Tutorial on Qualification of Nozzles attached to Spherical/Cylindrical Vessels using CAEPIPE

The following are the steps for qualifying nozzles welded to Spherical/Cylindrical Vessels such as pressure vessels, tanks etc. using CAEPIPE.

General

Often pipe stress engineers face difficulties on the following while analyzing any piping system.

• Obtaining or computing the allowable loads at nozzles attached to Spherical / Cylindrical Vessels and Torispherical Heads, and

• Keeping the external loads imposed by piping on equipment nozzles within allowable limits.

The above difficulties can be overcome in CAEPIPE by

- Using the module "Nozzle Evaluation" for calculating allowable loads at nozzles welded to Spherical / Cylindrical Vessels and Torispherical Heads.
- Incorporating the local shell flexibility at the nozzle-to-shell junctions while carrying out piping stress analysis.

This tutorial provides stepwise procedure for

- 1. Computing allowable loads on nozzles to Spherical / Cylindrical Vessels and Torispherical Heads,
- 2. Modeling the nozzle-to-shell junction as "Nozzle" to incorporate local shell flexibility, and
- 3. Inputting the nozzle allowable loads thus computed into CAEPIPE stress system as "User Defined Allowable" for equipment qualification.

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File	e Edit	t Viev	w Optio	ns Loads	s Misc	Wind	low	Help			e View Options Window Help			
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#	Node	Туре	DX (ft'in'')	DY (ft'in'')	DZ (ft'in'')	Matl	Sect	Load	Data	^	Z			^
1	Title =	Nozzle	s to Spheric	cal & Cylindi	rical Vessel:	3					1			
2	Nozzle	e-to-Sph	erical Shell	/ Torisphe	rical Head j	unctio	n at N	ode 10			🖍 y 🧈 🔎			
3	10	From							Nozzle	H	· · · · · · · · · · · · · · · · · · ·			
4	20	Bend			3.2808	PPI	510	L1			Т			
5	30			8.5302		PPI	510	L1						
6	40			0.9843		PPI	510	L1		H	1			
7	50	Bend		2'6''		PPI	510	L1		H	T			
8	60	Bend	6.0827			PPI	510	L1			4			
9	70	Bend	8.4022	-8.4022		PPI	510	L1		ч	T			
10	80	_			-12.0735	PPI	510	L1	Limit stop					
11	80	From							Limit stop		Ť			
12	90				-8.5302	PPI	510	LI			*			
13	100	. .			-6.2336	PPI	510				T.			
14	110	Bend	0.0040	0.0000	-15.1181	PPI	510		1.1.1.1					
15	120		0.6340	0.0686	-2.7620		510		Limit stop		Т			
10	130	D	4.1051	0.4438	-17.8825	PPI	510		Limit stop					
17	140	Бела	3.3022	0.3570	-14.3800		510		l insit stars					
10	150	From			-0.0020	FFI	510		Limit stop					
20	160	TION			.19.4390	PPI	510	11	Limit stop		(T			
21	160	From			10.4000		1010		Limit stop		↓			
22	170	. ioni			-21 8176	PPI	510	11	Limit stop					
23	170	From			21.0110		0.0		Limit stop		M 🖌			
24	180				-19.6850	PPI	510	L1	Limit stop		Ĵ			
25	190	Bend			-9.0978	PPI	510	L1			- ²⁰¹			
26	200		14.1864			PPI	510	L1	Limit stop					~
27	210		12'6''			PPI	510	L1	Limit stop	~				>:

Step 1:

From the attached model (snap shot shown above), assume the following.

- 1. Node 10 is the intersection of a Nozzle to a Spherical Shell / Torispherical Head of a vessel.
- 2. Node 420 is the intersection of a side Nozzle to a Cylindrical Vessel.

Step 2:

From the equipment drawings provided by the manufacturer for Spherical Shell / Torispherical Head, the following properties are entered into "Nozzle Evaluation" module of CAEPIPE through Main Frame > New > Nozzle Evaluation.



