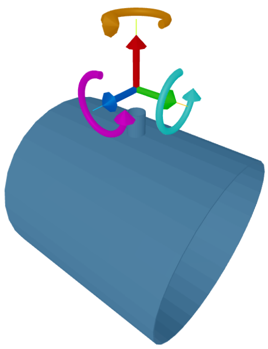
Cylindrical Shell Stress Analysis

Computation of Local Stresses in Cylindrical Shells with Circular Hollow Attachments



Nozzle Design 3D Model

Technical Report

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Prepared by:

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Chapter 1

Introduction

1.1 Methodology

The analysis follows the methodology outlined in WRC Bulletin 297 for the calculation of local stresses in cylindrical shells with hollow circular attachments. The stress concentration factors are determined based on the geometric parameters of the shell and attachment.

Table 1.1: Cylindrical Shell Stress Analysis - Computation Sheet for Local Stresses (Circular Hollow Attachment)

1. Applied Loads (First Load Case)	
Radial Load	$P = 1500$ N
Shear Load	$V_1 = 1250$ N
Shear Load	$V_2 = 1000$ N
Overturning Moment	$M_1 = 750$ N · m
Overturning Moment	$M_2 = 500$ N · m
Torsional Moment	$M_T = 250$ N · m
2. Geometry	
Vessel Thickness	$T = 10$ mm
Vessel Mean Radius	$R_m = 600$ mm
Nozzle Thickness	$t = 5.000$ mm
Nozzle Outside Radius	$r_o = 50.000$ mm
Vessel Length	$L = N/A$ mm
3. Geometric Parameters	
$\lambda = \left(\frac{d}{D}\right)\left(\frac{D}{T}\right)^{1/2} = 0.913$	
$\Lambda = \frac{L}{(DT)^{1/2}} = N/A$	
$L^{**} = \frac{8L_1L_2}{[(L_1)^{1/2}+(L_2)^{1/2}]^2} = N/A$ mm	
Notes: 1. Enter all force values in accordance with sign convention. 2. Use consistent set of units in all calculations. 3. For nozzle not centered in the vessel shell, an equivalent vessel length L can be calculated from the following formula where L_1 and L_2 are the distances from the nozzle center line to the vessel ends: $L^{**} = \frac{8L_1L_2}{[(L_1)^{1/2}+(L_2)^{1/2}]^2}$	

Table 1.2: Cylindrical Vessel Stress Analysis - Detailed Computation Results (Circular Hollow Attachment)

Reference Figure No.	**Read Curves For**	**Calculate absolute values of stress and enter result**	**STRESSES – If load is opposite that shown, reverse signs shown**							
			A_u	A_L	B_u	B_L	C_u	C_L	D_u	D_L
3-7 & 8-12	$\frac{N_rT}{P}$ $\frac{M_r}{P}$	$\sigma_a = \frac{P}{t^2}\left[\frac{t}{\pi d} \pm (6m_r - 3n_r)\right]$	-10.831	14.126	-10.831	14.126	-10.831	14.126	-10.831	14.126
23-26 & 27-31	$\frac{M_rd}{M_c}$ $\frac{N_rTd}{M_c}$	$\sigma_a = \frac{M_c}{t^2d}\left[\frac{4t}{\pi d} \pm (6m_r - 3n_r)\right]$	–	–	–	–	-58.272	73.455	58.272	-73.455
41-44 & 45-49	$\frac{M_rd}{M_L}$ $\frac{N_rTd}{M_L}$	$\sigma_a = \frac{M_L}{t^2d}\left[\frac{4t}{\pi d} \pm (6m_r - 3n_r)\right]$	69.043	-88.422	-69.043	88.422	–	–	–	–
8-12 & 13-17	$\frac{N_rT}{P}$ $\frac{M_r}{P}$	$\sigma_c = \frac{P}{T^2}(n_\theta)$	-5	10.269	-5	10.269	-5	10.269	-5	10.269
32-35 & 36-40	$\frac{M_\theta d}{M_c}$ $\frac{N_\theta Td}{M_c}$	$\sigma_\theta = \frac{M_c}{T^2d}(n_\theta)$	–	–	–	–	-41.674	49.533	41.674	-49.533
50-53 & 54-58	$\frac{N_\theta Td}{M_L}$ $\frac{M_\theta d}{M_L}$	$\sigma_c = \frac{M_L}{T^2d}(n_\theta)$	38.6	-67.588	-38.6	67.588	–	–	–	–
Shear stress due to Torsion, M_T		$\tau = \frac{2M_T}{\pi d^2 T}$	1.592	1.592	1.592	1.592	1.592	1.592	1.592	1.592
Shear stress due to load V_C		$\tau = \frac{2V_C}{\pi dT}$	0.637	0.637	0.637	0.637	0.637	0.637	0.637	0.637
Shear stress due to load V_L		$\tau = \frac{2V_L}{\pi dT}$	0.796	0.796	0.796	0.796	0.796	0.796	0.796	0.796
For the longitudinal plane (r)		$\sigma_r = \sigma_r(P) + \sigma_r(M_L)$;	58.212	-74.296	-79.874	102.548	–	–	–	–
For the longitudinal plane (θ)		$\sigma_\theta = \sigma_\theta(P) + \sigma_\theta(M_L)$;	33.599	-57.318	-43.6	77.857	–	–	–	–
For the transverse plane (r)		$\sigma_r = \sigma_r(P) + \sigma_r(M_c)$;	–	–	–	–	-69.103	87.581	47.441	-59.328
For the transverse plane (θ)		$\sigma_\theta = \sigma_\theta(P) + \sigma_\theta(M_c)$;	–	–	–	–	-46.674	59.802	36.674	-39.264
$\frac{1}{2}[\sigma_r + \sigma_\theta + [(\sigma_r - \sigma_\theta)^2 + 4\tau^2]^{1/2}]$			58.578	-56.796	-43.35	102.913	-46.274	87.907	48.232	-38.818
$\frac{1}{2}[\sigma_r + \sigma_\theta - [(\sigma_r - \sigma_\theta)^2 + 4\tau^2]^{1/2}]$			33.233	-74.818	-80.124	77.492	-69.504	59.477	35.882	-59.774
$[(\sigma_r - \sigma_\theta)^2 + 4\tau^2]^{1/2}$			25.344	18.022	36.775	25.421	23.23	28.43	12.35	20.956
COMBINED STRESS INTENSITY - S (MPa)			A_u	A_L	B_u	B_L	C_u	C_L	D_u	D_L
			58.578	74.818	80.124	102.913	69.504	87.907	48.232	59.774

