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Research Article

Design and Analysis of a Process Plant Piping System

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Abstract

Piping systems are designed to perform a definite function. Piping system designing and construction of any plant or services are time consuming, complex, and expensive effort. Designing of piping systems are governed by Industrial/International Codes and Standards. Piping codes defines the requirements of design, fabrication, use of materials, tests and inspection of piping systems and the standards are more on defining application design and construction rules and requirements for piping components. The basic design code used in this paper is ASME B31.3 Process Piping code which includes petroleum refineries, chemical plants, textile plants, paper plants and semiconductor plant. The objective of this paper is to explain the basic concept of flexibility such as flexibility characteristics and flexibility factor, and also stress intensification factor (SIF) referring to this code. CAD Packages like CAEPIPE has been developed for the comprehensive analysis of complex systems. This software make use of Finite Element Methods to carry out stress analysis. However this require the pipe system to be modelled before carrying out stress analysis. Static analysis is carried out in order to find the sorted code stresses, code compliance stresses, element forces and moments in coordinates and displacement at all nodes in the piping layout. Compare the SIF results against the results obtained with CAEPIPE by using some observations on SIF equations. In CAEPIPE, if the ratio of Maximum Stress Induced to Maximum Allowable Stress is below 1 then the pipe system is safe else redesigning is required.

Keywords: *ASME B31.3, CAEPIPE, Flexibility characteristics, Flexibility factor, Stress intensification factor*

1. Introduction

Piping System is a network of Pipes by using Pipe Fittings and other special components to perform the required mode of transferring fluids (Liquids/ Gas/ Slurry) from one location to another location. It is the effective method for transferring fluids without considerable or about zero losses in properties and quality of fluid. Industrially, all piping activities are performed with the compliance and guidelines of International and Industrial Codes & Standards as well as the laws and regulations of respective local authority. Generally, Piping Engineering is applied among the following Industrial systems;

1) Building Services Piping System
2) Refrigeration and Heat Transfer Piping System
3) Liquid transportation and distribution piping (Pipelines) System
4) Gas Transmission and Distribution Piping System
5) Power Piping System
6) Process Piping System
7) Slurry Transportation Piping Systems

In this paper we discussed about the Process Piping system is a form of pipework used to transport materials used in industrial processes and manufacturing. It is specially designed for particular applications to ensure that it will meet health and safety standards, in addition to suiting the needs of a given manufacturing process. Process piping can be installed by plumbers, as well as contractors who specialize in installing factory components, and like other fixed elements of a manufacturing facility, it is subject to inspection and approval by government regulators.This type of piping can be used in a wide variety of ways. In food manufacturing, for example, process piping can be used to transport food ingredients to various points on the assembly line. Chemical manufacturing facilities use process piping to transport components of their products along with materials like natural gas used in manufacturing. Refineries and similar facilities also utilize processpiping to move chemical compounds.

This paper mainly discusses about the SIF calculations followed in Process Piping Plants referring to code ASME B31.3. And also explain the basic concept of flexibility such as flexibility characteristics and flexibility factor. CAD Packages like CAEPIPE has been developed for the static analysis in order to find the sorted code stresses, code compliance stresses, pipe support load, element forces and moments (in local and global coordinates) and displacement at all nodes and hangers in the piping layout.Compare the SIF results against the results obtained

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with CAEPIPE by using some observations on SIF equations. If the value of SIF which is obtained by the ordinary formula is same as that obtained by the CAEPIPE software then we can say that the geometry characteristics and the installation of pipe layout is safe and we can calculate all the forces, moments, stresses and the displacements at all the nodes of the piping system. This research paper mainly focused on analysis of process plant piping system by using CAEPIPE software. The layout of process plant and its observations are to be taken from the "Mathura Refinery", Mathura (Uttar Pradesh), India.

2. Methodology

2.1. Stress categories

There are various failure modes which could affect a piping system. The piping engineer can provide protection against some of these failure modes by performing stress analysis according to the piping codes. Protection against other failure modes is provided by some methods other than stress analysis. For example, protection against brittle fracture is provided by material selection. The piping codes address the following failure modes: excessive plastic deformation, plastic instability or incremental collapse, and high strain–low-cycle fatigue. Each of these modes of failure is caused by a different kind of stress and loading. It is necessary to place these stresses into different categories and set limits to them.(C. Basavaraju et al, 1996)

The major stress categories are primary, secondary, and peak. The limits of these stresses are related to the various failure modes as follows:

- The primary stress limits are intended to prevent plastic deformation and bursting.
- The primary plus secondary stress limits are intended to prevent excessive plastic deformation leading to incremental collapse.
- The peak stress limit is intended to prevent fatigue failure resulting from cyclic loadings.

2.2. Load categories

2.2.1. Sustained loads

These loads are expected to be present throughout normal plant operation. Typical sustained loads are pressure and weight loads during normal operating conditions.

2.2.2. Expansion loads

Expansion loads are those loads due to displacements of piping. Examples are thermal expansion, seismic anchor movements, thermal anchor movements, and building settlement.

