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Vol. 32, No. 4. \ 2024 ISSN: 2616 - 9916

Rubber Seal used in Self-drill Bolt from an old Tire Tube by Design a using Finite Element Analysis Method

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Received:	29/5/2024	Accepted:	24/7/2024	Published:	14/8/2024

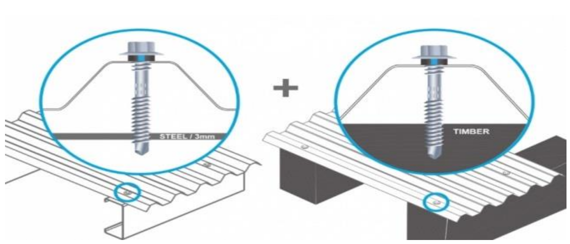
Abstract: -

This paper looks for the possibility of using a seal, formed from an old truck's tube, in self-drill bolt to mount sheets on solid frame. A general study of a seal's strength in self-drill bolt is performed with Ansys workbench 2022R1, which is a finite element model software to analysis the stresses and deformations. Two types of rubber's seal are used in the analysis, Neoprene and Elastomer, the elastomer is an equivalent rubber of tire's tube. The metal washer, which is a part of self-drill bolt and located above the seal, is involved in all the simulations. Also, the shape of metal washer is considered in analysis for both rubber's types. The shape used in the simulation are a semi conic and conic. Because there are several rubber's types and metal washer's shapes, five different modeling analyses are made with Workbench 2022R1. All dimensions and sizes of the parts in all modeling are taken from dimensions of the real parts available in local markets. The results show the tube's rubber is a good replacement and has the best results with conic metal washer. In the case of not using tube's rubber, a Neoprene seal bonded to conic metal washer is a second good choice. To make sure of the success of tube's rubber, a simple experiment is made and its results approve, without debt, the possibility of using tube's rubber as a seal.

Keywords: Stress, Deformation, Pressure, Impact, Friction, Displacement

Introduction: -

The self-screw bolt or self-drill bolt is used to mount a sheet in the roof or in the window awning to the solid frame as shown in Figure 1. The function of the rubber seal in self-drill bolt is to create a leak proof part in the sheet i.e. it prevents the droplets of water or rain to be penetrated through the hole in the sheet and reach beneath the ceiling which might cause corrosion in roof and damage to the stored items as well [1].



a- self-drill bolt

b- awing window

Fig. 1 self-drill bolt and metal awning window [1]

There are many types of self-screw bolt but the most popular one used in the roofing and window awning is hexagonal with flange as shown in Figure 2 [1]. The self-screw or self-drill bolt consists of three parts, which are the metal washer, seal, and the bolt. The task of metal washer is to distribute the load, resulting in tighten the bolt in, on the rubber seal. This type of self-drill bolt provides the user or worker flexibility in handling especially when using hex socket driver for installation [2].

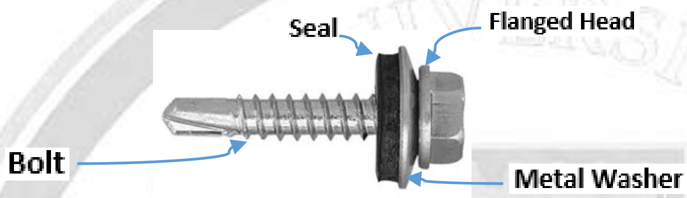


Fig. 2 Self-drill Screw [1]

The rubber seal is most part expose to failure in the self-screw bolt [3] and therefore, it causes the droplets of water or rain to be penetrated through the hole in the sheet and reach beneath the ceiling. That is the reason why sheet or metal sheet window awning is not popular in Iraq despite of its being lighter weight, less cost and having a nicer shape as a compare with concrete one, which is a rained forced cantilever beam extended from main construction [4] as shown in figure 3. Therefore, this paper is to study the loads of the rubber seal and its strength besides the possibility to use alternative or a replacement seal from an old tire's rubber tube.

Fig. 3 the reinforced concrete awning

Commercially description of self-drill bolt: -

Manufacturers produce different types of self-drill bolt depending on customers' request. In most cases, there is no standard specification can be followed in manufacturing the self-drill bolt i.e. the dimensions and materials' type of the rubber and the metal washer differ depending on customer demands [2]. But the main type of self-drill bolt used to amount sheets to solid frame is 10 mm hexagonal with flange as shown in Figure 2 [2]. The flange or washer's face of the bolt works as bearing surface [5]. There are two standard rubber's types usually used in seal of self-drill bolt, which are Neoprene and EPDM. The EPDM is abbreviation of Ethylene Propylene Diene Monomer. Neoprene has more ability to resist flame, gas and oil than the EPDM but EPDM can tolerate higher temperature and less cost [6]. In some markets, the self-

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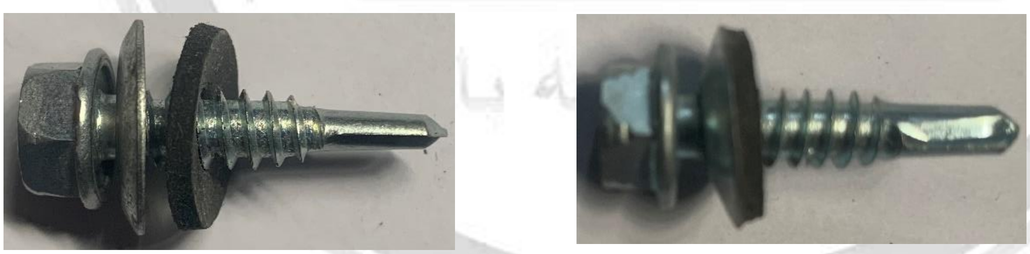
drill bolts are sold separately i.e. metal washer and seal are separately sold to be gather later with the self-drill bolt before tightening in. In such form, the rubber seal is usually bonded to the metallic washer and the latter has conic shape as shown in figure 2 [7].

Dimensions used for Modeling: -

In Iraqi markets, it can be said that the only one size available is a 10 mm hexagonal with flange self-drill bolt. This 10 mm self-drill bolt comes in different lengths depending on the application. Also, the metallic washer, rubber seal and self-drill bolt are previously assembled, as shown in figure 2 above, to be tightened in at once. The metal washer comes with different shapes like conic or semi conic as shown in figure 4. The rubber seal comes separate from metal washer or come bonded to metallic washer as shown in figure 5. The dimensions of the metallic washer and rubber seal are different from one-part shop to another. Therefore, in this paper, two shapes of metallic washer and rubber seal will be tested according to dimensions computed as average of different dimensional measurements of the parts.

Semi conic metal Washer **Conic metal Washer**

Fig. 4 Pictures of Metal Washer



a- Seal is separated from Washer **b- Seal is bonded to Washer**

Fig. 5 Self-drill Bolt with separated or bonded Seal

Sizes and dimensions used in the simulation:

Both the semi conic and conic metal washers are considered in the Finite element analysis. Also, a separate rubber seal and boned rubber seal are considered too. The self-drill bolt is neglected in the analysis but its effects on the metal washer are highly considered in the modeling. Many self-drill bolt samples are picked up from different tool shops and a measurement is done for each sample's dimensions. So, the dimensions used in all simulations are based on the average of the samples' dimensions. The washers and seal are drawn using

Catia software v5r17 as shown in Figure.7a, b, c besides the dimensions are indicated there too which are the dimensions that will be used in Workbench simulations.

