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A new mechanized valve

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Abstract: Valves are mechanical or natural devices that control, regulates, or directs the flow and pressure of a fluid (liquids, gases, slurries) within a system or process by opening or closing various passageways. They are very essential components of a piping system in homes as well as at industry levels. Different types of valves are available: plug, ball, diaphragm, pinch, gate, globe, butterfly, etc. These different valves have different features and functions. Unlike other valves, the moving part of this new valve moves linearly up and down inside the body. This paper attempts to explain clearly the working principle of a new mechanized valve, its advantages, and its practical implementation. Computational design is carried out in 2D and 3D using SOLIDWORKS and ANSYS software. In SOLIDWORKS 2D and 3D model of the valve is created and assembled while in ANSYS, Finite Element Analysis of the valve is carried out.

Keywords: Plug Valve, Diaphragm Valve, Pinch Valve, Finite Element Analysis.

I. INTRODUCTION

Valves are very essential components in modern-day societies. Valves are used in various places like in houses, industrial processes and nature. In houses valves are used in daily lives e.g. gas control valves in cookers, safety valves fitted to hot water systems, plumbing, valves in washing machines and dishwashers, agricultural spray motors. In industries, valves are used in chemical industries, power generation, oil processing, petroleum and gas, manufacturing of food, etc. In nature, valves are present in the heart.

This newly designed valve is a linear-motion valve i.e. one-dimensional motion along a straight line which is characterized by a cylindrical shape body and a plug that assist smooth flow passages. It has a single-round port orifice. The full flow is achieved when the plug is in the extreme top position i.e. when the hollow passageway or port of the plug is aligned with the direction of flow and when the plug is in the extreme bottom position the flow is blocked as there is no passageway for fluids. This type of valve can be relatively flexible and its efficiency may be as good as plug valve. It can be made up of the same materials as used in the plug valves. Like other valves especially plug valve and ball valve, it can also have an excellent sealing, making them an ideal choice for controlling the gaseous flow as well and is also lubricated through grease/lubricant fitting. This newly designed valve can be used for steam, water, oil, gas, etc depending upon the material of construction. It consists of only one hollow passageway/port to allow flow through the valve. Unlike plug valves in which the plug is rotated inside the valve body to control flow, its plug moves linearly or slides vertically up and down in the valve body so that fluid can flow through the valve when the valve is open. It is a full-port valve which means its orifice has an inside diameter equal to the inside diameter of the pipe.

II. 2D AND 3D MODELING OF THE VALVE

Modeling is a technique or method in Computer graphics for producing a 3D digital (or a mathematical coordinate-based) representation of any object or surface. The 2D and 3D model of the valve is created by using SOLIDWORKS software because it has broader capabilities and is relatively easier than other software. As modifications are likely going to be made along the way, we can achieve design intent as well. 2D and 3D models are shown below:

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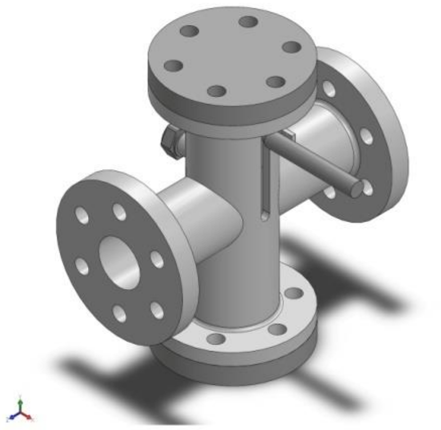

Fig. 1 3D front view of a valve (open)

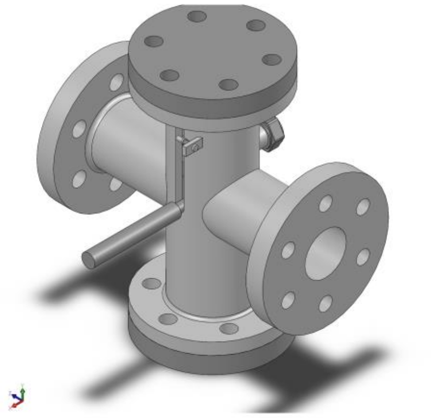

Fig. 2 3D front view of a valve (closed)