2.2.3. Occasional loads

These loads are present at infrequent intervals during plant operation. Examples of occasional loads are earthquake, wind, and fluid transients such as water hammer and relief valve discharge.

2.3. Piping design code

The basic design code for engineers working with topside offshore projects is the ASME B31.3 Process Piping Code. The ASME B31.3 Process Piping Code is originally a design code for process plants to be placed on land. It is however the most used piping code for process piping on oil and gas platforms and has been widely used for subsea installation. (D. N. Veritas, 2008)

Abbreviations and Acronyms

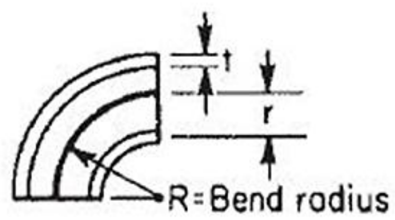


Fig 1. Sketch for pipe bend

R = Bend Radius of a pipe bend
r = Mean Radius of matching pipe
t = Nominal wall thickness of pipe bend
h = Flexibility characteristics
n = Flexibility factor

3. Structural Analysis

3.1. Flexibility analysis

Flexibility analysis is done on a piping system to study its behavior when its temperature changes from ambient to operating, so as to arrive at the most economical layout with adequate safety. (A. A. Joshi et al, 2001)

The following are the considerations that decide the minimum acceptable flexibility on a piping configuration.

1) Maximum allowable stress range in the system.
2) The limiting values of forces and moments that the piping system is permitted to impose on the equipment to which it is connected.
3) The displacements within the piping system.
4) The maximum allowable load on the supporting structure.

3.1.1. Flexibility Characteristics

It is a geometric characteristics based on the nominal wall thickness and mean radius of the fitting. ASME B31.3 defines it as a unit less number calculated based on type of fitting. (G. Bhende et al, 2013)

In case of a pipe bend,

$$h = \frac{tR}{r^2} \quad (1)$$

3.1.2. Flexibility Factor

A flexibility factor is defined as the rotation of a pipe bends. It is the ratio of the flexibility of a bend to that of a straight pipe having the same length and cross section.

In case of a pipe bend,

$$n = \frac{1.65}{h} \quad (2)$$

3.2. Stress Intensification Factor (SIF)

It is defined as the ratio of the maximum stress intensity to the nominal stress, calculated by the ordinary formulas of mechanics. It is used as a safety factor to account for the effect of localized stresses on piping under a repetitive loading. In piping design, this factor is applied to welds, fittings, branch connections, and other piping components where stress concentrations and possible fatigue failure might occur. Usually, experimental methods are used to determine these factors.

In case of a pipe bend,

$$\text{In-plane, } i = \frac{0.9}{h^{\frac{2}{3}}} \quad (3)$$

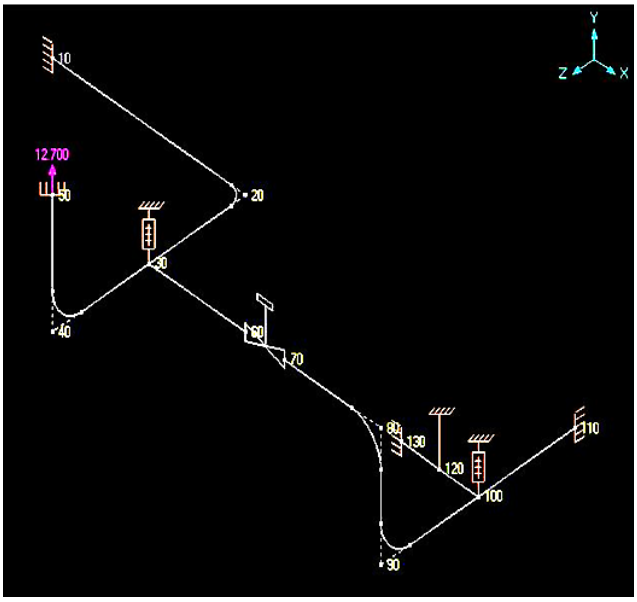
$$\text{Out-plane, } i_0 = \frac{0.75}{h^{\frac{2}{3}}} \quad (4)$$

3.3. Static Analysis

Static analysis is carried out in order to find the sorted code stresses, code compliance stresses, pipe support load, element forces and moments (in local and global coordinates) and displacement at all nodes and hangers. This comprehensive analysis is done using a CAD package like CAEPIPE.

4. Plant Layout

The layout of the piping system should be performed with the requirements of piping stress and pipe supports in mind (i.e., sufficient flexibility for thermal expansion; proper pipe routing so that simple and economical pipe supports can be constructed; and piping materials and section properties commensurate with the intended service, temperatures, pressures, and anticipated loadings). If necessary, layout solutions should be iterated until a satisfactory balance between stresses and layout efficiency is achieved. Once the piping layout is finalized, the piping support system must be determined. Possible support locations and types must be iterated until all stress requirements are satisfied and other piping allowable (e.g., nozzle loads, valve accelerations, and piping movements) are met. Fig. 2. Shows a plant layout of a process piping system which have a three sections A, B and C. these sections can be shown in figure 3. The insulation which we have used in our piping system is Calcium Silicate. The section properties with insulation density and thickness is shown in Table 1.



