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Design And Analysis of Check Valves used in Hydraulics

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Abstract-- **A hydraulic check valve is a device that is installed to keep fluid from flowing backwards through the valves. Hydraulic check valves do not require any external activation; instead contain a mechanism that moves according to the flow of fluid through the valves. Hydraulic check valves are zero leakage devices, which can be used in locking hydraulic systems. When the fluid flows forward towards the valve, the mechanism allows it flow, whereas when the fluid stops flowing the mechanism plugs up the valve opening so that the fluid cannot flow backwards This project work is addressed to analyze the check valve under static and thermal load conditions. The pressure of 48.26Mpa has showed the check valve design is safe by obtaining factor of safety 3.15 under static load conditions respectively. Preheating the component from room temperature 250C to 400C at temperature of 71.10C and pressure 48.26Mpa has showed the check valve design is safe by obtaining factor of safety 3.022 under thermal load conditions.**

Introduction

A check valve is a mechanical device which has two port valves, which means to say it has two openings in the body, one for the fluid to enter and other for fluid to leave. An important function of the check valves is that they are activated at the upstream cracking pressure.Check valves are often used in household items and are generally very simple, small and inexpensive, though they are available in wide range of costs and sizes. Check valves are controlled manually or through an external source; but mostly they work automatically. Check valves commonly use a poppet and light spring to control flow as shown in the Fig 1.1.If P1A1 > P2A2 + spring force, then flow occurs in the direction of the arrows. If P1A1 < P2A2 + spring force, then the poppet would be pushed to the left i.e., against the stop and prohibiting flow in reverse direction.

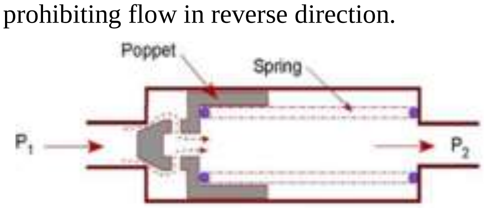


Fig 1: Check valve shown in open position

A check valve mainly consists of three types: Manifold, Seat and Retainer related to the project. Manifold is a part which is used to hold the entire parts inside it. It is like a supporting body for the individual parts. The valve seat may be formed separately or as a part of the valve body. Seat is mainly used to avoid the leakages when the fluid is flowing through the part itself. It must be capable of avoiding leakage from low to high pressure fluid passing through it. The retainer may be split lengthwise and compressed into the valve body for holding the seat cages that are assembled inside the Manifold.

A hydraulic check valve is a device that is installed in a valve to keep fluid from flowing backwards through the valve. It does not require any external activation; instead, it contains a mechanism that moves according to the flow of the fluid through the valves.

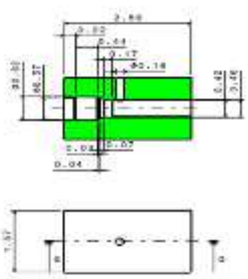
An actuator is a type of moving mechanism which is used to control a system or it is also defined as type of motor which is used for controlling a mechanism through a source of energy which is usually in the form of an electric current, pneumatic current or hydraulic fluid pressure.

In earlier days check valves created lot of problems when loads were applied without proper selection of the material, which caused leakages in the valves and damaged the parts of the device. In present scenarios, despite using different materials with good strength check valves must withstand high loads and must operate without any damage. Structural failure occurs due to static loads and thermal loads. In this paper the analysis of check valves through static loads and thermal loads is addressed. Finite Element Analysis was used for the analysis under different boundary conditions.