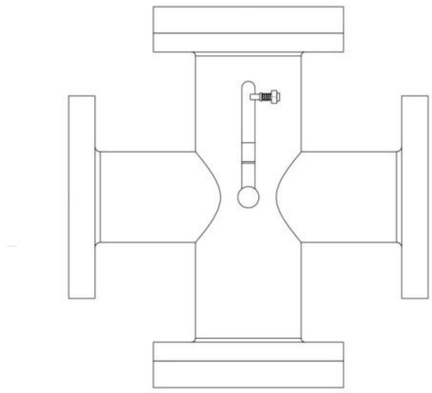

Fig. 3 2D front view of a valve (closed)

III. COMPONENTS OF THE VALVE

There are two types of components, pressure-containing components and non-pressure-containing components. The pressure-containing components are designed to withstand pressure and temperature conditions. Since the pressure-containing components are in direct contact with the fluid, their materials should be compatible with the service and non-pressure-containing components are those components which are not in contact with the fluid. Following are the components of the valve:

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1. Valve Body: The valve body is the main pressure-containing component or part of the valve. The body of the valve can be a cast or forged construction like others. The body's control section is cylindrical-shaped to fit the cylindrical-shaped plug inside it. There is a space made through the surface by removing some part of the material to connect the handle to the plug. It is designed with flanges that are usually welded to connect pipes, valves, pumps, etc.

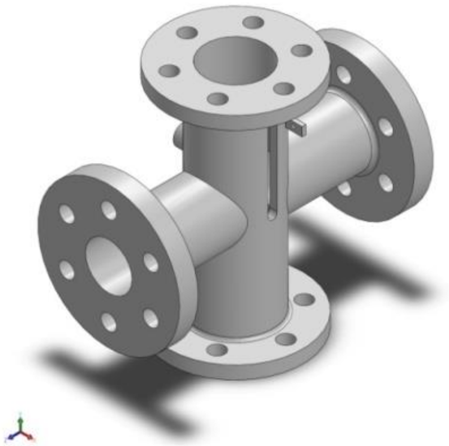

Fig. 4 Valve body

2. Cover Body: Cover body covers the valve body and also acts as packing. The cover body is bolted or screwed to the valve body. There are two cover bodies one at the top and the other at the bottom, both of them have the same designs. The material of the cover body will be the same as the valve body. As the cover bodies are bottled or screwed, gaskets or sealing should be used and should also be suitable for the design conditions of the valve.

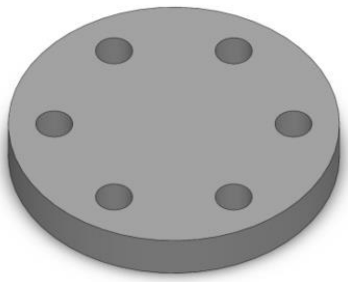

Fig. 5 Cover body

3. Plug: This valve consists of a cylindrical plug. The plug is provided with a single port opening having an area equal to the pipe flow area i.e. the area of the port is 100 percent of the internal pipe area. The port in the cylindrical plug is made round. It can be entered into the valve body either from the top or from the bottom.

For lubrication, the plug has a cavity along its center axis just like in the plug of a plug valve. The lubricant reduces the force which is required to open or close the valve and also allows smooth movement of the plug inside the body. It should be taken into consideration that lubricant must be compatible with the fluid of the pipeline and should not dissolve or wash away by the flow medium as this could contaminate the fluid. Lubricant when injected into the cavity through lubricant fitting, discharges out from the cavity which is along the axis through radial holes into the lubricant grooves (as shown in the figure) that extends along the length of the outer surface of the plug and thus plug surface gets constantly lubricated. In the cavity, a check valve is provided which prevents the lubricant from flowing in the reverse direction once the lubricant is injected into the cavity. The lubricant in other words becomes a structural part of the valve, as it provides a flexible seat. As this valve is lubricated, it can also be used in high-temperature systems. The mechanism of lubrication is the same as that of the plug valve.