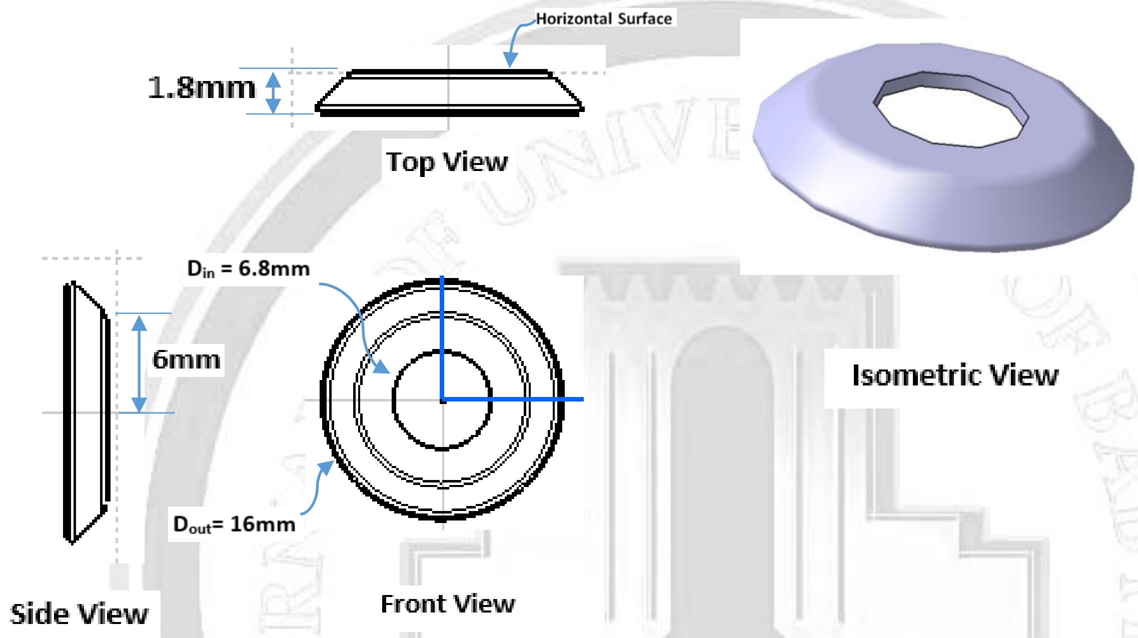


Fig. 6a Semi Conic Metal Washer and its Dimensions

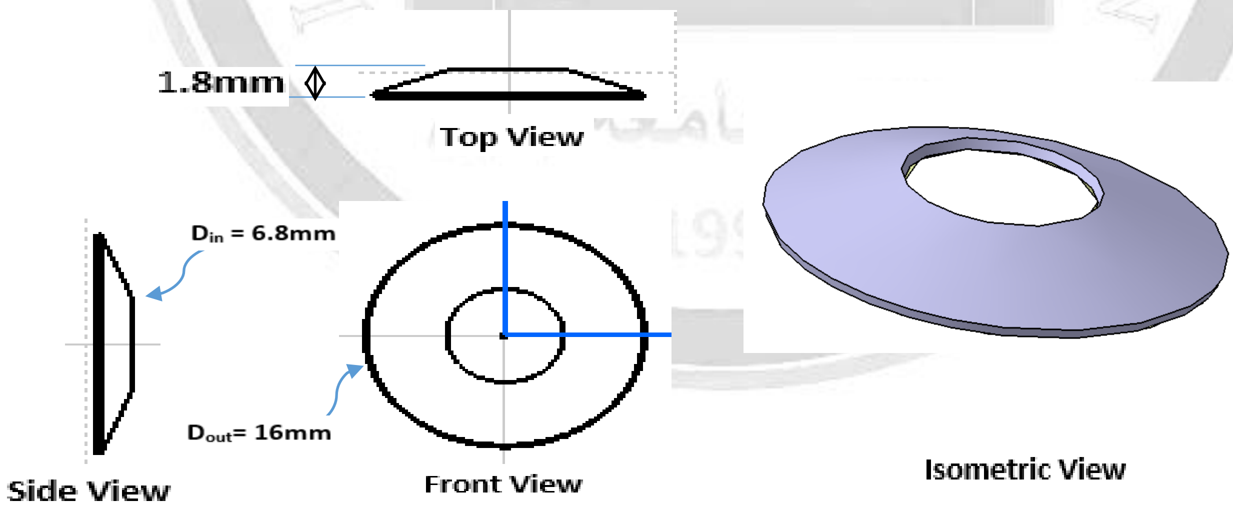


Fig. 6b Conic Metal Washer and its Dimensions

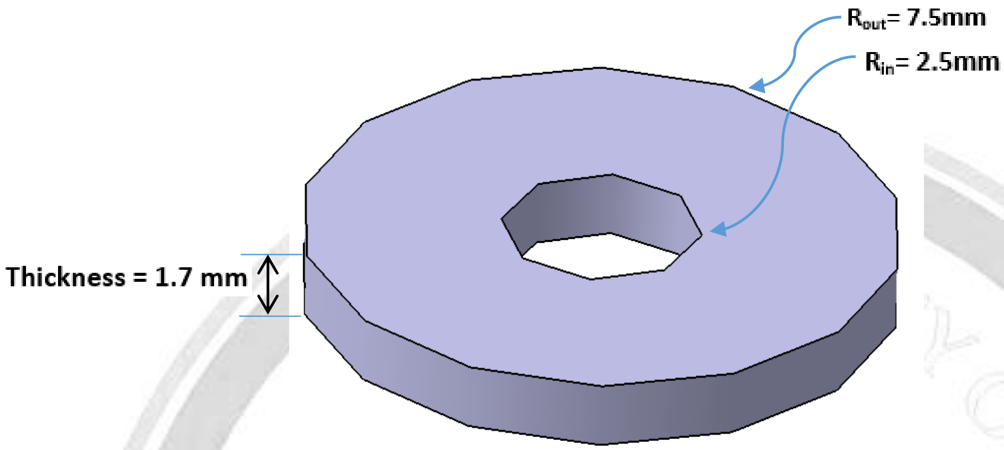


Fig. 6c Rubber Seal and it's Dimensions

Note: The thickness of the rubber seal, used in all simulations, is 1.7 mm which is the same thickness of the tire's tube and, by coincidence; it is the same average thickness of self-drill bolt's seal brought from tool shops.

Modeling forms:

As previously explained, two standard rubbers are usually used in seal manufacturing, which are Neoprene and EPDM, but to save time and size of this paper, only Neoprene rubber is considered here in simulations and be compared with tire's tube rubber.

Because, in this research, there are two rubber's types and two metal washer's shapes as well as rubber bonded to metal washer's case, five different forms of Finite Element Modeling are built as described below:

1. Modeling for semi conic metal washer and Neoprene rubber seal. This modeling is called, in this paper, Semi and Neoprene simulation for recognition.
2. Modeling for semi conic washer and tire's tube rubber seal. This modeling is called, in this paper, semi and tube simulation for recognition.
3. Modeling for Neoprene rubber seal bonded to conic metal washer. This modeling is called, in this paper, boned Neoprene simulation for recognition
4. Modeling for conic metal washer and neoprene rubber seal. This modeling is called, in this paper, conic and Neoprene simulation for recognition
5. Modeling for conic metal washer and tire's tube rubber seal. This modeling is called, in this paper, conic and tube simulation for recognition

The first two modeling are for checking the deformation and stresses of both rubbers' types (Neoprene and tube's rubber) when using a semi conic washer shape. While the other three modeling are for the same purpose but when a conic washer shape is used. Also, in the case of bonded Neoprene, the modeling is with only Neoprene rubber i.e. there is no modeling for tube's rubber as bonded to the washer because the tube's rubber seal is formed in local industrial shops and is not bonded to any washer. Also, in the case of bonded Neoprene, an extra part is added to modeling, as will be shown later in Figure 14, to represent the effect of solid frame because both bonded rubber and washer will simultaneously move down and be in touch with that solid frame.