After entering the details, press the button "OK", save the model and perform the analysis through File > Analyze. This computes the allowable radial nozzle load as well as the allowable bending moment on nozzle welded to Spherical Shell. See snap shot below for details.

Caepipe : Nozzle Evaluation (24)	- [S	phericalVessel_Allowabl — 🔲 🗙	
File <u>E</u> dit <u>O</u> ptions <u>H</u> elp			
Allowable Loads on Nozzles as per EN 134	45-3:	2014/A8:2019	
Input Data:			
Local Loads on Nozzle attached to Spheric	al Ve	essel	
Mean Shell Radius [R]:	150	(inch)	
Nominal Shell Thk. [e]: 0).75	(inch)	
Nozzle OD [de]:	20	(inch)	
Nozzle Thickness [eb]: 0.3	937	(inch)	
Mean Nozzle Dia. [d]: 19.6	606	(inch)	
Rein. Pad Thk. [e2]:	0	(inch)	
Rein. Pad OD [d2]:	0	(inch)	
Shell Design Stress [f]: 233	206	(psi)	
Rein. Pad Design Stress [f2]: 233	206	(psi)	
Nozzle Design Stress [fb]: 233	206	(psi)	
Corrosion Allowance [c]: 0.03	937	(inch)	
Allowable Loads on Nozzles-to-Spherical Sk	hells	as per EN 13445-3:2014/A8:2019	
Clause 16.4.3: Conditions of applicability			
Analysis Shell Thk.[ea]/Mean Shell Radius	[R] s	hould be >= 0.001 and <= 0.1	
a) ea/R = 0.005 which is >= 0.001 and <= 0 $($	0.1. 0	Condition Passed.	
b) Distances to any other local load in any o	direct	ion shall not be less than SQRT(R.ec) = 10.324 (inch)	
c) Nozzle thickness shall be maintained ove	era d	listance of SQRT(D.eb) = 2.7783 (inch)	
Clause 16.4.5: Maximum allowable individua	al loa	ds	
Allowable radial nozzle load [Fz.Max]: 84816	6.63	(lb)	
Allowable bending moment [Mb.Max]: 4547	6.08	(ft-lb)	-
<			>

In a similar fashion, from the equipment drawings provided by the manufacturer for Cylindrical Vessel, the following properties are entered into "Nozzle Evaluation" module of CAEPIPE through Main Frame > New > Nozzle Allowable Loads.

Nozzle Evaluation	×
Code Allowable Loads on Nozzles - EN 13445-3:201	4/A8:20° 👻
O Nozzle to Spherical Shell • Nozzle to Cylindria	cal Shell
Mean Shell Diameter [D] 240	(inch)
Nominal Shell Thk (e) 0.4	(inch)
Nozzle OD (de) 20	(inch)
Nozzle Thickness (eb) 0.4	(inch)
Mean Nozzle Dia (d) 19.606	(inch)
Rein. Pad Thk (e2) 0	(inch)
Rein. Pad OD (d2) 0	(inch)
Shell Design Stress (f) 23206	(psi)
Rein. Pad Design Stress (f2) 23206	(psi)
Nozzle Design Stress (fb) 23206	(psi)
Corrosion Allowance (c) 0.03937	(inch)
(OK)	Cancel

After entering the details, press the button "OK", save the model and perform the analysis through File > Analyze. This computes the allowable radial nozzle load as well as the allowable bending moments in the circumferential and longitudinal directions as shown below.

