Design and Analysis of Emergency Shut Off Valve by Using Finite Element Analysis

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Abstract - In chemical ,nuclear, petroleum industries emergency shutdown valve (ESDV) acts as a safeguard against exceeding set point Pressure. During normal operation, the valve remains open for an extended period of time months or sometimes even years and must function as called upon during an emergency situation. This project focuses on the exchange of liquid between two chambers, where it is required that flow be shut off when a certain pressure is reached. The pressure valve is to design the, with regards to a pushing load and the valve countered by a bending load by the flowing liquid. The dimensionality should be such that, self weight should be the operational parameter for the valve with an integrated spring design to create an emergency shut off operation

Keywords— *Pressure Valve Design, FEA, Combined Bending and Axial loads*

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I. INTRODUCTION

Pressure vessels store energy and as such, have inbuilt safety risks. Many stages began to enact rules and regulations regarding the construction of pressure vessels. An important responsibility of a chemical plant designer is to make sure that a plant under design can be operated safely, it is provided with primary, secondary safety arrangement. One of the unsafe situations that can be arise during operation inability of a system to a pressure higher than that for which it was designed with help of sensor or actuator, in such circumstances we rely on mechanical system. If the system is not protected, the excess pressure may be lead to failure causing mechanical indemnity, loss of costly material, emission of toxic chemical and maybe loss of life

Process plants consist of hundreds, or even thousands, of control elements all networked together to perform specific function . Each of these control elements is designed to keep some important process variable such as pressure, flow, level, temperature ,etc. within a required operating range. Each of these elements receives and internally creates disturbances that affect the process variable. The most common final element in the process industries is the shut off valve.

The current design in the shut off valve is controlled electronically. The Electronics valves are available .A problem with using electronic valve is that a battery operated back-up system is needed or else the system is useless during power cut off. Also, the components needs to be in an environment that is rendered safe, meaning a non-explosive environment. Electronic valve automatically close if the pressure sensors near the valve detect a pressure drop that is representative of the large fluid loss that would be associated with a pipeline rupture. However, since the valve operates automatically without human evaluation or interpretation of system operating data, there is a possibility of an unintended valve closure and related consequences. Since the valve is programmed to close under these types of conditions, it may incorrectly sense that there is a failure and close the valve. Electronic valve can be use under limited pressure range but mechanical operated valve can be used over high operating pressure range. Electronic valve cannot be used in case of excessive rise in pressure which requires emergency shut off .Hence the intent of this design project is have a total mechanical system, which has an in built response mechanism. The design will be done using suitable modelling software. With the help of finite element analysis, Non Linear FEA, FEA based SIF calculations, a set of ranges for significant design parameters of shut off valve which will help have a total mechanical system, which has an in built response mechanism. Ultimately, this type of safety release system is one time usable safety system in pressure vessel, after break up there is need of replacement of other emergency shut off valve.

II. DESIGN CALCULATIONS FOR PRESSURE VALVE

The input parameters which is recived from company for design pressure vessel is tabulated in Table I.

TABLE I. INPUT CONDITION AND OPERATING PARAMETERS

Sr No	Parameter	Intensity
1	Valve Close Pressure	0.368 Mpa
2	Max Operating Pressure	0.500 Mpa
3	Valve Diameter	60mm
4	Regulating Pipe Diameter	60mm
5	Springs	4

A. *Further Calculating:- (According to ASME code)*

TABLE II. FINAL DIMENSIONS OF PRESSURE VESSEL

Thickness of shell	6 mm
Thickness of burst nozzle	6 mm
Thickness of circular plate	4 mm
Thickness of rectangular plate	3 mm

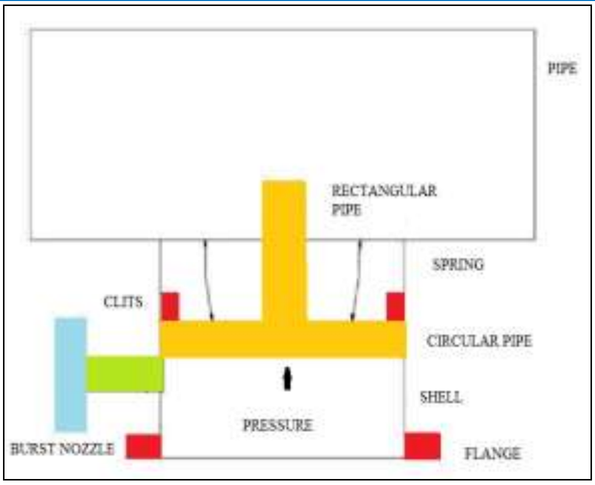


Figure 1. Emergency Shut off valve model

B. *Procedure for Static Analysis*

1 .Analysis Type

Static structural analysis is used to determine deformation, stresses etc. under static loading condition for both linear and non linear analysis. Non linearity can include plasticity, hyper elasticity, large deflection, stress stiffening, contact surface and creep. Five steps are applied in static structural setting. Each step is having 50 sub steps because of nonlinear analysis. As sub steps increased, the accuracy of the results.

