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Effect of Distance between Openings on Stress Concentration Factor of Cylindrical Pressure Vessel

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ABSTRACT: Openings in cylindrical shell are unavoidable in the construction of pressure vessels but ever opening in the shell leads stress concentration. This fact is significant because the structural failure of these components usually begins near the openings/cutouts due to high stress concentrations that initiate the formation of cracks. The objective of the present paper is to study the stress analysis and stress concentrations in cylindrical shell with circular opening that can be used to investigate the distance between two holes along the length of cylindrical shell using finite element analysis code namely.

KEYWORDS: Opening, SCF, FEA, Structural Analysis, Pressure vessel.

I. INTRODUCTION

Openings in cylindrical shell are unavoidable in the construction of pressure vessels but ever opening in the shell leads stress concentration. This fact is significant because the structural failure of these components usually begins near the openings/cutouts due to high stress concentrations that initiate the formation of cracks [1]. Hence, an opening can trigger a local failure at a load level lower than the global failure load of a corresponding shell without an opening. As a result, preliminary design sizing of a cylindrical shell with an opening is often based on the magnitude of the stress concentrations near the opening [2]. Therefore, an accurate assessment of the stress concentrations in a given shell subjected to various types of loading and support conditions is essential to the development of safe and reliable designs. Moreover, validated analysis tools that enable rapid parametric studies would be very valuable to structural designers, for development of new design criteria and design concepts. Several analytical, numerical, and experimental studies have been conducted during the past sixty years to determine stress distributions in cylindrical shells with an opening and a cutout subjected to various types of loadings, such as axial tension and compression, torsion, and internal and external pressure [3].

Most of the researchers have used the analytical formulae to calculate SCF but the formulae do not cover the wide range of the openings, distance of hole from shell end, and distance between two holes along the length and perpendicular to the length of cylindrical shell [6]. To study these effects on openings the finite element method is best able method by which stress concentration around openings is well estimated. The finite element method is used by many researchers to study the effects which are not covered by codes and analytical formulae. Hence for further study the finite element analysis method is used to estimate the stress concentration for distance between two holes along the length and perpendicular to the length of cylindrical shell.

II. PROBLEM DEFINITION

Section the effect of distance between two openings in longitudinal direction of the cylinder is worked. Here four case studies are taken with different diameters of opening keeping internal pressure and thickness constant. In each case study three cases are included with different shell diameter parameters.



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Case 1 for 30mm opening:

In this case following parameters given in Table 1 to 3 are taken with internal pressure of 1.5Mpa applied inside the cylinder. At the first case the reading for 30mm opening diameter with three different shell diameters are taken.

σ Μπο	D (mm)	d (mm)	R (mm)	L	С
мра	(11111)	(11111)	(11111)	(11111)	
60	400	30	15	40	2.7r
60	400	30	15	50	3.3r
60	400	30	15	60	4r
60	400	30	15	70	4.7r
60	400	30	15	80	5.3r
60	400	30	15	90	бr
60	400	30	15	100	6.7r
60	400	30	15	200	13.4r
60	400	30	15	400	26r
60	400	30	15	500	33.3r
60	400	30	15	600	40r
60	400	30	15	700	46.6r

Table 1: Case.1 various parameters of cylindrical shell case1

Where,

 σ = Stress applied, (Mpa)

