Shells of Revolution, Pressure Vessels, Pipes

i **Calculation without errors.**

ii **Project information**

? **Input section**

1.0 Selection of material and units setting

1.1	Calculation units		SI Units (N, mm, kW...)	
1.2	Material		Structural steel EC 3, EN 10025; Fe 360 / Sy=235 MPa	
1.3	Modulus of elasticity	E	210000	[MPa] ☑
1.4	Modulus of shearing	G	80769	[MPa]
1.5	Poisson's ratio	ν	0.300	
1.6	Temperature coefficient of expansion	γ	11.700	[m/m/C*e-6]
1.7	Specific mass	Ro	7850.00	[kg/m^3]
1.8	Yield strength	σ_y	235.00	[MPa]

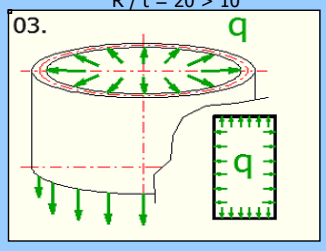
2.0 Cilindricall shells (thin-walled)

2.1 Shape and loading type

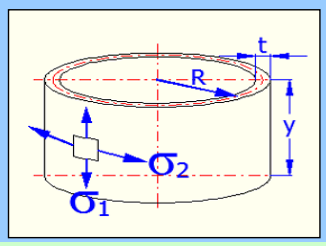
03. Uniform internal or external pressure (ends capped)

Conditions:

R / t = 20 > 10



2.2	Shell thickness	t	10.000	[mm]
2.3	Mean radius of curvature	R	200.000	[mm]
2.4	Length of cylindrical shell	y	508.000	[mm]
2.5	Length of cylindrical shell	l		[mm]
2.6	Load per length unit / Total applied force (Force)	P		[N]
2.7	Load per unit area	q	10.000	[MPa]
2.8	Speed	ω		[rpm]
2.9	**Results**			
2.10	Ratio of the radius of curvature and the shell thickness	R / t	20.000	
2.11	Shell weight	m	50.11	[kg]
2.12	Meridional stress	σ_1	100.00	[MPa]
2.13	Circumferential stress	σ_2	200.00	[MPa]
2.14	Radial displacement of a circumference	dR	0.1619048	[mm]
2.15	Change in the height dimension	dy	0.0967619	[mm]
2.16	Rotation of a meridian from its unloaded position	Ψ	0.0000E+00	[deg]



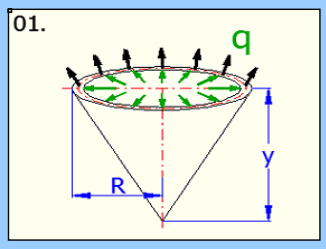
3.0 Cone shells (thin-walled)

3.1 Shape and loading type

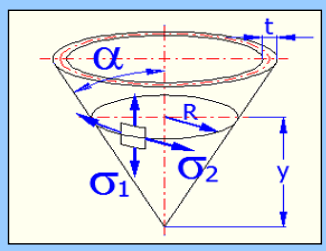
01. Uniform internal or external pressure, tangential edge support

Conditions:

R / t = 20 > 10



3.2	Shell thickness	t	10.000	[mm]
3.3	Mean radius of curvature (R, alfa => y)	R	200.000	[mm]
3.4	Length of conical shell	y	549.495	[mm]
3.5	Half-angle of cone	α	20.000	[deg]
3.6	Mean radius of curvature	r		[mm]
3.7	Filled to depth with liquid	d		[mm]
3.8	Liquid specific mass	Ro		[kg/m^3]
3.9	Load per length unit / Total applied force (Force/mm)	p		[N/mm]
3.10	Load per unit area	q	10.000	[MPa]
3.11	Speed	ω		[rpm]
3.12	**Results**			
3.13	Ratio of the radius of curvature and the shell thickness	R / t	20.000	
3.14	Shell weight	m	28.842	[kg]
3.15	Meridional stress	σ_1	106.42	[MPa]
3.16	Circumferential stress	σ_2	212.83	[MPa]
3.17	Radial displacement of a circumference	dR	0.172295449	[mm]
3.18	Change in the height dimension	dy	0.0003588	[mm]
3.19	Rotation of a meridian from its unloaded position	Ψ	0.0317033	[deg]
3.20	Meridional stress - max. value	σ_{1max}	~	[MPa]
3.21	Circumferential stress - max. value	σ_{2max}	~	[MPa]



