Elastic Behavior of Cylindrical Vessels with Lateral Nozzle under internal pressure

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ABSTRACT

The objective of this work is to study the elastic stress distribution, deformation, characteristic and stress concentration factor (SCF) of a cylindrical vessel with lateral nozzle.

Three full scale vessels under internal pressure with different geometric dimensions and lateral angle θ (θ =30deg, θ =45deg, θ =60deg,) are investigated by both experimental and three dimensional finite element methods under internal pressure.

***Keywords* -** cylindrical vessel,stress concentration factor,lateral nozzle,finite element analysis.

I. INTRODUCTION

Lateral connection configurations are widely used in the pressure vessel and piping industries. Because of the peculiarity of this structure (an elliptical hole is produced in the cylinder.), a distinct stress concentration occurs at the intersection area of the cylinder and lateral nozzle (or main pipe and branch pipe), which affects the strength of this structure much more than that of an orthogonal intersection structure.

The primary purpose of the present work is to study elastic behavior including elastic stress distribution, stress concentration factor, and deformation characteristic of three full scale cylindrical vessel under internal pressure with different geometric dimensions and lateral pressure with different geometric dimensions and lateral angle Θ by both experimental and three dimensional finite element methods.

II. EXPERIMENTS

<u>Model Vessel</u>

Three model vessels with a lateral nozzle and different geometric dimensions were fabricated for testing and analysis. Each model vessel consists of a cylinder Lateral nozzle and elliptical heads, as well as supports. The lateral nozzle was placed in the middle of the cylindrical vessel. The lateral angle is defined as the angle between central lines of the cylinder and nozzle.

<u>Materials and Properties</u>

The materials of the cylinder and the nozzle are Q235-B and 20# respectively. The actual chemical composition and typical mechanical properties of the materials are given

<u>Local Weld structure of the Vessel and Lateral Nozzle.</u>

A set on full penetration weld was employed in the cylinder lateral nozzle joint Argon arc welding and carbon dioxide arc welding were used in the weld for root and deposit, respectively the details of the welds are shown in Fig.

<u>Experimental Techniques and Process.</u>

The testing was performed by means of electric resistance strain measurement method. Strain gauges were mounted in the longitudinal and transverse sections and intersections area on the outside surface of the cylindrical vessel and lateral nozzle

The strain values of the measurement points were measured and recorded automatically under increasing internal pressure loading.

<u>III.Test Result</u>

The distribution of the experimental elastic stress for the model under 1.5 Mpa are in the fig 1 which illustrate the variation in the stress versus the distance from the welding seam to measuring points on the cylinder. The ordinate represents the equivalent distance (in mm) the maximum elastic stress and SCF of key locations (deviating from a welding seam of 5mm).

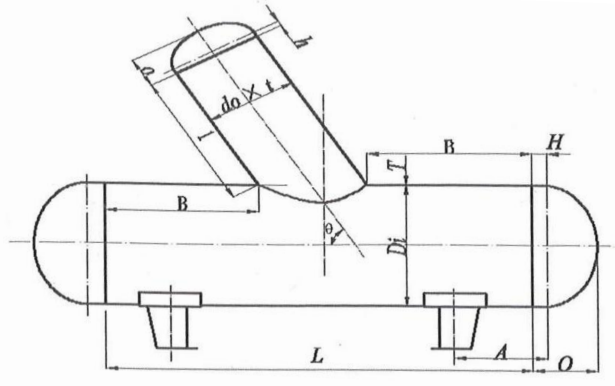
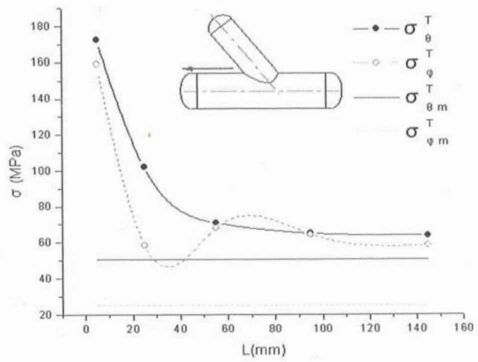
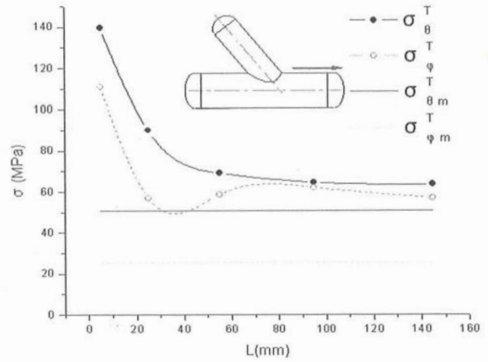


Fig. 1 Structure of experimental models



(a)