2.Engineering Data

Following are the properties of the material (AISI 309) which used for clip ON:

TABLE III. CLIP ON MATERIAL

Sr.No	Description	Quantity
1	Material	AISI steel 409
2	Young’s Modulus	2e11 Pa
3	Density	7850 Kg/m^3
4	Poisons ratio	0.3
5	Ultimate strength	480 MPa
6	Yield strength	230 MPa
7	Tangent modulus	20 MPa

Material for rest of the pressure safety release valve components.

TABLE VI.PRESSURE SAFETY VALVE MATERIAL SA 516 GR70

Sr.No	Description	Quantity
1	Material	SA 516 Gr 70
2	Density	7850 Kg/m^3
3	Ultimate strength	480 MPa
4	Young’s Modulus	2e11 Pa
5	Poisons ratio	0.3
6	Yield strength	260 MPa

Material for spring is ASTM A913-50

TABLE V. SPRING MATERIAL

Sr.No	Description	Quantity
1	Allowable shear stress (τ)	420 MPa
2	Modulus of rigidity (G)	80 KN/m^2
3	Modulus of elasticity (E)	210 KN/mm^2

3.Mesh Sensitivity Analysis

Size of elements influences the convergence of the solution directly and hence it has to be chosen with care. If the size of elements is small, the final solution is expected to be more accurate. However, it should be remembered that the use of elements of smaller size will also mean more computational time. As the number of elements increases, the size of each element must decrease, and consequently the accuracy of the model generally increases.

In the valve assembly, key component is CLIP ON. By plotting the graph for actual stress value and displacement verses no. of elements for five different Mesh sizes, the stress convergence is checked while calculating spring force. Other bodies are designed by calculation and experiencing not much stresses so mesh controls are taken as per experiences. Also they are selected after considering the hardware capacity of the system.

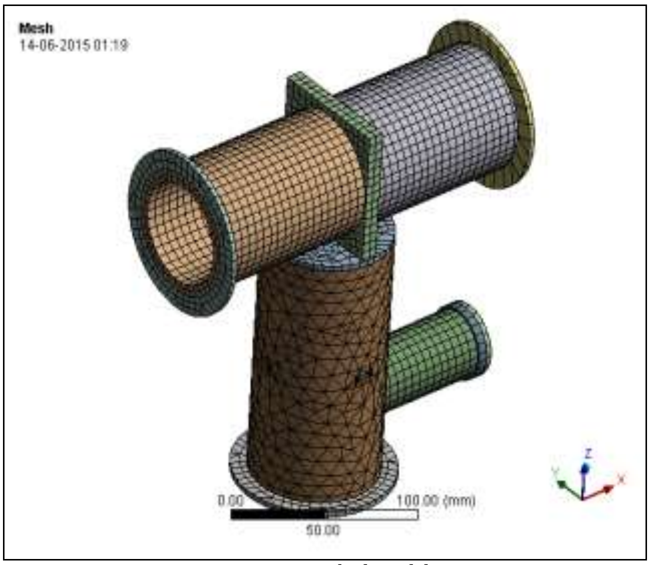


Figure 2. Meshed Model

4.Check for Dimension

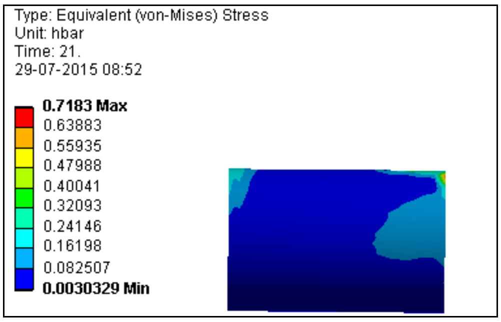


Figure3 :Equivalent stresses in horizontal pipe

Figure shows equivalent von mises stress in horizontal pipe its maximum value is 1.7183Mpa . The stresses in pipe are within the permissible limit so the horizontal pipe is safe from dimensional point of view