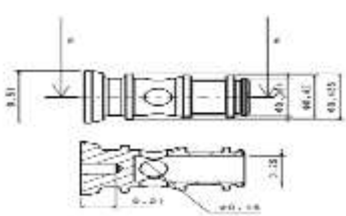
2. Modelling and Finite Element Analysis:

2.1 Geometrical modelling

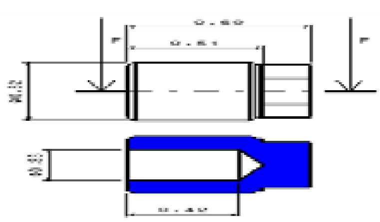
In this study the design of Check Valves were referred from different designs available from the journals of science direct and Moog India controls. With respect to those designs geometrical models were created in CATIA V5 R19 Cad Software. There are three parts: Seat, Retainer and Manifold. The geometrical details are shown in Fig 2. The Assembled Part of the check valve generated in CATIA V5 R19 is shown in the Fig 3.



Manifold



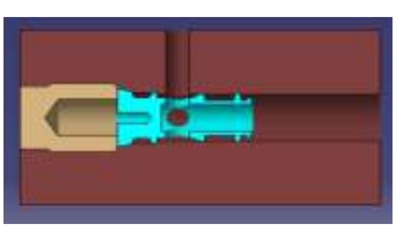
Seat



Retainer

Fig 2: Geometrical details of Individual parts.

Fig 3: The Assembled Part of the check valve generated in CATIA V5 R19.



2.2 Finite Element Analysis

In the software ANSYS R14.5, geometrical model was imported from cad software in the form of STEP file. The later analysis steps will be as follows:

2.2.1 Material Selection

The material selected for individual parts are given as Manifold – Al T7050, Seat – Steel 440C, Retainer – Al T6061. These are materials selected for the analysis which satisfies the boundary conditions according to the Aircraft Industry. Table 2.1a, b and c shows the different material properties for different materials.

TABLE 1: MATERIAL PROPERTIES OF ALT7050

Material Properties	
Young's modulus	71700Mpa
Poisson's ratio	0.33
Density	2830 kg / m3
Tensile yield strength	469 MPa
Tensile ultimate strength	524 MPa
Elongation	11%

TABLE 2: MATERIAL PROPERTIES OF STAINLESS STEEL 440C

Material Properties	
Young's modulus	2*105 Mpa
Poisson's ratio	0.30
Density	7800 kg / m3
Tensile yield strength	965 MPa

TABLE 3: MATERIAL PROPERTIES OF AL T606

Material Properties	
Young's modulus	68900Mpa
Poisson's ratio	0.33
Density	2.7 * 10-9 kg / m3
Tensile yield strength	276 MPa
Tensile ultimate strength	310 MPa
Elongation	11%

2.2.2 Mesh Generation

The model was meshed using automatic meshing in the software; this automatic meshing creates tetrahedral mesh elements. Fig 4 shows the mesh generated model. In order to obtain accurate results near the contact regions a refinement of three levels was done. The mesh size is taken as 10mm. The total mesh comprises 465804 elements and 98781nodes. ANSYS SOLID185 element is used for the mesh representation. The Model was meshed in ANSYS R14.5.

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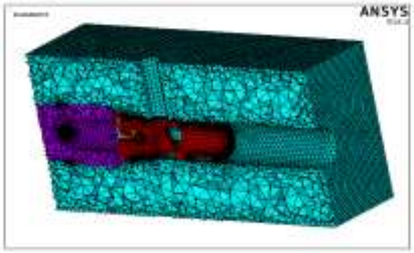


Fig 4: Sectional view of the check valve Meshed in ANSYS R14.5

2.2.3 Boundary Conditions

Since the manifold is fixed in the wall, all outer surfaces except the flow path of fluid from the top case of the body to the end of seat are constrained.The fluid operating pressure of 68.94Mpa (10000psi) is applied for the check valve. The component must be suited for the pressure applied; this is accomplished by Static analysis. The fig 5 shows the flow region inside the check valve and full body is constrained. The two flow region inlet and outlet is mounted to the Seat.

