Design and Analysis of Pressure Safety Release Valve by using Finite Element Analysis

Mr.V.D.Rathod*[1], Prof.G.A.Kadam*[2], Mr.V. G. Patil*[3]
*[1]M.E. Design (Pursuing), SKN Sinhgad Institute of Technology& Science,
Lonavala, University of Pune, Maharashtra, India.

***Abstract*- Safety systems are installed in various industries to prevent undesirable events and to minimize the adverse effects of such events if they occur. Because of their nature, safety systems must be highly reliable. From a safety point of view, it should operate accurate at set pressure. For economic reasons, it is better to replace the safety valve devices than the total safety valve and pressure operating devices.**

Generally, there are different methods which are used to attain high system reliability.

The majority of oil and refined-product pipelines, vessel etc. have their protection system designs based on spring-type pressure relief valves. Thus, the proper design and operation of these valves is essential to ensure the safety of operations. In simple terms, these valves have a plates which is pressed by a spring against the inlet pressure of the pipes, vessels etc.& hold these plate with help of clip ON. This arrangement helps, in quick response to release the exceed pressure inside the vessel. In these case plate is subjected to two forces, at one side a spring force & at other side is vessel pressure force. When the pressure rises in the vessel, the force generated on that side is increases and at opposite side of plate the force exerted by the spring is already present, causing, the plate to rise & break the ''clip on'' which is provided at back side of the plate and overpressure generated inside the pressure equipment is relief through the nozzle, so, line reducing the pressure level inside the equipment.

The focus of this paper is to design, analyze and optimize a pressure vessel safety release valve which is" use as one time", which save bursting the pressure vessel.

To simulate such a process, FEA is an extremely convenient tool which has reduced both the design costs and times to deliver the product. This paper explains the strategies used in the design of the safety release valve and results of the operational simulation in FEA.

Keywords- Pressure safety release Valve, clip ON spring design, Non- linear FEA,

I. INTRODUCTION

A. Background Theory

In process industry, a process is continuously, further optimized to operate more efficiently closer to its mechanical limits such as its maximum allowable operating pressure. Besides the organizational and process control measures to maintain safe plant operation, the last stage of protection of a process apparatus against excess pressure is often through the use of a mechanical pressure safety release valve device.
In pressure safety release valve, have a plate which is pressed by a spring against the inlet pressure of the vessels & hold this plate with help of clip ON. When the pressure rises inside the vessel, the force generated on the surface of the plate increases and, depending on the pressure relief valve set point clip ON design stress, these force due to pressure rises, overcomes, causing the plate to rise breaking the ''clip on'' which is provided at back side of the plate and overpressure generated inside the pressure equipment is relief through the nozzle, so, line reducing the pressure level inside the equipment**.**

Safety Release valves work on the outlet side, wherein if a particular pressure is reached the valves burst open resulting in a pressure safety relief and prevention of bursting. The idea is applicable into the vessel, when critical pressure is induced.

B. *Operation*

When the vessel pressure exceeds the
permissible pressure, clip ON plate is pushed against the spring load due to that the load on clip ON is exceeds ,caused break it which results into the movement of the valve plate to release the inside pressure of the vessel. Block diagram of the pressure safety release system is provided as illustrated in figure 1.

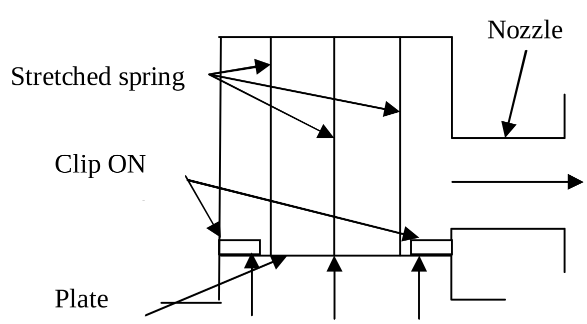


Fig. 1 A Pressure safety release valve set

C. Objectives

1) Design and thickness optimization of clip ON, plate and valve.
2) Design of other key components of valve
Table.1 input condition and operating parameters