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The lubricant performs the following functions:

1. It protects the seating surfaces of the plug and valve body against corrosion.
2. It acts as a seal between the plug and the valve body so that the internal leakage is minimized to a greater extent.
3. It minimizes the force required to operate the valve.

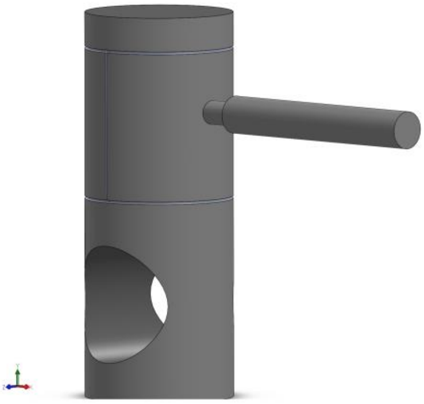

Fig. 6 Plug with handle

4. Handle/Arm: It is the main part of the valve and is connected to the plug to move the plug up and down inside the body. It is installed on the plug perpendicular to its axis by a thread that may be tapered or parallel. As a good amount of force is to be exerted on the handle to move the plug inside the cylinder, it should be made of the same material as valve body or different hard material. The shape of the handle can be anything from simple to ergonomic design.

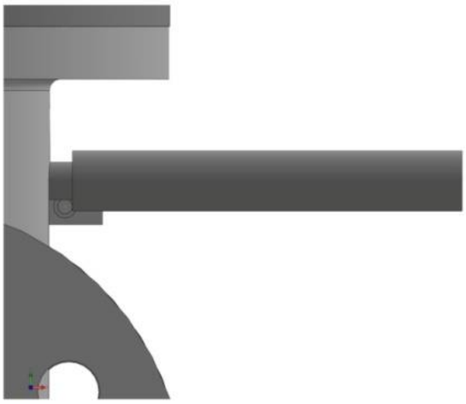

Fig. 7 Handle

5. Pin: When the plug is in the extreme top position, it may come down after some time due to various circumstances like the force of fluid flow, the weight of the plug itself plus the weight of the handle. To hold the plug at the extreme top position, a pin is used as shown in the figure below. It holds the plug at the extreme top position easily. It moves along the pin holder horizontally with the help of the retaining spring. It is pulled from the base before the plug is moved upwards and when the plug is at the extreme top position, a pin is released thus holding the handle at the same position.

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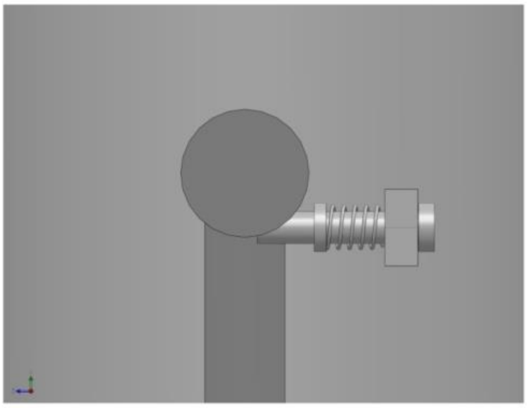

Fig. 8 Pin

6. Grease Fitting: Grease fitting, also known as zerk fittings, named after Oscar Zerk, serves as a lubrication point to feed into the plug and is installed permanently on the valve body as shown in the figure below. For lubrication of the plug, a grease gun is attached to the screw. A bearing ball is installed into the screw placed on the retaining spring. A small bearing ball in the fitting is forced to moves back against the force of its retaining spring when the grease gun supplies pressure. Thus bearing ball acts as a check valve to prevent grease or lubricant from flowing in the reverse direction once the lubricant is injected. Its design provides a secure connection to a grease gun for delivering precise amounts of grease into the plug. The lubricant can be fed only when the plug is at the extreme bottom end or when the valve is closed.