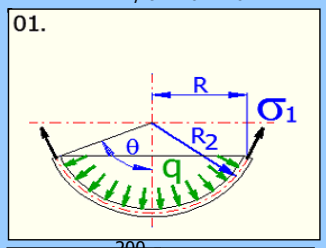
4.0 Spherical shells (thin-walled)

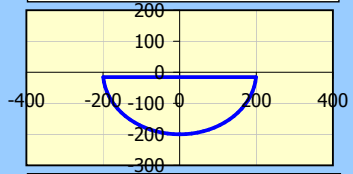
4.1 Shape and loading type

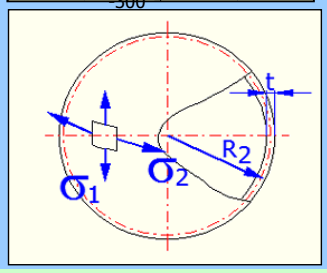
01. Uniform internal or external pressure, tangential edge support

Conditions:

R2 / t = 20 > 10







4.2	Shell thickness	t	10.000	[mm]
4.3	Sphere shell mean radius	R2	200.000	[mm]
4.4	Angle from centerline to edge	θ	90.000	[deg]
4.5	Angle from centerline to edge	θ0		[deg]
4.6	Distance from centerline to edge	R	200.000	[mm]
4.7	Distance from centerline to edge	r		[mm]
4.8	Height of section	y	200.000	[mm]
4.9	Filled to depth with liquid	d		[mm]
4.10	Liquid specific mass	Ro		[kg/m^3]
4.11	Load per length unit / Total applied force (Force/mm)	p		[N/mm]
4.12	Load per unit area	q	10.000	[MPa]
4.13	Speed	ω		[rpm]

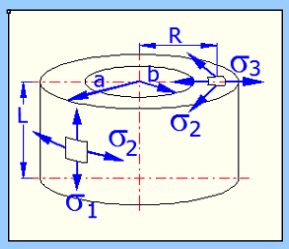
4.14 **Results**

4.15	Ratio of the radius of curvature and the shell thickness	R2 / t	20.000	
4.16	Shell weight	m	19.729	[kg]
4.17	Meridional stress	σ_1	100.00	[MPa]
4.18	Circumferential stress	σ_2	100.00	[MPa]
4.19	Radial displacement of a circumference	dR	0.0666667	[mm]
4.20	Radial displacement of a circumference	dR2	0.0666667	[mm]
4.21	Change in the height dimension	dy	0.0666667	[mm]
4.22	Rotation of a meridian from its unloaded position	Ψ	0.00000000	[deg]
4.23	Weight of liquid	mL		[kg]

5.0 Cone and spherical shells (thick-walled)

5.1 Shape and loading type

01. Cylinder - Uniform internal radial pressure, longitudinal pressure zero or externally balanced, for a disk or a shell



5.2	Outer radius	a	200.000	[mm]
5.3	Inner radius	b	160.000	[mm]
5.4	Length of cylindrical shell	L	500.000	[mm]
5.5	Load per unit area	q	10.000	[MPa]

5.6 **Results**

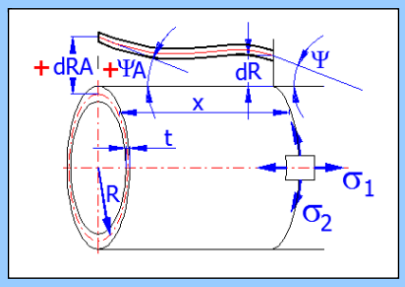
5.7	Shell weight	m	177.562	[kg]
5.8	Stress in the longitudinal direction	σ_{1max}	0.00	[MPa]
5.9	Stress in the circumferential direction	σ_{2max}	45.56	[MPa]
5.10	Stress in the radial direction	σ_{3max}	-10.00	[MPa]
5.11	Shear stress (max.) at inner radius	τ_{max}	27.78	[MPa]
5.12	Change of the outher radius	da	0.03386243	[mm]
5.13	Change of the inner radius	db	0.03699471	[mm]
5.14	Change of the length	dL	-0.02540	[mm]
5.15	Point of interest along radius	R [mm]	161.600	<160...200>
5.16	Stress in the longitudinal direction	σ_1	0.00	[MPa]
5.17	Stress in the circumferential direction	σ_2	45.01	[MPa]
5.18	Stress in the radial direction	σ_3	-9.45	[MPa]

