DESIGN AND ANALYSIS OF ELECTRONICALLY CONTROLLED PNEUMATIC BRAKE VALVE COMPONENTS FOR COMMERCIAL VEHICLES

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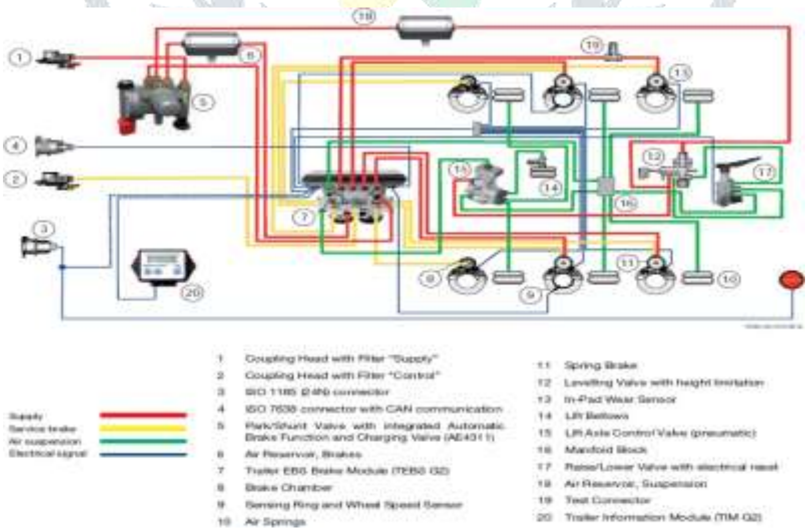
Abstract: The primary aim is to design a solenoid retainer plate to hold the solenoid valves without any leakage when pressurized air passed through solenoid valves. Analyzing the solenoid retainer plate by finding out maximum reaction forces at the contact of solenoid valve and solenoid retainer plate when pressurized air passed through solenoid valves at the time of actuation of brake and maximum stresses on the retainer plate with the help of ANSYS software. For justifying the results, computational analysis results are compared with computational analysis and experimental results of existing solenoid retainer plate.

***Index Terms* – solenoid retainer plate, design, analysis, electronically controlled valve**

1. INTRODUCTION

An electronically controlled pneumatic brake system is used in heavy commercial vehicles for the purpose to stop or slow down the vehicle. Air brakes are used in large heavy vehicles, particularly those having multiple trailers which must be linked into the brake system, such as trucks, buses, trailers, and semi-trailers, in addition to their use in railroad trains. Pneumatic Electric Braking Systems (EBS) are getting wide-spread in commercial vehicles. Such systems ensure a fast-response, intelligently controlled braking process, fulfilling several demands related to brake and vehicle dynamics. We have designed a solenoid retainer plate for Trailer EBS Brake Module (7) as shown in figure. Electronically controlled valves are operated with the help of solenoid valves. Because of their actuation main valve perform their functions with fast response. Solenoid valve have magnetic coils and bar to open and close area of ports. At high pressure and vibration during running of vehicles those solenoid valves should hold their position for that solenoid retainer plate is used to fix the position solenoid valve to avoid any leakages.

Figure 1: Trailer brake valve arrangement

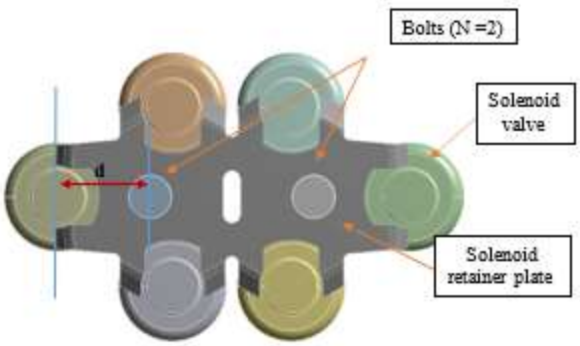


2. SOLENOID RETAINER PLATE DETAILS

Solenoid retainer plate is made of material X6Cr17, there are three different retainer plates are designed and analyzed with the help of solenoid valves position. There are total 8 valves are present. Each valve has different functionality. Three solenoid retainer plates are designed such a way that, one retainer plate is for 5 solenoid valves, second retainer plate is for 2 solenoid valves, third retainer plate is for one solenoid valve.

3. DESIGN CONSIDERATION PARAMETERS

Figure 2: Layout of existing solenoids



From design point of view, we required 1000 N – 2000 N. While designing a solenoid retainer plate some of the important parameter takes into the consideration to hold the solenoid valves firmly while they are in working condition.

