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Optimization of Safety Valve's Design with the Help of Digital Prototype

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Abstract:* This paper is presenting optimization of a valve assembly's design. The pressure safety relief valve is the key component in any system where pressure rising could be hazardous to the safety of the workers as well as the plant. Safety valves are designed to provide protection from overpressure in steam, gas, air and liquid lines. Safety valve should be a reliable and more precise design that will be working at more accuracy. In refinery distribution sector, safety is of prime important. Home appliance is also required pressure safety in the modern era. The key requirement of the process is to relieve this pressure rise in no time. Old technological design valves are unable to fulfill that requirement. Design and analysis of an emergency safety valve. From the data, the suitable valve is designed using FEA. In this project is focused on change old technological safety valve with new 3D prototype valve that has less equip parts, where in it is required that flow be shut off when a certain pressure is reached. Electronic valves are available, however the intent of this design project is have a total mechanical system, which has an in built response mechanism. The working environment is hazardous & explosive. This safety valve is an auto regulate operating valve used as tertiary safety arrangement for critical applications.

***Keywords:* Digital Prototype of Pressure Safety Valve, Non-linear FEA, Ansys (Workbench).**

I. INTRODUCTION

Pressure relief device protects process equipment from the hazards of high pressure in a process. It operates by opening at a recognize pressure and ejected mass from its. The ejected mass containing energy which is reduced during pressure realized. The purpose of design a safety valve to determine the physical and mechanical properties of this and optimizing the performance during critical condition. In presently used safety valve sizing standards the gas discharge capacity is based on a nozzle flow gas theory. At high pressures or low temperatures real-gas effects can no longer be neglected, so the discharge coefficient corrected for flow losses cannot be assumed constant anymore. Also the force balance and as a consequence, the opening characteristics will be affected. In former Computational Fluid Dynamics studies, valve capacities have been validated at pressures up to 1.5-10 bar with focusing on the opening characteristic. In this paper, alternative valve sizing models and a numerical FEA tool are developed to predict the opening characteristics of a safety valve at moderate higher pressures. The first alternative valve sizing method is the real-average method that averages between the valve inlet and the nozzle throat at the critical pressure ratio. The second real-integral method calculates small isentropic state changes from the inlet to the final critical state. In a comparison, the simplest ideal method performs slightly better than the real-average method and the dimensionless flow coefficient differs less than 3% from the most accurate real-integral valve sizing method. Benchmark validation test cases from which field data is available are used to investigate the relevance of the physical effects present in a safety valve and to determine the optimal settings of the ANSYS workbench. Shock strength in a safety valve flow is small enough to be accurately computed. In digital prototype is tested this model at a statically. In this design, Safety valve is operating with normal pressure and adjust higher pressure by releasing access mass through escapes hole on body. Spring loaded valve is adjusting pine of safety valve with compression and expansion of spring by storing and release internal energy of helical spring.

II. LITERATURE REVIEWS

Ron Darby [1] studied a model for the opening lift dynamic response of a pressure relief valve in gas/vapor service was presented which accounts for all of these effects through a set of five coupled nonlinear algebraic/differential equations. These equations were 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.

Abhijit S. Adadande, A. M. Naniwadekar, Rajkumar B. Patil [2] studied for manufacturing reliable products, system reliability should be maintained over the time. Hence it was required to design reliable manufacturing system. In proposed work pressure relief valve manufacturing system is selected for analysis. This valve was used in two wheeler bikes having capacity 150CC and above. To carry out this study, a large literature survey is carried out. Based on this survey, work objectives are decided and analysis methodologies are selected. It was found that fault tree analysis method was effective in such fault oriented analysis. Weibull++ software has been used for time to failure data analysis. Statistical data were analyzed by Normal distribution model. The focus was on event or faults instead of the reliability of each component. System reliability and critical events are found out.

Ms. Megharani .S. Kashid, Mr. D. P. Patil, Mr. A. A. Kumbhojkar [3] had 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, the design of various components of valve and analysis of gradual flow reducing valves for both axial and bending had been discussed.

Xue Guan Song [4] 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., and the 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.

