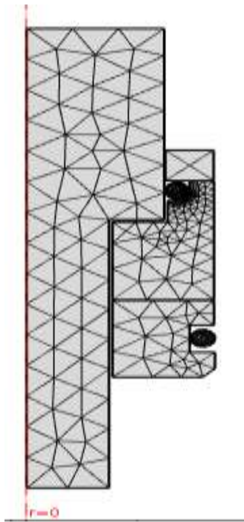


Fig 5 (a) : COMSOL 5.3 software model Fig 5(b):COMSOL 5.3 software meshing

5. RESULT and DISCUSSION

5.1 WORK IN PROGRESS

As discussed in the above material selection of the mechanical face seal for maximum efficiency and to decrease the environment damages, the design and material plays important role. While solving in COMSOL 5.3 software there are different type of error occurred which will be discussed in the given topic.

Fig 6 (a) deal with the error after meshing was error in Multiphysics compilation which leads to illegal domain selection in pair:p1. The above mention error meant that the domain selected at O-ring and rotating face in between had a problem of clearance given property and also the material selection as earlier it was selected was Graphite 3474 A which can be only used for low pressure and when used in the software applied load was not showing any result as stress generation. So the failure occurred and the solution for this was to select the different material which can bear the high pressure and can stand the hydraulic pressure too.

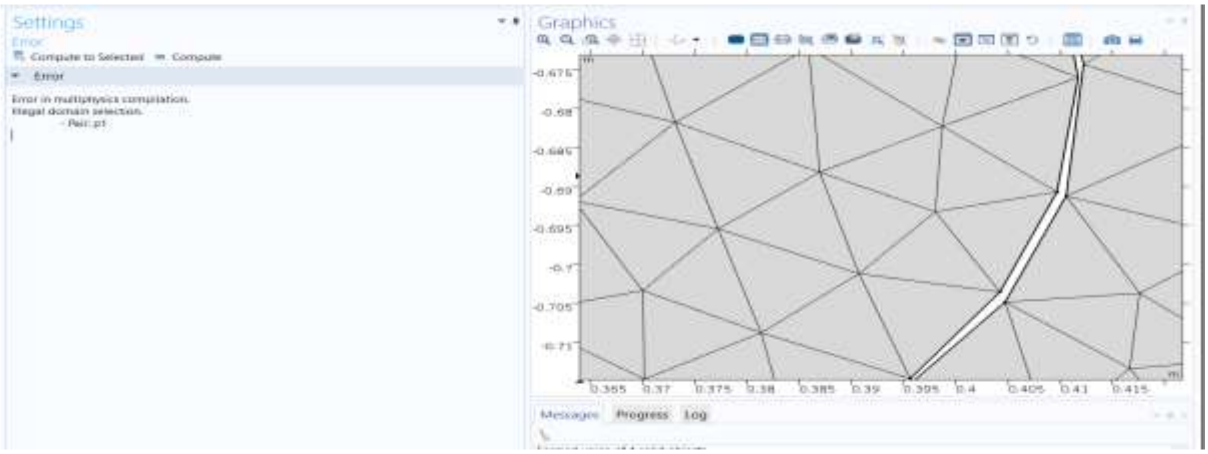


Fig 6(a) : Error in solving the problem

In fig 6(b) deal with another set of problem after meshing in the face between the rotating and stationary. The set of error in the given figure was undefined variable in source offset, which means in giving the clearance.

By failing to evaluate the expression of the boundary deals with the Jacobian expression. As in the figure it is clearly mentioned the mess area which is being predefine.