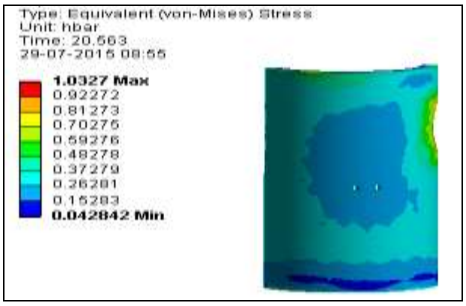


Figure 4:Equivalent stresses in main shell

Figure shows equivalent von mises stress in main shell its maximum value is 10.327MPa . The stresses in shell are within the permissible limit so the shell is safe from dimensional point of view

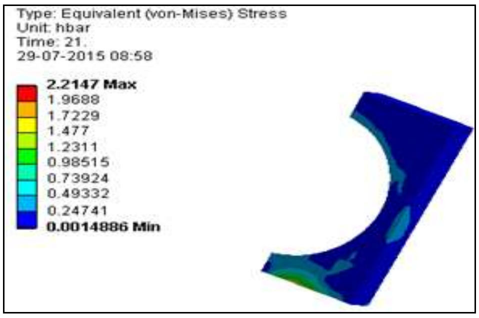


Figure 5. Equivalent stresses in sleve

Figure shows equivalent von mises stress in sleve its maximum value is 22.147MPa . The stresses in sleve are within the permissible limit so the sleve is safe from dimensional point of view

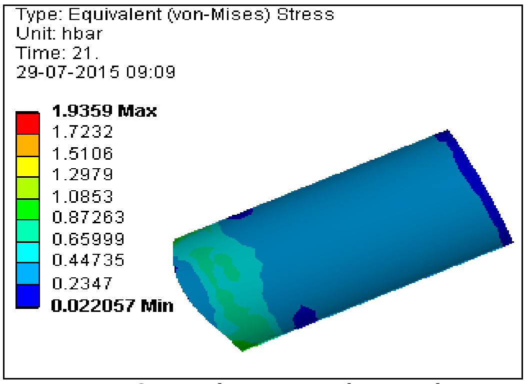


Figure 6 :Equivalent stresses in burst nozzle

Figure shows equivalent von mises stress in burst nozzle its maximum value is 19.359MPa . The stresses in burst nozzle are within the permissible limit so the burst nozzle is safe from dimensional point of view.

TABLE VI. ANALYTICAL VS THEORETICAL STRESSES

Sr No	Component	Analytical	Theoretical
1	Horizontal Pipe	1.7183MPa	260MPa
2	Main Shell	10.327MPa	260MPa
3	Sleve	22.147MPa	260MPa
4	Burst Nozzle	19.359MPa	260MPa

C. Stiffness Optimization of Spring

1. Stiffness at 10.5

To get the δ=64 the spring is optimsed for different stiffness. The stiffness of spring is found from total deformation and equivalent von mises stress.

From above graph we come to know that, upto 10 sec deformation is slightly increases after that it suddenly increases and reaches to 6.4899e $^{-2}$m at stiffness of 10.5 and remain uniform

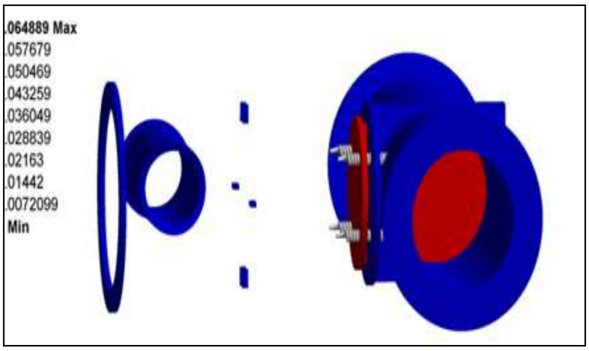
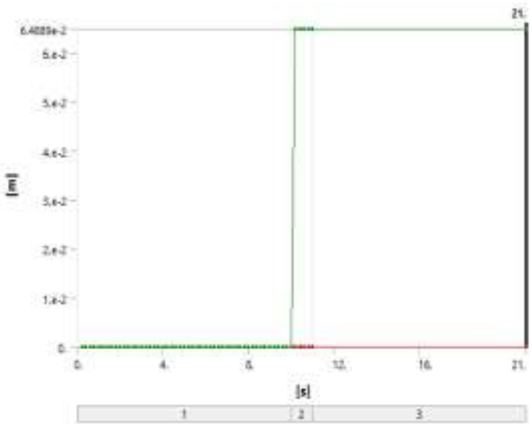