Caepipe : Layout (18) - [process piping.mod (F:\Documents\Con

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#	Node	Type	DX (mm)	DY (mm)	DZ (mm)	Matl	Sect	Load	Data
1	Title = Process Piping								
2	10	From							Anchor
3	20	Bend	3048			A53	A	1	
4	30				1524	A53	A	1	Hanger
5	40	Bend			1524	A53	A	1	
6	50			1524		A53	A	1	Anchor
7	6" STD pipe								
8	30	From							
9	60		1524			A53	B	1	
10	70	Valve	609.6			A53	B	1	
11	80	Bend	1524			A53	B	1	
12	90	Bend		-1524		A53	B	1	
13	100				-1524	A53	B	1	Hanger
14	110				-1524	A53	B	1	Anchor
15	4" sch 40								
16	100	From							
17	120		-609.6			A53	C	1	Rod hanger
18	130		-609.6			A53	C	1	Anchor

Fig. 2 (a) & (b). Plant Layout of a Piping System

4.1. Sections in Piping plant layout

Figure 3 shows the section of piping plant layout. There are three sections A, B and C which are shown by different colors. Section A is from node 10-50, section B from node 30-110 and section C from node 100-130.

Table 1. Pipe Section Properties with Insulation density and thickness

Name	Nominal Dia. (mm)	Schedule	Outside Dia. (mm)	Insulation Dens (kg/m^3)	Insulation Thickness (mm)
A	203.2	80	219.07	240.28	50.8
B	152.4	STD	168.27	240.28	50.8
C	101.6	40	114.30	240.28	50.8

Table.2.Theoretical calculations of Flexibility Characteristics, Flexibility Factor and SIF

Node	R (mm)	r (mm)	t (mm)	h	n	SIF (In-plane)	SIF (Out-plane)
20	228.6	101.6	12.192	0.27	6.11	2.14	1.78
40	457.2	101.6	12.192	0.54	3.05	1.35	1.12
80	457.2	76.2	6.09	0.49	3.36	1.43	1.19
90	457.2	76.2	6.09	0.49	3.36	1.43	1.19

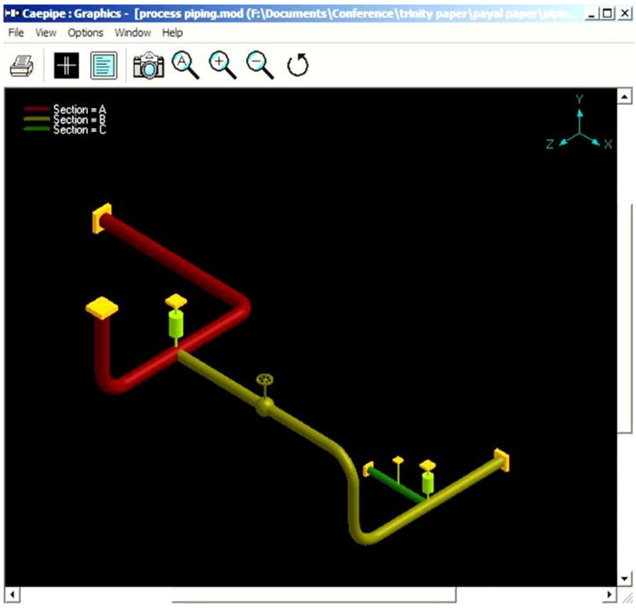

Fig. 3. Sections in Piping plant layout

t = 12.192 mm

5. Theoretical Calculation

For a pipe section A, the pipe is bend at node 20 and node 40. So,

At node 20;

R = 228.6 mm

r = $\frac{NominalDiameter}{2} = \frac{203.2}{2}$ = 101.6 mm

Out-plane, $i_0 = \frac{0.75}{h^{\frac{2}{3}}}$

Flexibility Characteristics, $h = \frac{tR}{r^2}$

$h = \frac{(12.192 \times 228.6)}{101.6^2} = 0.27(5)$

Flexibility Factor, $n = \frac{1.65}{h}$

$i_0 = \frac{0.75}{0.27^{\frac{2}{3}}} = 1.78$ (8)

$n = \frac{1.65}{0.27} = 6.11$ (6)

Calculation of SIF,

In-plane, $i = \frac{0.9}{h^{\frac{2}{3}}}$

$i = \frac{0.9}{0.27^{\frac{2}{3}}} = 2.14$ (7)

6. Working using CAEPIPE

The constraints used for designing and analysis of piping system are as follows:

1) The Piping code select for analysis is ASME B31.3 (2010) Process Piping
2) A53 Grade B type material is chosen from Material Library
3) There are three Pipe Sections A, B and C which has been discussed in Plant Layout and its properties are given in Table 1.
4) There are one type of load is to be considered which contains temperature, pressure and specific gravity and its values are as follows:
   a. Temperature (T1) = 315.6 °C
   b. Pressure (P1) = 13.8 bar
   c. Specific gravity = 0.8
5) There are two hangers at node 30 and 100 which are Grinnell type, one valve at node 60-70 and one rod hanger at node 120.
6) The Load Cases select for analysis are Sustained (W+P), Expansion (T1) and Operating (W+P1+T1)

A53 Grade B is a carbon steel alloy, used for structural steel pipe. It is intended for mechanical and pressure applications and is also acceptable for ordinary uses in steam, water, gas, and airlines. It is suitable for welding, and suitable for forming operations involving coiling, flanging and bending. It has a following properties:

Table 3. Properties of A53 Grade B type material

Caepipe : Materials (1) - [process piping.mod (F:\Documents\Conference\trinity paper\paya

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#	Name	Description	Type	Density (kg/m3)	Nu	Joint factor	Yield (MPa)	#	Temp (C)	E (MPa)	Alpha (mm/mm/C)	Allowable (MPa)
1	A53	A53 Grade B	CS	7833	0.3	1.00	241.3	1	-198.3	216495	9.00E-6	137.9
2								2	-128.9	212359	9.63E-6	137.9
								3	-73.33	208222	10.17E-6	137.9
								4	21.11	203395	10.93E-6	137.9
								5	93.33	198569	11.48E-6	137.9
								6	148.9	195122	11.88E-6	137.9
								7	204.4	190985	12.28E-6	137.2
								8	260	188227	12.64E-6	131.0
								9	315.6	184090	13.01E-6	123.4
								10	343.3	179953	13.19E-6	119.3
								11	371.1	175816	13.39E-6	115.1
								12	398.9	170990	13.57E-6	95.84
								13	426.7	166853	13.77E-6	78.60
								14	454.4	160648	13.95E-6	59.98
								15	482.2	154443	14.11E-6	40.68
								16	510	147548	14.24E-6	27.58
								17	537.8	140653	14.35E-6	17.24
								18	565.6	132379	14.49E-6	11.03
								19	593.3	124106	14.62E-6	6.895

After following this procedure and giving all inputs like loads on the pipe, material of the pipe, operating temperature, diameter of the pipe and types of bends etc. CAEPIPE produce a 3-D orientation of pipe in space as shown below,

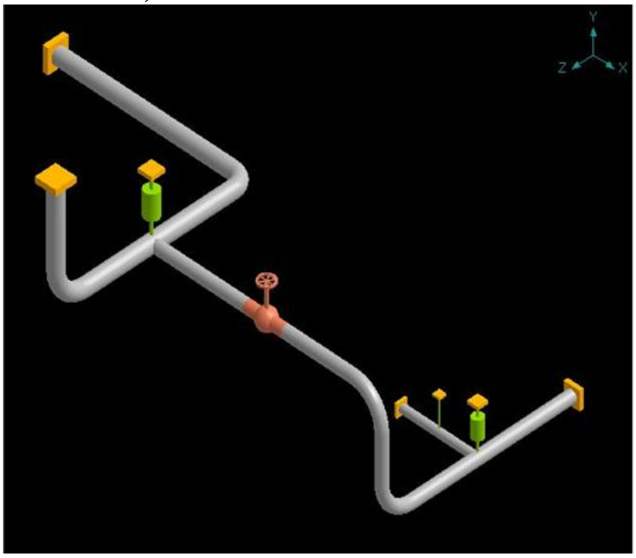

Fig. 4. 3-D orientation of Pipe in space

7. Experimental Results and discussion

Following results are obtained using CAEPIPE,

7.1. Sorted Code Stresses

When the stress ratio exceeds 1 then the maximum Stress induced and stress ratio become red in color in the table. In this particular case, the high thermal stresses may be induced.

So, in this particular case the high thermal stresses may be induced at node 100 and 130 which can be shown in table 4. These high thermal stresses may be reduced by replacing hanger at Node 100 and anchor at Node 130. These are the two points at which pipe will fail. SE/SA ratio being the maximum at Node 100.

Table 4. Code compliance (Sorted Stresses)

Caepipe : B31.3 (2010) Code compliance ...

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#	Sustained				Expansion			
	Node	SL (MPa)	SH (MPa)	SL/SH	Node	SE (MPa)	SA (MPa)	SE/SA
1	100	25.11	123.4	0.20	100	358.3	203.2	1.76
2	30	18.33	123.4	0.15	130	307.0	203.2	1.51
3	110	14.51	123.4	0.12	110	149.1	203.2	0.73
4	70	14.29	123.4	0.12	20B	120.2	203.2	0.59
5	60	13.06	123.4	0.11	20A	113.0	203.2	0.56
6	90A	11.38	123.4	0.09	10	100.3	203.2	0.49
7	80A	10.94	123.4	0.09	50	87.13	203.2	0.43
8	80B	10.44	123.4	0.08	80A	77.15	203.2	0.38
9	90B	9.878	123.4	0.08	120	56.11	203.2	0.28
10	10	9.686	123.4	0.08	80B	52.66	203.2	0.26
11	50	7.952	123.4	0.06	90A	43.34	203.2	0.21
12	40B	7.635	123.4	0.06	90B	43.25	203.2	0.21
13	20A	7.551	123.4	0.06	40B	37.55	203.2	0.18
14	120	7.310	123.4	0.06	70	35.91	203.2	0.18
15	130	7.269	123.4	0.06	40A	29.49	203.2	0.15
16	20B	7.020	123.4	0.06	60	23.69	203.2	0.12