Sr.no	Parameter	Intensity
1	Feedback error	Less than 3%
2	pressure	0.14 MPa
3	Valve inlet dia.	50mm
4	Valve opening dia.	36mm
5	Spring Nos	3
6	Spring travel	40mm(min)
7	Spring length	10mm(un-loaded)
8	Clip ON	2.5 mm thick
9	Valve shell length	120 mm
10	Tension Spring	
11	Stiffness	2.5 N/mm
12	Spring outside diameter	12.9 mm
13	Spring wire diameter	2.8 mm
14	Spring Free Length	42.5 mm
15	Max Extension	53.5mm(134)N
16	Nozzle Length	52 mm

Operational Temperature: 70 - 350 °C

II.DESIGN PROCEDURE

Design by Analysis (DBA) approach is used to finalize the dimensions. Suitable dimensions are initially assumed. Finite element analysis is then undertaken with necessary boundary conditions, type of material and type of load. Subsequently, the dimensions are optimized such that the maximum stress remains within the allowable limit.

A. Design of plate

For design of a pressure safety release valve, the most important component is the plate and the clip ON design that will actually restrict the fluid flow in the safety line. The plate will be subjected to a bending load as well as axial load and shearing load. The basic design problem of a safety release valve, which is set to close at a particular pressure.

To instant opening of safety valve the plate is loaded by stretched spring due to this concept, the plate which is hold against the out coming fluid line is subjected by vessel inside pressure and spring force. To holds plate with spring in stretched position the clip ON are required which is square in shape. So, plate is subjected to fluid pressure and spring force.

According to ASME section VIII div 1, UG-34
The minimum required thickness of flat unstayed circular plate shall be calculated by the,

$$t = d\sqrt{CP/SE}$$

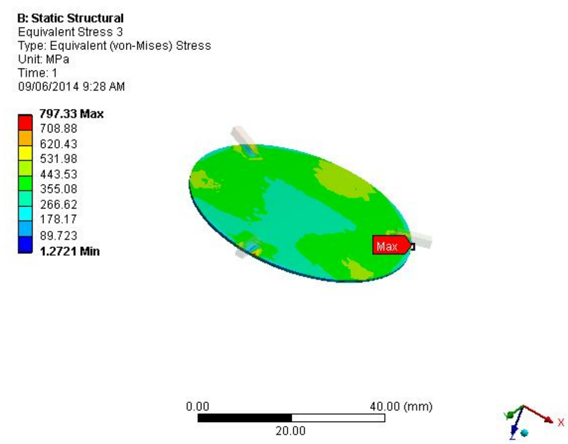
Where,

d- Plate diameter,
C-constant (0.2 to 0.25),
P-working pressure, S-allowable stress= 140 N/mm^2 (ASME section II D,
E-joint efficiency (ASME section VIII div 1, UW-12 radiographic examination of weld)

$$t = 50*\sqrt{0.2*0.14/140*1}$$
$$= 0.707 \text{ mm}$$

We have one equation for circular plate is,
$\sigma_{max} = (3/4)*P*(a^2/t^2)$,
(According to ASME section II A plate material SA 516 Gr 70, mechanical properties are
tensile strength-485 to 620 MPa,
yield strength-260 MPa, it is 140 MPa considering factor of safety 1.85)
Putting values,
$140 = (3/4)*0.14*(25^2/t^2)$
$t = 0.6846$ mm

This is the thickness which comes to take pressure in consideration which is pressure 0.14 MPa or force 274.889 N also plate is fixed, then result in Ansys is



SA 516 Gr 70 has 482 to 620 MPa ultimate tensile strength but in above example it is 797.33 MPa so, plate is fail to its function. In ASME no equation present for spring force consideration that is 402 N is act and plate is movable, so to take t=0.707 or 0.6846 is not justification. So, extra thickness should be considered.

After checking various analysis for plate thickness, t=4 mm is justified and found safe.
Main aim is to optimize thickness of the plate with referring ASME codes and analsys results.