Figure 7.Stiffness at =10.5



Graph 1. Total Deformation at stiffness =10.5

2. Stiffness at 10.1

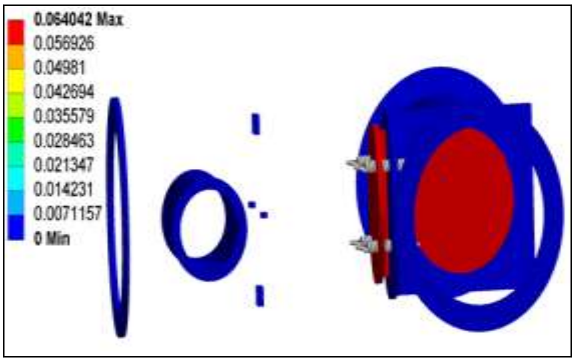
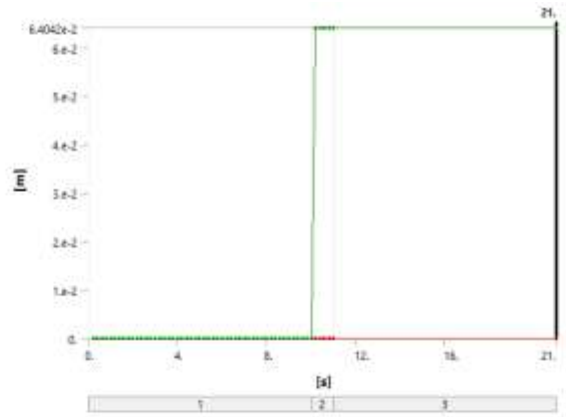


Figure 8 . Stiffness at 10.1



Graph 2.Total Deformation at stiffness =10.1

From above graph we come to know that, upto 10 sec deformation is slightly increases after that it suddenly increases and reaches to 6.4042e $^{-2}$m at stiffness of 10.1 and remain uniform. The deformation again further decreases as the stiffness decreases.

TABLE VII. ANSYS RESULTS FOR STIFFNESS OPTIMISTION OF SPRING

Spring Stiffness	ANSYS RESULTS		AllowableStress (MPa) (ASME Code)
	Von-mises Stress (MPa)	Deformation (m)	
10.5	74.221	0.064889	420
10.2	74.559	0.064384	420
10.1	74.796	0.064042	420
10	74.897	0.063896	420

D. Boundary conditions

Faces of washer size are imprinted on upper flange and fixed support is applied there. Pressure of 0.500 mpa is applied on plate and valve body at suitable step. Displacement of 64 mm is given to the plate for achieving initial position.

E . Results

1.Total Deformation at 5 sec

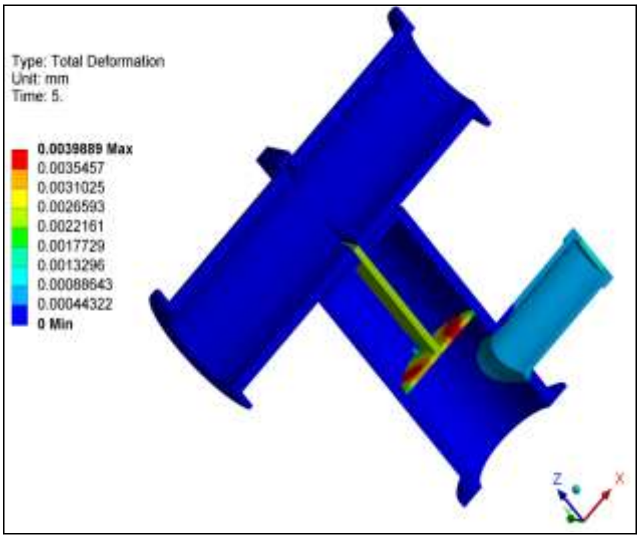


Figure 9. Total Deformation at 5 sec

From figure at 5 sec the deformation in valve shell , pipes , and flange are very low ie the deformation are within limit of the material . so the design is safe at time 5 sec . the maximum deformation acts on circular plate it is shown by red colour.

2.Total Deformation in Valve for 10 sec

At time period of 10 sec there is slight increasse in deformation of circular plate and rectangular plate , the maximum deformation is indicated by red colour which is acting o circlar plate. The deformation in rest of the parts of valve body is very low indicated by blue colour.