Arend Beune [5] studied the performance of a spring-loaded safety relief valve, especially a conventional valve, was studied which is influenced by back pressure. In presently used safety valve sizing standards the gas discharge capacity is based on a nozzle flow derived from ideal gas theory. At high pressures or low temperatures real-gas effects can no longer be neglected, so the discharge coefficient corrected for flow losses cannot be assumed constant anymore. Also the force balance and as a consequence, the opening characteristics will be affected. 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.

III. METHOLOGY & COMPONENT DETAIL

Most The aim of safety systems in processing plants is to prevent damage to equipment, avoid injury to personnel and to The aim of safety systems in processing plants is to prevent damage to equipment, avoid injury to personnel and to eliminate any risks of compromising the welfare of the community at large and the environment. Proper sizing, selection, manufacture, assembly, test, installation, and maintenance of a pressure relief valve are critical to obtaining maximum protection.

A. Modeling of Safety Valve

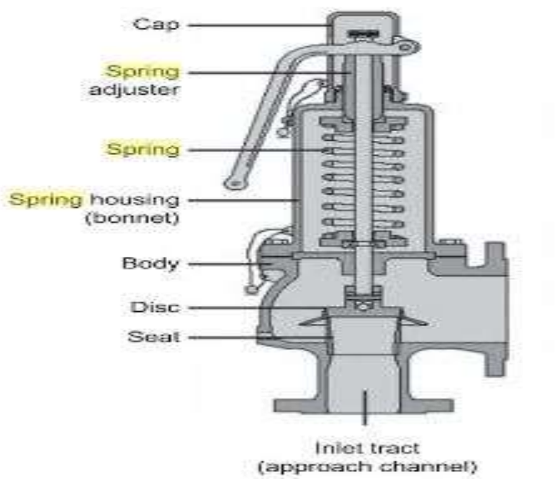


Fig. 1. Classical Model of Safety Valve

Classical Model at High Pressure Rated with More Complex Design and High Weight and Cost.

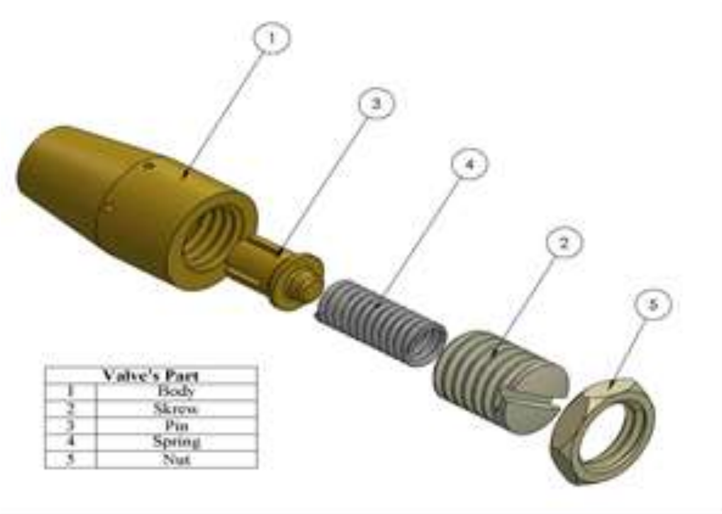


Fig. 2. Explode Model of Safety Valve

Digital prototype of a new model with rated low pressure valve with reliable design and less weight and cost.

The standard design safety relief valve is spring loaded with an adjusting ring for obtaining the proper blow down and is available with many optional accessories and design features. Refer to Figure for cross-sectional views of typical valves. The bellows and balanced bellows design isolate the process fluid from the bonnet, the spring, the stem, and the stem bushing with a bellows element. Jacketed valve bodies are available for applications requiring steam or heat transfer mediums to maintain viscosity or prevent freezing. Pilot-operated valves are available with the set pressure and blow down control located in a separate control pilot. This type of valve uses the line pressure through the control pilot to the piston in the main relief valve and thereby maintains a high degree of tightness, especially as the set pressure is being approached. Another feature of the pilot-operated valve is that it will permit a blow down as low as 2 %. The disadvantage of this type of valve is its vulnerability to contamination from foreign matter in the fluid stream.