The results, obtained from all these five analyses, will show if the tire's tube rubber seal can work probably as a compare to Neoprene rubber seal. Also, the results will show which washer's shape is the best for the seal in case of using tube's rubber and neoprene rubber. The bonded Neoprene simulation will show deformation and stresses and will be compared with other corresponding simulations

Because an impact driver is used to tighten the self-drill bolt in, as shown in Figure 7, an Explicit Dynamic analysis is used for all five modeling. The Explicit Dynamic analysis itself is a nonlinear modeling [8] and the rubber material is nonlinear modeling too [9], so the resultant modeling will be an extremely nonlinear modeling which require huge time for solving and need a lot of settings in program's details.

Fig. 7 Use of an impact Driver to tighten the Bolt in

Based on the reasons above, a two dimensional finite element analysis is used for the first two modeling related to semi conic washer. While, for the other three modeling related to conic washer, a three dimensional modeling with quarter the geometry is used.

Material Properties:

The washer material is structural steel which its specifications are in Workbench 2022R1 library. As it was previously explained, two rubber's types will be used in the analysis, which are Neoprene and tube's rubber, some processes of curve fitting will be made for each rubber's type.

1. For Neoprene rubber: the mechanical properties of Neoprene rubber are in ANSYS WORKBENCH 2022 R1 library. A process of fitting the uniaxial test data, biaxial test data, and shearing test data is done in the software by using 3rd order Ogden model which is recommended for compressive load [10]. The strain energy potential equation for (3rd order Ogden form) model is [10]:

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$$W = \sum_{i=1}^{N} \frac{\mu_i}{\alpha_i}\left(J^{\alpha_i^{1\,3}}\left(\bar{\lambda}_1^{\alpha_i} + \bar{\lambda}_2^{\alpha_i} + \bar{\lambda}_3^{\alpha_i}\right) - 3\right) + \sum_{i=1}^{N} \frac{\mu_i}{\alpha_i \beta_i}\left(J^{\alpha_i \beta_i} - 1\right)$$

<u>Where:</u>

W is the strain energy potential

$\bar{\lambda}_1^{\alpha_i}, \bar{\lambda}_2^{\alpha_i}, and\ \bar{\lambda}_3^{\alpha_i}$ are deviatoric principal stretch

J is the determinant of the elastic deformation gradient

$N, \mu_i, \alpha_i, and\ \beta_i$ are the material constants

The fitting curves, resulting in 3rd order Ogden modeling, are shown in Figure 8 after computing all parameters and constant with Workbench 2022 R1.

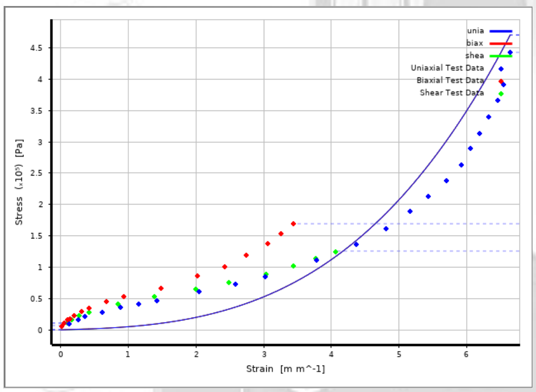

Fig. 8 Curve Fitting for Neoprene Rubber

2. Elastomer rubber: the tube's rubber specifications are equivalent to those of elastomer rubber in Workbench 2022 R1 material library when using Yeho fitting model based on the results obtained from practical experience in a former paper [11]. So, the uniaxial test data, biaxial test data, and shearing test data are fitted by using 3rd order Yeho modeling to obtain curves with a minimum error [12]. The strain energy function for the third order Yeho hyperelastic model is [11]:

$$\psi = C_{10}(\bar{I}_1 - 3) + C_{20}(\bar{I}_1 - 3)^2 + C_{30}(\bar{I}_1 - 3)^3 + \frac{1}{d_1}(J-1)^2 + \frac{1}{d_2}(J-1)^4 + \frac{1}{d_3}(J-1)^6$$

Where: -

C_{10}, C_{20}, C_{30} are material constants

d_1, d_2, d_3 are incompressibility parameters

$\bar{I}_1$- is the deviatoric first principal invariant

J is the Jacobian

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After computing all the parameters and constants with Workbench 2022R1, the fitting curves resulting in 3rd order Yeho modeling, is shown in Figure 9:

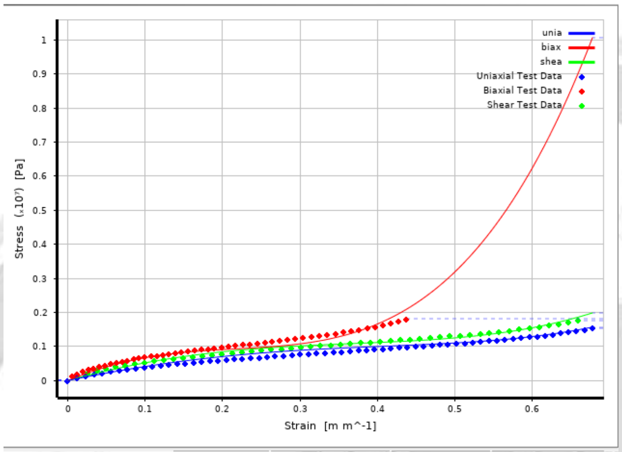

Fig. 9 Curve Fitting for Elastomer (Yeho)

Meshing Type: -

To get a homogenous mesh and uniform distribution of elements, several options were followed in mesh details and a quadrilateral element type is used for two dimensional simulations while a hexahedron element type is used for a three dimensional modeling [13]. The explicit dynamic analysis is very time consuming therefore the number of elements should be as little as mantaining enough accuracy in simulation. All elements have linear order and the table.1 below shows meshes details for all five modeling.

Table 1 Mesh Details

	Process	Size of element (m)	No. of elements	No. of nodes
1	Semi and Neoprene	$3*10^{-4}$	1218	1338
2	Semi and Tube	$3.12*10^{-4}$	1223	1346
3	Bonded Conic	$3.2*10^{-4}$	3058	4572
4	Conic and Neoprene	$3*10^{-4}$	2558	3690
5	Conic and Tube	$3*10^{-4}$	2558	3690

In the table above, the number of elements includes the elements of metal washer and rubber seal only but, for the bonded conic washer, the number of elements includes the elements of extra piece of frame besides elements of washer and seal therefore, it has the highest number of elements and nodes. Figure 10 shows the mesh of two and three dimensional modeling.