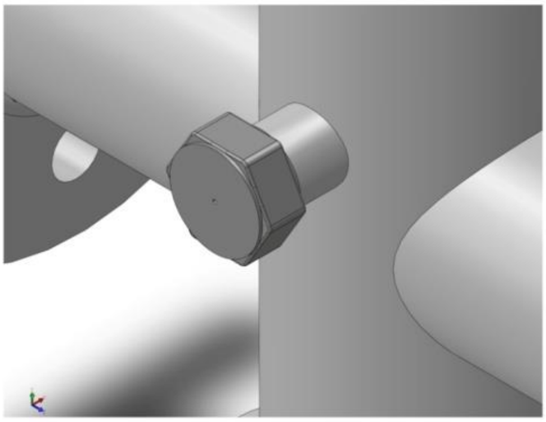

Fig. 9 Grease fitting

Advantages:
Some of the advantages of this valve are given below

1. It has a simple design with few components assembled.
2. As this design is taken into consideration, this valve has low flow resistance.
3. This valve can also provide leak-proof service/facility.
4. Quick and easy to operate i.e. opening and closing service.
5. Compared to the gate and plug valves, they are lighter because of fewer parts.
6. They can also provide leak-proof, as lubricant also acts as a sealant.
7. Low maintenance cost as repairing of this valve can be done at the same place of operation.
8. Maintenance costs can be low as compared to some other valves.
9. Inexpensive due to simple construction.
10. They are easy to clean by removing two cover bodies and plug simply.

Applications:
This valve possesses many applications, some are listed as:

1. This newly designed valve can be used in many types of industries and can also be used in homes if the size is small.

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2. It can also be used for oil and coal slurries services, fluid services such as feedwater, steam, hydrocarbon, etc.
3. As no thermoplastic material is used as a sealant, it can be useful in both high-temperature and high-pressure applications.
4. The design of the valve is such that it can provide bubble-tight sealing which can be used in high-pressure situations.
5. It can be used in situations where the flow must stop gradually.

IV. MODELING BY USING FINITE ELEMENT ANALYSIS (FEA)

Finite Element Analysis (FEA) is a widely used method for simulation. It is a numerical method that is used to solve partial differential equations. It is a computational tool, for performing stress and other engineering analysis. As a computational tool, it is used to find the stress distribution for complex geometries. FEA simulations provide a valuable resource and are given preference to decrease the need for physical prototypes in the design process.
The steps of the finite element analysis are briefly explained below:
1. Creating 3D Model: Different 3D CAD modeling tools like SOLIDWORKS, CATIA, etc are available for creating the 3D geometry of the model on which you want to perform an analysis.
2. Importing 3D CAD geometry to FEA software: In this step, after creating a 3D model, we import the geometry/model into the FEA software.
3. Defining Material Properties: In this step, we assign material properties in FEA software. In this process, we assign different properties like modulus of elasticity, poisons ratio and all other necessary properties required for the analysis.
4. Meshing: In this step, we create a mesh i.e. splitting the domain into a discrete number of elements for the solution to be calculated. The data is then interpolated across the whole domain.
5. Defining Boundary Condition: In this step, we apply loads. The main types of loading available in FEA software include force, pressure and temperature. Points, surfaces, edges, nodes and elements are different options on which we can apply these loads.
6. Solve: In this step, FEA software solves the problem for the defined material properties, boundary conditions and mesh size.
7. Post Processing: Results of the solution after solving the problem are available in this step. The result can are available in various formats like a graph, value, animation, etc.

1. Mesh generation

Mesh generation is also known as meshing. Meshes are created by computer algorithms and are composed of simple cells like triangles. For 2D models, triangular and quadrilateral elements can be used while In the case of 3D models, tetrahedral, hexahedral, triangular prismatic and pyramidal elements can be used. The mesh should also be fine (have small elements/areas) that are important for the subsequent calculations. For more accurate solutions, smaller mesh size is required. The purpose of meshing is to make the problem solvable. The picture below shows meshed model before calculations.

