Literature Review on Weight Optimization of Pressure Relief Valve for Emergency Relief Operation

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Abstract— Pressure relief valves are designed 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. In many systems, the key requirement of process is to relieve this pressure rise in no time. Conventional valves are unable to fulfill that requirement. This paper focuses on the review on design, analysis and weight optimization of pressure relief valve by using transient finite element analysis. There are many authors work on this pressure valve. This paper includes study of various papers related to pressure valve.

Keywords- *Pressure Relief Valve Design, FEA, ASME, Transient Dynamic Analysis.*

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I. INTRODUCTION

A relief system is an emergency system for discharging fluid during abnormal conditions, by manual or controlled means or by an automatic pressure relief valve from a pressurized vessel or piping system, to the atmosphere to relieve pressure in excess of the maximum allowable working pressure.

In below figure, pressure plate is pressured by a spring against the inlet pressure and this plate is held with the help of failure inserts i.e clip. When pressure rises above maximum allowable working pressure the clip breaks and overpressure generated inside the equipment is relief through the nozzle, so pressure inside the equipment reduce.

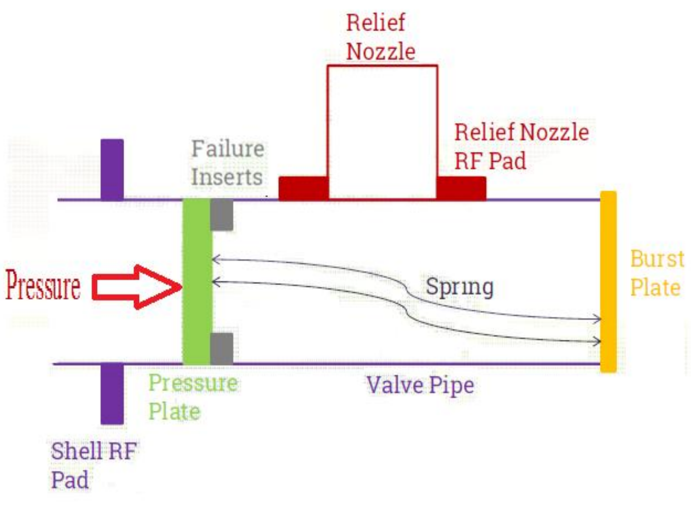

Fig.1 Pressure relief valve for emergency relief operation

1.1. Objective

1) To study the current valve design and its performance aspects.
2) To explore new material replacements that will make the valve light weight.
3) To reduce valve weight using these materials without compromising on the performance aspects.

II. LITERATURE SURVEY

J. Ortega, B. N. Azevedo, L. F. G. Pires, A. O. Nieckele, L. F. A. Azevedo [1] has predicted that relief valves manufactures generally only provide information on valve characteristics under full opening stage which is obtained under steady state regime, therefore, valve and flow's transient behaviour are neglected. Understanding the transient behavior of relief valves is crucial because critical conditions may be attained, damaging the pipeline. In order to overcome this lack of information, they developed a direct acting spring loaded pressure relief valve's computational model was developed. A simplified two dimension model was built based on the valve geometrical and constructive characteristics.

Xue Guan Song, Ji Hoon Jung, Hyeong Seok Lee, Dong Kwan Kim, Young Chul Park [2] They developed a three-dimensional computational fluid dynamics (CFD) model in combination with a dynamics equation to study the fluid characteristics and dynamic behaviour of a spring-loaded PSV. The CFD model, which includes unsteady analysis and a moving mesh technique, was developed to predict the flow field through the valve and calculate the flow force acting on the disk versus time. To overcome the limitation that the moving mesh technique in the commercial software program ANSYS CFX (Version 1.0, ANSYS, Inc., USA) cannot handle complex configurations in most applications, some novel techniques of mesh generation and modeling were used to ensure that the valve disk can move upward and downward successfully without negative mesh error. Subsequently, several constant inlet pressure loads were applied to the developed model. Response parameters, including the displacement of the disk, mass flow through the valve, and fluid force applied on the disk, were obtained and compared with the study of the behaviour of the PSV under different overpressure conditions. In addition, the modeling approach could be useful for valve designers attempting to optimize spring-loaded PSVs.

Ron Darby [3] In this study a model for the opening lift dynamic response of a pressure relief valve in gas/vapor service is presented which accounts for all of these effects through a set of five coupled nonlinear algebraic/differential equations. These equations are solved by a numerical method that can be implemented on a spreadsheet to predict the position of the valve disk as a function of time for given valve characteristics, operating conditions, and installation parameters. The model incorporates the influence of the various parameters on the stable/unstable nature of the disk response.

K. Dasgupta,J. Watton [4] In this study dynamics of a proportional controlled piloted relief valve have been studied through Bondgraph simulation technique. The governing equations of the system have been derived from the model. While solving the system equations numerically, various pressure-flow characteristics across the valve ports and the orifices are taken into consideration. The simulation study identifies some critical parameters, which have significant effect on the transient response of the system. The simulation results are also verified with experimental results.

