International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 07 | July 2018 www.irjet.net p-ISSN: 2395-0072

Computational Fluid Dynamics of Air Release Valve for Hydro Power Plant by Using Finite Element Method: A Review

Siddalingeshwara K L[1], Ravi Kumbar[2]

[1]*M.Tech Student, Machine Design, Mechanical Department SJBIT, Bangalore, India*
[2] *Assistant Professor, Mechanical Department SJBIT, Bangalore, India*

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Abstract – *In presently safety valves sizing standards the gas discharge capacity is based on a nozzle fl0w derived from ideal gas theory. At high pressure or low temperatures real gas effects can no longer be neglected. Filling and emptying penstock pipe systems involves the movement of large volume of water and air. During initial filling of penstock pipe, the water which flows into the empty penstock pipe, displaces the air and pushes it to be higher elevation. If the air at this location is not removed from penstock pipe the flowing water compress the air to such extent that penstock pipe may damage. Computational fluid dynamics analysis is performed to determine the pressure, velocity distribution and flow characteristics of air relief valve. Hence all hydro power plants is compulsory to use the air release valve in order to protect penstock pipe.*

Key Words: FEM, Ansys, Air Release valve, CFD.

1. INTRODUCTION

A relief valve is a type of valve to control or limit the pressure in a system by allowing the pressurized fluid to flow out from the system. Pressure relief valves must be designed with materials compatible with many process fluids from simple air and water to the most corrosive media.[1]

A valve is device that regulates, controls the flow of fluid by opening, closing or partially obstructing various passage ways they are used in various applications like industrial oil, gas and power generation. Valves are various types having wide range of size and applications. Spring loaded pressure relief valves are widely used in lots of hydraulic systems. [2]

Knife gate valves were originally designed for use of pulp and paper industry. By using a sharp, beveled edge, a knife gate was ideally designed to cut through the chewy pulp and paper industries. The benefits of knife gates also include that they are easy to actuate and cheap to produce.[3]

2. LITERATURE SURVEY

Jadhav S.G. et al. [1] designed pressure relief valves to provide protection from overpressure in steam, gas, air and liquid lines. An overpressure event refers to any condition which would cause pressure in a vessel or system to increase beyond the specified design pressure or maximum allowable working pressure. He focused on the review on design, analysis and weight optimization of pressure relief valve by using transient finite element analysis.

Aniket A. Kulkarni et al. [2] focused on a review of a structural analysis and optimization of pressure vessel to identify the existing work made in the analysis of pressure vessel and to form a theoretical foundation for understanding the recent developments, then to gain some insight into which domains are relevant in order to position the research. Pressure vessel has several functions apart from holding the gas pressure. Also it appears that pressure vessel can be designed using experimental, analytical and numerical techniques.

A.R. Champneys et al. [3] Summarized and extended recent scientific investigations into the mechanisms of instability in pressure relief valves (PRVs) and considers their implications for practical operation. The overall aim was to develop a new comprehensive understanding of the issues that affect valve stability in operation, in order to influence a new set of design guidelines for their operation and manufacture. They focused

specifically on direct spring-loaded PRVs in gas service, particularly considering the combined effect of the valve dynamics with acoustic pressure waves within its inlet pipe.

Prof. Vishal V. Saidpatil et al. [4] carried out detailed design & analysis of Pressure vessel used in boiler for optimum thickness, temperature distribution and dynamic behavior using Finite element analysis software. They designed a cylindrical pressure vessel to sustain 5 bar pressure and determine the wall thickness required for the vessel to limit the maximum shear stress. Geometrical and finite element model of Pressure vessel was created using CAD CAE tools. Geometrical model was created on CATIA V5R19 and finite element modeling was done using Hypermesh. ANSYS was used as a solver.

M. V. Awati et al. [5] focused on design of an emergency shut of valve. Non-linear analysis is carried out to obtain the results. Stresses and deformations are within permissible values. Additional reinforcement pad is attached to nozzle part to avoid failure. From the results we can say valve performs functionally well. Nonlinear analysis gives more accurate results regarding the stresses.

Sushant M. Patil et al.[6] designed "gradual flow reducer valve" with available data on field. The thickness optimization of this gradual flow reducer valve had been done by using finite element analysis. The optimum thickness of the valve was finalized as 2mm. After finalizing the optimum design, same design had been taken for the further analysis. A basic model of the valve suitable for design purposes and optimization had been developed.