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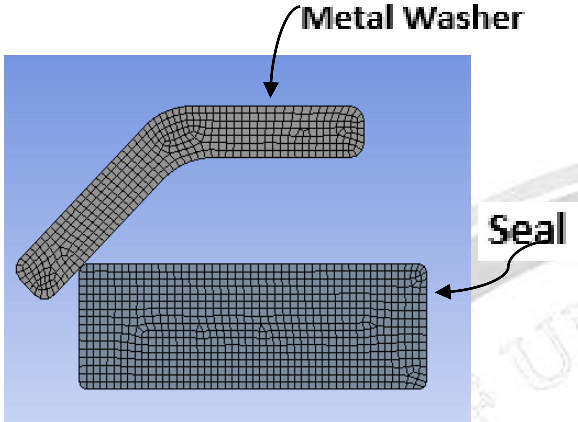
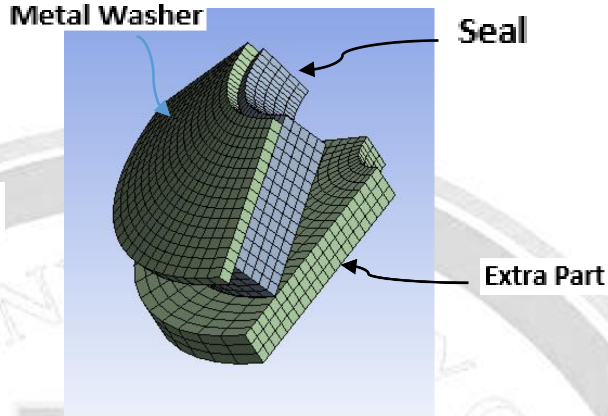
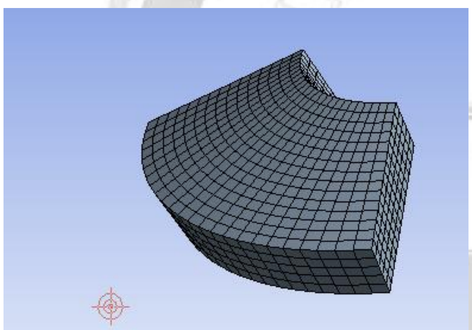


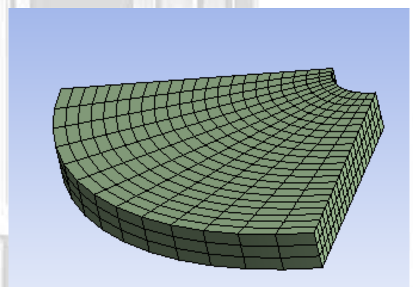
a- Two dimensional Model's Mesh



b- Three Dimensional Model's Mesh



c- Meshing of the Seal



d- Meshing of the extra part (frame)

Fig. 10 Mesh of the Models

Note: The mesh of washer and rubber in all three dimensional modeling are all the same.

Measuring the static coefficient of friction:

Before explaining the boundary conditions, there is a need to measure the coefficient of friction, between the washer and the seal, to be used in defining the contact in the modeling. The method of measuring this parameter is to place a piece of the metal washer on a strip of rubber from which the seal will be cut and used. Then by inclining the rubber strip gradually until the piece of washer is just to slide down along the strip, at this moment, the instantaneous tangent angle of inclination represents the static coefficient of friction [14]. As shown in figure 11:

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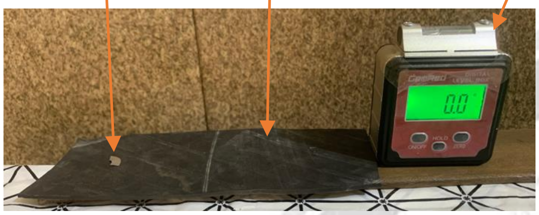


a- horizontal position

b- Inclined position

Fig.11 Measuring the angle of friction

From the Figure 11b, it can be noted that the angle at which the piece of metal is just to slide down is about 30o and by taking the tangent of this angle, the static coefficient of friction is about 0.55

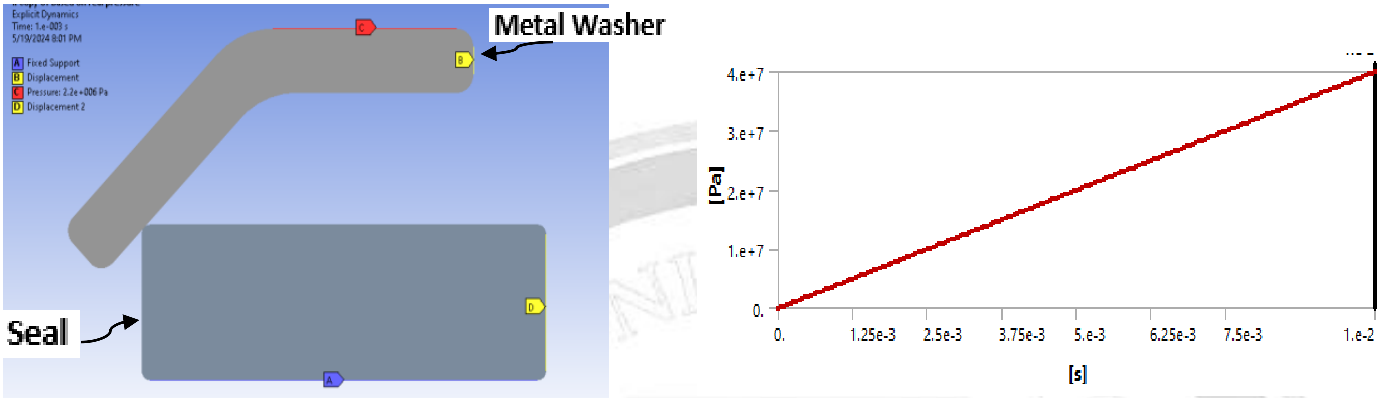
The same procedures are done with all washer types and seal used in this paper to measure the coefficient of friction which is found to have nearly the same value.

Boundary Conditions: -

In all modeling here except for bonded conic, a fixed boundary condition is applied to the lower surface of the rubber seal as shown in Figure 12. A coefficient of friction is specified to 0.55 between the rubber seal and washer, based on practical experiment. An only free vertical displacement boundary condition is applied to the surfaces of washer and seal touching the self-drill bolt to insure only free vertical motion of washer and seal along the axis of self-drill bolt as shown in Figure 12.

The self-drill bolt applies force on the inner circular edge of the conic metallic washer in three dimensional modeling. The maximum amount of this force is 3000 N based on specification of self-drill bolt [15]. In two dimensional modeling this force will be changed to its corresponding equivalent pressure because there is only line. This pressure is applied to the upper horizontal line as shown in Figure 12 a, and this pressure is applied within ten steps as shown below in Figure 12b

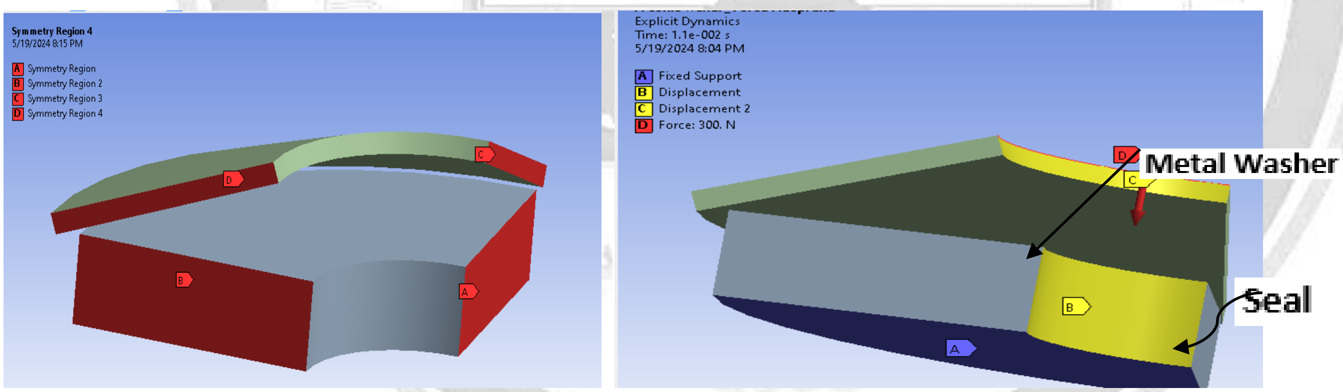
$$Pressure = \frac{Force}{Horizontal\ Area\ of\ washer} = \frac{3000}{\pi\left(\left(\frac{6}{1000}\right)^2 - \left(\frac{3.4}{1000}\right)^2\right)} \cong 40\ MPa$$



a- Boundary Conditions b- Loading Steps

Fig. 12 Boundary Conditions and loading Steps for two Dimensional Model

In the three dimensional modeling, a quarter the geometry is used for the analysis. So, the quarter the 3 KN force is applied to quarter the metallic washer. Also, symmetrical region boundary condition is applied to faces of cutting as shown in Figure 13. The 750 N force is quarter the 3KN force and it applied with five steps



a- Symmetry Regions b- Loading & displacement boundary Conditions

	Steps	Time [s]	X [N]	Y [N]	Z [N]
1	1	0.	= 0.	= 0.	0.
2	1	1.e-004	0.	0.	150.
3	2	1.1e-002	= 0.	= 0.	300.
4	3	1.2e-002	= 0.	= 0.	450.
5	4	1.3e-002	= 0.	= 0.	600.
6	5	1.4e-002	= 0.	= 0.	750.