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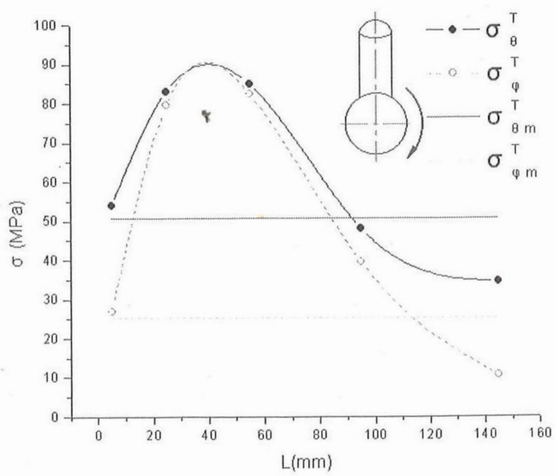

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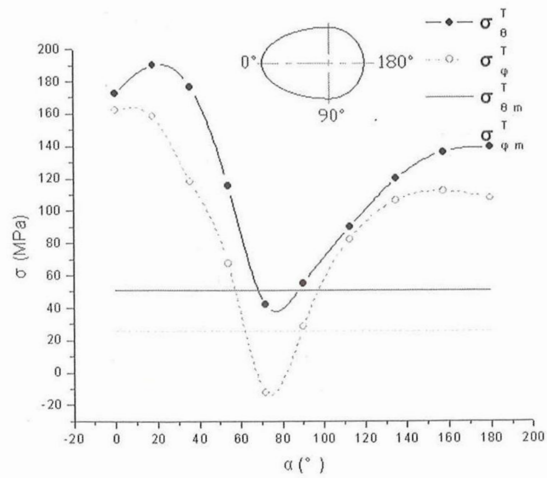

(d)

Fig. 2 Stress distribution from experiment for model $1(\theta = 60deg)$ under 1.5 MPa. (a) Stresses in longitudinal section of cylinder on acute side; (b) stresses in longitudinal section of cylinder on obtuse side; (c) stresses in transverse section of cylinder; and (d) stress distributions in connection area.

Table 3 Maximum stress and stress concentration factor in cylindrical vessels under internal pressure of 1.5 MPa

Vessel No.		Longitudinal Section				Transverse Section		α=20 degree	
		σ_{max} /MPa	SCF*	σ_{max} /MPa	SCF*	σ_{max} /MPa	SCF*	σ_{max} /MPa	SCF*
No.1	Test	172.5	3.40	139.5	2.75	90.1	1.78	190.3	3.75
	FEM	192	3.78	137.5	2.71	100.5	1.98	210.2	4.14
No.2	Test	182.2	3.19	172.2	3.02	63.2	1.11	199.6	3.51
	FEM	203.3	3.56	163.2	2.86	69.4	1.21	220.2	3.86
No.3	Test	172.1	2.72	146.2	2.28	66.0	1.04	250.2	3.95
	FEM	191.8	3.03	128.8	2.03	62.1	0.93	265.6	4.19

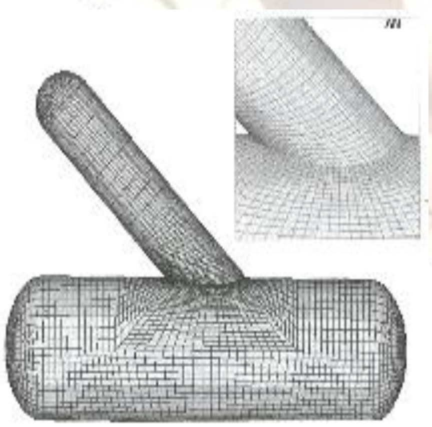

Fig. 3 Finite element mesh of model 1

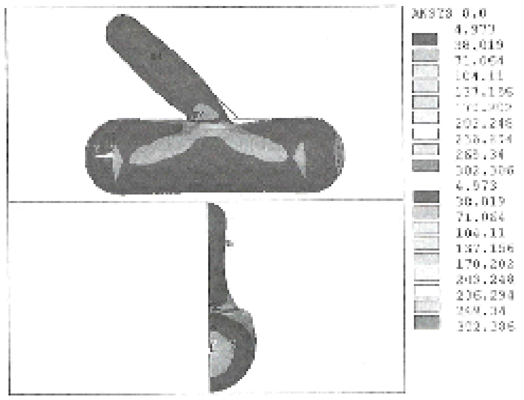

Fig. 4 Deformation of the elastic area of model 2 under 1.0 MPa (MPa, scale=250)