C. Bazsó et al. [7] presented detailed experimental results on the static and dynamic behaviour of a hydraulic pressure relief valve with poppet valve body, with a special emphasis on the parameters influencing the valve instability. A systematic experimental study was presented on relief valve instability for slightly compressible fluid (hydraulic oil). The experimental system consisted of a positive displacement pump, a simple direct spring loaded valve and a hydraulic hose connecting them. Pressure and displacement time histories were recorded for a large number of flow rates and set pressures.

Arindam Kundu et al. [8] investigated the flow through valve at different valve opening and different pressure drop were presented. Flow through a spool type valve at different opening corresponding to pre-set pressure difference had been considered. The commercial code FLUENT was found to aptly model the complicated flow processes inside the domain of interest. That involves compressible flow with high level of turbulence. An axisymmetric 2-D formulation was found to perform reasonably well in comparison with resource intensive three-dimensional mesh.

B.S.Thakkar et al. [9] determined the performance of a pressure vessel under pressure by conducting a series of tests to the relevant ASME standard. They observed that all the pressure vessel components were selected on basis of available ASME standards and the manufactures also follow the ASME standards while manufacturing the components. So that leaves the designer free from designing the components.

Qin Yang et al. [10] conducted three-dimensional numerical simulations to observe the flow patterns and to measure valve flow coefficient and flow fluctuations when stop valve with different flow rate and uniform incoming velocity were used in a valve system. The spectra characteristics of pressure fluctuation on the flow cross section were also presented here to investigate the wake induce of the valve part. These results not only provided people with the access of understanding the flow pattern of the valve with different flow rate, but also were made to determine the methods which could be adopted to improve the performance of the valve.

J. Ortega. et al. [11] developed computational model of a direct acting spring loaded pressure relief valve. A simplified two dimension model was built based on the valve geometrical and constructive characteristics. Further, a dynamic equation, which defines the valve disc position, was implemented. From the solution of the transient form of the conservation equations, the velocity and pressure distributions were obtained, allowing the determination of the discharge coefficient versus valve opening under its transient state.

Comparisons with one-dimensional integral approach model were performed to evaluate the model. From above literature review it is shows that thickness optimization of gradual flow reducer valve had been done by using finite element analysis, the same technique is applied to the pressure relief valve and the valve will be redesign with the buffer chamber and at the same time weight optimization will be carried out.

3. DIFFERENT TYPES OF VALVES

3.1 Butterfly Valve

The working principle of butterfly valves is similar to ball valves. In this operation the circular disc is mounted in the valve body instead of ball. The circular disc called a butterfly because the circular disc consists of two half circles around the vertical shaft and it looks like wings. The result of full flow rate is caused when the butterfly is oriented in same direction as the pipe. In next turn the flow rate will be restricted if the butterfly is oriented in opposite direction or away from the direction of pipe, and at the end cut off permanently when the butterfly is oriented at an angle of 90 degrees to the pipe direction.

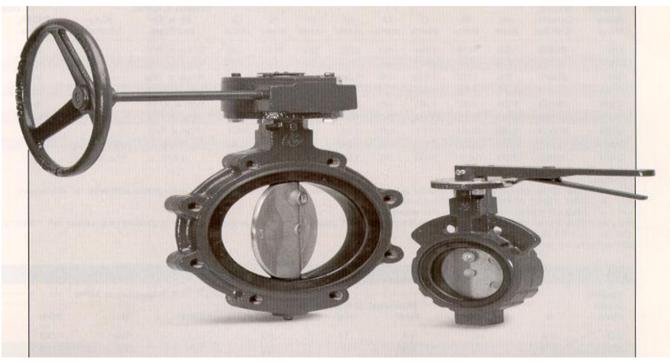

Fig -1: Butterfly valve

3.2 Check Valve

The check valve is also known as non-return valves. These types of valves are designed to ensure only one way flow. The valves are used in water pipe work system and immediately installed after the pump. The check valve is of different type but the most common used valve is the disc type. The disc type may be vertical or horizontal. The operation of this valve is that the disc is pushed out when the flow is sufficient. Suppose if the pump fails the flow reduces or reverses, the disc comes back into a seat restrict the flow.

Fig -2: Check valve

3.3 Pressure Reducing Valve

Generally, they are used for the operation of branch circuits where the pressure may vary from the main hydraulic pressure lines. These are open type valve and have a spring chamber with an adjustable spring, a movable spool as shown in figure. A drain is provided to return the leaked fluid in the spring chamber. A free flow passage is provided from inlet port to the outlet port until a signal from the outlet port tends to throttle the passage through the valve. The pilot pressure opposes the spring force and when both are balanced, the downstream is controlled at the pressure setting. When the pressure in the reduced pressure line exceeds the valve setting, the spool moves to reduce the flow passage area by compressing the spring. It can be seen from the figure that if the spring force is more, the valve opens wider and if the controlled pressure has greater force, the valves moves towards the spring and throttles the flow.

