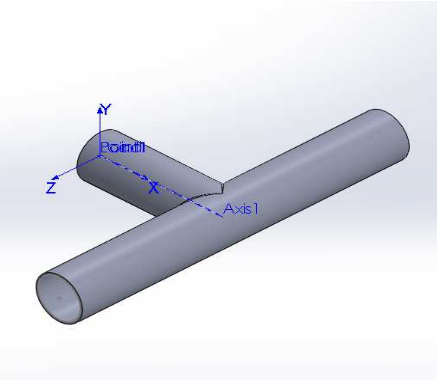
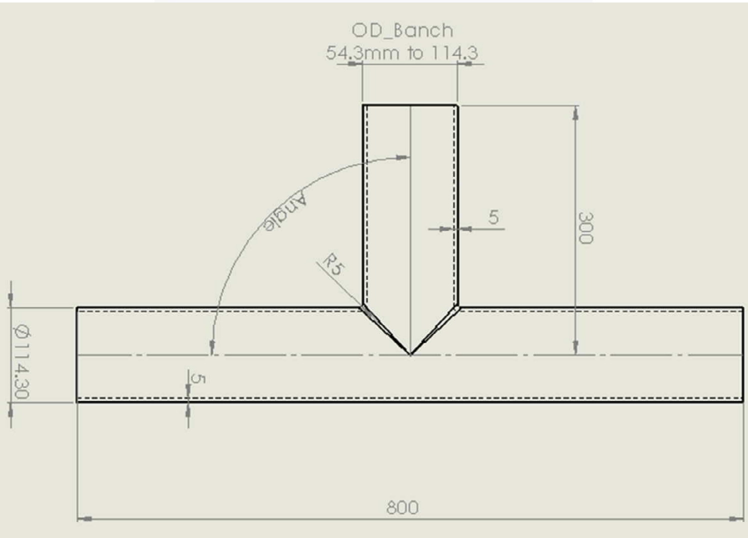
STRESSMAN ENGINEERING





Simulation of Tees

Date: 22. May 2012
Designer: Sondre Luca Helgesen, MSc
Study name: Design study
Analysis type: Design Study, static

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***NOTE:** The standard SolidWorks Simulation standard report was chosen to ease the reporting time. Please note that this is not common practice at Stressman Engineering. For paid projects we are using more professional and in depth reports.*

Description

This report studies a Tee component and the correlation between stresses, SIFs at different branch angles due to in-plane and out-of-plane bending moment.

The reason for the initialization of the report was discussion thread in the LinkedIN community and my own curiosity. I hope this report might shed some light on the discussion.

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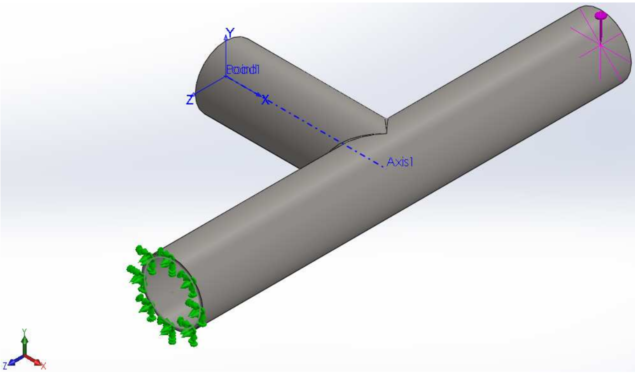
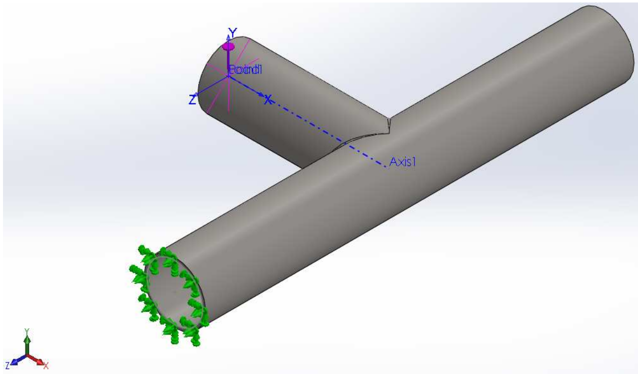
Input and Assumptions