c- Loading Steps

Fig.13 Boundary Condition and load steps for three dimensional Modeling

In bonded conic modeling, referred to number 3 in the modeling, an extra piece of frame is added to the modeling besides the washer and seal because the seal is bonded to the washer and they move down together, due to applied force, until they are stopped by frame. Therefore, the frame is assumed to be rigid in the modeling. A bonded contact boundary conditions is applied to the touching surfaces of washer and seal. The other boundary condition like force and displacements are applied in the same way as with other former modeling. the boundary conditions of this modeling are shown in Figure 14.

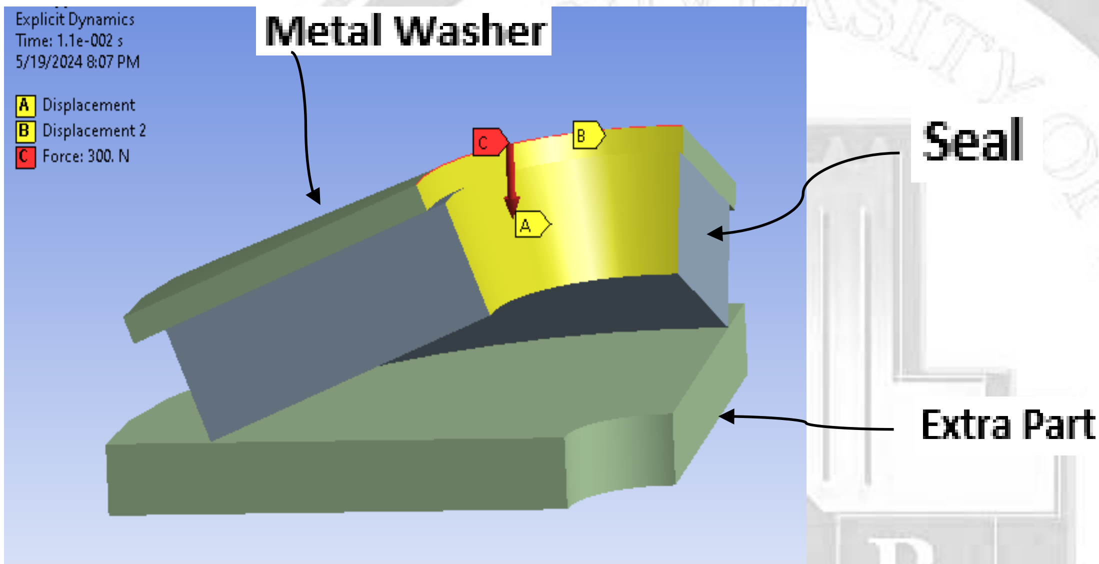
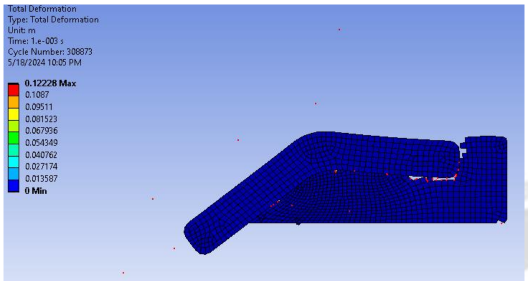


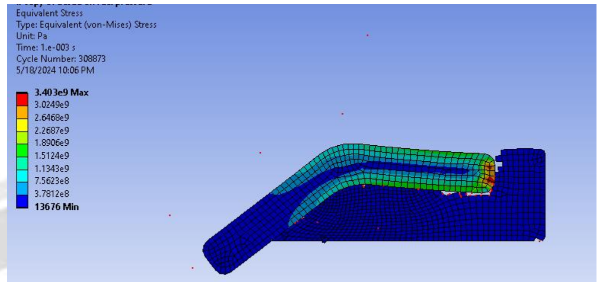
Fig. 14 Boundary conditions for bonded Neoprene Modeling

Solution and Results' Discussions:

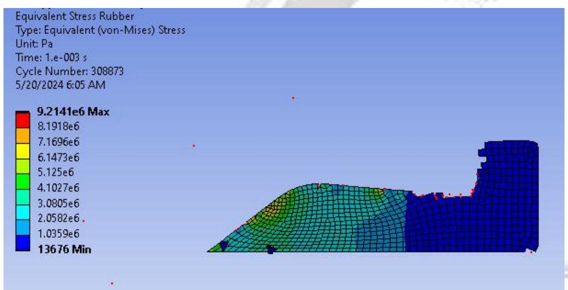
The Solution is performed with all modeling above by an Intel core i7with 2.77 GHz computer. The Explicit Dynamic analysis is very time consuming process, especially where there is a hyperelastic material [16], and it requires changes in some parameters to reach the solution like, the load is gradually applied within certain steps to a void the extreme high impact and an end time is set to 0.01 sec [17]. The maximum number of cycle is set to 100000 cycles and maximum energy error is set to 0.1. To reduce the hourglass energy, an hourglass damping method is set to Flanagan Belytschko [18] and both stiffness coefficient and viscous coefficient are set to 0.05.

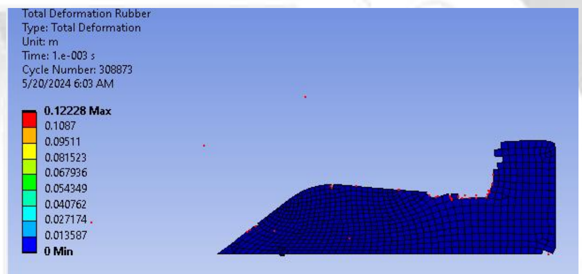
1) The first modeling results of using semi conic washer and Neoprene rubber types is shown in Figure 14.



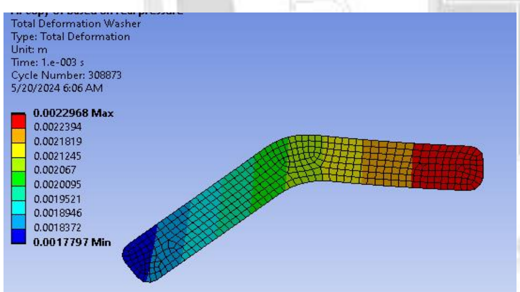


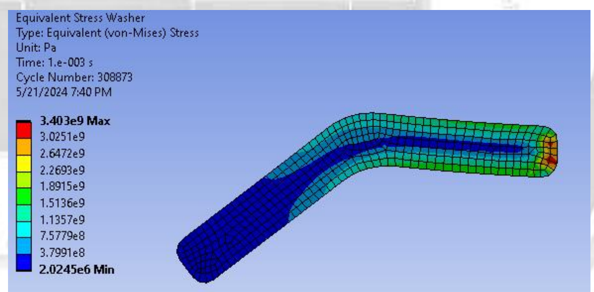
a- Total Deformation for the whole model **b- Stress for the whole Model**





c- Stress of the Seal **d- Deformation of the Seal**





e-Deforamtion of Washer **f- Stresses on the Washer**

Fig. 14 Stress and Deformation for the semi conic and Neoprene (1st modeling)