D = Diameter of the shell in mm

d = Opening diameter in mm

r = Opening radius in mm

L/d =length to opening diameter

C = Distance between two hole with reference to opening radius

Kt = stress concentration factor



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Case2					
σ	D	d	R	L mm	С
47.25	315	30	15	40	2.7r
47.25	315	30	15	50	3.3r
47.25	315	30	15	60	4r
47.25	315	30	15	70	4.7r
47.25	315	30	15	80	5.3r
47.25	315	30	15	90	6r
47.25	315	30	15	100	6.7r
47.25	315	30	15	200	13.4r
47.25	315	30	15	400	26r
47.25	315	30	15	500	33.3r
47.25	315	30	15	600	40r
47.25	315	30	15	700	46.6r
Case3					
σ	D	d	R	L mm	С
σ 52.25	D 355	d 30	R 15	L mm 40	C 2.7r
σ 52.25 52.25	D 355 355	d 30 30	R 15 15	L mm 40 50	C 2.7r 3.3r
σ 52.25 52.25 52.25 52.25	D 355 355 355	d 30 30 30	R 15 15 15	L mm 40 50 60	C 2.7r 3.3r 4r
σ 52.25 52.25 52.25 52.25 52.25	D 355 355 355 355	d 30 30 30 30 30	R 15 15 15 15	L mm 40 50 60 70	C 2.7r 3.3r 4r 4.7r
σ 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25	D 355 355 355 355 355 355	d 30 30 30 30 30 30	R 15 15 15 15 15	L mm 40 50 60 70 80	C 2.7r 3.3r 4r 4.7r 5.3r
σ 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25	D 355 355 355 355 355 355	d 30 30 30 30 30 30 30	R 15 15 15 15 15 15	L mm 40 50 60 70 80 90	C 2.7r 3.3r 4r 4.7r 5.3r 6r
σ 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25	D 355 355 355 355 355 355 355 355	d 30 30 30 30 30 30 30 30	R 15 15 15 15 15 15 15 15	L mm 40 50 60 70 80 90 100	C 2.7r 3.3r 4r 4.7r 5.3r 6r 6.7r
σ 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25	D 355 355 355 355 355 355 355 355	d 30 30 30 30 30 30 30 30 30 30	R 15 15 15 15 15 15 15 15	L mm 40 50 60 70 80 90 100 200	C 2.7r 3.3r 4r 4.7r 5.3r 6r 6.7r 13.4r
σ 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25 52.25	D 355 355 355 355 355 355 355 355 355 35	d 30 30 30 30 30 30 30 30 30 30 30	R 15 15 15 15 15 15 15 15 15 15	L mm 40 50 60 70 80 90 100 200 400	C 2.7r 3.3r 4r 4.7r 5.3r 6r 6.7r 13.4r 26r
σ 52.25	D 355 355 355 355 355 355 355 355 355 35	d 30 30 30 30 30 30 30 30 30 30 30 30	R 15 15 15 15 15 15 15 15 15 15	L mm 40 50 60 70 80 90 100 200 400 500	C 2.7r 3.3r 4r 4.7r 5.3r 6r 6.7r 13.4r 26r 33.3r
σ 52.25	D 355 355 355 355 355 355 355 355 355 35	d 30 30 30 30 30 30 30 30 30 30 30 30 30	R 15 15 15 15 15 15 15 15 15 15 15 15	L mm 40 50 60 70 80 90 100 200 400 500 600	C 2.7r 3.3r 4r 4.7r 5.3r 6r 6r 6.7r 13.4r 26r 33.3r 40r

Table 2: Case.2 And 3 various parameters of cylindrical shell case1

Table No .2 represents various parameter of the cylindrical pressure vessel taken for study of stress analysis in case 2 and case3 the σ i.e stress value is changes from 47.25 to 52.25 and keep constant for the 355 mm Diameter of cylinder.

III. FEA RESULTS

Three-dimensional solid axi-symmetric brick (solid45) element models are used with Young's modulus = 210,000 MPa, Poisson's ratio = 0.3. For meshing solid45 element is used Model size was minimized by invoking symmetry boundary conditions. Then by formula of SCF is calculated by using the stress values by FEA and compared with the SFC obtained by Peterson's stress concentration factor for this condition.



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Fig.3.1 L= 40mm at C=2.7r

Fig3.2. L= 50mm at C=3.3r





Fig 3.3 and Fig. 3.4 shows the results of stress analysis for the distance 60mm and 50mm for 500mm opening diameter.



Fig3.5.L=600mm at C=40

Fig.3.6. L=700mm at C= 46.6r

Fig 3.5 and Fig. 3.6 shows the results of stress analysis for the distance 600mm and 700mm for 30mm opening

diameter.

The above Fig.3.1 to Fig. 3.6 shows the FEA stress analysis results for opening 30mm. The distance between two openings is increased from 40mm to 700mm. The results show that the least amount of the stress is generated when the distance between two openings is maximum but not close to the edge of the cylinder.