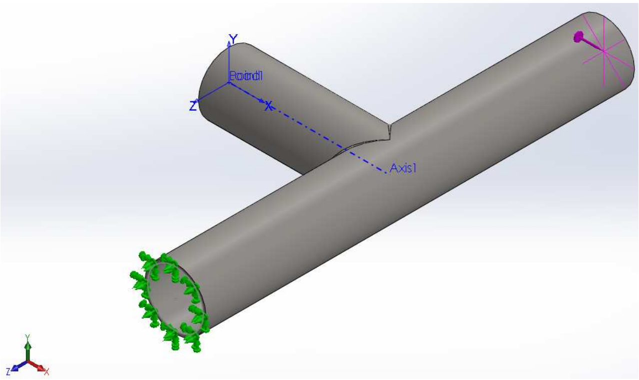
Header input
OD = 114.3 (4ND), WT = 5mm
Length of header = 800mm.
Branch input
OD_Branch = From 54.3mm to 114.3mm in steps of 10mm
Angle = From 30 degrees to 90 degrees in steps of 10 degrees
WT = 5mm
Length of branch = 300mm

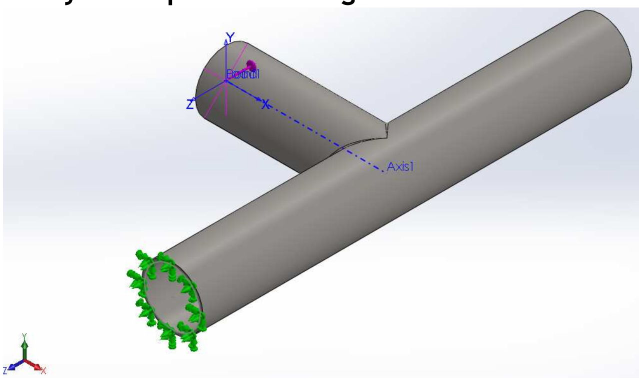
Crotch radius (rx) = 5mm

Boundaries


Study 1 - In-plane bending of header


Study 2 - In-plane bending of branch


Study 1 - Out-of-plane bending of header


Study 2 - Out-of-plane bending of branch

Abbreviations

Deg = Degrees, FEA = Finite Element Analysis, LC = Load case, ND = Nominal diameter, Nom = Nominal stress, OD = Outer diameter, OP=Out-of-Plane, IP = In-plane, SIF = Strength intensification Factor, WT = Wall thickness.

Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/mm^2 (MPa)

Calculation of SIF

The ASME codes use girth welds as "base lines" /1/. This means that a SIF of 2.0 is already incorporated into the code and its safety factors. Therefore should the peak stress found in an FEA be divided by 2 times the nominal stress in a straight pipe.

$$\boldsymbol{SIF} = \frac{\text{Peak stress}}{2\ \textit{Nominal stress in pipe}}$$

Design Study Setup

Design Variables

Name	Type	Values	Units
Angle	Range with Step	Min:30° Max:90° Step:10°	deg
Branch OD	Range with Step	Min:54.3 Max:114.3 Step:10	mm