Y.S. Lai [5] In this study the performance of a spring-loaded safety relief valve, especially a conventional valve, is studied which is influenced by back pressure. A bellows safety relief valve, since its disc is subjected to a much smaller downward force resulting from back pressure, is able to remain stable under much higher back pressure conditions. Due to the wide range of bellows manufacturing tolerances, the bellows safety relief valves can substantially reduce, but cannot totally eliminate, the back pressure effects on its set point and relieving capacity.

N.N. Manchekar and V. Murali Mohan [6] has shown that design of gradual flow reducing valve by finite element analysis. In modern industries like chemical, petroleum, nuclear and oil gas, involves so many processes deals with high temperature and high pressure fluid flow. To control this fluid flow electronically actuated valves are generally used. Also there is a need of mechanical actuated valve by considering the safety and reliability. The secondary objective is to maintain pressure inside the pressure vessel at specific level to avoid bursting of pressure vessel. At present this is achieved by incorporating electronic pressure control valves, which regulates pressure in the system and avoid failure of system, but these valves are failed due to electronic malfunction and high operating temperature. This paper work presents to fulfill these objectives by employing a 'Gradual Flow Reducing Valve' controlled by using purely mechanical actuation thus serving primary purpose of self-actuation. However key constraints in designing the valve are geometrical parameters as well as operating parameters. These parameters are analyzed by FEA.

Restrictor plate thickness is finalized with Design by Analysis approach such that it can well account for the Bending as well as Axial loading. In theoretical design the spring stiffness were designed based on the sliding distance calculations, however while designing the spring following parameters are ignored. The friction in between sliding plate and jacket wall. The Bending pressure exerted on the valve also reduces the sliding distance of valve.

The Transient solution was extremely useful in order to know the effects of the above two parameters, and enabled us to finalize the spring stiffness, saving on crucial prototype and testing costs. In order to observe performance characteristics of the valve transient structural analysis is done over valve assembly. This analysis shows maximum stress developed is 62.5 MPa which is within the permissible safety limit. By introducing non linearity (geometric) more realistic simulations were achieved. More ever these simulations gave complete idea about the operation of the valve enabling us to predict any parameters that might not have been considered during the theoretical design. The dimensions of the constituent parts of the gradual flow reducing valve were finalized. In this paper transient structural analysis has been introduced in order to finalize the geometrical parameter of gradual flow reducing valve.

David Kazmer & Mahesh Munavalli [7] has predicted that design and performance analysis of a self regulating melt pressure valve. A design for a self-regulating pressure valve is analyzed using a 3D flow analysis that utilizes independent shear and elongation viscosities for the polymer. The regulator is derived from a low force valve design that enables the outlet pressure to be directly regulated by a provided force on a valve pin without need for pressure sensors or a closed loop control system. Analytical and experimental results indicate an excellent level of response and consistency given the simplicity of the design.

If dynamic control of the polymer melt is to become common, it is necessary to design more compact valves that have improved dynamic response with lower actuation forces. Other essential objectives include ease of use, ease of maintenance, and positive shut-off of the molten plastic at the gate as in a conventional valve gated hot runner system. As per standard valve pin design, the valve pin is designed such that the polymer melts flows around the circumference of the pin to avoid lateral loading and bending of the pin. However, the valve pin design includes a flow port in which the axial forces due to shear. Stress and pressure drop are negligible. Instead, the pressure drop for the valve is governed by the juncture loss between the valve choke and the drop bore, which imparts negligible forces on the valve pin. While this design could be used to produce a melt valve with very low forces, the design provided allows the melt pressure to act on the end of the pin to produce a force that is proportional to the melt pressure. If a control force is applied to the top of the pin, then a resultant force will act on the valve pin to move the valve pin to a different position such that the force due to the melt pressure equals the control force. In this way, the pressure valve is "self-regulating".

Since the dynamic repositioning of the pin is accomplished through Newton's second law of motion ($F=ma$) and no external feedback control is necessary. In the current design, the control force is provided through a pneumatic actuator with regulated air pressure. Similar to the melt pressure on a hydraulic moulding machine, the melt pressure downstream of the valve is governed by an intensification ratio relating the size of the pressure valve to the size of the pneumatic cylinder:

$$I=\frac{A(cylinder)}{A(annulus)}=\frac{R^2(cylinder)}{R^2(annulus)}\approx 100$$

Finally this paper concludes that the melt flow in the self-regulating melt pressure valve has been analyzed with respect to steady state behaviour, dynamic behaviour, and steady state error.

Sushant M. Patil , Ramchandra G. Desavale , Imran M. Jamadar [8] has shown that conceptual structure design through thickness optimization of high pressure and high temperature self regulated pressure valve using non-linear transient finite element method. In this paper the optimization of thickness of valve plate, material selection, design of various components of valve and analysis of gradual flow reducing valves for both axial and bending has been discussed.

III. 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. Above all paper helps in finalization of material, plate thickness and spring stiffness.

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