For the first modeling shown in Figure 14 above, though the solution is done correctly, it can be observed, there is a damage in the rubber especially in the upper region between the self-drill bolt and washer. In this region, there is something like a tear in the rubber because the bottom horizontal surface of washer holds the top surface of the rubber due to friction and prevents sliding when the washer moves down. This case leads to form tensile stress in this region, between the self-drill bolt and washer, causing tearing as a result that Neoprene is soft and weak rubber and does not resist the tensile loads [19]. Also, in Figure 14c, though there is tearing in the region, between the self-drill bolt and washer, the von-mises stresses do not show high values in this region because the tearing has already happened and the washer with its load

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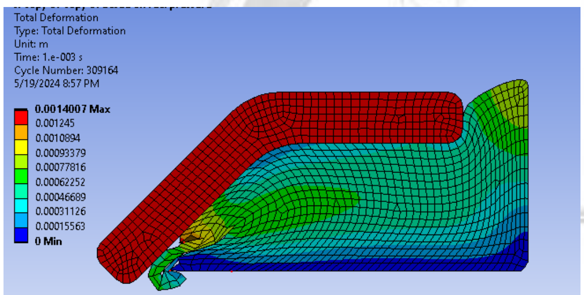
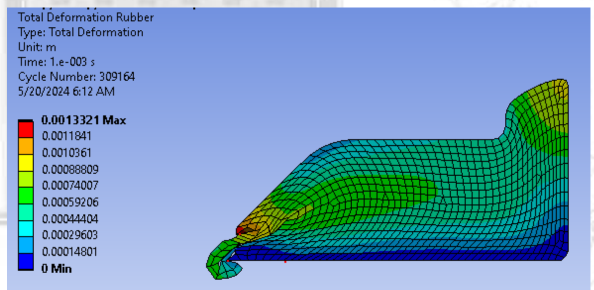
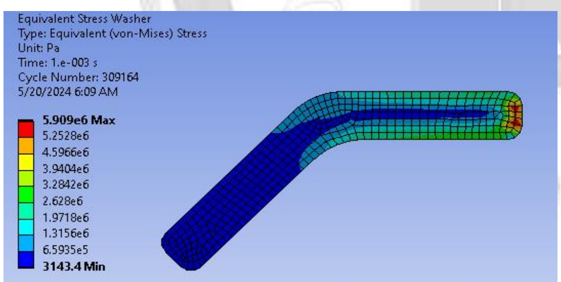
are supported by another region of the seal where von-mises stresses are high as shown in Figure 14c above. The deformation of the rubber seems to be non-realistic and that is because the impact is strong and the neoprene rubber is weak which leads to some small pieces of seal to be thrown away. The maximum von-mises stresses in the metal washer is at the region where tearing in seal is, as shown in Figure 14f , because in this region, the washer is no longer supported by seal and there will be bending and tensile load concentrated in this region of washer.

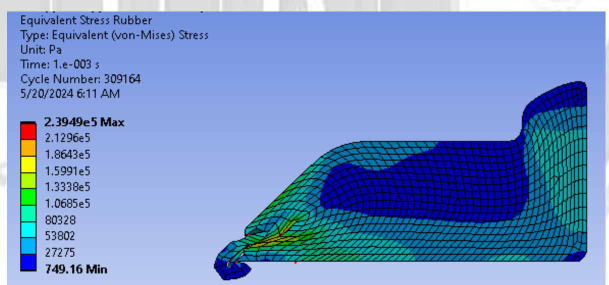
2) The second two dimensional modeling of using semi conic washer and elastomer(Yeho) which is equivalent to tube's rubber, is shown in Figure 15





a- Total deformation for the whole Model **b- Deformation of the Seal**





c- Stress of the Washer **d- Stress on the Seal**

Fig. 15 Stress and Deformation for the semi conic and tube Rubber (2^{nd} modleing)

For the second modeling shown in Figure 15 above, it can be seen the rubber seal, which is equivalent to tire's rubber, tolerates load better than neoprene rubber in the 1st modeling. In a region between self-drill bolt and washer, the rubber is squeezed out between the washer and bolt because this type of rubber has a high tensile property as a compare to neoprene. Also, there is a damage in the rubber at lower left region of the seal on the inclined surface as shown Figure 15b because at this region, the washer is first to touch the rubber or seal at the first moments of its motion down and the stresses concentrate at this region due to high reaction generated by inclined surface especially the other surface regions of the seal still do not support the load at the

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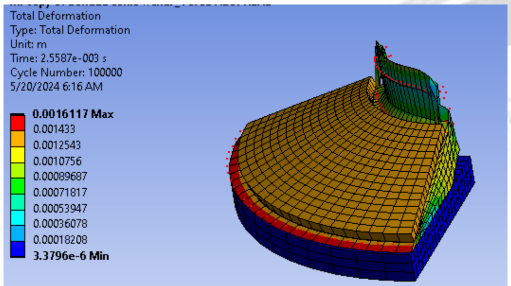
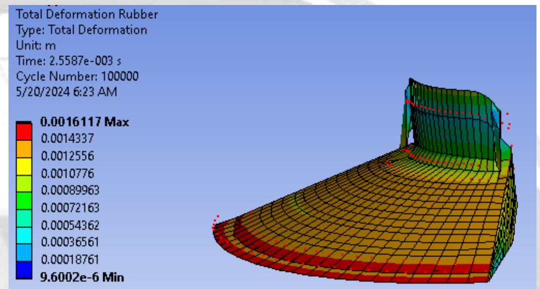
beginning. Generally, this model has better results to resist the load of tightening the bolt despite the damage.

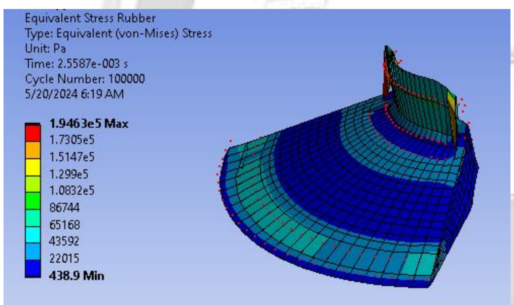
3) Results of the third modeling which is a three dimensional modeling of using Neoprene rubber bonded to conic washer as shown in Figure 16



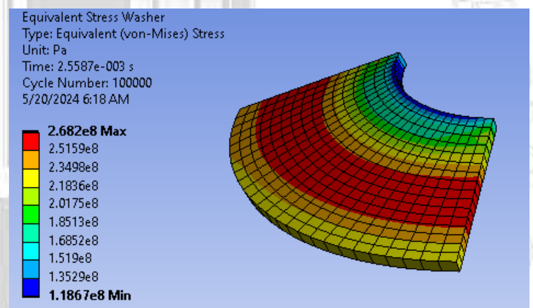
a- Deformation for whole Model



b- Deformation of Seal



c- Stress in Seal

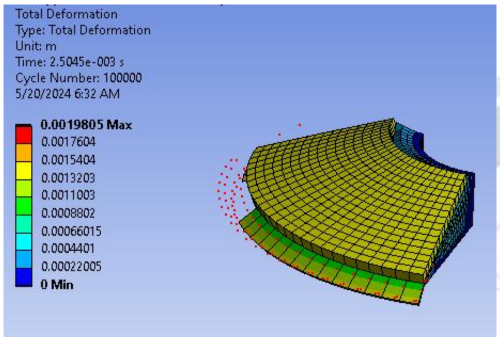


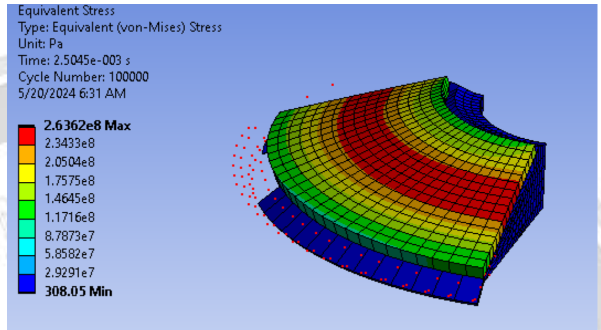
d- Stress of the Washer

Fig. 16 Stress and Deformation for Neoprene bonded to Washer (3rd modleing)