Table 1.3: Cylindrical Nozzle Stress Analysis - Detailed Computation Results (Circular Hollow Attachment)

Reference Figure No.	**Read Curves For**	**Calculate absolute values of stress and enter result**	**STRESSES – If load is opposite that shown, reverse signs shown**							
			A_u	A_L	B_u	B_L	C_u	C_L	D_u	D_L
3-7 & 8-12	$\frac{N_r T}{P}$ $\frac{M_r}{P}$	$\sigma_a = \frac{P}{t^2}\left[\frac{t}{\pi d} \pm (6m_r - 3n_r)\right]$	-68.682	31.149	-68.682	31.149	-68.682	31.149	-68.682	31.149
23-26 & 27-31	$\frac{M_r d}{M_c}$ $\frac{N_r T d}{M_c}$	$\sigma_a = \frac{M_c}{t^2 d}\left[\frac{4t}{\pi d} \pm (6m_r - 3n_r)\right]$	–	–	–	–	-339.741	187.168	369.36	-157.549
41-44 & 45-49	$\frac{M_r d}{M_L}$ $\frac{N_r T d}{M_L}$	$\sigma_a = \frac{M_L}{t^2 d}\left[\frac{4t}{\pi d} \pm (6m_r - 3n_r)\right]$	453.419	-176.44	-408.991	220.868	–	–	–	–
8-12	$\frac{N_r T}{P}$ $\frac{M_r}{P}$	$\sigma_c = \frac{P}{T^2}(n_\theta)$	2.635	2.635	2.635	2.635	2.635	2.635	2.635	2.635
36-40	$\frac{N_\theta T d}{M_c}$ $\frac{M_\theta d}{M_c}$	$\sigma_c = \frac{M_c}{T^2 d}(n_\theta)$	–	–	–	–	3.93	3.93	-3.93	-3.93
54-58	$\frac{N_\theta T d}{M_L}$ $\frac{M_\theta d}{M_L}$	$\sigma_c = \frac{M_L}{T^2 d}(n_\theta)$	-14.494	-14.494	14.494	14.494	–	–	–	–
Shear stress due to Torsion, M_T		$\tau = \frac{2M_T}{\pi d^2 T}$	3.183	3.183	3.183	3.183	3.183	3.183	3.183	3.183
Shear stress due to load V_C		$\tau = \frac{2V_C}{\pi d T}$	1.273	1.273	1.273	1.273	1.273	1.273	1.273	1.273
Shear stress due to load V_L		$\tau = \frac{2V_L}{\pi d T}$	1.592	1.592	1.592	1.592	1.592	1.592	1.592	1.592
For the longitudinal plane (r)		$\sigma_r = \sigma_r(P) + \sigma_r(M_L)$;	384.738	-145.291	-477.672	252.018	–	–	–	–
For the longitudinal plane (θ)		$\sigma_\theta = \sigma_\theta(P) + \sigma_\theta(M_L)$;	-11.859	-11.859	17.129	17.129	–	–	–	–
For the transverse plane (r)		$\sigma_r = \sigma_r(P) + \sigma_r(M_c)$;	–	–	–	–	-408.423	218.317	300.678	-126.4
For the transverse plane (θ)		$\sigma_\theta = \sigma_\theta(P) + \sigma_\theta(M_c)$;	–	–	–	–	6.564	6.564	-1.295	-1.295
$\frac{1}{2}[\sigma_r + \sigma_\theta + [(\sigma_r - \sigma_\theta)^2 + 4\tau^2]^{1/2}]$			384.83	-11.586	17.202	252.173	6.652	218.489	300.799	-1.003
$\frac{1}{2}[\sigma_r + \sigma_\theta - [(\sigma_r - \sigma_\theta)^2 + 4\tau^2]^{1/2}]$			-11.952	-145.564	-477.746	16.973	-408.511	6.391	-1.416	-126.691
$[(\sigma_r - \sigma_\theta)^2 + 4\tau^2]^{1/2}$			396.781	133.979	494.949	235.2	415.163	212.098	302.215	125.688
COMBINED STRESS INTENSITY - S (MPa)			A_u	A_L	B_u	B_L	C_u	C_L	D_u	D_L
			396.781	145.564	494.949	252.173	415.163	218.489	302.215	126.691