-II Caepipe : Nozzle Evaluatio	n (28) - [C	ylindricalVessel_Allowal	b — 🗆 🗡	<
File <u>E</u> dit <u>Options</u> <u>H</u> elp				
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Allowable Loads on Nozzles as per	EN 13445-3:	:2014/A8:2019		
Input Data:				
Local Loads on Nozzle attached to	Cylindrical V	esse		
Mean Shell Diameter [D]:	240	(inch)		
Nominal Shell Thk. [e]:	0.4	(inch)		
Nozzle OD [de]:	20	(inch)		
Nozzle Thickness [eb]:	0.4	(inch)		
Mean Nozzle Dia. [d]:	19.606	(inch)		
Rein. Pad Thk. [e2]:	0	(inch)		
Rein. Pad OD [d2]:	0	(inch)		
Shell Design Stress [f]:	23206	(psi)		
Rein. Pad Design Stress [f2]:	23206	(psi)		
Nozzle Design Stress [fb]:	23206	(psi)		
Corrosion Allowance [c]:	0.03937	(inch)		
Allowable Loads on Nozzles-to-Cyli	ndrical Shells	as per EN 13445-3:2014/	A8:2019	
Clause 16.5.3: Conditions of applic	ability			
a) Analysis Shell Thk.[ea]/Mean Sh	nell Diameter I	[D] should be >= 0.001 an	d <= 0.1	
a) ea/D = 0.002 which is >= 0.001	and <= 0.1. 0	Condition Passed.		
b) Lambda C should be <= 10.0				
Lambda C = 2.107 which is <= 10.0	Condition Pa	assed.		
c) Distances to any other local load	l in any direct	tion shall not be less than 9	QRT(D.ec): 9.3033 (inch)	
d) Nozzle thickness shall be mainta	ained over a d	listance of SQRT(D.eb): 2.	8004 (inch)	
Clause 16.5.5: Maximum allowable	individual loa	ıds		
16.4.5.5: Allowable radial nozzle lo	ad [Fz.Max]: 7	7897.67 (Ib)		
16.5.5.5: Allowable circumferential	moment [Mx.]	Max]: 6393.96 (ft-lb)		
16.5.5.6: Allowable longitudinal mo	ment [My.Max	x]: 14637.12 (ft-lb)		
<				>

For both types of nozzles, the allowable loads in the two shear directions and in the torsional direction can be assumed to be very much larger than the corresponding allowable for the radial load and bending moment directions, as the shell is very stiff in those directions.

Step 3:

Enter the data type of Node 10 as "Nozzle" and input the properties as shown below.

Nozzle at node 10 X
Nozzle Tag Time Cylindrical Vessel
✓ Spherical Vessel Nozzle
Vessel R 150 (inch) Thk 0.75 (inch)
Elastic modulus of vessel material 29.0E+6 (psi)
Vessel axis direction X comp Y comp Z comp
OK Cancel Displacements

Step 4:

Similarly, enter the data type of Node 420 as "Nozzle" and input the properties as shown below.



From the snap shot shown above, Lengths L1 and L2 on either side of the nozzle, which are the distances from the nozzle center line to the nearest location on vessel where the "ovalization deformation" of the vessel is stopped such as at a stiffener on the inner or outer surface of the vessel, or at the center of a saddle support to the vessel or at the junction to the torispherical enclosure (also called the head) or at a tube sheet inside the vessel etc.

Step 5:

Input the allowable loads on the two Nozzles computed in Step 2 above in CAEPIPE through Layout window > Misc > User Allowables.

Allowables X	Allowables ×
Node III FX/P (lb) FY/VL (lb) FZ/VC (lb) 84817.63 848176.31 848176.31 MX/MT (ft-lb) MY/MC (ft-lb) MZ/ML (ft-lb) 454771.19 45477.12 45477.12	Node 420 FX/P (lb) FY/VL (lb) FZ/VC (lb) 7590.84 75908.40 75908.40 MX/MT (ft-lb) MY/MC (ft-lb) MZ/ML (ft-lb) 138339.80 6330.81 13833.98
OK Cancel Only for Nozzle, enter Radial (P), y Shear (VL,) z Shear (VC) , Torque (MT), Circ. Mom (MC) & Long. Mom (ML)	OK Only for Nozzle, enter Radial (P), y Shear (VL,) z Shear (VC) , Torque (MT), Circ. Mom (MC) & Long. Mom (ML)

The allowable loads for the two shear and torsional directions are <u>assumed</u> to be ten (10) times the corresponding allowables for the radial and bending directions.