6.0 Cilindricall shells loaded with end moment, radial load, axial load and pressure

6.1 First calculation (left side)

Conditions:

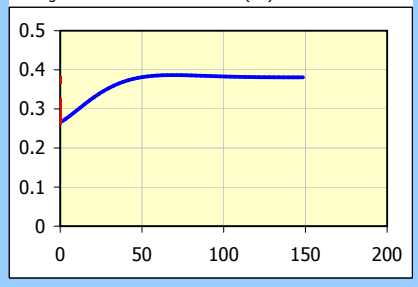
L > 148.53 [mm]; R / t = 40 > 10



6.2	Modulus of elasticity		E	210000	[MPa] ☑
6.3	Poisson's ratio		ν	0.300	
6.4	Mean radius of curvature		R	200.000	[mm]
6.5	Shell thickness		t	5.000	[mm]
6.6	Load per unit area		q	10.000	[MPa]
6.7	Axial force from the pressure q		Fx	975.156	[N/mm]
6.8	Load per length unit / Total applied force	Force/mm	p	0.000	[N/mm]
6.9	Force per unit length (circuit)		Vo	53.741	[N/mm]
6.10	Moment per unit length (circuit)		Mo	0.422	[Nm/mm]
6.11	**Results**				
6.12	Change in radius of circumference (A)		dRA	**0.265148591**	[mm]
6.13	Change in meridional slope (A)		ΨA	**-0.143595281**	[deg]
6.14	Coordinates, where are calculated values		x	0.00000	[mm]
6.15	Results for type of load and type of graph			Sum	
6.16	Meridional radial shear		V(x)	-53.74089	[N/mm]
6.17	Meridional bending moment		M(x)	0.42180	[Nm/mm]
6.18	Change in radius of circumference		dR(x)	0.26515	[mm]
6.19	Change in meridional slope		Ψ(x)	-0.14360	[deg]
6.20	Meridional membrane stress		$\sigma_1(x)$	0.00	[MPa]
6.21	Circumferential membrane stress		$\sigma_2(x)$	279.91	[MPa]
6.22	Meridional bending stress		$\sigma'_1(x)$	-101.23	[MPa]
6.23	Circumferential bending stress		$\sigma'_2(x)$	-30.37	[MPa]
6.24	Meridional radial shear stress		$\tau_1(\omega)$	-10.75	[MPa]

◀ ▶ to: 148.53000 ☑

Change in radius of circumference (dR)



6.25 Second calculation (right side)

Conditions:

L > 211.34 [mm]; R / t = 20 > 10

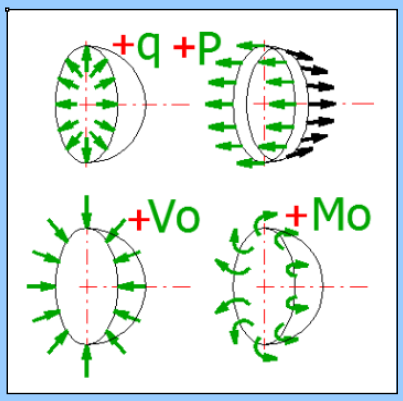
6.26	Modulus of elasticity		E	210000	[MPa] ☑
6.27	Poisson's ratio		ν	0.300	
6.28	Mean radius of curvature		R	200.000	[mm]
6.29	Shell thickness		t	10.000	[mm]
6.30	Load per unit area		q	10.000	[MPa]
6.31	Axial force from the pressure q		Fx	950.625	[N/mm]
6.32	Load per length unit / Total applied force	Force/mm	p	0.000	[N/mm]
6.33	Force per unit length (circuit)		Vo	-53.741	[N/mm]
6.34	Moment per unit length (circuit)		Mo	0.422	[Nm/mm]
6.35	**Results**				
6.36	Change in radius of circumference (A)		dR	**0.265147667**	[mm]
6.37	Change in meridional slope (A)		ΨA	**0.143595281**	[deg]