Fig 6(b) : Error in solving after mesh

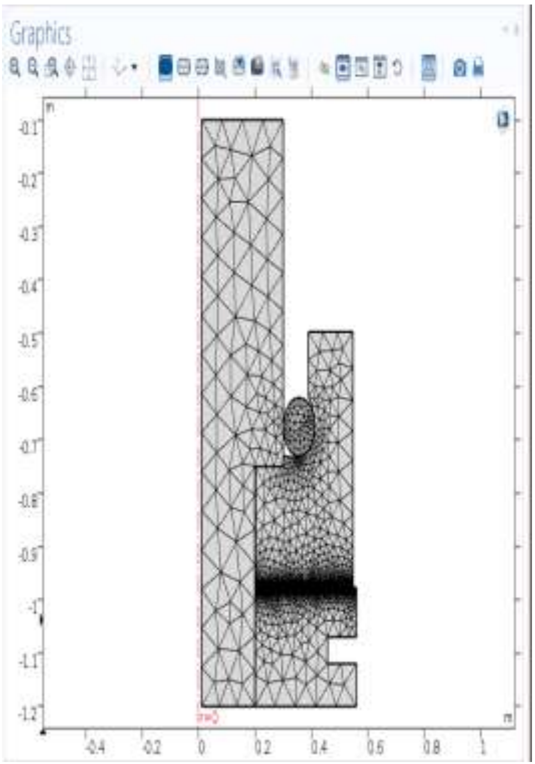


Fig 6(c): Error while meshing

5.2 RESULT

Fig 7(a) shows the stress generation between the shaft and rotating face. Boundary condition applied in the COMSOL 5.3 software at the rotating face, the O-ring and the shaft. At the top of the rotating face, upper half of the O-ring and the side of the shaft portion, the uniform distributed force is applied of 5000 pa and a fixed constraint is applied at the outer surface of the rotating face. As in the first phase the consideration is done only for the mechanical force which will be applied by the spring to front surface of rotating face. The analysis between the rotatory and stationary face will not be observe as the force applied by the fluid is resistant by spring which work as a damper and only the result is visible on the rotatory O-ring, shaft and the rotatory face.

In fig 7(a) the stress generation at 5000 pa is high near the shaft and rotating 0ring as because there is no clearance given between them due to the same rotating condition but the clearance is provided between thee O-ring and the rotatory face to keep eye on the wear condition which will lead to the heat generation and can hamper the face seal and will not be able to fulfil its function. Fig 7(b) and Fig 7(c) gives the clear focused view of the von mises stress generation at the shaft and O-ring but the less von mises stress generation at the rotatory face and O-ring which gives the benefit of selecting the material as mentioned above.