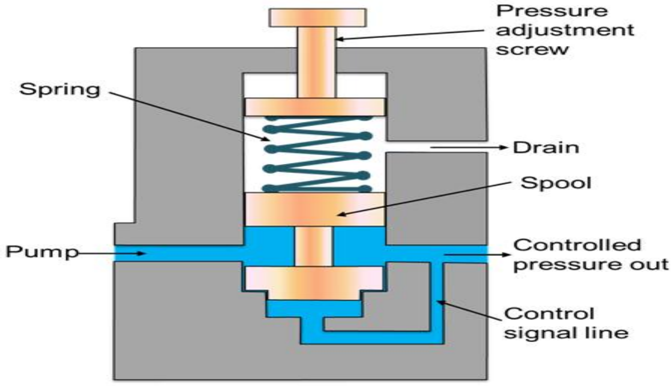

Fig -3: Pressure reducing valve

3.4 Pilot Operated Pressure Relief Valve

The pilot worked weight relief valve has a weight port that is associated with the pump line and the tank port is associated with the tank. The pilot relief valve is a poppet sort. The primary or main relief valve consists of a stem and a piston. The primary relief piston will have orifice penetrated through it. Top and bottom portion of the piston will exposed to pressure and due to equivalent force acting on both the portions the piston will be in balanced condition. In closed position it will remains stationary. The piston consists of light bias spring. When the pressure is lower than that of the relief valve setting, the pump stream or flow will goes to the system. When the pressure becomes high in the system it will moves the pilot poppet off its seat. A little amount of flow starts to go through the pilot line back to the tank. If the flow starts through the pilot line and the piston orifice, a pressure or weight drop is prompted across the piston because of the limitation of the piston orifice. This weight or pressure drop will make the stem and piston to lift off their seats and the stream or flow goes specifically from weight or pressure port to the tank.

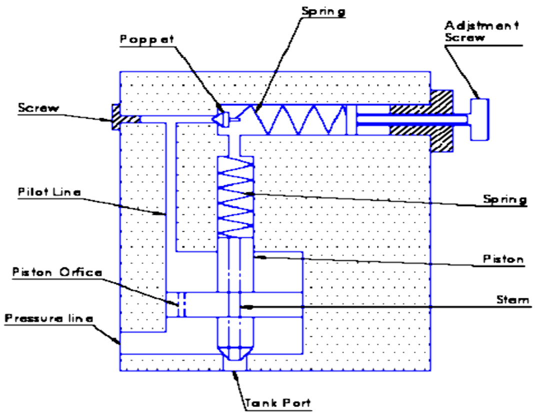

Fig -4: Pilot operated pressure relief valve

3.5 Gate Valve

A gate valve also known as a sluice valve is a valve which opens by lifting a rectangular gate/wedge out of the path of the fluid. The distinct feature of a gate valve is the sealing surface between the gate and seats are planar, so gate valves are often used when a straight line flow of fluid and minimum restriction is desired. The gate faces can be parallel, but are most commonly wedge shaped. Gate valves are primarily used to prevent the flow of liquids, but typical gate valves should not be used for regulating flow, unless they are specially designed for that purpose. Because of their ability to cut through liquids, gate valves are often used in the petroleum industry. Gate valves are primarily designed to serve as isolation valves. In service, these valves generally are either fully open or fully closed. When fully open, the fluid or gas flows through the valve in a straight line with very little resistance.

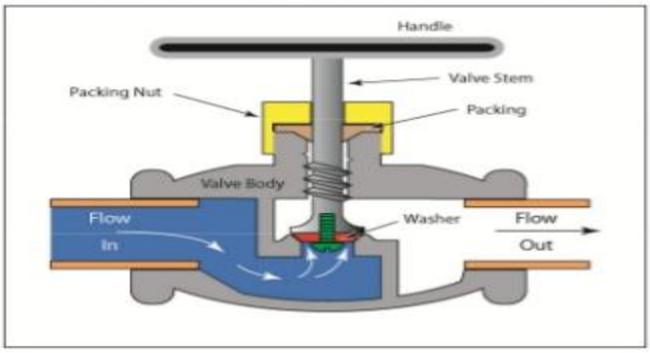

Fig -5: Gate valve

4. CONCLUSIONS

All the above paper were related to design and FEA of pressure valve and optimization concept. Understanding the transient behaviour of relief valve is crucial because critical conditions may be attained, damaging the pipeline. In this paper transient structural analysis has been introduced in order to finalize the geometrical parameter of pressure relief valve

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