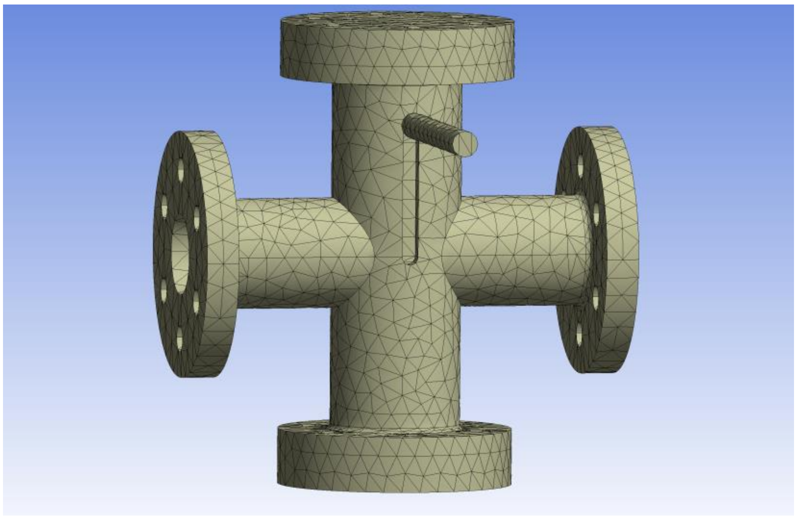

Fig. 10 Meshed model

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2. Results of analysis

The selected material properties are listed as;

Material used : Carbon Steel
Poisson's Ratio : 0.3
Ultimate tensile strength : 4.6e8 Pa

The results of analysis after assigning material properties to the mesh are listed under:

The valve was analyzed at different internal pressures of 2MPa, 3 MPa and 4 MPa. At 2 MPa internal pressure, the maximum and minimum equivalent (von-mises) stresses obtained were 9.1644 MPa and 1.0183 Mpa respectively on stress areas and maximum and minimum principal stresses obtained were 9.5815 MPa and 578.65 KPa respectively on stress areas. At 3MPa, the following results were obtained, maximum and minimum equivalent stresses on the valve were 13.747 MPa and 1.5274 MPa respectively and maximum and minimum principal stresses obtained were 14.372 MPa and 867.97 Kpa respectively. When the valve was analyzed at 4 MPa, the following results were obtained, the maximum and minimum von-mises stresses on stress areas obtained were 18.329 MPa and 2.0365 MPa respectively while maximum and minimum principal stresses were obtained on stress areas obtained were 19.163 MPa and 1.1573 MPa respectively. Animated results of FEA are shown below:

