Several ASME B31 & EN 13480 Issues Needed to Know for Pipe Stress Engineer. Part 1

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Axial Stress from Pressure Load, Axial Force and Torsion Moment

This issue lead to serious under-estimation sustained and expansion stresses in pipes and fittings in ASME B31.1-2016, ASME B31.4-2016, ASME B31.5-2016, ASME B31.8-2016, EN 13480-2017, ISO 14692 codes.

Let's take for example ASME B31.4-2016 code that requires using following equation for stress from sustained loads (104.8.1):

$$S_L = \frac{PD_o}{4t_n} \pm \frac{0.75iM_A}{Z}$$

First problem is with axial stress from pressure load, and it is not serious for above ground piping. Instead of simplified axial stress from pressure load

$$\frac{PD_o}{4t_n}$$

More accurate equation can be used for axial stress instead of simplified $PD_o/4t_n$ equation 102.3.2 a (3):

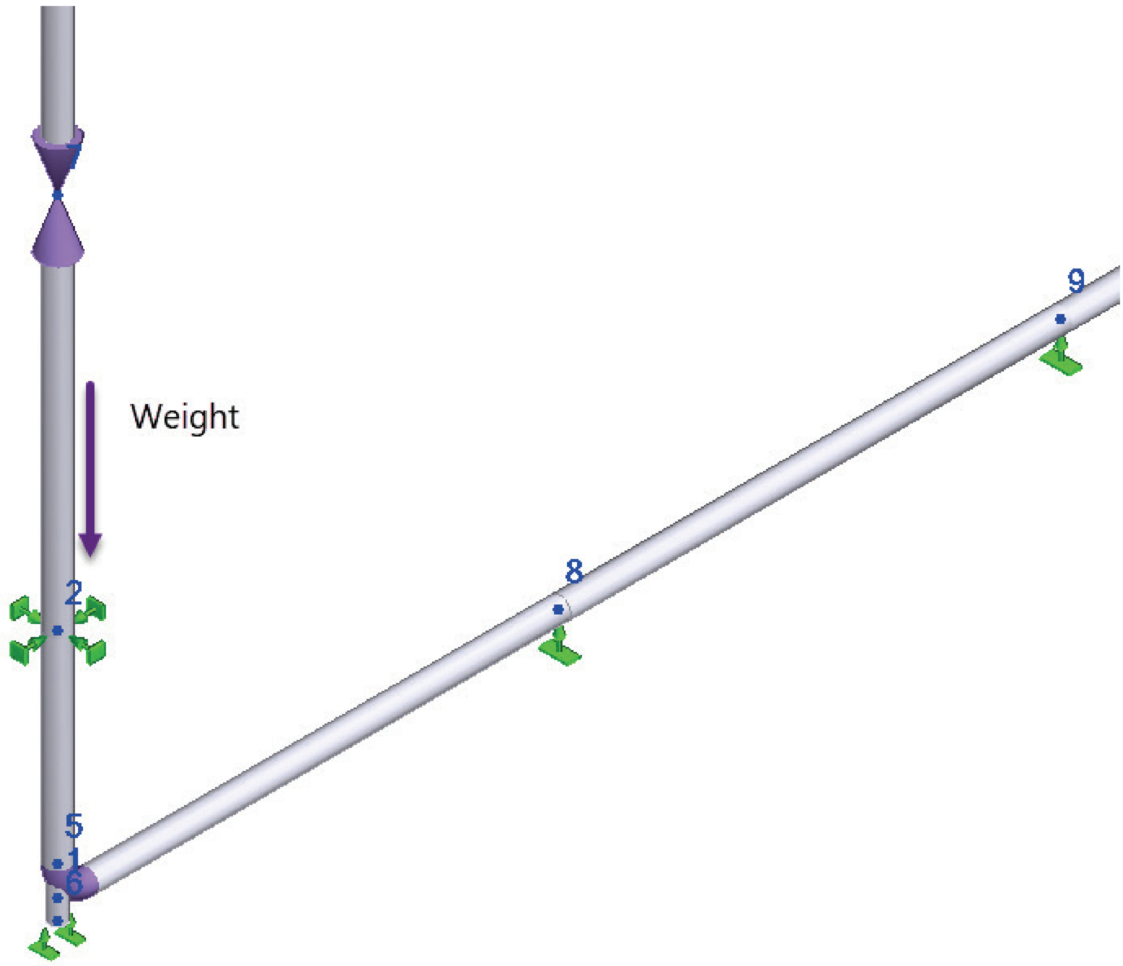
$$\frac{P(D_o - 2t_n)^2}{D_o^2 - (D_o - 2t_n)^2}$$

This equation is suitable only for **totally unrestrained pipes**, but it is easy to use in manual calculations, and it is always conservative. For more information please refer to article **What is Restrained and Unrestrained Pipes**.

Second and most serious problem is with formula (104.8.1). It doesn't take into account axial force in the pipe.

Sometimes, axial force from sustained loads can be so huge, that axial stress becomes greater than allowable. Engineers can easily overlook this problem when using pipe stress analysis software for big models.