Monitors

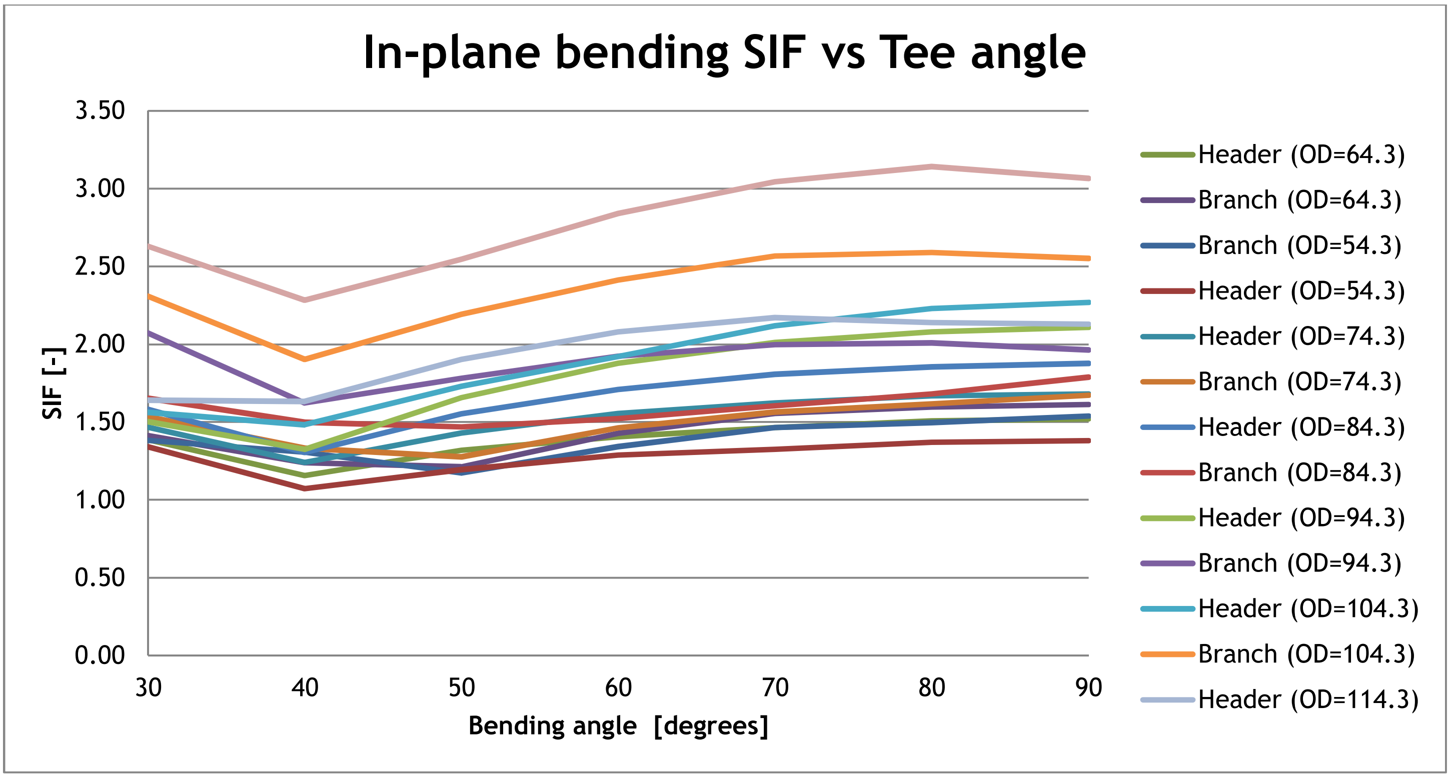
Sensor name	Condition	Study name	Comment
Stress1	Monitor Only	Study 1 - IP Header	In-plane moment applied on header
Stress2	Monitor Only	Study 2 - IP Branch	In-plane moment applied on branch
Stress1	Monitor Only	Study 1 - OP Header	Out-of-plane moment applied on header
Stress2	Monitor Only	Study 2 - OP Branch	Out-of-plane moment applied on branch