- **Analysis at 2 MPa internal pressure:**

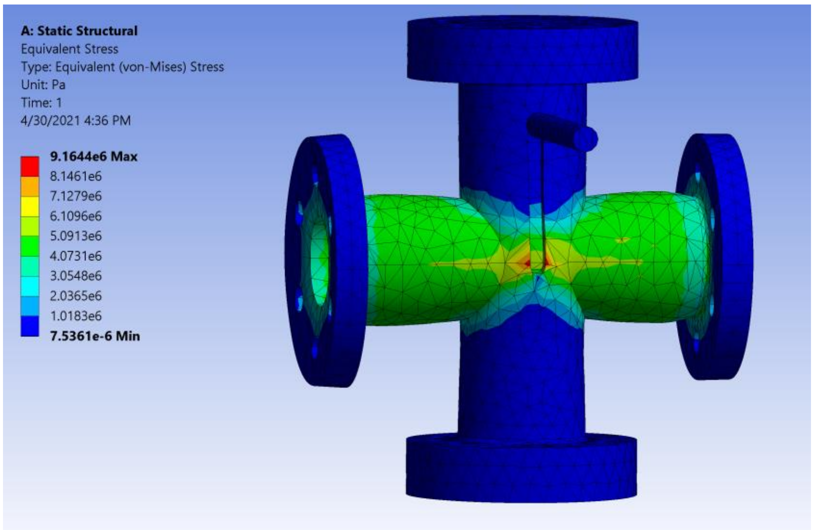

Fig. 11 Equivalent stress at 2 MPa internal pressure

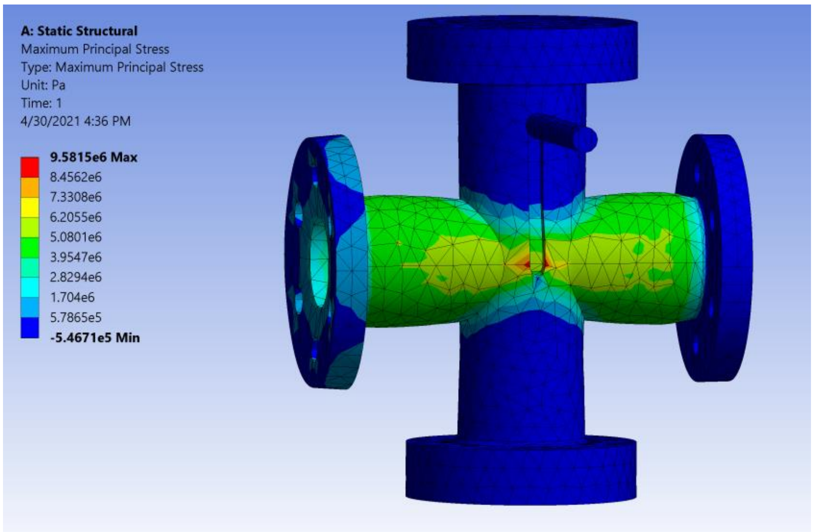

Fig. 12 Maximum principal stress at 2 MPa internal pressure

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- **Analysis at 3MPa internal pressure:**