7.0 Spherical shells loaded with end moment, radial load, axial load and pressure

7.1 First calculation (left side)

Conditions:

19.3 < ϕ < 160.7 R2 / t = 48 > 10



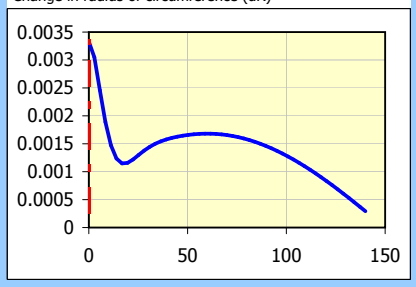
7.2	Modulus of elasticity		E	210000	[MPa] ☑
7.3	Poisson's ratio		ν	0.300	
7.4	Angle from centerline to edge		ϕ	150.000	[deg]
7.5	Shell thickness		t	6.350	[mm]
7.6	Sphere shell mean radius	-> R2	R2	304.800	[mm]
7.7	Distance from centerline to edge		R	152.400	[mm]
7.8	Load per unit area		q	0.069	[MPa]
7.9	Tangential force from the pressure q		Ft	9.650	[N/mm]
7.10	Radial part of tangential force Ft		Fty	-8.357	[N/mm]
7.11	Axial part of tangential force Ft		Ftx	4.825	[N/mm]
7.12	Load per length unit / Total applied force	Force/mm	p	4.825	[N/mm]
7.13	Force per unit length (circuit)		Vo	-4.312	[N/mm]
7.14	Moment per unit length (circuit)		Mo	-0.038	[Nm/mm]

7.15 Results

7.16	Change in radius of circumference		dRA(ω=0)	**0.003330745**	[mm]
7.17	Change in meridional slope		ΨA(ω=0)	**-0.000307044**	[deg]
7.18	Coordinates, where are calculated values		ω	0.000	[deg]
7.19	Results for type of load and type of graph			Sum	
7.20	Meridional radial shear		V(ω)	2.15618	[N/mm]
7.21	Meridional bending moment		M1(ω)	-0.03770	[Nm/mm]
7.22	Circumferential bending moment		M2(ω)	-0.01117	[Nm/mm]
7.23	Change in radius of circumference		dR(ω)	0.0033307	[mm]
7.24	Change in meridional slope		Ψ(ω)	-0.0003070	[deg]
7.25	Meridional membrane stress		$\sigma_1(\omega)$	1.07	[MPa]
7.26	Circumferential membrane stress		$\sigma_2(\omega)$	4.91	[MPa]
7.27	Meridional bending stress		$\sigma'_1(\omega)$	5.61	[MPa]
7.28	Circumferential bending stress		$\sigma'_2(\omega)$	1.66	[MPa]
7.29	Meridional radial shear stress		$\tau_2(\omega)$	0.34	[MPa]

◀ ▶ to: 140.00000 ☑

Change in radius of circumference (dR)



7.30 Second calculation (right side)

Conditions:

19.3 < ϕ < 160.7 R2 / t = 48 > 10

ϕ = 30 ϕ = 150

7.31	Modulus of elasticity		E	210000	[MPa] ☑
7.32	Poisson's ratio		ν	0.300	
7.33	Angle from centerline to edge		ϕ	150.000	[deg]
7.34	Shell thickness		t	6.350	[mm]
7.35	Sphere shell mean radius	-> R	R2	304.800	[mm]
7.36	Distance from centerline to edge		R	152.400	[mm]
7.37	Load per unit area		q	0.069	[MPa]
7.38	Tangential force from the pressure q		Ft	9.650	[N/mm]
7.39	Radial part of tangential force Ft		Fty	-8.357	[N/mm]
7.40	Axial part of tangential force Ft		Ftx	4.825	[N/mm]
7.41	Load per length unit / Total applied force	Force/mm	p	4.825	[N/mm]
7.42	Force per unit length (circuit)		Vo	-8.357	[N/mm]
7.43	Moment per unit length (circuit)		Mo	-0.072	[Nm/mm]