3.1 Centre to center distance between bolt and solenoid valve (d):

As we know that if a force is applied on a body then values of reaction forces near to that area are more. Same case is here, we have given bolt pretension where claw position of solenoid retainer plate which is near to the axis of bolt will experienced more reaction force as compared to far one.

3.2 Offset between center of solenoid valve and retainer plate claws:

If position of claws placed has offset with respect to the center of solenoid valve, then it will be imbalance. It will not hold the solenoid properly.

3.3 No. of bolts (N):

For clamping action bolt pretension has been given in other words force is applied on a solenoid retainer plate. If no. of bolts increased force will be increased ultimately will get more reaction forces but at the same time stresses value also increase so these things considered while deciding no. of bolts.

3.4 Bolt size:

M6 has been used for bolt pretension. Selection of bolt size depends on minimum wall thickness of bolted area.

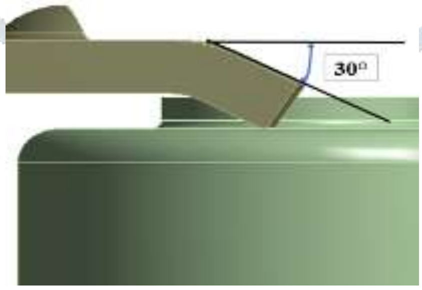
3.5 Claw size:

This one is another main factor in design point of view. Design of claw in such a way that it should hold maximum surface of the solenoid valve.

3.6 Claw angle:

To hold the solenoid valves claws should have some angle to hold it firmly. From the claw position, consider it is a resultant force and it has two component-one is horizontal component and another one is vertical component. So, if claw angle reduced with respect to horizontal direction, claw will skid on solenoid valve surface, and if claw angle increased, claw experienced more forces, but it will make dent to solenoid valve.

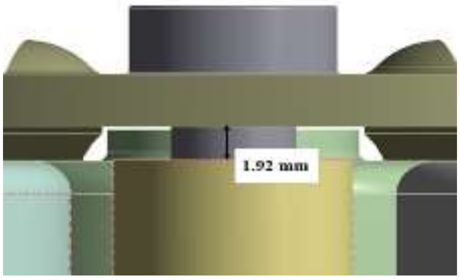
Figure 3: Claw angle



3.7 Distance between retainer plate and solenoid valve:

In ANSYS either we can give bolt preload or displacement, so in the analysis we have considered displacement as input parameter.

Figure 4: Claw angle



4. MODELLING OF SOLENOID RETAINER PLATE

With the help of Creo Parametric 4.0 software solenoid retainer plate has been designed to sustain high amount of pressure (10 - 12.5 bar) while solenoids are in working conditions. Pressure coming from supply port is around 10 -12.5 Bar. To hold this pressure solenoid valve should sustain that much of pressure.

Figure 5: Isometric view and geometric details of solenoid valves

Our main aim is to get reaction forces value near to the experimental results on each claw of the solenoid plate which is in contact with solenoid valve and stresses value should be minimum to ultimate strength of that material to avoid the failure of the plate. In a existed design bolt pretension was given to tighten the solenoid retainer plate to the solenoid valve from that we have calculated the reaction forces, total deformation and equivalent stresses.

To achieve the desired values, we have considered different things according to that we are doing the modelling of solenoid retainer plate –

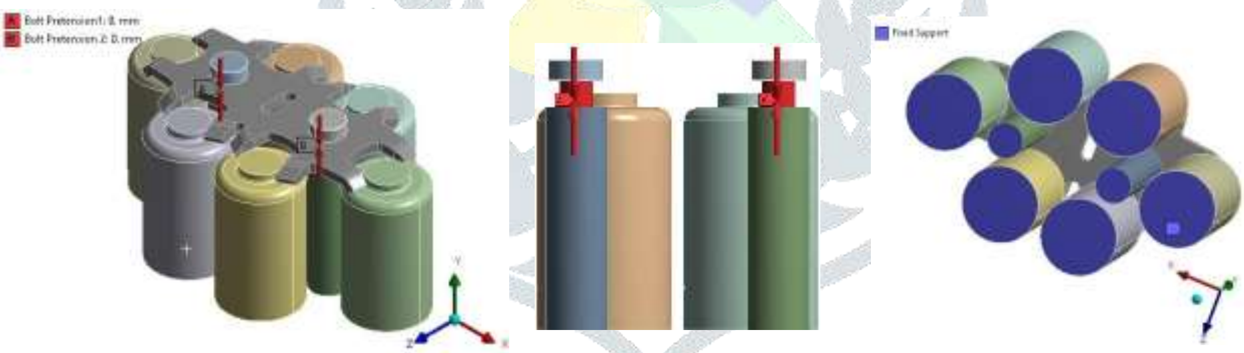
i. In existed design bolt pretension was 1.6 mm from which we haven't got desired values. So, we increased the bolt pretension value which is 1.95 mm. the reason behind to increase the bolt pretension value is we know that as if we applied more force, we will get equal and opposite force.