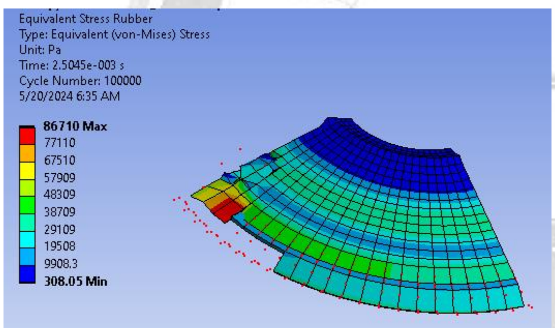
For the third modeling shown in Figure 16 above, it can be observed that there are high stresses in the region between the bolt and washer which cause the rubber to be squeezed out. At this region, there is high von-mises stress concentration which causes some little damage, as a compare to the damage in the first modeling. The interpretation of this case is, the washer has a conic shape i.e. it has inclined lower surface bonded to the seal which makes the seal having conic shape too. Therefore, the generated internal forces in the seal, when it touches the solid frame, will not be high to cause big damage i.e. the washer holds the seal. The conic washer has high von-mises stress which might cause plastic deformation in the region between the inner and outer circumference of the washer. This region subjects to compressive and bending load simultaneously i.e. it might be subjected to kind of buckling because the outer circumference or edge is supported by seal which touches the solid frame while the inner circumference or edge is subjected to external force which will cause high compressive force, as a reaction, in washer besides bending as a result of circumferential stresses in the washer [20]

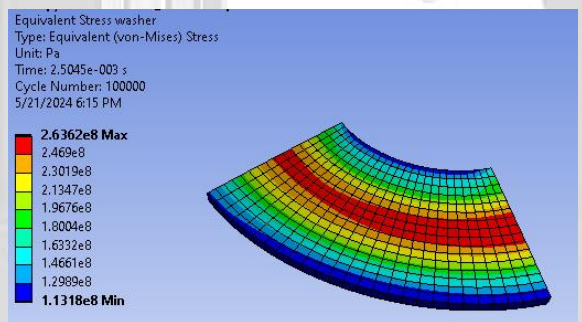
4) Results of the forth modeling of Neoprene rubber and conic washer are shown in Figure 17





a- Deformation for whole Model **b- Stress of whole Model**





c- Stress of the Seal **d- Stress of the Washer**

Fig. 17 Stress and Deformation for Neoprene and conic Washer (4th modleing)

For the fourth modeling shown in Figure 17 above, it can be clearly seen there is a damage in neoprene rubber seal at external edge or the outer circumference because at the first moments of washer's motion down, the washer is first touching the seal within its motion down causing stress concentration in this region, while the other top surface regions of the seal are still not in touch fully with washer i.e. the load on the top surface of rubber does not distribute uniformly, it concentrates on the outer edge and it has no value on the inner edge. That loading causes stress concentration which cannot be tolerated by Neoprene rubber because neoprene is soft and weak material [19]. In Figure 17c, the von-mises stresses do not show there are high stress' values in the seal though because the damage has already happened at the edge, when the washer moved down due to applied force, and the other top surface regions of the seal contribute or take part in loading leading to form more uniform distributed load. The von-mises stresses in the metal washer has big magnitudes that they might cause plastic deformation in the region between the inner and outer circumference of the washer. This region subjects to compressive and bending load simultaneously i.e. it might subject to kind of buckling because the outer circumference is supported by seal which its lower surface has fixed boundary condition while

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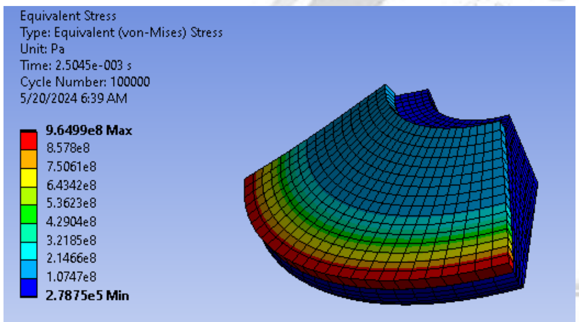
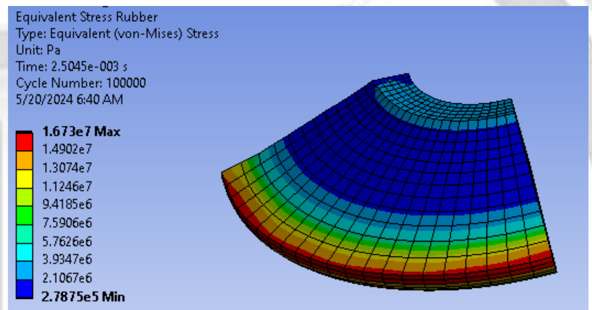
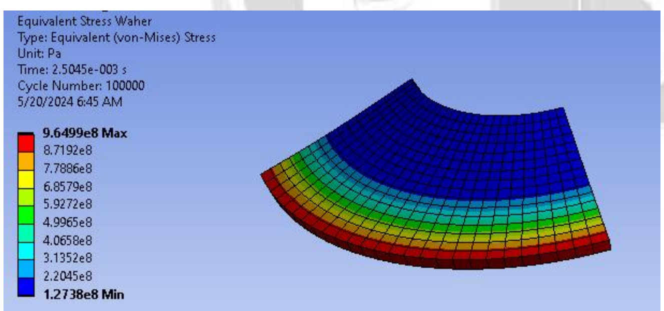
the inner circumference or edge of washer is subjected to external force causing high compressive force in washer, as a reaction, besides bending due to circumferential stresses in the washer [20] .as a compare with bonded Neoprene in the former modeling, the high Von-Mises stresses in the conic Neoprene modeling is concentrated on smaller region of the washer because the Neoprene seal here does not bonded to the washer or it is separated so, the seal does not redistribute the reactions as the washer moves down.