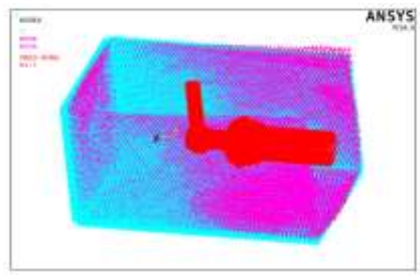


Fig 5: Point of application of the pressure acting on the check valve (ANSYS 14)

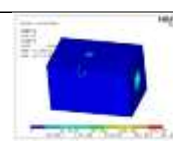
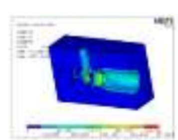
3. Results and Discussion

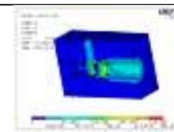
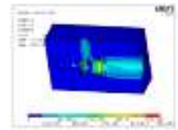
3.1 Static Analysis for the Check Valve

The pressure given for the model was 68.94Mpa (10000psi). If the model is not satisfied for the given load, then again suitable pressure is applied till it suits for the design given. This is obtained by decreasing the pressure until the model is considered to be safe, i.e. should be below the yield strength and greater than minimal factor of safety. The factor of safety is calculated for the check valve by using the formula of factor of safety. The factor of safety is defined as the ratio of the breaking stress of a structure to the estimated maximum stress obtained in ordinary use. Equation 1 shows the formula to calculate the factor of safety.

Factor Of safety = (Yield strength)/ (Developed stress) (1)

TABLE 4: COMPARISON AT DIFFERENT PRESSURES FOR THE VON MISES STRESS

Pressure in Mpa	Material	Developed stress (Mpa)	Yield strength (Mpa)	Factor Of safety	Von mises Stress
68.94	Check valve (Steel)	441.197	965	2.18	
62.05	Check valve (Steel)	397.103	965	2.43	

55.15	Check valve (Steel)	352.945	965	2.73	
48.26	Check valve (Steel)	308.851	965	3.15	

From Table 4 it can be concluded that from the Von mises stress results obtained for the check valve, factor of safety is calculated at different pressures form 68.94Mpa (10000Psi) to 48.26Mpa (7000Psi). The check valve is not safe at the pressure 68.94Mpa, the factor of safety is below the minimal factor of safety, i.e. should be greater than 3. Hence the given check valve design is not suited at the pressure 68.94Mpa. Pressure is decreased to find the pressure for which the valve design is suitable. It is concluded when it is greater than minimal factor of safety, i.e. greater than 3. The predicted values are shown in the table3.1 by comparing to the Pressure in Mpa and factor of safety. Obtained FOS is 3.15 at the pressure 48.26Mpa (7000Psi). Since it is proved that at the pressure 48.26Mpa the design is suited, the design is safe and satisfying the minimal factor of safety.

3.2 Thermal Analysis for the check valve

The main goal is to show how the temperature impacts on the structures. The engineers always control the temperature in the generalized format. This is done either by increasing or decreasing the temperature at a constant rate, and by also working with predetermined different temperatures. The pressure was chosen from the previous static analysis which was considered to be safe for the check valve design. The temperature applied for the Check valve is 71.10 C and pressure of 48.26Mpa (7000psi) is shown in fig 6.

From table 5, it can be concluded that the Von mises stress results is obtained for the check valve and factor of safety is calculated at the pressure 48.26Mpa (7000Psi) and temperature 71.10C. The pressure was chosen from the previous static analysis as it was considered to be safe for the given design.

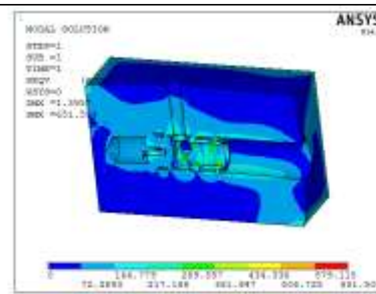


Fig 6: Result for Check Valve at pressure of 48.26Mpa and Temperature at 71.1^0 C

TABLE 5: TYPE OF MATERIAL USED AND FOS AT PRESSURE OF 48.26MPA AND TEMPERATURE AT 71.10 C.