III. ANALYSIS

Description of Element used for meshing

SOLID186 is a higher order 20 node hexahedron and Tetrahedron.

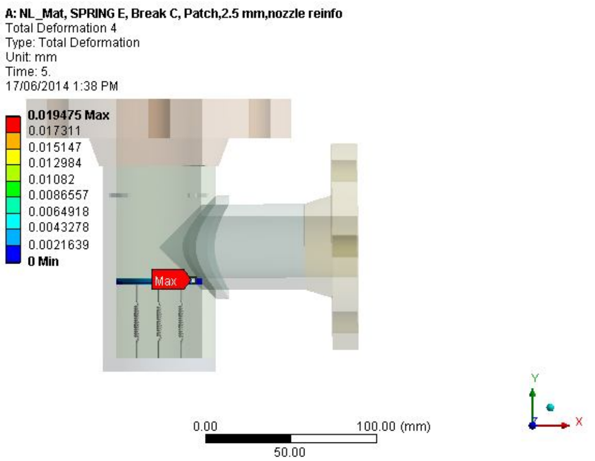


Figure-2 Basic conceptual model of pressure safety release valve

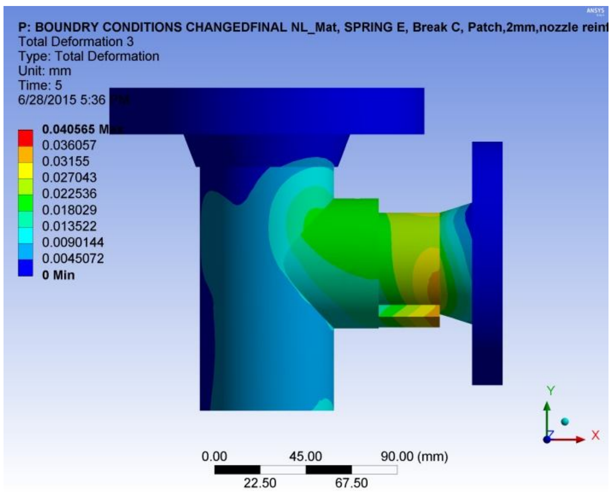


Figure-3 Final modified model of pressure safety release valve with rib support to nozzle

Element :- Hex Dominant/ Tetrahedrons			
Number of Nodes	Maximum Deformation	Maximum Stress	Location
79347	53.599	1888.99	Plate
79900	53.499	1584.4	Plate
80,033	0.019475	85.406	Plate
1,33,997	0.019615	85.4	Plate
1,78,426	0.0089063	85.941	Plate
2,36,936	0.0089027	85.31	Plate
80,033	0.13298	487.54	clip ON
1,21,683	0.011398	472.75	clip ON
1,60,006	0.0027874	247.86	clip ON
2,01,072	0.0023017	138.91	clip ON
1,50,416	1.1487	3092	Nozzle-shell junction
2,03,089	0.13298	740	Nozzle-shell junction