Figure 5 shows the stress analysis of piping system. Different color in piping layout shows the maximum and minimum value of stresses. Maximum stress is shown by the red color and it is induced at node 100 with the value of 25.11 MPa and minimum stress is shown by dark blue color and it is induced at node 40A with the value of 6.69 MPa.

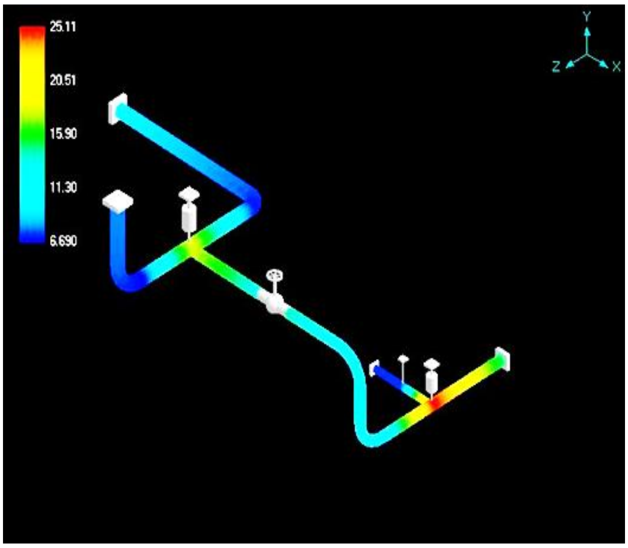

Fig. 5. Stress analysis of Piping System

7.2. Element Forces and Moments in Local coordinate

Table 5, 6 and 7 shows the Element Forces and Moments in local coordinate for Sustained, Expansion and Operating Load cases. These three tables consist of nine columns. First column shows the element number so there are 15 elements including bends also. The second column shows the node number. Every element consist of two nodes. The third column shows the axial force at all the nodes. Fourth and fifth column consist of shear force in y and z direction at all the nodes. Sixth column shows the torque at all the nodes. This torque is generated due to the displacement of the pipe form their initial position. Seventh and eighth column shows the moment and SIF value at all the nodes in case of In-plane and Out-plane. There is a SIF value at nodes 20, 40, 80 and 90 because the pipe are bend at these four nodes. The SIF values obtained from the software are same as that of calculated by the theoretical calculation. The ninth column shows the stresses at all the nodes.

The negative signs in the table shows the direction of forces and moments in local coordinates.

From Table 5, it is clear that the maximum and minimum axial forces are at node 90A and 100-130 with the value of 1400 N (negative direction) and 7 N respectively. The maximum and minimum shear force in y-direction are at node 30 and 80B-90A with the value of 2590 N and 55 N respectively.

Table 5. Element Forces and Moments in Local coordinate for sustained

Caepipe : Pipe forces in local coordinates: Sustained (W+P) - [process

File Results View Options Window Help

#	Node	Axial (N)	y Shear (N)	z Shear (N)	Torque (Nm)	Inplane(Nm) Moment	Inplane(Nm) SIF	Outplane(Nm) Moment	Outplane(Nm) SIF	SL (MPa)
1	10 20A	53 53	-1727 993	-80 -80	-477 -477	-1466 -432		114 -111		9.686 7.161
2	20A 20B	53 -80	-80 -53	-993 -1340	-477 -687	111 141	2.14 2.14	-432 200	1.78 1.78	7.551 7.020
3	20B 30	-80 -80	1340 2590	-53 -53	-687 -687	200 -2346		-141 -210		6.765 11.92
4	30 40A	-264 -264	-2339 -1310	-108 -108	616 616	-2079 -133		314 199		11.25 6.688
5	40A 40B	-264 -617	-1310 264	-108 -108	616 150	-133 230	1.35 1.35	199 -665	1.12 1.12	6.690 7.635
6	40B 50	-617 413	-108 -108	-264 -264	150 150	665 780		230 -51		7.633 7.952
7	30 60	-55 -55	-1646 -876	184 184	266 266	-1303 619		-524 -243		18.33 13.06
8	70 80A	-55 -55	191 729	184 184	266 266	827 337		-131 66		14.29 10.78
9	80A 80B	-55 -1092	-729 55	-184 -184	266 -150	-337 32	1.43 1.43	-66 -351	1.19 1.19	10.94 10.44
10	80B 90A	-1092 -1400	55 55	-184 -184	-150 -150	32 -2		-351 -463		10.44 11.15
11	90A 90B	-1400 -184	-184 1763	-55 -55	-150 -27	463 -199	1.43 1.43	-2 125	1.19 1.19	11.39 9.878
12	90B 100	-184 -184	1763 2302	-55 -55	-27 -27	-199 -2366		125 66		9.792 25.11
13	100 110	-163 -163	-2430 -1660	-48 -48	-9 -9	-2226 891		49 -23		24.10 14.51
14	100 120	7 7	-95 78	-21 -21	141 141	-18 -13		17 4		7.506 7.310
15	120 130	7 7	-96 77	-21 -21	141 141	-13 -7		4 -8		7.310 7.269