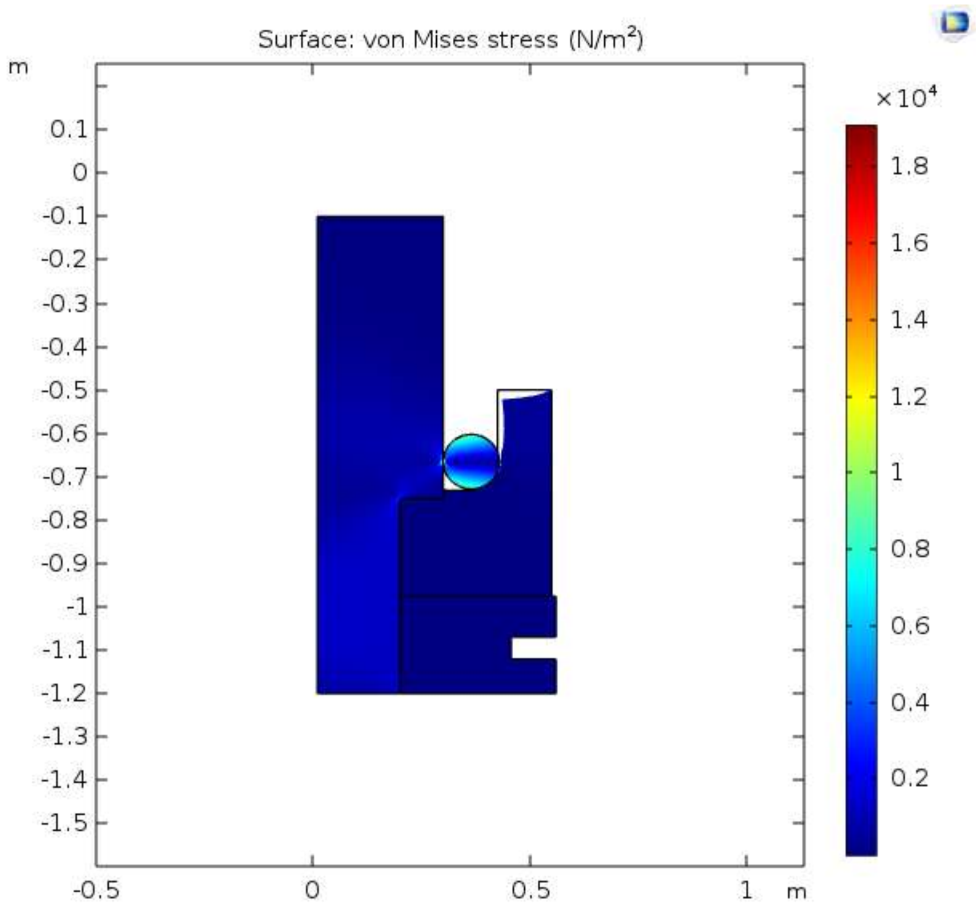


Fig 7(a): Stress generation between rotatory O-ring, shaft and rotatory face seal