ii. Another changed we have done from existing design is increase the angle of claws of solenoid plate. In ANSYS more are will be in contact more accurate will we get so from this concept we have changed the angle of solenoid retainer plate.

iii. Another changed we have done that we have increase bolts so that bolt preload will increase which give more reaction forces at the contact of solenoid plate and solenoid valve but at the same time equivalent stress value has been increased but those values are below the ultimate limit.

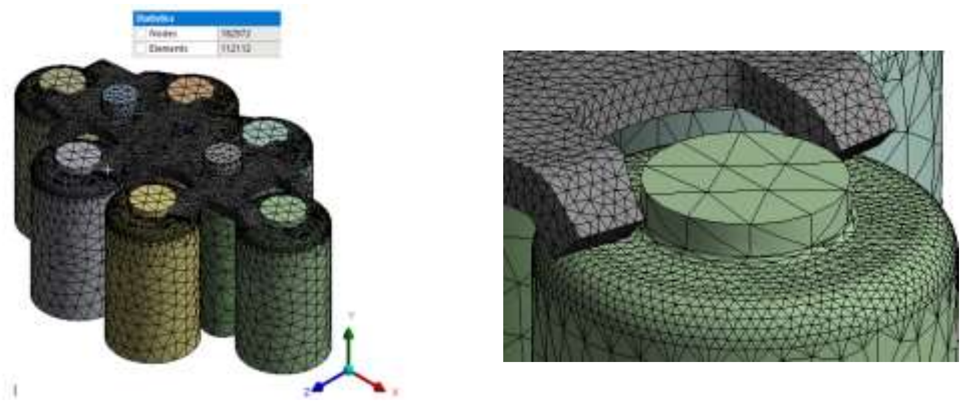
5. BOUNDARY CONDITIONS AND MESHING

Figure 6: Boundary conditions and meshing (bolt pretension and fixed support)



Bolt pretension is given to get reaction forces at the contact of the solenoid plate claws and solenoid valve face. While simulation fixed support is given to the bottom face of the solenoid valve in boundary conditions.

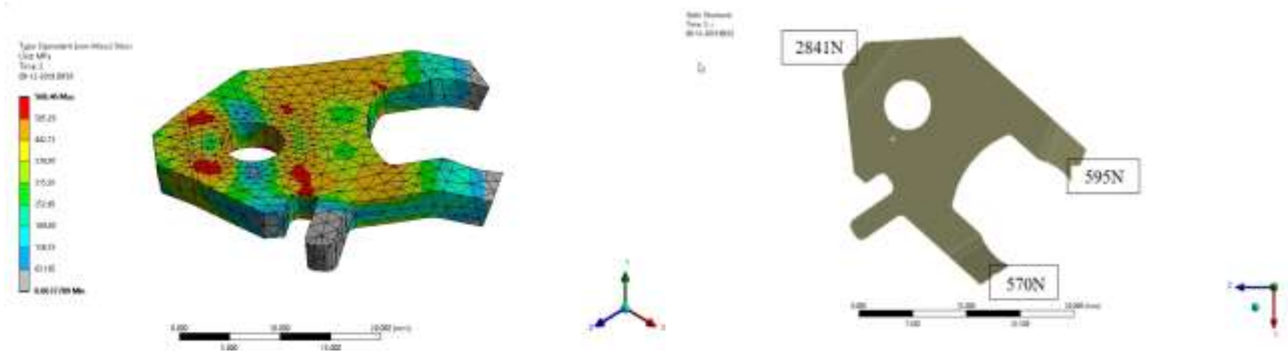
Fine meshing is given where contact between solenoid retainer plate claw and solenoid valve to get more accurate results in simulation