For example it could be very tall vertical pipes or heavy valve on vertical pipe code sustained stress is almost zero (see "Sl" stress in the screenshot below). But real sustained stress is greater than allowable (see "Sl*" stress in the screenshot below).



Input | Stress

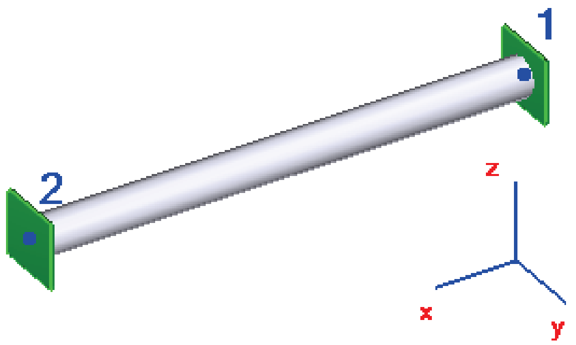
Operating Mode: 1 'Operation mode'
Expansion Range with Mode: 1 'Operation mode' (Cold State)
☑ Show Equations ☐ Creep Stress
☐ Stress Range from Operation to C
☑ Add Axial Force and Torsion Stre

Object	Start End node	Weight+Pressure Stress in Hot State, (kgf/sq.cm)				Expansion Stress Range, (kgf/sq.cm)						Notes
		Sl	Sl*	Sh*Wc/E	%	Se	Sa	%	Se*	Sa*	%	
Forged Elbow	1	24.34	28.07	1179	2.4	152.96	2928.20	5.2	153.07	2924.50	5.2	
Above ground pipe	1	8.48	12.17	1179	1.0	50.37	2939.03	1.7	50.48	2935.33	1.7	
	5	8.40	12.10	1179	1.0	50.81	2939.11	1.7	50.92	2935.41	1.7	
Above ground pipe	5	17.13	1104.34	1179	93.7	117.72	2930.38	4.0	117.91	1843.17	6.4	
	6	0	1087.77	1179	92.3	0	2947.51	0.0	0.19	1859.74	0.0	
Above ground pipe	5	21.91	1285.77	1179	109.1	42.04	2925.60	1.4	42.36	1768.51	2.4	2
	2	0	1260.62	1179	106.9	0.01	2947.51	0.0	0.33	1768.51	0.0	2
Forged Elbow	1	24.34	28.07	1179	2.4	152.96	2928.20	5.2	153.07	2924.50	5.2	
Above ground pipe	1	1.24	3.21	1179	0.3	11.79	2946.26	0.4	22.50	2944.30	0.8	

The same problem with expansion stress equation (104.8.3), it doesn't include axial force too

$$S_E = \frac{iM_C}{Z} \leq S_A$$

For example for totally restrained pipe code expansion stress range will be zero (see "Se" stress in the screenshot below). But real stress range is greater than allowable (see "Se*" stress in the screenshot below).

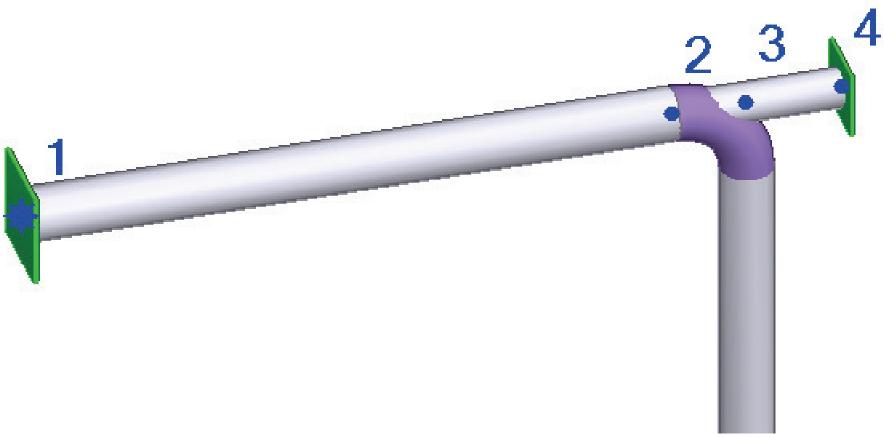


Input | Stress

Operating Mode: 1 'Operation mode' — Expansion Range with Mode: 1 'Operation mode' (Cold State) — [x] Show Equations — [ ] Creep Stress — [ ] Stress Range from Operation to Cold — [x] Add Axial Force and Torsion Stress — ?

Object	Start End node	Weight+Pressure Stress in Hot State, (kgf/sq.cm)				Expansion Stress Range, (kgf/sq.cm)						Notes
		Sl	Sl*	Sh*Wc/E	%	Se	Sa	%	Se*	Sa*	%	
Above ground pipe	1	23.48	23.48	1179	2.0	0	2924.03	0.0	3805.73	2924.03	130.2	4
	2	23.48	23.48	1179	2.0	0	2924.03	0.0	3805.73	2924.03	130.2	4

Sometimes even experienced piping designer can make a mistake and create wrong design. For example in piping system below, the 1-2 pipe is restrained by trunnion 2-4. Code stress range is zero, but if we choose the option to include axial force the stress range is greater than allowable!