Material	Check valve (Steel)
Developed stress (Mpa)	651.504
Yield strength (Mpa)	965
Factor Of safety	1.48

Obtained FOS is 1.48 at the pressure 48.26Mpa (7000Psi) and temperature 71.10C. The factor of safety is below the minimal factor of safety, i.e. should be greater than 3. Hence the check valve is not safe at the pressure and temperature applied. To overcome this problem the component is preheated and then analyzed.

3.3 Preheating the check valve

Preheating the component from room temperature to certain temperature to check whether the component is below the yield strength and to check whether the model satisfies the minimal factor of safety. Preheating is carried out if the component is not safe for the loads applied. This is checked by analyzing the check valve under thermal analysis. The room temperature considered is 250C and preheated to 400C and stress is calculated. The overall temperature applied to the body is 71.10C and pressure applied is 48.26Mpa (7000psi). The check valve after preheating from room temperature 250 C to 400C was checked at the pressure of 48.26Mpa (7000psi) is shown in fig 7 and the factor of safety is calculated.

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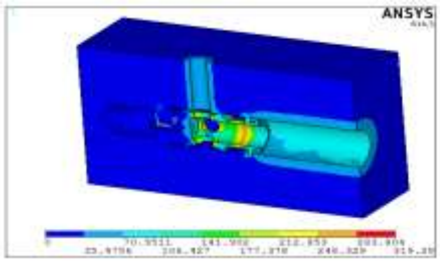

Fig 7: Result for Check Valve after preheating at a pressure of 48.26Mpa and Temperature at 71.1^0 C

TABLE 6: TYPE OF MATERIAL USED AND FOS AT PRESSURE AFTER PREHEATING AT PRESSURE OF 48.26MPA AND TEMPERATURE AT 71.10 C.

Material	Check valve (Steel)
Developed stress (Mpa)	319.28
Yield strength(Mpa)	965
Factor Of safety	3.022

This is accomplished by analyzing the check valve under thermal analysis. The room temperature considered is 250C. The component is preheated from the room temperature to certain degree of temperature to get the correct result. This is done by preheating the check valve from 250C to 400C and calculating the FOS. The overall temperature applied to the check valve is 71.10C and pressure applied is 48.26Mpa (7000psi). From table 6, it can be concluded that the Von mises stress results is obtained for the check valve and factor of safety is calculated at the pressure 48.26Mpa and temperature 71.10C.Obtained FOS is 3.022 which is greater than minimal FOS. Hence it is concluded that the design is safe after preheating the component.

4. Conclusion

Stress analysis is carried out to determine whether the design is safe for the different pressures applied. From the analysis it results that the design is safe at the pressure of 48.26Mpa (7000psi). This validation is correct when the component satisfies the minimal factor of safety, i.e. greater than 3. The FOS of the check valve by accomplishing Static analysis was 3.15 at the pressure 48.26Mpa, which is greater than 3. Hence it is proved the design is safe. By this we can conclude FEA software used for analysis is valid.

After the Static analysis is done by applying only pressure, it was necessary to check the safety of the design when both temperature and pressure boundary condition is applied. This was checked by Thermal load conditions which were again analyzed using the software ANSYS 14.5. The pressure was chosen from the static analysis as it was considered to be safe for the given design. The pressure chosen for thermal analysis was 48.26Mpa (7000psi) andtemperature 71.10C. When the temperature and pressure applied on the check valve the result showed the component is not safe. Hence the component was again preheated from 250C to 400C and results were validated. The FOS of the check valve by accomplishing thermal analysis was 3.022 after preheating. This result satisfied that the component is safe and greater the minimal factor of safety. Hence it is proved the design was safe after preheating the component.

Acknowledgment

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[Hydraulic check valves are zero leakage devices, which can be used in locking hydraulic systems]

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