6. ANALYSIS RESULTS BY CONSIDERING DESIGN PARAMETERS

6.1 Single Solenoid Retainer Plate:

Figure 7: Equivalent stress and reaction forces



Though our aim is to get equivalent stress below the ultimate limit (590 MPa) and reaction forces at claws which is holding one solenoid is 1200 N -2000 N. So, from the analysis results-
Equivalent stress = 568 MPa below the ultimate limit (590MPa)
Reaction forces = (570 +595 =1165 N)

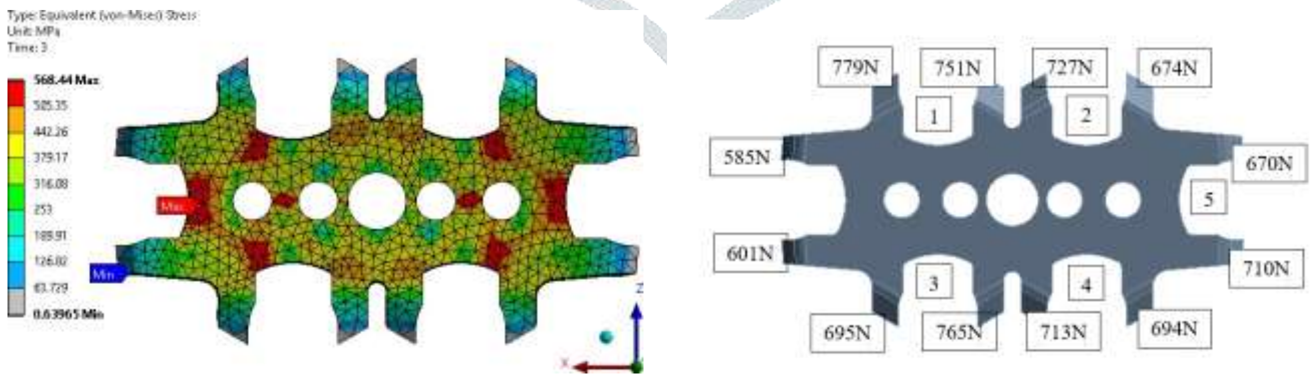
6.2 Two Solenoid Retainer Plate:

Figure 8: Equivalent stress and reaction forces

Equivalent stress = 556 MPa below the ultimate limit (590MPa)
Reaction forces = for solenoid 1 (681 + 900 =1581 N)
Reaction forces = for solenoid 2 (590 + 950 =1540 N)

6.3 Five Solenoid Retainer Plate:

Figure 9: Equivalent stress and reaction forces



Equivalent stress = 568 MPa below the ultimate limit (590MPa)
Reaction forces = for solenoid 1 (779 + 751 =1530 N)
Reaction forces = for solenoid 2 (727 + 674 =1401 N)
Reaction forces = for solenoid 3 (695 + 765 =1460 N)
Reaction forces = for solenoid 4 (713 + 694 =1407 N)
Reaction forces = for solenoid 2 (670 + 710 =1380 N)

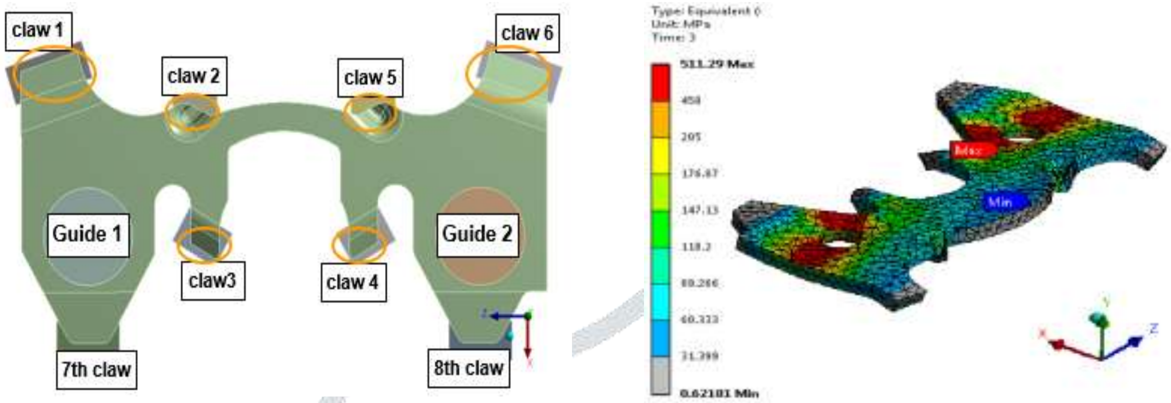
7. ANALYSIS AND EXPERIMENTAL RESULTS OF EXISTING RETAINER PLATE

Trailer Electronic Brakes Module (TEBs) has only two functions which one is-

1. Service braking EBS
2. Emergency brake

These are two functions were in the TEBs valve and has different Lift axle valve and overflow valve in the trailer.

