DESIGN AND ANALYSIS OF FEED CHECK VALVE

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ABSTRACT

Check valves are generally used as flow control equipment in many industries. The Feed check valve is fitted to the boiler, slightly below the working level in the boiler. It is used to supply high pressure feed water to boiler and to prevent the returning of feed water from the boiler if feed pump fails to work. The parameter for the performance of control valve analysis is flow coefficient. There is an experimental method to calculate the flow coefficient value of the valve, but the setup for the experimental validation is not readily available as these valves work at high pressure. Due to the progress of the flow simulation and numerical technique (CFD), it becomes possible to observe the flows inside a valve and to estimate the performance of a valve. The Feed check valve is fitted to the boiler, slightly below the working level in the boiler. It is used to supply high pressure feed water to boiler and to prevent the returning of feed water from the boiler if feed pump fails to work. With rapid advancement in flow simulation, CFD and thermal Numerical technique, the flow characteristics of the feed check valve can be studied effectively. Water is working fluid here and at different fluid inlet velocity's compared rapid advancement in the area of flow simulation, CFD and Numerical technique, the flow characteristics of the feed check valve can be studied valve is carried out using SOLIDWORKS™ FLOW SIMULATION software to understand the inside flow characteristics and to determine prominent factors such as Pressure drop, Valve co-efficient for various materials (Cast iron, Brass). In the final phase, the discharge of the valve for a constant pressure drop of 1 bar is determined.

Key words: Feed check valve, CFD, SOLIDWORKS™ flow simulation.

1.INTRODUCTION

A valve is a device or natural object that regulates, directs or controls the flow of a fluid (gases, liquids, fluidized solids, or slurries) by opening, closing, or partially obstructing various passageways. Valves are technically fittings but are usually discussed as a separate category. In an open valve, fluid flows in a direction from higher pressure to lower pressure. The word is derived from the Latin valve, the moving part of a door, in turn from evolver, to turn, roll. The simplest, and very ancient, valve is simply a freely hinged flap which swings down to obstruct fluid (gas or liquid) flow in one direction but is pushed up by the flow itself when the flow is moving in the opposite direction. This is called a check valve, as it prevents or "checks" the flow in one direction. Modern control valves May regulate pressure or flow downstream and operate on sophisticated automation systems.

2.LITERATURE REVIEW

1. R. NIKHIL, “Design and Analysis of Feed Check Valve as Control Valve Using CFD Software”

2. Tansen Chaudhary et al., compares the flow coefficient value at different openings of the valve calculated by ANSYS Fluent 14.5 with the experimental values. Result of the analysis shows reduction in discharge with decrease in opening which satisfies the physics of fluid flow.

3. Brian Nesbitt gave a handbook on valves and actuators which provide the understanding of valves and actuators, properties of fluids (change of state, viscosity, density, compressibility, pH valve, hazards), valve sizing parameters, and serve as a guide for valves installation and maintenance. Brain Nesbitt classifies needle valve into two types, i.e. Straight needle valve, and angle needle valve.

4. Anna Budziszewski and Louise Thoren did CFD simulations of a safety relief valve for improvement of one-dimensional valve model in RELAP5. The purpose of their work was to investigate how a safety relief valve can be modelled with CFD and to find

parameter relations to be implemented in RELAP5 to obtain more realistic results of generated forces in the pipe system.

5. V. J. Sonawane et al., designed and analysed the globe valve as control valve using CFD software. They analysed globe valves of different sizes and for different opening conditions. The boundary conditions used were pressure inlet and pressure outlet. They calculated the discharge in every case.

6. José R. Valdés et al., gave a methodology for parametric modelling of the flow coefficients and flow rate in hydraulic valves. The proposed methodology was based on the derivation from CFD simulations, of the flow coefficient of the critical restrictions as the function of Reynolds number, using a generalized square root function with two parameters.

7. Hongjun Zhu et al. analysed the flow erosion and flow-induced deformation in needle valve for different inlet rate, opening conditions and different particle sizes. They analysed an angled needle valve, with the help of ANSYS Fluent. The boundary conditions used were velocity inlet and pressure outlet. They analysed the valve for 20, 30, 40 m/s inlet speed 16 and for different opening sizes. Total seventeen permutations were taken for analysing the effect on the valve. The conclusion from the analysis was that the effect of particle diameter on erosion is most significant followed by inlet rate.