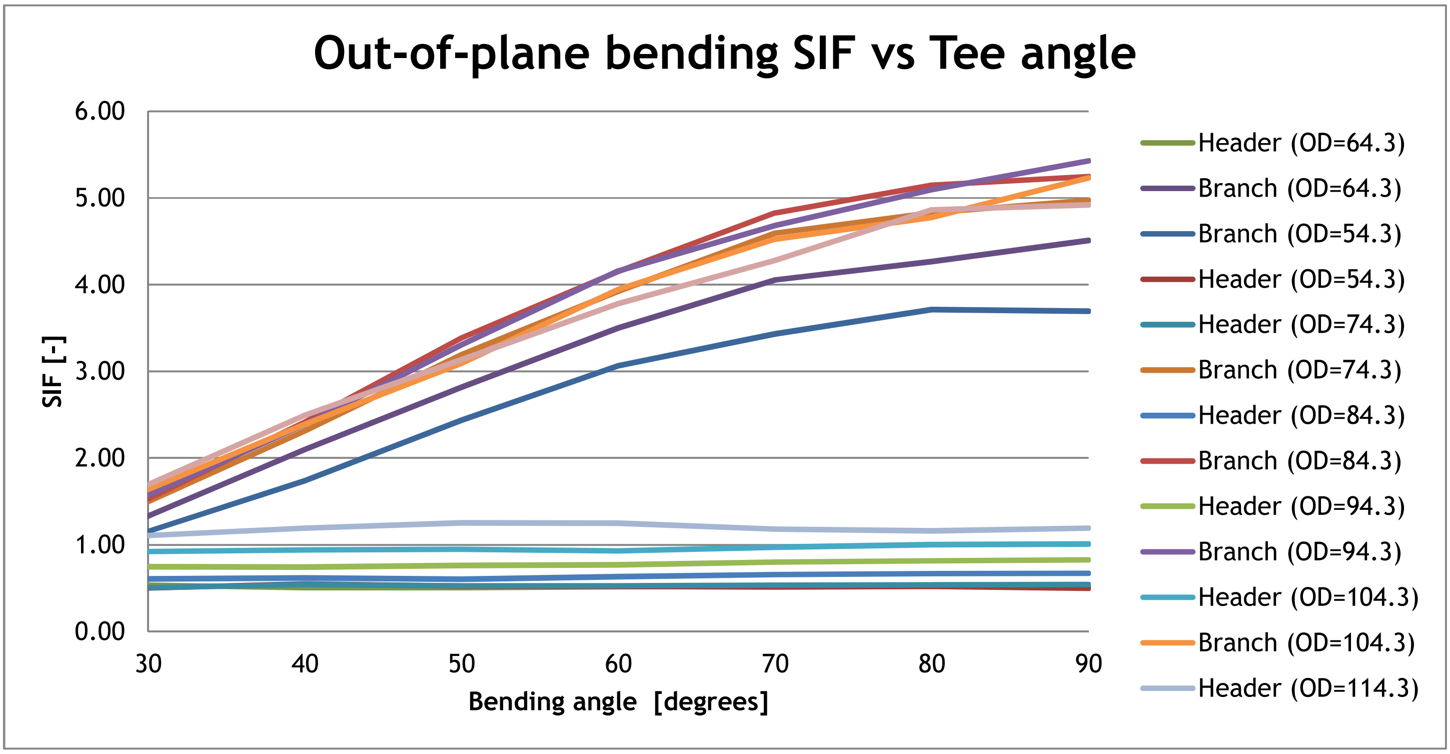
Study Results

The table below shows the results from the studies.

Angle [deg]	OD Branch [mm]	In-plane stresses [Mpa]		In-plane SIFs [-]		Out-of-plane stresses [Mpa]		In-plane SIFs [-]	
		Stress 1	Stress 2	SIF 1	SIF 2	Stress 1	Stress 2	SIF 1	SIF 2
Nom	54.3	22.40	114.22	0.50	0.50	22.40	114.22	0.50	0.50
30	54.3	60.06	315.85	1.34	1.38	22.55	263.63	0.50	1.15
40	54.3	48.08	298.31	1.07	1.31	24.68	396.93	0.55	1.74
50	54.3	53.54	267.78	1.20	1.17	23.53	556.69	0.53	2.44
60	54.3	57.74	306.54	1.29	1.34	23.29	700.35	0.52	3.07
70	54.3	59.36	334.54	1.32	1.46	22.94	784.42	0.51	3.43
80	54.3	61.43	342.16	1.37	1.50	23.34	848.39	0.52	3.71
90	54.3	61.89	351.60	1.38	1.54	22.40	844.31	0.50	3.70
Nom	64.3	22.40	77.97	0.50	0.50	22.40	77.97	0.50	0.50
30	64.3	62.18	220.31	1.39	1.41	23.93	207.17	0.53	1.33
40	64.3	51.81	193.05	1.16	1.24	22.71	327.50	0.51	2.10
50	64.3	59.04	189.00	1.32	1.21	22.62	439.40	0.51	2.82
60	64.3	63.06	222.66	1.41	1.43	23.21	545.88	0.52	3.50
70	64.3	65.60	242.46	1.46	1.55	23.32	632.17	0.52	4.05
80	64.3	67.51	249.03	1.51	1.60	23.33	665.32	0.52	4.27
90	64.3	68.12	251.62	1.52	1.61	23.20	703.22	0.52	4.51
Nom	74.3	22.40	56.56	0.50	0.50	22.40	56.56	0.50	0.50
30	74.3	65.71	173.71	1.47	1.54	22.75	169.64	0.51	1.50
40	74.3	55.58	150.69	1.24	1.33	24.34	261.89	0.54	2.32
50	74.3	64.14	144.34	1.43	1.28	23.65	361.03	0.53	3.19
60	74.3	69.64	165.42	1.55	1.46	23.60	443.80	0.53	3.92
70	74.3	72.69	177.06	1.62	1.57	23.92	519.76	0.53	4.60
80	74.3	74.78	182.86	1.67	1.62	24.19	546.47	0.54	4.83
90	74.3	75.27	189.28	1.68	1.67	24.31	562.62	0.54	4.97
Nom	84.3	22.40	42.88	0.50	0.50	22.40	42.88	0.50	0.50
30	84.3	70.89	141.67	1.58	1.65	27.26	131.21	0.61	1.53
40	84.3	58.48	128.51	1.31	1.50	27.58	207.13	0.62	2.42
50	84.3	69.58	125.88	1.55	1.47	27.03	290.35	0.60	3.39
60	84.3	76.53	130.64	1.71	1.52	28.29	355.94	0.63	4.15
70	84.3	80.97	137.71	1.81	1.61	29.40	413.98	0.66	4.83
80	84.3	83.11	144.08	1.86	1.68	29.85	441.33	0.67	5.15
90	84.3	84.08	153.43	1.88	1.79	30.11	449.93	0.67	5.25
Nom	94.3	22.40	33.62	0.50	0.50	22.40	33.62	0.50	0.50
30	94.3	67.29	139.44	1.50	2.07	33.49	105.55	0.75	1.57
40	94.3	59.33	109.12	1.32	1.62	33.31	160.47	0.74	2.39