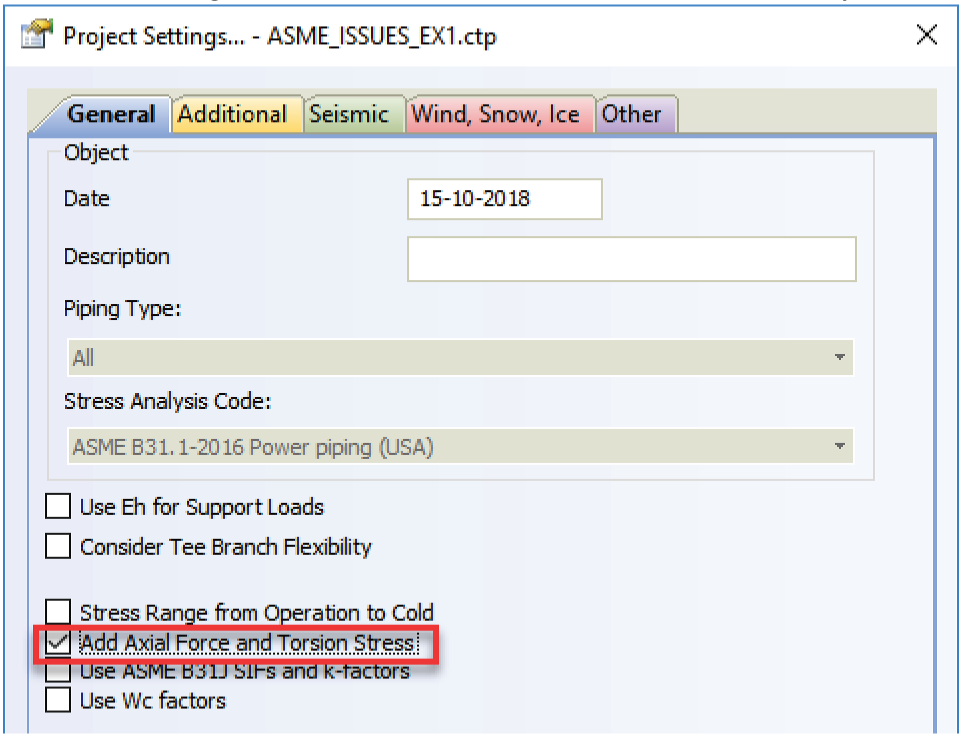
Input | Stress

Operating Mode: 1 'Operation mode' — Expansion Range with Mode: 1 'Operation mode' (Cold State) — [x] Show Equations — [ ] Creep Stress — [ ] Stress Range from Operation to — [x] Add Axial Force and Torsion Stre

Object	Start End node	Weight+Pressure Stress in Hot State, (kgf/sq.cm)				Expansion Stress Range, (kgf/sq.cm)						Notes
		Sl	Sl*	Sh*Wc/E	%	Se	Sa	%	Se*	Sa*	%	
Above ground pipe	5	0	0	1179	0.0	0	2947.51	0.0	0	2947.51	0.0	
	3	0	4.38	1179	0.4	0	2947.51	0.0	0	2943.13	0.0	
Bend	3	65.02	65.02	1179	5.5	0	2947.51	0.0	0	2943.13	0.0	
Above ground pipe	3	28.55	28.55	1179	2.4	0	2918.96	0.0	0	2918.96	0.0	
	2	28.76	28.76	1179	2.4	0	2918.75	0.0	0	2918.75	0.0	
Above ground pipe	2	107.07	107.07	1179	9.1	0	2840.43	0.0	3362.93	2840.43	118.4	4
	4	15.31	15.31	1179	1.3	0	2932.20	0.0	3362.93	2932.20	114.7	4
Above ground pipe	2	55.69	55.69	1179	4.7	0	2891.82	0.0	3920.79	2891.82	135.6	4
	1	70.86	70.86	1179	6.0	0	2876.65	0.0	3920.79	2876.65	136.3	4

To protect users from mistakes we add the special option in PASS/Start-Prof software that allows taking into account stress from axial force and torsion moment for sustained stress S_L and for expansion stress range S_E. User can simultaneously see official code stresses (Sl, Se) and modified stress (Sl*, Se*) in the same table. It is also automatically solves the first described problem with axial stress from pressure load for restrained, totally unrestrained and middle behavior systems. Axial stress from pressure load (Sl*) will also be more accurate.

This option may be activated using “Add axial force and torsion stress” checkbox in Project Settings.



For modified stresses PASS/Start-Prof software use the equations similar to ASME B31.3 code:

$$S_L = \sqrt{(|S_a| + S_b)^2 + (2S_t)^2}$$

$$S_a = \frac{i_a F}{A_p}$$

$$S_t = \frac{i_t M_t}{2Z}$$

$$S_b = \frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z}$$

We recommend to always switching this option on!