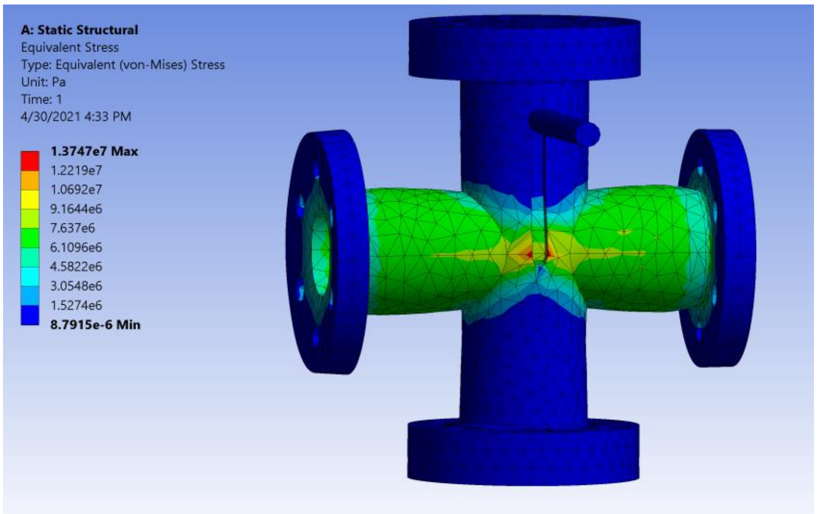

Fig. 13 Equivalent stress at 3 MPa internal pressure

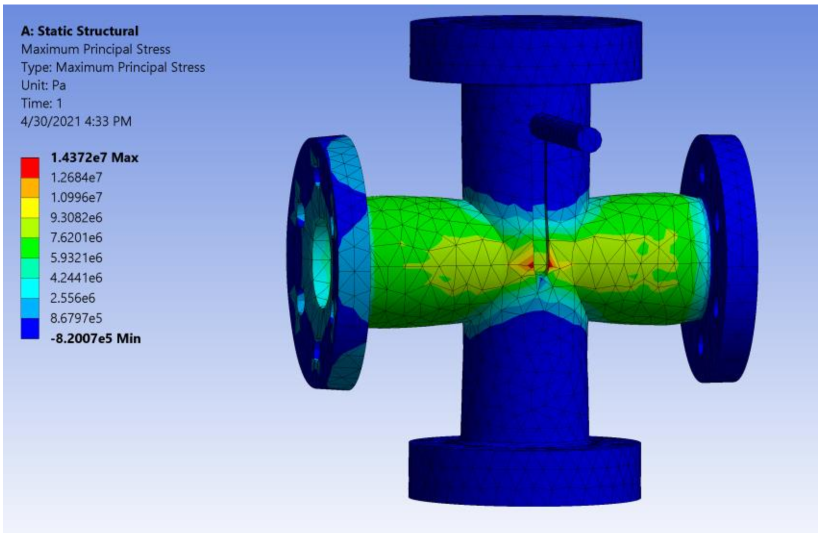

Fig. 14 Maximum principal stress at 3 MPa internal pressure

- **Analysis at 4MPa internal pressure:**

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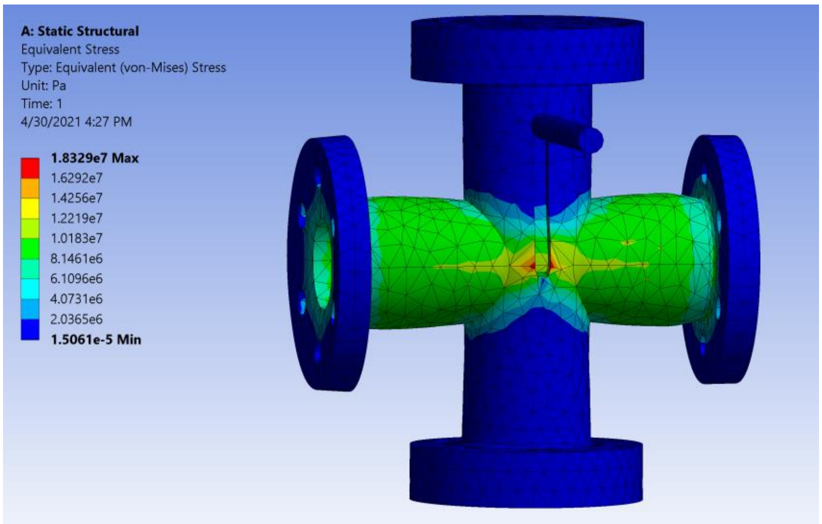

Fig. 15 Equivalent stress at 4 MPa internal pressure

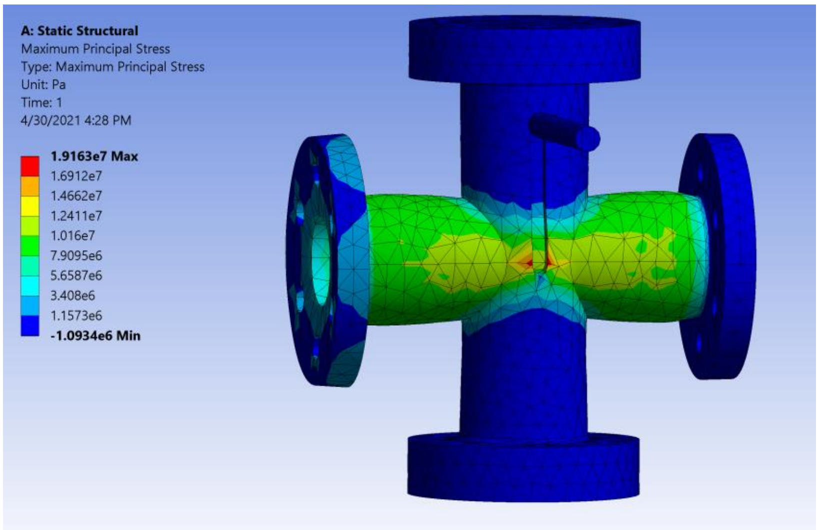

Fig. 16 Maximum principal stress at 4 MPa internal pressure

V. CONCLUSION

The valve is designed to be as simple as it can be. There is a reduction or absence of complex components which could be the reason for its less cost. It can be designed to be both low-pressure and high-pressure valve. In this paper, the design is taken as high pressure one. From the static structural analysis on ANSYS software at different pressures, it was found that the maximum stress developed on the valve body was 19.163 MPa. Since the ultimate tensile strength of the material is 480 MPa therefore it can be said that the design is completely safe. Taking the valve's design and functions into consideration, a suitable name can be taken as "up-down valve".

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