A pressure relief valve must be capable of operating at all times, especially during a period of a power failure; therefore, the sole source of power for the pressure relief valve is the process fluid.

B. **Methodology**

Spring loaded valve defines pressure on the properties of spring and area of reliving discharge.

Calculate the minimum required reliving area:

$$A=(w\sqrt{TZ})/(CKP_1 \sqrt{M}) \qquad (1)$$

Where A, minimum effective discharge area, C, coefficient determined from an expression of the ration of gas, K, effective coefficient of discharge, Z is compressibility factor, T is absolute temperature, P1 is relieving pressure, M is molecular weight.

Mode of loading: Cyclic loading

Where Outer diameter of coil Do, Inner diameter of coil Di, Wire diameter, di Pitch, P Mean diameter of coil D, Number of active coil N, Total Number of coil Nt, Free Length, Lo=P*Nt, Solid Length Ls= d*Nt, Spring Index C =D/d

The necessity of guide: Compression spring may buckle at low axial force for this reason spring needs to guide its necessity is checked. The combined effect of direct shear and curvature correction is accounted by Wahl's correction factor and is given as:

$$Kw=(4C-1)/(4C-4)+0.615/C \qquad (2)$$

Shear stress:

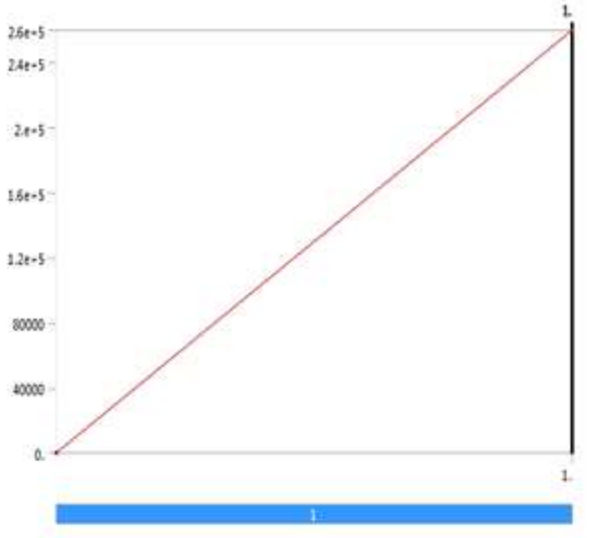
$$\tau=8FD/(\pi d^3)\, K_w \qquad (3)$$

Axial Deflection

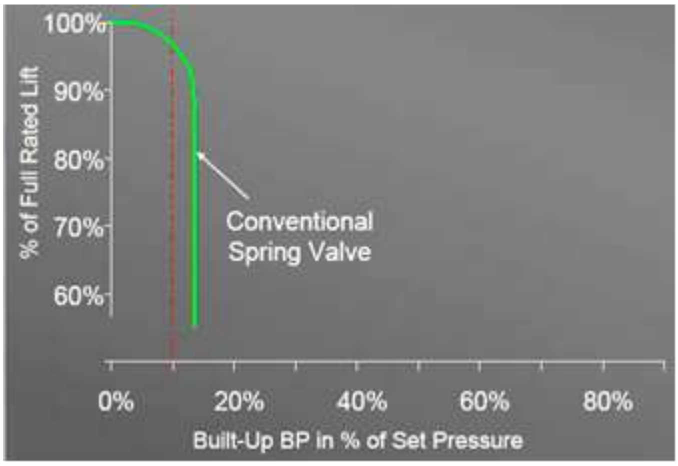
$$y=(8FD^2\times i)/(Gd^4) \qquad (4)$$

Units:

Unit System Metric (m, kg, N, s, V, A) Degrees rad/s Celsius
Angle- Degrees
Rotational Velocity- rad/s
Temperature- Celsius
Environment Temperature- 22. °C



Graph 1. Pressure increment with Time



Graph 2. Pressure Drop with Built-Up Back Pressure

C. **Component Detail**

In this safety valve design, we consider light weight material with low cost and more safety factor. This model is testing mechanically. There is three material use for a different part for:

1. Body Part & Pin

Material = Copper Alloy

Density =8300 Kg/m3

COTE* = $1.8x10^{-5}$ /0C

EX =$1.1x10^{11}$ Pa

PRXY=0.34

*COTE is stood for coefficient of thermal expansion

2. Spring

Material = Stainless Steel
Density = 7750 Kg/m3
COTE = 1.7×10^{-5} /0C
EX = =1.93×10^{11} Pa
PRXY=0.31

3. Screw and Nut

Material = Aluminum Alloy
Density = 2770 Kg/m3
COTE = 2.3×10^{-5} /0C
EX = 7.4×10^{10} Pa
PRXY=0.33

IV. RESULTS

Test the model at the static nonlinear condition in Ansys workbench.

Ansys Model

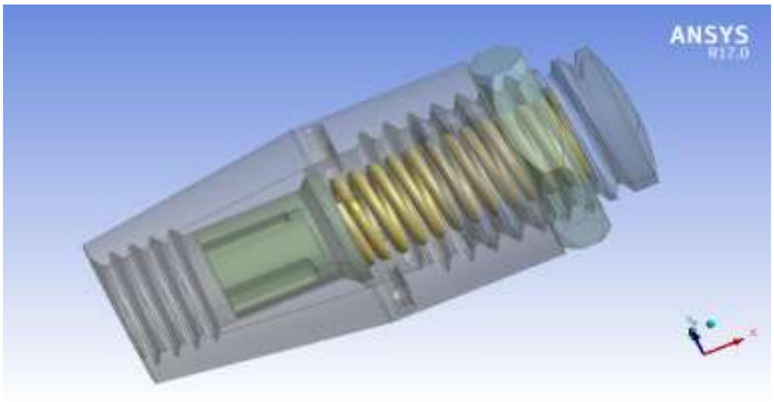


Fig. 3. 3D Model of Safety Valve in Ansys Design Modular

Meshing Model

Element Matrix Formulation Times

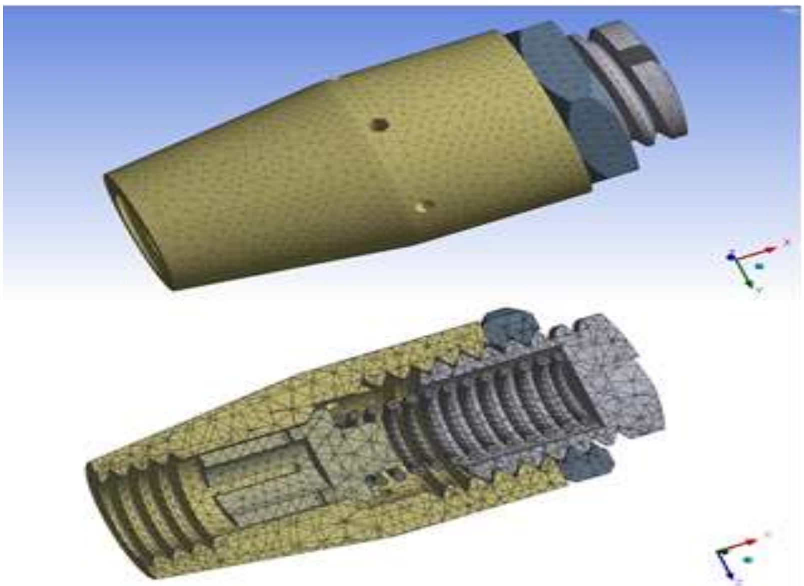


Fig. 4. Meshed Element View of Safety Valve

Type	Number	Ename	total cp	ave cp
1	26443	SOLID187	5.226	0.000198
2	9783	SOLID187	1.903	0.000195
3	1965	SOLID187	0.406	0.000206
4	6800	SOLID187	1.232	0.000181
5	5400	SOLID187	0.983	0.000182
6	1643	CONTA174	0.187	0.000114
7	1643	TARGE170	0.031	0.000019
8	339	CONTA174	0.062	0.000184
9	339	TARGE170	0.000	0.000000
10	237	CONTA174	0.031	0.000132
11	237	TARGE170	0.016	0.000066
12	1246	CONTA174	0.109	0.000088
13	1246	TARGE170	0.031	0.000025
14	291	CONTA174	0.031	0.000107
15	291	TARGE170	0.016	0.000054
16	24	SURF154	0.000	0.000000