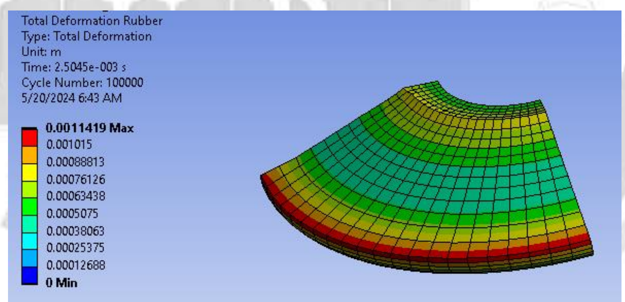
5) The fifth modeling of using Elastomer (Yeho), which is equivalent to tube's rubber, and conic washer. The results are shown in Figure 18





a- Deformation for whole Model **b- Stress of Seal**





C- Stress of Washer **d- Deformation of Washer**

Fig. 18 Stress and Deformation for tube's rubber and conic Washer (5th modleing)

For the fifth modeling, which is called conic and tube, an equivalent elastomer is used as tube's rubber in the modeling. It can be noted in Figure 18, there is high stresses on the outer edges or outer circumference of the seal where this place is the first to be touched by the washer at the first moments. The seal seems withstanding the stresses without significant damage as shown in Figure 18b . The washer has high stresses on the outer edge too as shown in Figure 19c, because it is subjected to uniform support by the seal. That can be interpreted as, at the first moments of loading when the washer moves down, it touches the outer edge of seal and deform it without significant damage and by continuing moving the washer down, the other top surface

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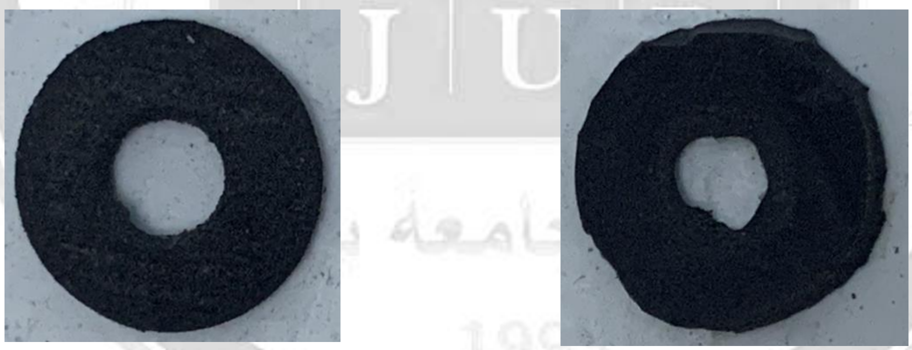
region of the seal will be touched by the washer and will take part in supporting the load. But the outer edge of the seal seems still continuing holding load without changes or damage. Therefore, the outer edge of the washer has the highest stresses among other regions.

Practical Work:

Generally, the damage in the seal might cause small hole or pores by which water can go through. Therefore, the results above show that tube’s rubber can work probably as a seal with conic shape washer in self-drill bolt without significant damage in the seal. Based on this conclusion, a practical simple experiment is made, to check the results above, and the steps of the experiment are:

1. The tube’s rubber is cut with scissor to form a seal as shown in Figure 19b below. the dimensions of this seal is the same as the dimensions of the seal in modeling.
2. A metal pod is prepared to be like sheet metal and to seize water after tightening the self-drill bolt in. Also, another similar metal pod is prepared to be just water’s can for evaporation’s comparison as shown in Figure 20.
3. The cut seal is placed into the bolt, after placing the conic washer, and the pod is placed above the solid frame to be drilled and mounted by self-drill bolt.
4. After the tightening the self-drill bolt in, the pod is filled with water and be left for 15 hours to check for leaking as shown in Figure 21. Also, the another pod is filled with water to compute the evaporation in water within 15 hours’ time.



a- seal in tool shop **b- seal is cut with scissor**

Fig. 19 the rubber seal

Note: the seal cut with a scissor does not have that regular shape as a compare with that seal available in markets or tool shop because the latter is produced with mass production process.

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Fig. 20 Water pod for evaporation's compares with the pod used as metal sheet

Fig. 21 Pod is mounted to frame with self-drill bolt

This practical work showed an excellent result that the water was held without leak for more than 20 hours. Also, the decrement in level of water is caused by environmental evaporation as it is compared with level's decrement in the another pod, shown in Figure 20 above, where the same level of water is left by the environmental evaporation.

Conclusions and Recommendations: -

The seal generally seems to be subjected to only compressive stresses but in all modeling above, it has internal tensile stresses among the elements and those stresses might pass the strength limit of the rubber causing tearing or damage.

Based on the results obtained from all modeling in this paper, the semi conic washer does not work properly with all kinds of rubber used in this paper. It was the worst with Neoprene rubber and better when using tube's rubber but that does not mean it is good because a little damage in seal occurs at the tip of the inclined surface of rubber as it was shown previously in Figure 15b.

For the bonded Neoprene modeling, the rubber seal can resist the loads better than in semi conic washer. Also the seal in this modeling can resist the load better than the seal in forth modeling where Neoprene seal comes in separated form with the conic washer.

From the analytical simulation and experimental work, the tube's rubber seal is the best to resists the loads without damage when it is used with conic shape metal washer. It is better than bonded Neoprene because the latter is soft and weak for tensile loads.

Therefore, some recommendation can be listed down:

1. Before talking about using the tube's rubber to be as a seal i.e. in a case of not using tube's rubber, it is better to choose the bonded rubber to conic washer type among other types in markets when there is a need to mount sheet metal to frame with sefl-drill bolt.
2. It is strongly recommended to import or to build a cutting machine or punching machine for an old tire's tube rubber to form a seal instead of importing the seal from abroad which might not follow the standard specifications and it is money waste as well. Also, it is very important to import or build an assembly machine to assemble the self-drill bolt's parts. The exploiting of an old tube rubber contributes to keep the environment clean especially the old tubes are buried in ground or might be burned in air [21].
3. In case of using of the tube's rubber, the tube's rubber thickness should be (1.7mm-2mm) thickness and that thickness can be found in tube of truck and some heavy equipments.

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تصميم ومحاكاة حلقة مطاطية مانعة للتسرب المستخدمه في البراغي الثاقبه من مخلفات مطاط إطارات المركبات

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الخلاصه

هذا البحث عبارة عن دراسة في إمكانية إستخدام حلقة مانعه للتسريب من مخلفات الانابيب القديمه لإطارات المركبات لاستخدامها في البراغي الثاقبه التي تُستخدم في تثبيت الصفائح على الهياكل المعدنية. تم عمل دراسة عامة لمقاومة الحلقات المانعه للتسريب الموجودة في البراغي الثاقبة التي تُستخدم في تثبيت الصفائح على الهياكل المعدنية باستخدام برنامج Workbench 2022 حيث تم عمل نموذج رياضي لمحاكاة الاجهادات والتشوهات الناتجة. تم استخدام نوعيتين من المطاط للمحاكاة وهما النيوبرين والمطاط المكافئ لمطاط الانبوب المطاطي للاطارات. وتم ادخال الحلقة المعدنية التي توضع فوق الحلقة المطاطيه لغرض توزيع الوزن ضمن المحاكاة في البرنامج. وأيضا تم اخذ شكل الحلقة المعدنية بالاعتبار في المحاكاة حيث لوحظ هنالك شكل مخروطي واخر شبه مخروطي. لذلك وبسبب تعدد أنواع المطاط وتعدد اشكال الحلقات المعدنية، تم عمل خمسة نماذج رياضية مختلفة في برنامج Workbench 2022. تم اعتماد ابعاد جميع الأجزاء في هذا البحث على قياسات ابعاد الأجزاء الحقيقية الموجوده في الأسواق المحلية. وبينت نتائج المحاكاة بالبرنامج ان مطاط انابيب الإطارات اعطى افضل النتائج مع استخدام الحلقة المعدنية المخروطيه بينما تحصل تشققات بسيطه في الحلقه المطاطيه عندما يتم استخدامها مع الحلقة المعدنية الشبه مخروطية. وفي حالة عدم استخدام مطاط انابيب الإطارات فان النتائج بينت ان مطاط النيوبرين الملتصق والمربوط بالحلقة المعدنية المخروطية هو الأفضل. وللتأكد من النتائج الخاصه بمطاط انابيب الإطارات، تم عمل تجربة عملية بسيطه وكانت نتائجها ان ذلك النوع من المطاط يمكن استخدامه بما لا يقبل الشك كحلقة مانعة للتسرب.

الكلمات الدالة: اجهادات، تشوهات، ضغط، احتكاك، إزاحة، اصطدام.