From Table 6 it is clear that the maximum and minimum axial forces are at node 100-110 and 40B-50 with the value of -29921 N and -1649 N respectively. The maximum and minimum shear force in y-direction are at node 40B and 10-20A & 20B-30 with the value of 23098 N and -342 N respectively.

Table 6. Element Forces and Moments in Local coordinate for expansion

Caepipe : Pipe forces in local coordinates: Expansion (T1) - [process pip

File Results View Options Window Help

#	Node	Axial (N)	y Shear (N)	z Shear (N)	Torque (Nm)	Inplane(Nm) Moment	Inplane(Nm) SIF	Outplane(Nm) Moment	Outplane(Nm) SIF	SE (MPa)
1	10 20A	-16085 -16085	342 342	-21324 -21324	-2555 -2555	2552 1587		39353 -20769		100.3 54.19
2	20A 20B	-16085 -21324	-21324 16085	-342 -342	-2555 1509	20769 21967	2.14 2.14	1587 2477	1.78 1.78	113.0 120.2
3	20B 30	-21324 -21324	342 342	16085 16085	1509 1509	2477 2034		-21967 -1131		57.75 9.494
4	30 40A	-23098 -23098	-1649 -1649	7753 7753	786 786	1816 3576		223 8493		7.763 25.83
5	40A 40B	-23098 -1649	-1649 23098	7753 7753	786 12037	3576 -6230	1.35 1.35	8493 2758	1.12 1.12	29.49 37.55
6	40B 50	-1649 -1649	7753 7753	-23098 -23098	12037 12037	-2758 -11029		-6230 -30871		34.63 87.13
7	30 60	-8332 -8332	2209 2209	1774 1774	-217 -217	723 -2644		-1354 1349		13.45 23.69
8	70 80A	-8332 -8332	2209 2209	1774 1774	-217 -217	-3991 -6348		2430 4323		35.91 57.50
9	80A 80B	-8332 -2209	-2209 8332	-1774 -1774	-217 -5133	6348 3548	1.43 1.43	-4323 -594	1.19 1.19	77.15 52.66
10	80B 90A	-2209 -2209	8332 8332	-1774 -1774	-5133 -5133	3549 -1531		-594 -1675		45.64 40.93
11	90A 90B	-2209 -1774	-1774 2209	-8332 -8332	-5133 -5340	1675 1476	1.43 1.43	-1531 1324	1.19 1.19	43.34 43.25
12	90B 100	-1774 -1774	2209 2209	-8332 -8332	-5340 -5340	1476 -881		1324 -7565		41.41 67.30
13	100 110	-29921 -29921	1681 1681	-19671 -19671	-3354 -3354	-453 -3015		10906 -19073		90.33 149.1
14	100 120	-11339 -11339	479 479	28147 28147	428 428	-1987 -2279		-18471 -1312		358.3 56.11
15	120 130	-11339 -11339	-5281 -5281	28147 28147	428 428	-2279 941		-1312 15846		56.11 307.0

From Table 7 it is clear that the maximum and minimum axial forces are at node 100-110 and 50 with the value of -30084 N and -1237 N respectively. The maximum and minimum shear force in y-direction are at node 20A and 110 with the value of -21404 N and 21 N respectively.