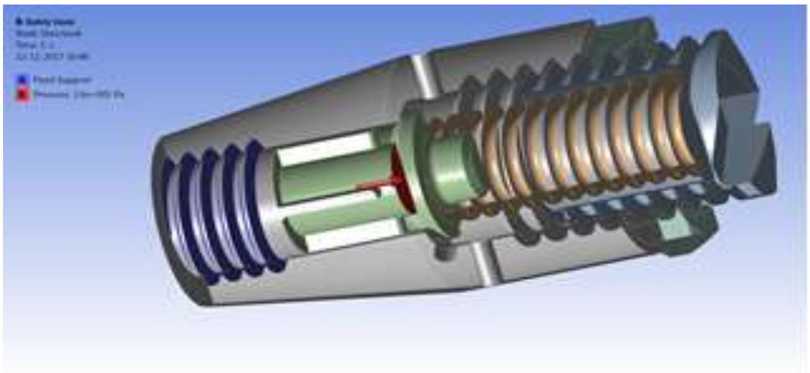


Fig. 5. Constrain Applied to Model

The safety valve is constrained bottom edge threads with fixed and pressure with magnitude 2.6xe5 Pa applied on pin inner phase.

RESULT

Total pressure applied on valve pine is distributed over valve spring. An axial direction deflection requires at 2.8 mm for the full reliving condition as design as per required.

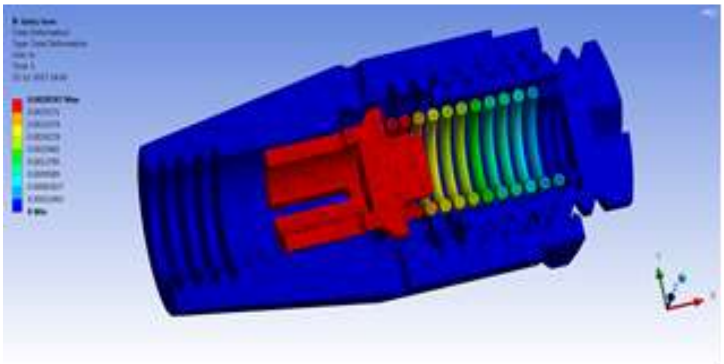


Fig. 6. Directional Deformation Section view of Model

Axial deflection in X- Axis ix 0.0028767m that is approximate 2.8 mm at pressure 2.6 bar.