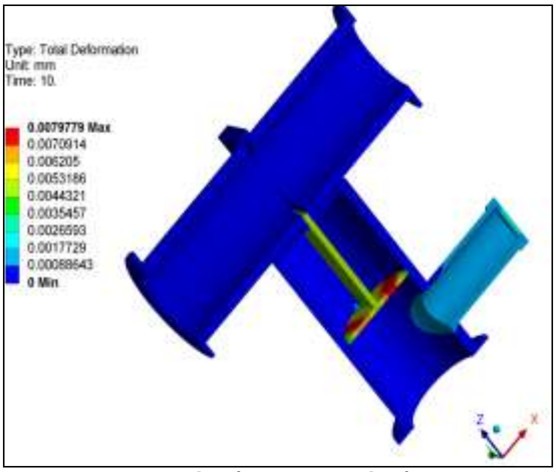


Figure10 .Total Deformation in Valve for 10 sec

3.Total Deformation at 11 sec

At time period of 11 sec there is sudden increase in deformation .At 11 sec the circular plate gets lifted up by breaking all the 6 Clip ON and by compressing the 4 springs. The Rectangular plate enters into the pipe through the sleeve cut inside it. The Circular plate and rectangular plate under goes maximum deformation of 50.318 mm which is indicated by red colour.

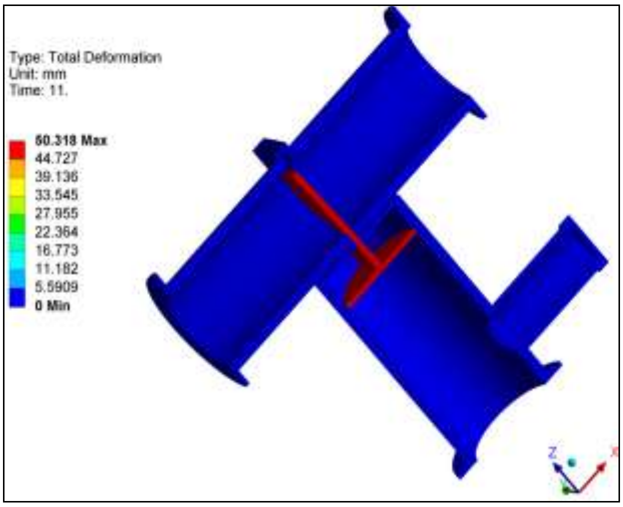


Figure 11. Total Deformation at 11 sec

4.Toal Deformation at 21 sec

At 21 sec there is complete travel of Rectangular plate inside the horizntal pipe through the sleve cut inside it the valve gets completely closed. and flow through horizantal pipe pipe to ressure vessel is completely stops . Thus the valve acts as safe gaurd against sudden increase in pressure in the system. From figure the Circular plate and Rectangular plate has further deform to maximum deformation of 64.298 mm as indicated by red colour. The deformation is rest of the parts of the valve body is very loowasindicated by blue colour

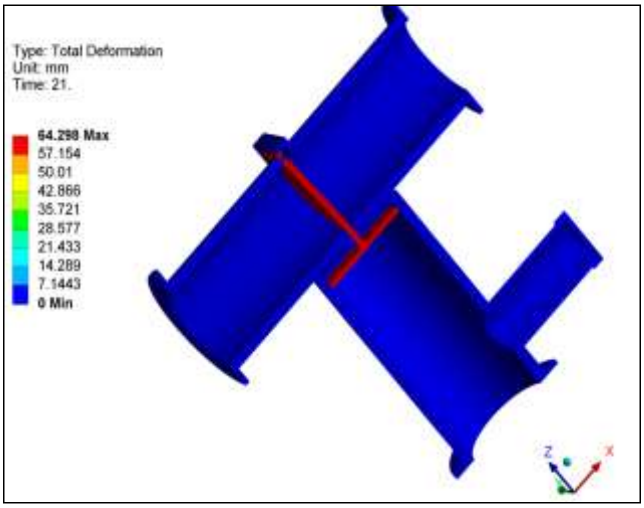


Figure 12. Total Deformation at 21 sec

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TABLE VIII. TIME VS TOTAL DEFORMATION

Sr.No	Time (Sec)	Total Deformation (mm)
1	5	0.003988
2	10	0.007977
3	11	50.318
4	21	64.298

III. CONCLUSIONS

1.The outputs obtained from structural analysis are stress and deformation. From safe structural design point of view it is necessary that the stress induced in structure must be less than permissible or design stress. In all parts, the actual stress are less than design stress, so the safety valve is safe from structural point of view.

2. Valve is operating at 0.49 as pressure required and Shut Off begins at 0.500 maximum operating pressure.

3. Spring design has added stability to valve . By Optimisation of spring stiffness of 10.1 resulted in finding the optimum value of stiffness of spring to cause the deflection of spring.

4. 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.

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