Table 7. Element Forces and Moments in Local coordinate for operating

Caepipe : Pipe forces in local coordinates: Operating (W+P1+T1) - [pro

File Results View Options Window Help

#	Node	Axial (N)	y Shear (N)	z Shear (N)	Torque (Nm)	Inplane(Nm) Moment	Inplane(Nm) SIF	Outplane(Nm) Moment	Outplane(Nm) SIF	Sopr (MPa)
1	10 20A	-16032 -16032	-1365 1336	-21404 -21404	-3032 -3032	1086 1156		39467 -20880		102.6 56.60
2	20A 20B	-16032 -21404	-21404 16032	-1336 -1682	-3032 821	20880 22108	2.14 2.14	1156 2676	1.78 1.78	115.6 121.8
3	20B 30	-21404 -21404	1682 2932	16032 16032	821 821	2676 -312		-22108 -1341		58.82 7.338
4	30 40A	-23362 -23362	-3989 -2959	7645 7645	1402 1402	-263 3443		537 8692		6.903 26.64
5	40A 40B	-23362 -2266	-2959 23362	7645 7645	1402 12187	3443 -6000	1.35 1.35	8692 2093	1.12 1.12	30.25 42.55
6	40B 50	-2266 -1237	7645 7645	-23362 -23362	12187 12187	-2093 -10249		-6000 -30923		39.89 92.38
7	30 60	-8387 -8387	563 1333	1958 1958	49 49	-580 -2026		-1877 1106		19.95 22.41
8	70 80A	-8387 -8387	2400 2939	1958 1958	49 49	-3163 -6011		2300 4388		33.92 59.29
9	80A 80B	-8387 -3301	-2939 8387	-1958 -1958	49 -5284	6011 3580	1.43 1.43	-4388 -944	1.19 1.19	77.96 60.65
10	80B 90A	-3301 -3609	8387 8387	-1958 -1958	-5284 -5284	3580 -1533		-944 -2138		53.58 49.55
11	90A 90B	-3609 -1958	-1958 3972	-8387 -8387	-5284 -5367	2138 1277	1.43 1.43	-1533 1449	1.19 1.19	52.89 50.17
12	90B 100	-1958 -1958	3972 4511	-8387 -8387	-5367 -5367	1277 -3247		1449 -7498		48.59 77.84
13	100 110	-30084 -30084	-749 21	-19719 -19719	-3363 -3363	-2678 -2124		10955 -19096		84.33 139.9
14	100 120	-11332 -11332	384 557	28126 28126	569 569	-2004 -2291		-18454 -1308		353.6 52.25
15	120 130	-11332 -11332	-5377 -5204	28126 28126	569 569	-2291 934		-1308 15838		52.25 302.4

7.3. Displacement at all Nodes

7.3.1. In case of sustained load

Table 8 shows the displacement of pipe inX, Y, Z and XX, YY and ZZ directions from their initial position at all the nodes in case of sustained load. This displacement occurs due to the pressure and weight load. The pipe is fixed at node 10, 50, 110 and 130 so the displacement is zero at these four nodes. The displacement layout of piping system is shown in figure 6. Table 9 shows the maximum and minimum displacement in all the directions.

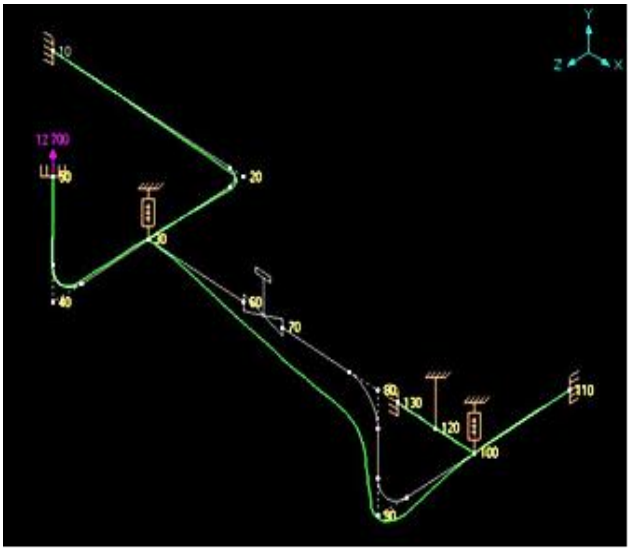

Fig. 6. Displacement layout of piping system at all nodes

Table 8. Displacement value at all nodes (Sustained)

Caepipe : Displacements: Sustained (W+P) - [process pipin

File Results View Options Window Help

#	Node	Displacements (global)					
		X (mm)	Y (mm)	Z (mm)	XX (deg)	YY (deg)	ZZ (deg)
1	10	0.000	0.000	0.000	0.0000	0.0000	0.0000
2	20A	0.000	-0.217	-0.018	-0.0112	0.0000	-0.0056
3	20B	-0.004	-0.199	-0.016	-0.0120	-0.0017	-0.0089
4	30	-0.058	0.033	-0.016	-0.0042	-0.0032	-0.0163
5	40A	-0.100	0.021	-0.016	0.0027	-0.0014	-0.0109
6	40B	-0.048	0.000	0.000	0.0006	-0.0013	-0.0049
7	50	0.000	0.000	0.000	0.0000	0.0000	0.0000
8	60	-0.059	-0.690	0.281	0.0085	-0.0172	-0.0253
9	70	-0.059	-0.945	0.468	0.0097	-0.0179	-0.0223
10	80A	-0.059	-1.186	0.819	0.0186	-0.0188	-0.0061
11	80B	-0.061	-1.199	0.742	0.0321	-0.0111	-0.0002
12	90A	-0.065	-1.198	0.372	0.0380	-0.0082	-0.0004
13	90B	-0.029	-0.788	0.000	0.0525	-0.0029	-0.0013
14	100	0.000	0.000	0.000	0.0209	-0.0005	-0.0004
15	110	0.000	0.000	0.000	0.0000	0.0000	0.0000
16	120	0.000	0.000	0.000	0.0104	0.0001	-0.0001
17	130	0.000	0.000	0.000	0.0000	0.0000	0.0000