50	94.3	74.27	119.76	1.66	1.78	34.07	222.25	0.76	3.31
60	94.3	84.17	129.27	1.88	1.92	34.44	279.71	0.77	4.16
70	94.3	90.12	134.20	2.01	2.00	35.88	314.87	0.80	4.68
80	94.3	93.16	135.12	2.08	2.01	36.57	342.56	0.82	5.10
90	94.3	94.47	131.93	2.11	1.96	36.94	364.84	0.82	5.43
Nom	104.3	22.40	27.06	0.50	0.50	22.40	27.06	0.50	0.50
30	104.3	70.02	124.99	1.56	2.31	41.28	88.58	0.92	1.64
40	104.3	66.46	102.93	1.48	1.90	42.22	129.26	0.94	2.39
50	104.3	77.58	118.71	1.73	2.19	42.45	167.36	0.95	3.09
60	104.3	86.10	130.55	1.92	2.41	41.64	213.60	0.93	3.95
70	104.3	94.97	138.89	2.12	2.57	43.55	244.88	0.97	4.53
80	104.3	99.87	140.17	2.23	2.59	44.83	258.53	1.00	4.78
90	104.3	101.68	138.04	2.27	2.55	45.23	283.25	1.01	5.23
Nom	114.3	22.40	22.24	0.50	0.50	22.40	22.24	0.50	0.50
30	114.3	73.53	117.00	1.64	2.63	49.53	75.22	1.11	1.69
40	114.3	73.20	101.54	1.63	2.28	53.49	110.99	1.19	2.49
50	114.3	85.25	113.21	1.90	2.54	56.21	139.41	1.25	3.13
60	114.3	93.11	126.35	2.08	2.84	56.04	168.15	1.25	3.78
70	114.3	97.29	135.36	2.17	3.04	52.93	190.44	1.18	4.28
80	114.3	95.82	139.75	2.14	3.14	52.05	216.36	1.16	4.86
90	114.3	95.39	136.35	2.13	3.06	53.42	218.90	1.19	4.92
			MAX	**2.27**	**3.14**			**1.25**	**5.43**


In-plane bending SIF vs Tee angle
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
SIF [-]
30
40
50
60
70
80
90
Bending angle [degrees]
Header (OD=64.3)
Branch (OD=64.3)
Branch (OD=54.3)
Header (OD=54.3)
Header (OD=74.3)
Branch (OD=74.3)
Header (OD=84.3)
Branch (OD=84.3)
Header (OD=94.3)
Branch (OD=94.3)
Header (OD=104.3)
Branch (OD=104.3)
Header (OD=114.3)


Out-of-plane bending SIF vs Tee angle
6.00
5.00
4.00
3.00
2.00
1.00
0.00
SIF [-]
30
40
50
60
70
80
90
Bending angle [degrees]
Header (OD=64.3)
Branch (OD=64.3)
Branch (OD=54.3)
Header (OD=54.3)
Header (OD=74.3)
Branch (OD=74.3)
Header (OD=84.3)
Branch (OD=84.3)
Header (OD=94.3)
Branch (OD=94.3)
Header (OD=104.3)
Branch (OD=104.3)
Header (OD=114.3)

ASME B31.3 SIF
The in-plane SIF calculated with ASME B31.3 Appendix D is 3.39 and the out-of-plane SIF is 4.18.

Error sources

This analysis was ONLY performed to get a rough estimate. Potential error sources are mesh and meshing settings, singularities, load settings, the 3D model, etc.

Discussion/Conclusion

The in-plane ASME B31.3 SIF (3.39) and the FEA SIF (3.14) are quite close in values.
The out-of-plane ASME B31.3 SIF (4.18) and the FEA SIF (5.43) which is a larger difference. Some of this difference could be that the crotch thickness in my model (7.1mm) is slightly less than what's required by the code (7.5mm). Other errors might be singularities.

The maximum SIFs are located at about 80 degrees of angle. The reason for this is most likely the non-symmetric boundary conditions. Anyhow the SIFs at 80 degrees are not very elevated compared to 90 degrees.

The origin of the LinkedIN discussion focused on whether a 45 degree branch should have an elevated SIF or not. The results from this simple analysis shows that a 45 degree branch have a much lower in-plane and out-of-plane SIFs than the 90degree branch.

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Referances

/1/ Paulin Reseach Group - http://www.paulin.com/WEB_Markl_SIFs_ASME_VIII_2.aspx

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