8. Rodrigo Alvite Romano and Claudio Garcia. describes two methods used to estimate the parameters of a Karnopp friction model applied to control valves. The methods are tested using simulated data of three valves with different friction levels

3.DESIGN / MODELLING

The modelling of Feed check valve is done with the help of SOLIDWORKS™ CAD software. This software is very user-friendly and easy to use. The assembly of the feed check valve is shown in the Fig.3.1 and the component of the valve is shown in the table 3.1 below.

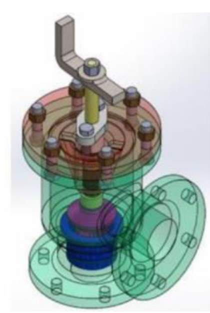

Fig. 3.1: Isometric view

Table 3.1 shows about the all the components that are assembled in the feed check valve and describes about the materials used for each component in the designing.

Table 3.1: List of Components in the Assembly

PART NO	COMPONENT	MATERIAL
1	Body	Cast iron & Brass
2	Cover	Cast iron & Brass
3	Hand Wheel	1023 carbon steel
4	Valve Seat	Tin bearing bronze
5	Valve	Tin bearing bronze
6	Gland	Tin bearing bronze
7	Spindle	1023 carbon steel
8	Stud	1023 carbon steel

All the components of the feed check valve are designed individually in SolidWorks. The isometric views of all the components are shown in the figures below.