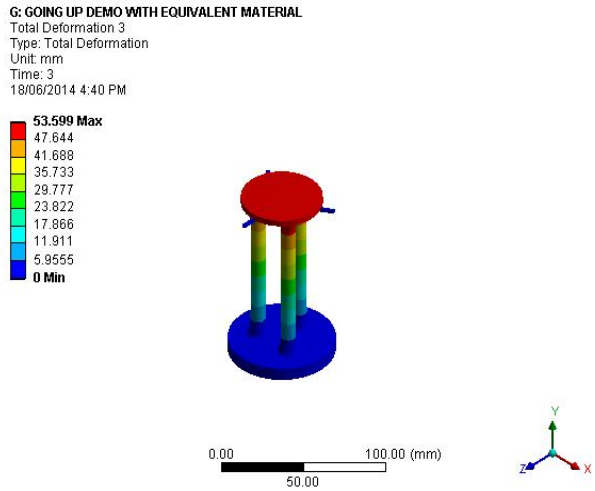


Figure-4 Spring analyze using equivalent spring property material

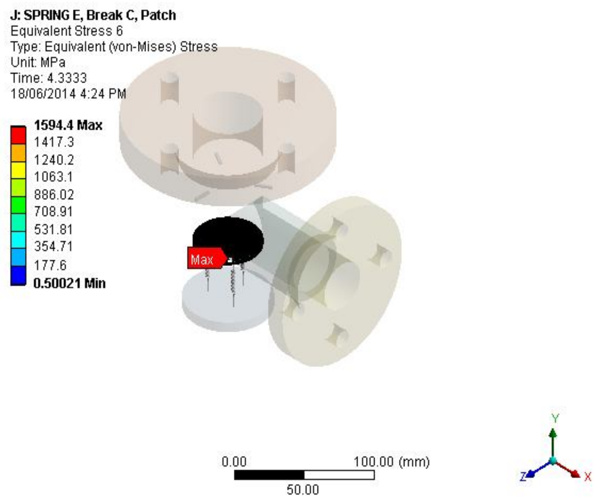


Figure-5 Plate analyzing less thickness

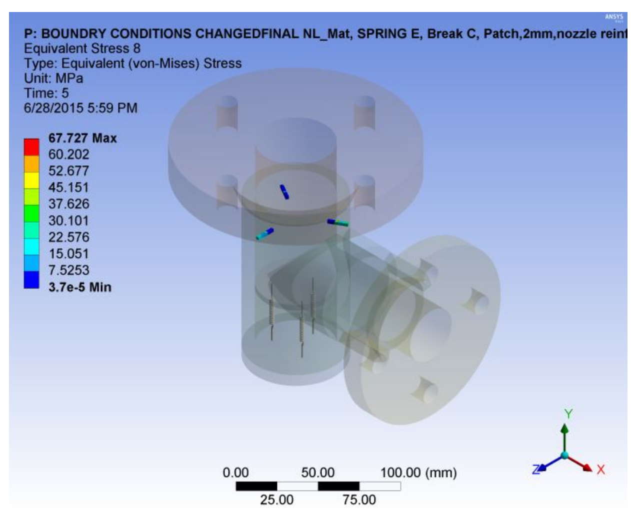
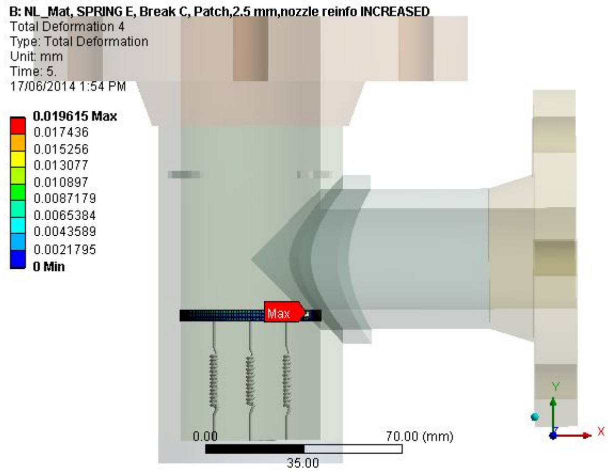