Figure 10: Equivalent stress and reaction forces for existing plate

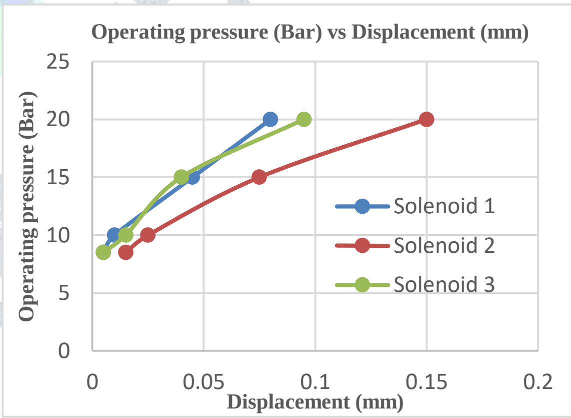


	Solenoid 1		Solenoid 2		Solenoid 3		Supporting beam	
Displacement (mm)	Claw1 Force (N)	Claw2 Force (N)	Claw3 Force (N)	Claw4 Force (N)	Claw5 Force (N)	Claw6 Force (N)	Claw7 Force (N)	Claw8 Force (N)
1.83 mm	850	692	717	722	708	868	627	652

Leak test has been carried out to check the displacement of solenoid valve when clamped with retainer plate with the help of bolting.
There are two trials has been taken while experimenting.

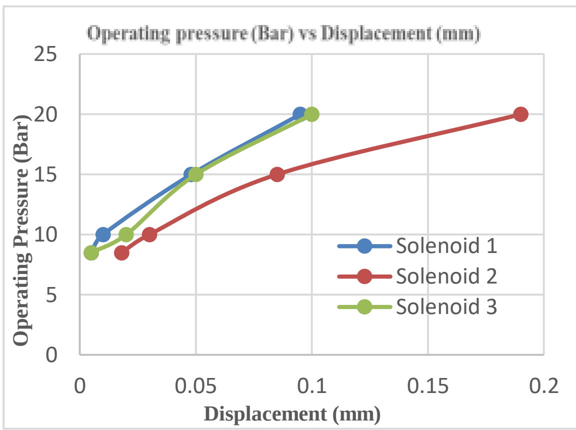
7.1 Trial 00: final results

Operating Pressure (Bar)	Displacement (mm)		
	Solenoid1	Solenoid2	Solenoid3
8.5	0.005	0.015	0.005
10	0.01	0.025	0.015
15	0.045	0.075	0.04
20	0.08	0.15	0.095



7.2 Trial 01: 0.5 mm milled off at the claw's corner

Operating Pressure (Bar)	Displacement (mm)		
	Solenoid1	Solenoid2	Solenoid3
8.5	0.008	0.025	0.010
10	0.018	0.040	0.032
15	0.055	0.095	0.05
20	0.12	0.20	0.13



From the experimental results they have found that –

1. Trial 00 is the final designed three solenoid plate but for additional information they have taken one more trial. This plate has 2 mm radius at the tip of the claw where it is touching to solenoid valve.
2. Trial 01 is another trial in which claw tip radius has milled off by 0.5 mm. but in ANSYS we observed that if we try to make sharp edge then there will be less area of contact that is why force transfer will be less

That is why Trial 00 has better results than Trial 01.

8. CONCLUSION AND FUTURE SCOPE

In experimentation they have taken two trials. In first trial (trail 00) which is the final one retainer plate displacement values were good as compared to other.

In trial 00 plate claws tip radius is 2 mm so that it will not dent to the solenoid valve when bolt pretension is given.

In trial 01, they have milled off the retainer plate claws tip by 0.5 mm but at 20 bar pressure we are getting more displacement of solenoid valve as compared to trial 00.

They have taken trial 00 is the final design of the solenoid retainer plate and validation point of view reaction forces of new retainer plate is near to same as of existing solenoid retainer plate.

The future scope for this study plays vital role here. While doing analysis for three plates each time we have to do number of iterations. For the design purpose Creo has been used and for analysis ANSYS has been used so interaction between this two is taking lot of time so time has been very important factor in any company. To reduce that time optimization of plate is one method to reduce time

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