7.44 Results

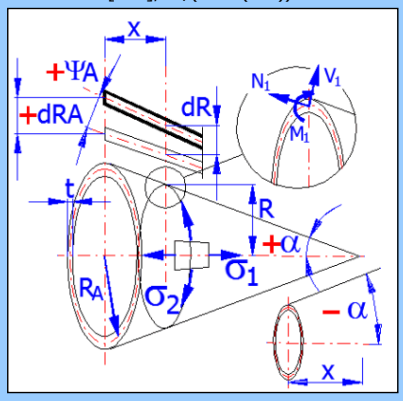
7.45	Change in radius of circumference		dR(ω=0)	**0.005755321**	[mm]
7.46	Change in meridional slope		Ψ(ω=0)	**1.2424E-17**	[deg]

8.0 Cone shells loaded with end moment, radial load, axial load and pressure

8.1 First calculation (left side)

Conditions: abs(k)=87.3>5

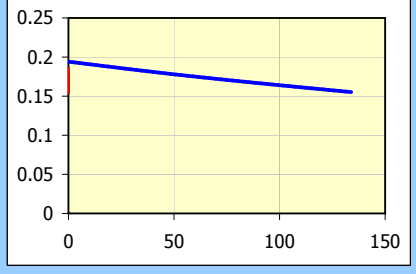
L>133.9 [mm]; R/(t*cos(alfa))=17.9>10



8.2	Modulus of elasticity		E	210000	[MPa] ☑
8.3	Poisson's ratio		ν	0.300	
8.4	Mean radius of curvature		RA	200.000	[mm]
8.5	Shell thickness		t	10.000	[mm]
8.6	Half-angle of cone		α	10.000	[deg]
8.7	Load per unit area		q	10.000	[MPa]
8.8	Tangential force from the pressure q		Ft	964.522	[N/mm]
8.9	Radial part of tangential force Ft		Fty	167.487	[N/mm]
8.10	Axial part of tangential force Ft		Ftx	949.868	[N/mm]
8.11	Load per length unit / Total applied force	Force/mm	p	4.825	[N/mm]
8.12	Force per unit length (circuit)		Vo	-3.194	[N/mm]
8.13	Moment per unit length (circuit)		Mo	-0.038	[Nm/mm]
8.14	**Results**				
8.15	Change in radius of circumference (A)		dRA	**0.194074528**	[mm]
8.16	Change in meridional slope (A)		ΨA	**0.02108924**	[deg]
8.17	Coordinates, where are calculated values		x	0.00000	[mm]
8.18	Results for type of load and type of graph			Sum	
8.19	Mean radius of curvature in point x		R	200.00000	[mm]
8.20	Tangential meridional shear		N1(x)	56.35401	[N/mm]
8.21	Tangential circumferential shear		N2(x)	2054.67397	[N/mm]
8.22	Meridional bending moment		M1(x)	-0.03770	[Nm/mm]
8.23	Circumferential bending moment		M2(x)	-0.01083	[Nm/mm]
8.24	Change in radius of circumference		dR(x)	0.19407	[mm]
8.25	Change in meridional slope		Ψ(x)	0.02109	[deg]
8.26	Meridional membrane stress		$\sigma_1(x)$	5.64	[MPa]
8.27	Circumferential membrane stress		$\sigma_2(x)$	205.47	[MPa]
8.28	Meridional bending stress		$\sigma'_1(x)$	2.26	[MPa]
8.29	Circumferential bending stress		$\sigma'_2(x)$	0.65	[MPa]
8.30	Meridional radial shear		V1(x)	0.12	[N/mm]

◀ ▶ to: 133.90 ☑

Change in radius of circumference (dR)