Figure-6 Analyze the clip ON for stress



Fgure-7 Analyze the plate for deformation

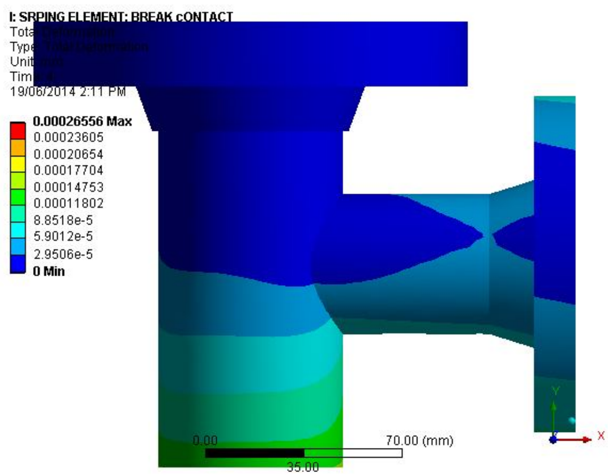


Figure-8 Analyze the whole assembly without Reinforcement pad and Nozzle Rib

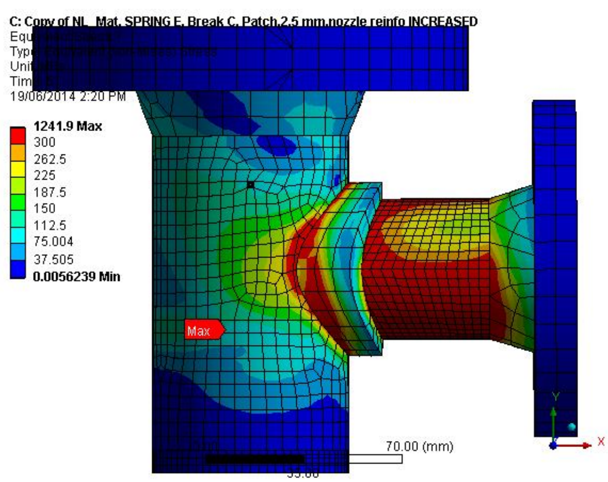


Figure-9 Analyze the whole assembly without Reinforcement pads

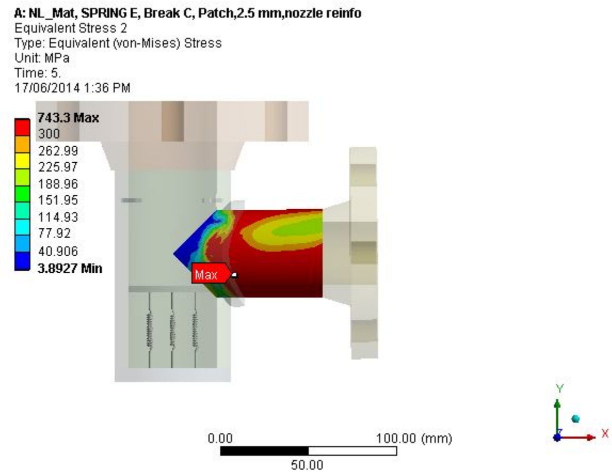
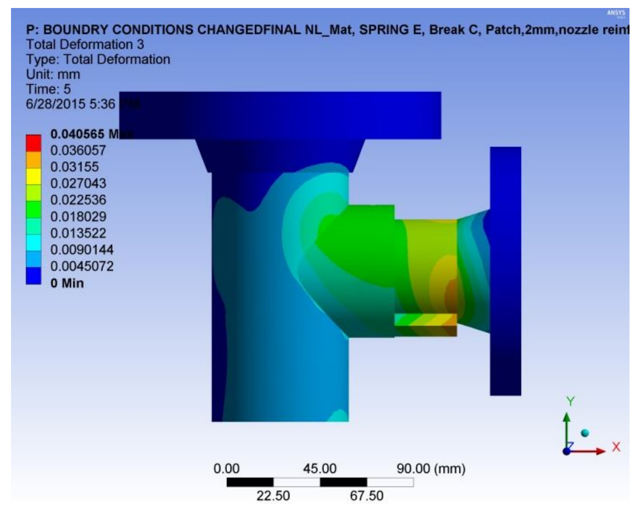


Figure-10 Analyzing the nozzle



IV. FUTURE SCOPE

Further analysis can be done for different components of the pressure vessel such as shell, flange, support etc for evaluating the results to improve efficiency and life of the pressure vessel.

V. CONCLUSION

1. Analysis results are reliable as seen in Mesh Sensitivity convergence and actual testing.

2. Concerned with FEA analysis more accurate results are achieved using HEX element compared to TET element with fine meshing but increased time.

3. FEA Validation shows we can increase efficiency of pressure safety release valve by providing rib at both side of nozzle.

4. When run for result the Analysis software, noticed if randomly change in size one by one of the components the stress on one component is reduces but stress increase for other components, so care taken must at the time of select the size of components of pressure safety release valve.

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