Stress Generation in Assembly

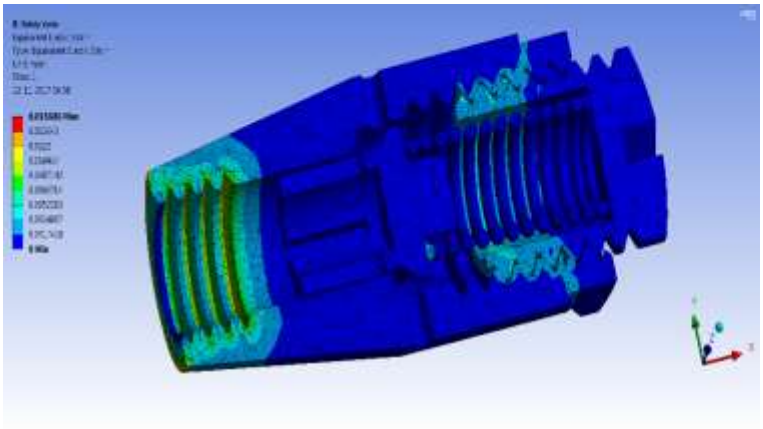


Fig. 7. A sectional View of Model for Stress Distribution

Strain Generation

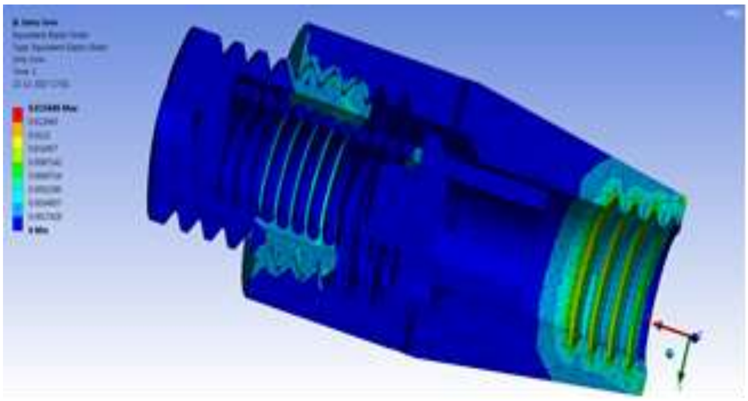


Fig. 8. . Strain Generation Inside of Model

Thermal Strain

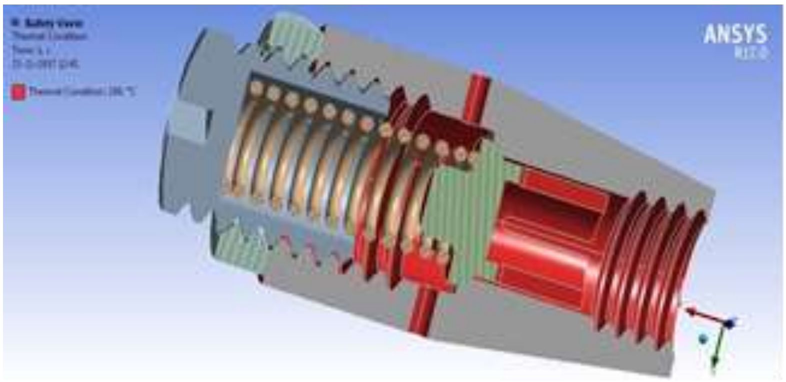


Fig. 9. Thermal Strain Cheeked 200 0C

Rest of body have environment condition. There have some temperature distribution occur but in this test neglected to assume.

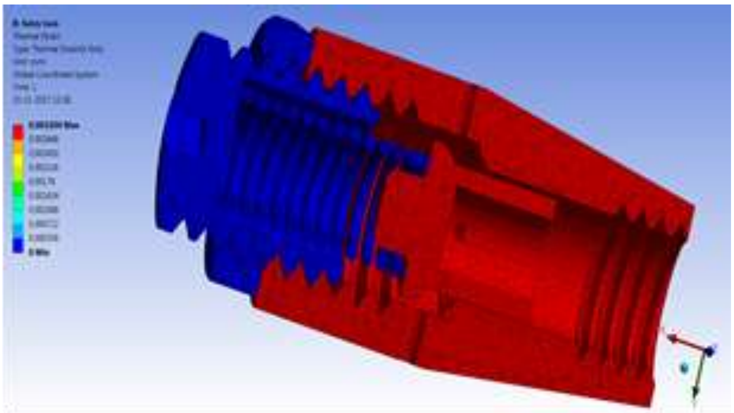


Fig. 10. Total Thermal Strain of Model

Total Max. The thermal strain is generated on body and pin of safety valve. Valve spring thermal strains is neglecting.

V. CONCLUSION

The objective of this study is to analyze the mass flow capacity and opening characteristics of spring-loaded safety valves at normal operating pressures simulations and high-pressure valve tests. Following conclusions are drawn from Reliability and cost analysis of pressure relief valve manufacturing system. Rejection of the valve is around 5%. Rework on pressure relief valve is around 40%. Reliability of the manufacturing system is 42%. Most of the rejection and rework is due to groove diameter, length 5 mm and length 3.6mm. These are the critical events. It is required to improve the accuracy of the machines used for the above operations. Nevertheless, the strength of the Safety tool is to optimize valve geometries in combination with sensitivity studies to account for small geometry changes (effect of mechanical wear and production tolerances) and real-pressure effects to find the cause for valve chatter and to avoid it in improved geometries.

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