8.31 Second calculation (right side)

Conditions: abs(k)=59.5>5

L>91.25 [mm]; R/(t*cos(alfa))=35.5>10

8.32	Modulus of elasticity		E	210000	[MPa] ☑
8.33	Poisson's ratio		ν	0.300	
8.34	Mean radius of curvature		RA	200.000	[mm]
8.35	Shell thickness		t	5.000	[mm]
8.36	Half-angle of cone		α	20.000	[deg]
8.37	Load per unit area		q	10.000	[MPa]
8.38	Tangential force from the pressure q		Ft	1036.049	[N/mm]
8.39	Radial part of tangential force Ft		Fty	354.350	[N/mm]
8.40	Axial part of tangential force Ft		Ftx	973.568	[N/mm]
8.41	Load per length unit / Total applied force	Force/mm	p	852.493	[N/mm]
8.42	Force per unit length (circuit)		Vo	310.282	[N/mm]
8.43	Moment per unit length (circuit)		Mo	4.735	[Nm/mm]
8.44	**Results**				
8.45	Change in radius of circumference (A)		dR	**0.027168865**	[mm]
8.46	Change in meridional slope (A)		ΨA	**0.691257072**	[deg]

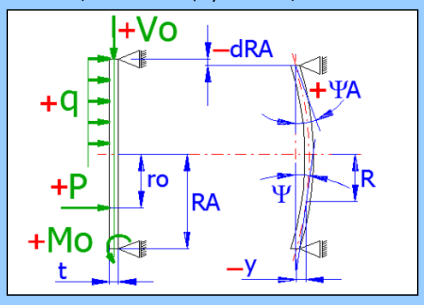
9.0 Plates loaded with end moment, radial load, axial load and pressure

9.1 Circular plate

9.2	Modulus of elasticity	E	210000	[MPa] ☑
9.3	Poisson's ratio	ν	0.300	
9.4	Outer radius	RA	200.000	[mm]
9.5	Plate thickness	t	10.000	[mm]
9.6	Load per unit area	q	0.500	[MPa]
9.7	Total applied force	P	0.000	[N]
9.8	Radial location of loading P	ro	0.000	[mm]
9.9	Force per unit length (circuit)	Vo	0.000	[N/mm]
9.10	Moment per unit length (circuit)	Mo	0.000	[Nm/mm]

Conditions:

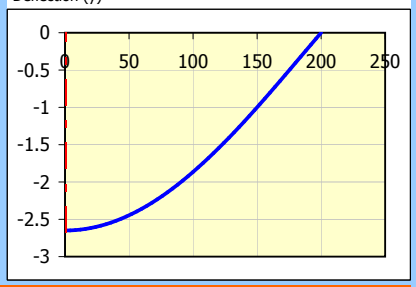
Ra / t = 20 > 10; ymax < t / 2



9.11 Results

9.12	Change in radius of circumference (A)	dRA	**-0.021547348**	[mm]
9.13	Slope change (A)	ΨA	**1.14591559**	[deg]
9.14	Coordinates, where are calculated values	R	0.00000	[mm]
9.15	Results for type of load and type of graph		Sum	
9.16	Deflection	y(R)	-2.65000	[mm]
9.17	Radial slope of plate	Ψ(R)	0.00002	[deg]
9.18	Radial bending moment	Mr(R)	4.12497	[Nm/mm]
9.19	Tangential bending moment	Mt (R)	4.12497	[Nm/mm]
9.20	Shear force	τ(R)	-0.00063	[MPa]
9.21	Radial bending stress	σr(R)	247.499	[MPa]
9.22	Tangential bending stress	σt(R)	247.499	[MPa]
9.23	Deflection max.	y(max)	0.00000	[mm]
9.24	Deflection min.	y(min)	-2.65000	[mm]

Deflection (y)



? **Additions section**

10.0 Solution of connection two shels an next static undetermined tasks

10.1 Connection type, releases, formulas — 10.2 Removal of formulas

01. Cylinder - Cylinder (internal / external pressure + axial load), R1=R2, dR1=dR2, Psi1=-Psi2

10.3	Number of approximation steps	i	10	
10.4	Sensitivity of the formula evaluation		1000	100000
10.5	The altered parameter 1	Variable1	53.74100242	
10.6	The altered parameter 2	Variable2	0.421801016	
10.7	The altered parameter 3	Variable3	0	
10.8	Equation 1		0.000924072	
10.9	Result 1	=	0.000	
10.10	Equation 2		0.000000	
10.11	Result 2	=	0.000	
10.12	Equation 3		0.000000	
10.13	Result 3	=	0.000