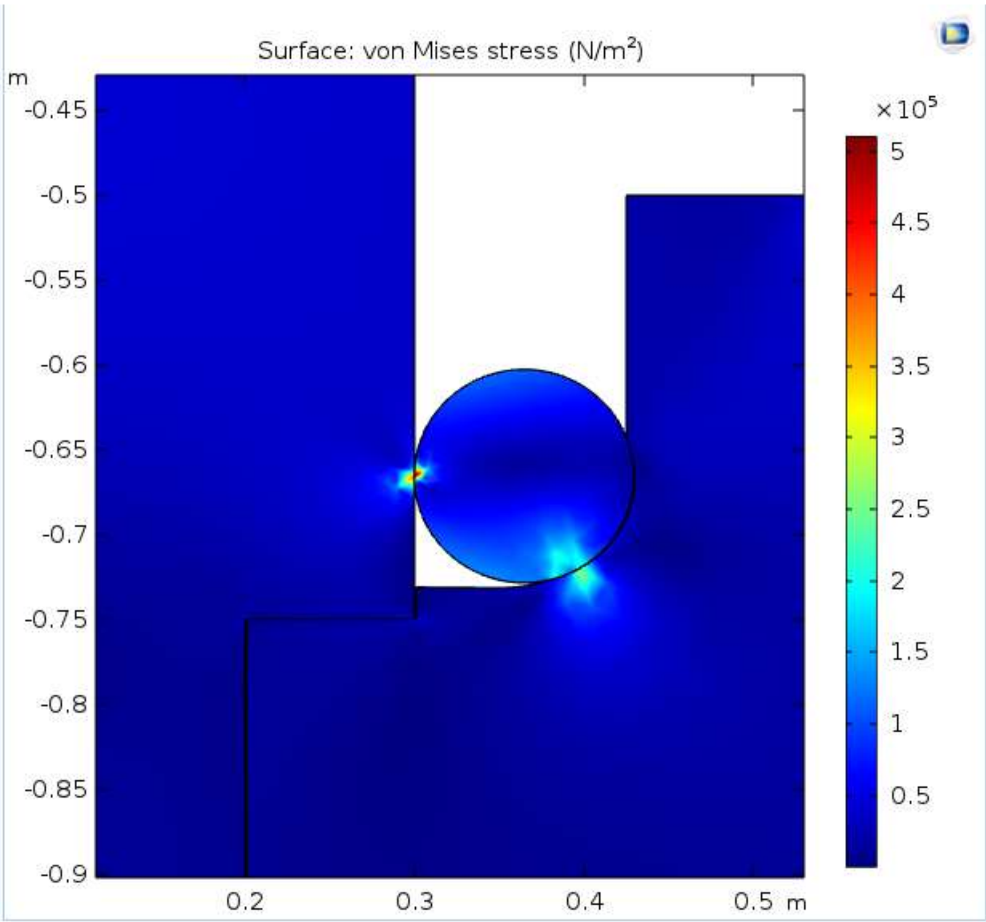


Fig 7(b): von mises stress generation between shat and O-ring

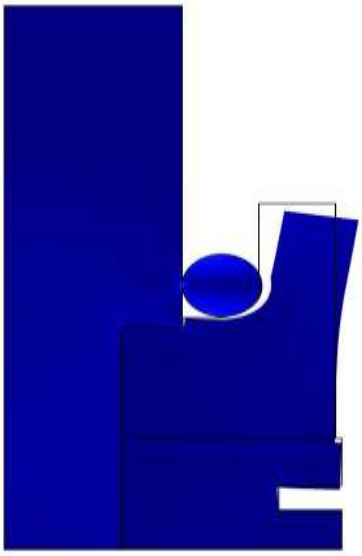


Fig 7(c): Failure of the mechanical face seal

Fig 7(d) defines in the given COMSOL 5.3 software shows that the von mises stress generation at the rotatory face and the O-ring at 5000 pa is less but on increasing the pressure there is chances of failure of the O-ring due to von mises stress which will lead to wear and heat generation. Basically the material selected in this research is good for the face seal.

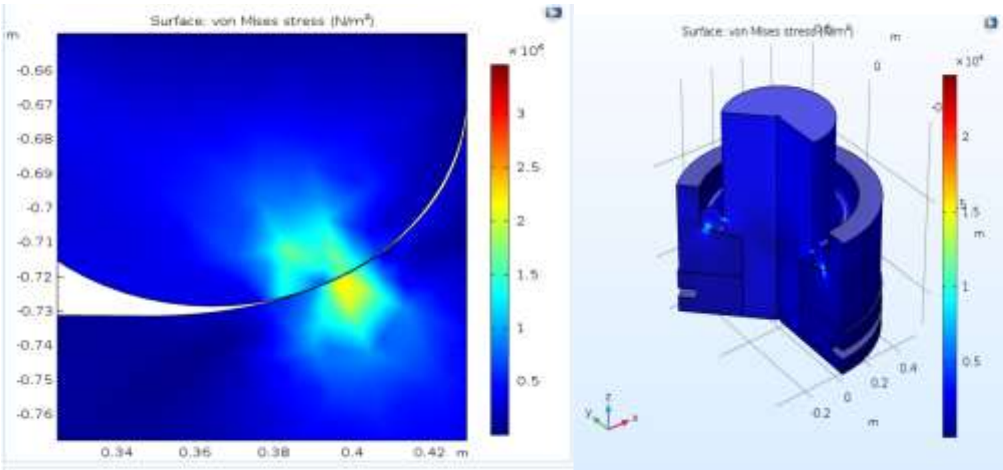


Fig 7(d): Von Mises stress between O-ring and Rotating face and 3D view

6. CONCLUSION

With stationary mechanical face seal the zero league condition requires a continuous solid to solid point contact around the rotatory O-ring and shaft, Rotatory face and shaft. The selection of material in mechanical face seal plays a important role. Boundary condition applied to the rotatory face on the top view was studied and analysed the reaction on the shaft and rotating face. The point contact pair was selected on four different region but we saw the result only at two different places the reason behind this was that the application of uniform pressure of 5000 pa was given directly to the spring and from spring it was transferred to rotatory face by this distribution the force was absorbed in spring and the rest amount was transferred so because of that less deformation was seen in the seal and only at two contact region.

Here forth at the end we conclude that the selection of material to the shaft and the O-ring was given with significant observation.

Boundary condition applied to the material was accurate and fixed constraint played its important role. Meshing of the mechanical seal was customized at the four contact reason to see the minute von mises stress and deformation in the seal. All total the result was observed to be worked for the pressure up to 5000pa and can withstand the load till that after increasing the load the mechanical face seal can show the failure in the shaft and O-ring contact region due to generation of wear and heat. The three dimensional view was also studied in the research. COMSOL 5.3 software was used for the simulation purpose whereas Solid Work 2017 was used for the designing purpose in three dimensional.

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