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IV. EXPERIMENTAL RESULTS

Above Figures shows the results of FEA stress analysis with the help of this analysis we calculate the Stress concentration for three cases and we got similar results with other size of the openings from 40mm to 60mm. Below the results represents the behaviour of 30mm opening diameter with different shell size.

Case 2 FEA results are shown from Fig. 3.1 to Fig. 3.6; similarly the structural analysis is done with two other cases. The results of stress concentration factor and equivalent stresses for each case are shown below in Tables 4.1 and 4.2

Tables 4.1 Equivalent Stress results by FEA with SCF for Case1 and 2.						
CASE 1 with shell Dia. D = 400mm						
Opening Dia. (d)	r in mm	L in(mm)	С	Stress result FEA Mpa	Kt	
30	15	40	2.7r	313	5.21	
30	15	50	3.3r	250	4.16	
30	15	60	4r	228	3.8	
30	15	70	4.7r	222	3.7	
30	15	80	5.3r	214	3.56	
30	15	90	6r	212	3.53	
30	15	100	6.7r	209	3.48	
30	15	200	13.4r	205	3.41	
30	15	400	26r	200	3.33	
30	15	500	33.3r	202	3.36	
30	15	600	40r	204	3.4	
30	15	700	46.6r	210	3.5	
Case2 with shell Dia. D = 315mm						
d	r	L mm	С	stress results FEA	Kt	
30	15	40	2.7r	254.88	5.39	
30	15	50	3.3r	201.1	4.25	
30	15	60	4r	189.6	4.01	
30	15	70	4.7r	182.72	3.86	
30	15	80	5.3r	177.6	3.75	
30	15	90	бr	174.82	3.69	
30	15	100	6.7r	174.32	3.68	
30	15	200	13.4r	167.74	3.55	
30	15	400	26r	163.24	3.45	
30	15	500	33.3r	164.07	3.47	
30	15	600	40r	165.76	3.50	
30	15	700	46.6r	172.77	3.65	

Table no.4.1 shows the stress analysis results for the opening diameter of 30mm for two cylinders having Diameter of 400mm and 315mm. The results shows that when the cylinder diameter the stress values are also changes.



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Case 3 with shell Dia. $D = 355 \text{ mm}$					
d	r	L mm	С	Stress result by FEA	Kt
30	15	40	2.7r	283.16	5.41
30	15	50	3.3r	234.86	4.49
30	15	60	4r	208.84	3.99
30	15	70	4.7r	203.51	3.89
30	15	80	5.3r	198.16	3.79
30	15	90	бr	195.87	3.74
30	15	100	6.7r	194.36	3.71
30	15	200	13.4r	190.82	3.65
30	15	400	26r	183.27	3.50
30	15	500	33.3r	183.49	3.51
30	15	600	40r	187.75	3.59
30	15	700	46.6r	207.05	3.96

Tables 4.2 Equivalent Stress results by FEA with SCF for Case3.

The Table No. 4.2 shows the stress analysis results for cylinder diameter 355mm its seen that the results get increased in stress values with compare to 315mm Dia. Of cylinder.



Fig 4.1: SCF Vs Distance between two openings C

From the graph of SCF Vs distance between two hole C which is shown in Fig.4.1 it is seen that the SCF is higher for C = 2.7r and decreases from 2.7r to 6.7r for all cases. After 6.7r it shows constant behavior between 13.4r to 40r and again increases at 46.6r.

V. CONCLUSION

In this paper the effect of size, location of the openings on the stress concentration at the openings of vessel subjected to internal pressure is studied by using Finite element analysis. The size of opening, the position of openings along the longitudinal axis is studied. There is no provision for such cases in traditional formulae or codes given by



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ASME except the limitation for opening sizes. A mong the significant observations and discussions from case following conclusions are derived.

The distance between two circular openings of equal sizes is less then SCF is higher. However, as distance between two opening L increases, the influence between two openings is decreases. So distance between two openings should keep maximum with avoiding the edges of the cylinder.

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