Step 6:

Save the model and perform the analysis through Layout window > File > Analyze. CAEPIPE will include in the pipe stress analysis the local shell stiffnesses internally computed at both nozzle-to-spherical and nozzle-to-cylindrical shell junctions. These local shell stiffnesses can be seen in CAEPIPE through Layout window > View > List > Nozzle stiffnesses.

1-0-	Caep	ipe : N	lozzle stiffne	esses (2) - [NozzleC	Qualification.mod	(C:\Tutorials\NozzleQ		×
File	e Edi	t Op	tions Hel	р				
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#	Node	Vess. Type	Radial (kp) (lb/inch)	Circumferential (kmc) (in-lb/deg)	Longitudinal (kml) (in-lb/deg)			
1	10	Sph	1.146E+6	1.821E+6	1.821E+6			
2	420	Cyl	3.005E+5	52707.66	3.085E+5			

Step 7:

Upon successful analysis, from the "Support load summary" results, it is to be noted that the CAEPIPE has included the "User Allowables" entered in the stress system for equipment qualification as shown below.

Caepipe : Su	pport load s	ummary for n	iozzle at nod	e 10 - [Nozz	leQualification.	res (C:\Tutorials'	\11 —		×	
<u>File R</u> esults	/iew Optio	ns <u>W</u> indow	<u>H</u> elp							
		6	ע ≣							
Load combination	Radial (P) (lb)	y Shear (VL) (Ib)	z Shear (VC) (Ib)	Torque (MT) (ft-lb)	Circ.Mom (MC) (ft-lb)	Long.Mom (ML) (ft-lb)				
Sustained	-9573	493	383	8567	25669	43497				
Operating1	9791	1052	5804	42588	-92265	-25967				
Maximum	9791	1052	5804	42588	25669	43497				
Minimum	-9573	493	383	8567	-92265	-25967				
Allowables	84818	848176	848176	454771	45477	45477				
■ Caepipe : Support load summary for pozzle at node 420 - [NozzleOualification res (C\Tutorials\1 — □ ×										
■III Caepipe : Su	pport load si	ummary for n	lozzle at nod	e 420 - [Noz	zleQualification	n.res (C:\Tutorial	s\1 —		×	
■ Caepipe : Su <u>F</u> ile <u>R</u> esults	pport load si <u>/iew Optio</u>	ummary for n ns <u>W</u> indow	ozzle at nod <u>H</u> elp	e 420 - [Noz	zleQualification	n.res (C:\Tutorial	s\1 —		×	
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Image: Caepipe : Sure in the second secon	pport load su /iew Option Image: Option Radial (P) (Ib) 3504 36376	ummary for n ns Window Difference y Shear (VL) (Ib) -296 -903	z Shear (VC) (lb) -4572 -10620	e 420 - [Noz	Circ.Mom (MC) (ft-lb) -1386 -1549	Long.Mom (ML) (ft-lb) 374 926	s\1 —		×	
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■ Caepipe : Su File Results M Code combination Sustained Operating1 Maximum Minimum	pport load st /iew <u>Option</u> E Radial (P) (b) 3504 36376 36376 3504	ummary for n ns <u>W</u> indow y Shear (VL) (Ib) -296 -903 -296 -903	z Shear (VC) (Ib) -4572 -10620 -4572 -10620	e 420 - [Noz Torque (MT) (ft-lb) -451 -159 -451 -451	Circ.Mom (MC) (ft-lb) -1386 -1549 -1549 -1549	n.res (C:\Tutorial Long.Mom (ML) (ft-lb) 374 926 926 374	s\1 —		×	
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