1. BODY

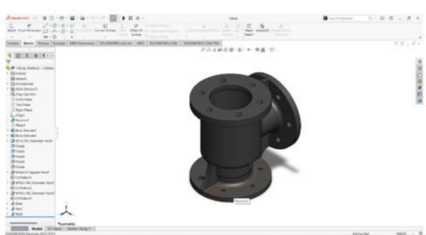

Fig. 3.2: Isometric view of body

2. COVER

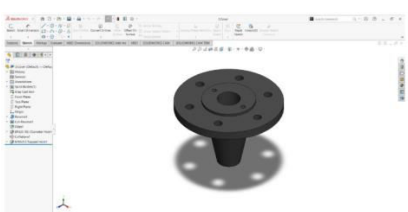

Fig. 3.3: Isometric view of cover

3. HAND WHEEL

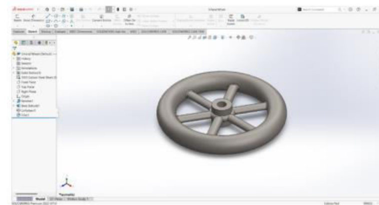

Fig. 3.4: Isometric view of hand wheel

4. VALVE SEAT

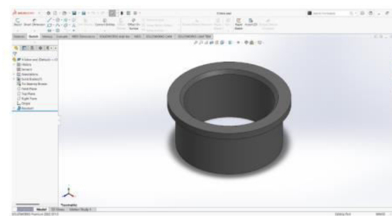

Fig. 3.5: Isometric view of valve seat

5. VALVE

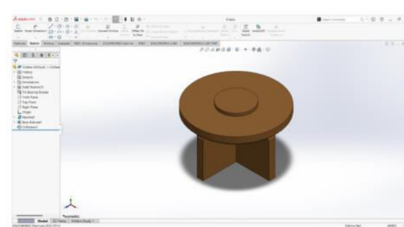

Fig. 3.6: Isometric view of valve

6. GLAND

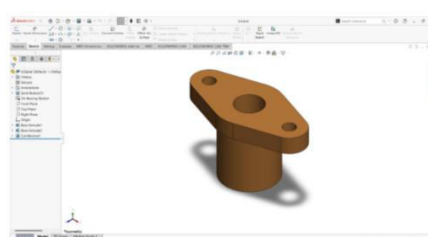

Fig. 3.7: Isometric view of gland

7. SPINDLE

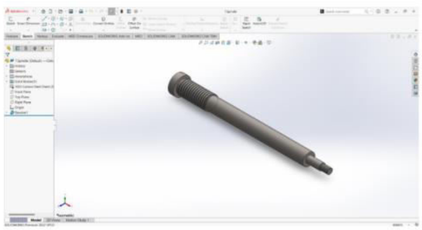

Fig. 3.8: Isometric view of spindle

8. STUD

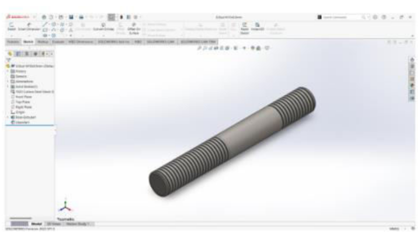

Fig. 3.9: Isometric view of stud

Assembly drawing of all components

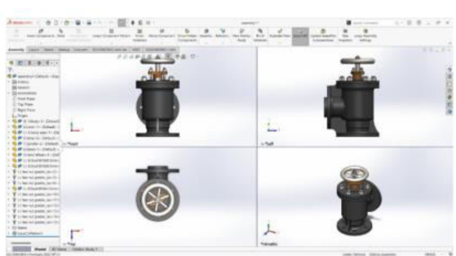

Fig. 3.10: Isometric view of all assembled components

4. RESULTS & DISCUSSIONS

After the component is designed and assembled, it is imported, and meshing is being done. By performing CFD analysis, various valve parameters like pressure drop, valve flow coefficient and discharge under constant pressure drop is identified. PRESSURE DROP

A. CAST IRON

For cast iron material, we set the parameters of inlet flow rate as 5 m3/hr and valve lifts are maintained from 3mm to 16 mm lift and pressure drop is identified at every valve lift as shown in table 5.1. Similarly, by changing the inlet flow rate to 10 m3/hr., the experiment is repeated, and pressure drop valves are tabulated as shown in table 5.2.

Inlet Volume flow rate = 5 m3/hr

Inlet Volume flow rate = 10 m3/hr

Outlet Static pressure = 101325 Pa

Table 5.1- Pressure drop at 5 m3/hr

Lift (mm)	Pressure drop (Bar)	Pressure drop (PSI)
3	0.5886	8.5363
4	0.1104	1.6017
5	0.0622	0.9016
6	0.0413	0.5987
7	0.0285	0.4130
8	0.0257	0.3730
9	0.0178	0.2582
10	0.0127	0.1839
11	0.0093	0.1355
12	0.0092	0.1333
13	0.0077	0.1122
14	0.0054	0.0785
15	0.0047	0.0682
16	0.0044	0.0642

Table 5.2- Pressure drop at 10 m3/hr

Lift (mm)	Pressure drop (Bar)	Pressure drop (PSI)
3	2.3279	33.7636
4	0.4300	6.2361
5	0.2423	3.5148
6	0.1623	2.3540
7	0.1119	1.6235
8	0.1001	1.4524
9	0.0696	1.0101
10	0.0499	0.7236
11	0.0369	0.5348
12	0.0371	0.5376
13	0.0277	0.4011
14	0.0215	0.3125
15	0.0185	0.2677
16	0.0175	0.2537

B. BRASS

For brass material, we set the parameters of inlet flow rate as 5 m3/hr and valve lifts are maintained from 3mm to 16 mm lift and pressure drop is identified at every valve lift as shown in table 5.3. Similarly, by changing the inlet flow rate to 10 m3/hr., the experiment is repeated, and pressure drop valves are tabulated as shown in table 5.4.

Inlet Volume flow rate = 5 m3/hr

Inlet Volume flow rate = 10 m3/hr

Outlet Static pressure = 101325 Pa

5.3- Pressure drop at 5 m3/hr

Lift (mm)	Pressure drop (Bar)	Pressure drop (PSI)
3	0.5446	7.8983
4	0.0987	1.4314
5	0.0590	0.8556
6	0.0340	0.4931
7	0.0239	0.3466
8	0.0212	0.3074
9	0.0146	0.2117
10	0.0099	0.1435
11	0.0086	0.1247
12	0.0080	0.1160
13	0.0065	0.0942
14	0.0050	0.0725
15	0.0043	0.0623
16	0.0039	0.0565

Table 5.4- Pressure drop at 10 m3/hr

Lift (mm)	Pressure drop (Bar)	Pressure drop (PSI)
3	2.1728	31.5121
4	0.4192	6.0796
5	0.2365	3.4299
6	0.1567	2.2682
7	0.1105	1.6025
8	0.0969	1.4053
9	0.0623	0.9035
10	0.0415	0.6018
11	0.0336	0.4873
12	0.0316	0.4582
13	0.0246	0.3567
14	0.0202	0.2929
15	0.0164	0.2378
16	0.0156	0.2262

On obtaining the pressure drop values for both cast iron and brass at different flows rates, a graph is being plotted and values are being analysed as shown in figure 5.1 below.