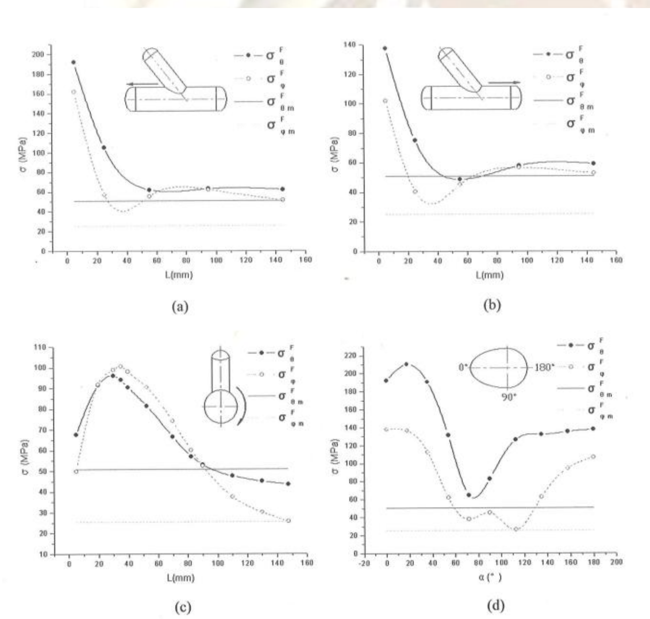

Fig. 5 FEM stress distributions for model $1(\theta = 60deg)$

Under 1.5 MPa. (a) Stresses in longitudinal section of cylinder on acute side; (b) stresses in longitudinal section of cylinder on obtuse side; (c) stresses in transverse section of cylinder, and (d) stress distributions in connection area.

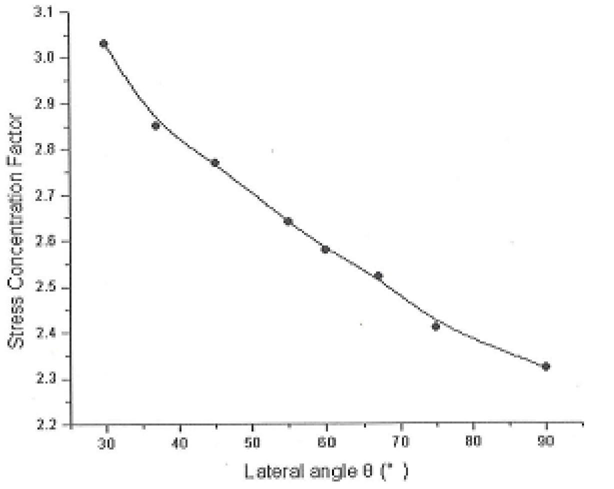

Fig. 6 Influence of lateral angle θ on SCF (on acute side of cylinder)

IV-Finite element Numerical Simulation

A static nonlinear finite numerical simulation of the test vessels was performed using Ansys Three dimensional iso parametric solid elements that are defined by eight nodal points were used to generate the FEM mesh of the nozzle The boundary conditions used in the finite element numerical simulation are the same as those in the experiments: All the nodes on the symmetry section (longitudinal plane of the vessel) are constrained against deformation in the direction normal to the symmetry plane. The nodes located at the center of the of the saddle supports are fixed and that of the other support are restricted in the vertical direction only. The internal pressure load increment of the analysis model coincides with that of the experiment.

Stress and Deformation

From the stress and deformation patterns of the test model under an internal pressure of 1.0 Mpa the maximum stress occurs at the acute side of the maximum von Misses equivalent stress is 302.4 Mpa. As shown in fig obvious deformation are produced. As the noozle bends the head of the nozzle rises up, which increases the angle between the axis of the cylinder and lateral nozzle. The intersection area in the longitudinal section of the cylinder shrinks, while bulges appear in the transverse section. As a result it is very likely that the failure under internal pressure will first occur at the acute side of the junction of the whole structure.

Effect of Lateral Angle on Elastic Stress Concentration Factors

In order to study the effects of lateral angle on the SCF s additional analysis model with the same geometrical parameters (d/D, D/T, t/T) as vessel No 3 but with different Lateral angles were modeled and analyzed when subjected to an internal pressure of 1.5 Mpa From the results of this analysis the values of the SCF scan be xcalculated and are given in when the geometries (d/D, D/T, t/T)Are the same the SCF of a cylinder vessel with lateral nozzle decreases with an increase in the lateral angle for the SCF is the lowest for a cylindrical vessel with an orthogonal nozzle (Θ=90deg) while it is highest for a lateral angle of about (Θ=30deg)The results are in accorded with those presented

Summary

The Table presents a summary of the maximum principle stress and SCF of key points (5 mm from weld edge) obtained from three vessel by both experiment and finite element analyses.

Conclusion

The maximum stress and SCF of the cylinders with a lateral nozzle were provided by using both experiment and FEA Locations of maximum stress were provided. The effect of lateral angle on the elastic stress concentration was also studied. From the results obtained.

The results indicated that the maximum stress of cylindrical vessels with a lateral nozzle occurs at the acute side of the cylinder lateral intersection and drifts of the longitudinal section of the cylinder for about 20 deg. When the geometric parameters of the vessels are fixed,SCF of the structure will increase with decreases in the lateral angle.

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