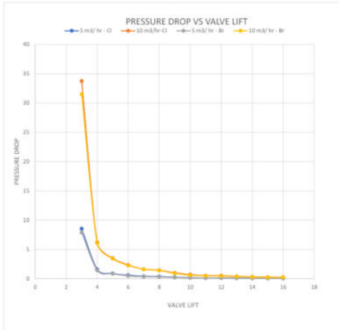

Fig 5.1: Pressure Drop (PSI) Vs. Valve lift(mm) for both cast iron and brass for different flow rates.

From the graph we can observe that brass material has lower pressure drops compared to cast iron at respective flow rates i.e, 5 m3/hr and 10 m3/hr since cast iron has higher surface roughness due to which more frictional loses arises while compared to brass.

FLOW COEFFICIENT (Cv)

For both cast iron and brass material, we set the parameters of inlet flow rate as 5 m3/hr and valve lifts are maintained from 3mm to 16 mm lift and Valve Flow coefficient is identified at every valve lift as shown in table 5.5. Similarly, by changing the inlet flow rate to 10 m3/hr., the experiment is repeated, and Valve Flow coefficient are tabulated as shown in table 5.6. P)ΔCv = Q*sqrt (SG/ Where: Q = Capacity in gallons per minute. Cv =Valve sizing coefficient determined experimentally for each style and size of valve, using water at standard conditions as the test fluid. ΔP = (P1-P2) Pressure differential in psi. SG = Specific gravity of fluid (water at 60°F = 1.0)

A. CAST IRON

TRIAL 1 TRIAL 2

Volume flow rate = 5 m3/hr

Volume flow rate = 10 m3/hr

Table 5.5- Valve Flow coefficient at 5 m3/hr

Lift (mm)	Flow co-efficient (C_v)
3	7.5348
4	17.3947
5	23.1843
6	28.4523
7	34.2572
8	36.0432
9	43.3273
10	51.3298
11	59.8006
12	60.2983
13	65.7155
14	78.5572
15	84.2778
16	86.8801

Table 5.6- Valve Flow coefficient at 10 m3/hr

Lift (mm)	Flow co-efficient (C_v)
3	7.5772
4	17.6311
5	23.4846
6	28.6965
7	34.5554
8	36.5332
9	43.8081
10	51.7608
11	60.2079
12	60.0495
13	69.5166
14	78.7651
15	85.1019
16	87.4129

B. BRASS

For brass material, we set the parameter of inlet flow rate as 5 m3/hr and valve lifts are maintained from 3mm to 16 mm lift and Valve Flow coefficient is identified at every valve lift as shown in table 5.7. Similarly, by changing the inlet flow rate to 10 m3/hr., the experiment is repeated, and Valve Flow coefficient are tabulated as shown in table 5.8.

TRIAL 1 TRIAL 2

Volume flow rate = 5 m3/hr

Volume flow rate = 10 m3/hr

Table 5.7- Valve Flow coefficient at 5 m3/hr

Lift (mm)	Flow co-efficient (C_v)
3	8.7624
4	19.7260
5	25.2361
6	30.3124
7	35.5621
8	39.0012
9	44.6945
10	53.3324
11	60.2938
12	62.6523
13	68.0033
14	79.7865
15	85.1209
16	88.0102

Table 5.8- Valve Flow coefficient at 10 m3/hr

Lift (mm)	Flow co-efficient (C_v)
3	8.9265
4	19.8256
5	25.5329
6	30.4156
7	35.8076
8	39.4308
9	44.9300
10	53.5179
11	60.6276
12	62.8726
13	69.5166
14	80.0025
15	85.5024
16	88.4965

On obtaining the Valve Flow coefficient values, for both cast iron and brass at different flows rates, a graph is being plotted and values are being analysed as shown in figure 5.2 below. We can observe that the valve coefficient of brass is higher when compared to cast iron material valve since valve coefficient is inversely related to pressure drop. The lower the pressure drop, the higher the valve coefficient.

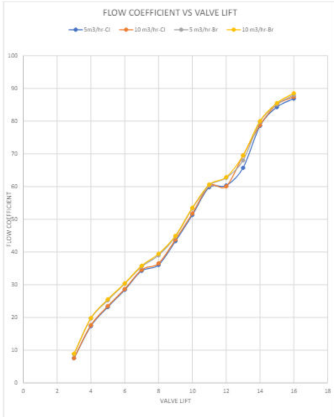

Fig 5.2: Valve flow coefficient (Cv) Vs. Valve lift(mm) for both cast iron and brass for different flow rates.

DISCHARGE UNDER CONSTANT PRESSURE DROP

For both cast iron and brass material, we set the parameters as Inlet Pressure = 40 Bar Outlet Pressure = 39 Bar and valve lifts are maintained from 3mm to 16 mm lift and discharge is identified at every valve lift and the values are noted down in table 5.9 and 5.10 We know that Discharge (Q) = V*A Where: V = outlet velocity (m/s), A= Area of outlet=0.0045 m2

Boundary conditions: Inlet Pressure = 40 Bar Outlet Pressure = 39 Bar Area of the outlet = 0.0045 m

A. CAST IRON

Table 5.9 – Discharge under constant pressure drop in LPM

Lift (mm)	Outlet velocity (V), (m/s)	Discharge (m3/s), Q=V*A	Discharge In LPM
3	0.408	0.0018	108
4	0.736	0.0033	198
5	1.19	0.0054	324
6	1.092	0.0049	294
7	1.759	0.0079	474
8	2.432	0.0109	654
9	1.922	0.0086	516
10	2.463	0.0111	666
11	2.383	0.0107	642
12	1.979	0.0089	534
13	2.741	0.0123	738
14	2.756	0.0124	744
15	3.66	0.0165	990
16	4.199	0.0189	1134

B. BRASS

Table 5.10 – Discharge under constant pressure drop in LPM

Lift (mm)	Outlet velocity (V), (m/s)	Discharge (m3/s), Q=V*A	Discharge In LPM
3	0.496	0.0022	132
4	0.812	0.0036	216
5	1.32	0.0059	354
6	1.214	0.0054	324
7	1.846	0.0083	498
8	2.610	0.0117	702
9	2.125	0.0095	570
10	2.586	0.0116	696
11	2.476	0.0111	666
12	2.099	0.0094	564
13	2.843	0.0127	762
14	2.916	0.0131	786
15	3.79	0.0170	1020
16	4.456	0.0200	1200

After obtaining discharge values for both materials (cast iron & Brass), discharge vs valve lift graph is plotted and compared as shown in the below figure.

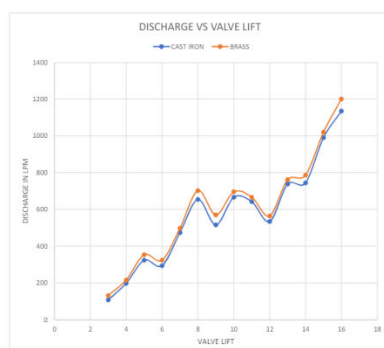

Fig. 5.3: Discharge (LPM) vs Valve lift (mm) characteristic curve

From the above readings and graphs, we can observe that brass material valve can discharge more amount of water than compared to cast iron material valve at constant pressure drop.This is because discharge is directly depending upon the velocity of the water flowing inside the valve. The velocity of water changes according to the pressure drop and material used for valve.

5.CONCLUSIONS

After designing a feed check valve in SolidWorks, the component is being imported and CFD analysis is being carried out to identify various valve parameters such as pressure drop, valve flow coefficient and discharge under constant pressure drop for both cast iron and brass at different lifts. After all these results and discussions, we can conclude that-

- ❖ The modelling of the feed check valve is done using SolidWorks and a method of performing CFD analysis using flow simulation software.
- ❖ The pressure drop curve is obtained for flow rates of 5 m3/hr and 10 m3/hr for both Cast iron and Brass. The results show that the pressure drop is more for higher flow rates and lower valve lifts and pressure drop is more for cast iron compared to Brass due to its rougher surface finish and increased friction.
- ❖ The obtained pressure drop values is used to calculate the flow co-efficient (Cv) for flow rates 5 m3/hr and 10 m3/hr using traditional valve sizing formula for different valve lifts i.e., from 3mm to 16mm. The results show that flow co-efficient increases in a linear fashion with the valve lift. On comparisons of cast iron and brass, brass has higher flow coefficient.
- ❖ When a constant pressure drop is set, brass valve higher discharge on compared to cast iron

6.REFERENCES

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