Table 9.Maximum and minimum displacements during sustained

Caepipe : Minimum & Maximum Displa

File Results View Options Window Help

Direction	Type	Value	Node
X	Minimum	-0.100	40A
(mm)	Maximum	0.000	20A
Y	Minimum	-1.199	80B
(mm)	Maximum	0.033	30
Z	Minimum	-0.018	20A
(mm)	Maximum	0.819	80A
XX	Minimum	-0.0120	20B
(deg)	Maximum	0.0525	90B
YY	Minimum	-0.0188	80A
(deg)	Maximum	0.0001	120
ZZ	Minimum	-0.0253	60
(deg)	Maximum	0.0000	10

7.3.2. In case of expansion load

Table 10 shows the displacement of pipe at all the nodes in case of expansion load. This displacement occurs due to thethermal expansion, seismic anchor movements, thermal anchor movements, and building settlement. The displacement layout of piping system is shown in figure 7. Table 11 shows the maximum and minimum displacement in all the directions.

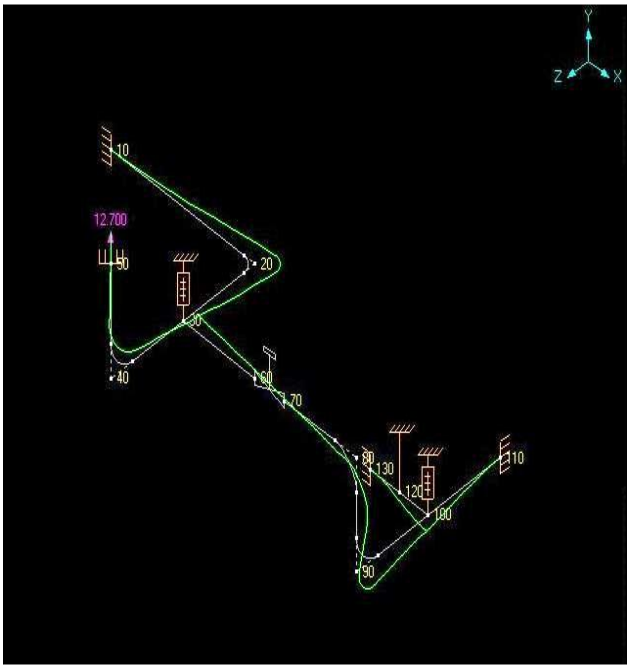

Fig. 7. Displacement layout of piping system at all nodes (Expansion)

Table 10. Displacement value at all nodes (Expansion)

Caepipe : Displacements: Expansion (T1) - [process piping.

#	Node	Displacements (global) X (mm)	Y (mm)	Z (mm)	XX (deg)	YY (deg)	ZZ (deg)
1	10	0.000	0.000	0.000	0.0000	0.0000	0.0000
2	20A	10.777	0.993	-8.763	-0.0600	0.1677	0.0374
3	20B	11.525	1.477	-8.120	-0.0865	-0.1458	0.0592
4	30	6.757	3.654	-3.172	-0.1053	-0.2415	0.0755
5	40A	2.423	5.761	0.901	-0.1237	-0.2118	0.0825
6	40B	0.552	8.613	1.517	-0.1267	-0.1069	0.0471
7	50	0.000	12.700	0.000	0.0000	0.0000	0.0000
8	60	12.579	5.491	3.492	-0.1156	-0.2416	0.0403
9	70	14.913	5.861	6.031	-0.1167	-0.2345	0.0279
10	80A	18.989	5.255	9.681	-0.1239	-0.1479	-0.1048
11	80B	18.138	1.631	10.916	-0.0645	0.0417	-0.4238
12	90A	13.448	-0.703	11.536	-0.0479	0.1395	-0.4386
13	90B	8.588	-2.294	9.863	0.0559	0.2297	-0.3379
14	100	4.639	-1.071	5.778	0.0635	0.1497	-0.1598
15	110	0.000	0.000	0.000	0.0000	0.0000	0.0000
16	120	2.319	0.000	3.287	0.0318	-0.4145	-0.0381
17	130	0.000	0.000	0.000	0.0000	0.0000	0.0000

Table 11. Maximum and minimum displacements during expansion

Caepipe : Minimum & Maximum Displa

Direction	Type	Value	Node
X	Minimum	0.000	10
(mm)	Maximum	18.989	80A
Y	Minimum	-2.294	90B
(mm)	Maximum	12.700	50
Z	Minimum	-8.763	20A
(mm)	Maximum	11.536	90A
XX	Minimum	-0.1267	40B
(deg)	Maximum	0.0635	100
YY	Minimum	-0.4145	120
(deg)	Maximum	0.2297	90B
ZZ	Minimum	-0.4386	90A
(deg)	Maximum	0.0825	40A

7.3.3. In case of operation load

Table 12 shows the displacement of pipe at all the nodes in case of operating load. This displacement occurs due to the temperature, pressure and weight load of the pipes. The displacement layout of piping system is shown in figure 8. Table 13 shows the maximum and minimum displacement in all the directions.

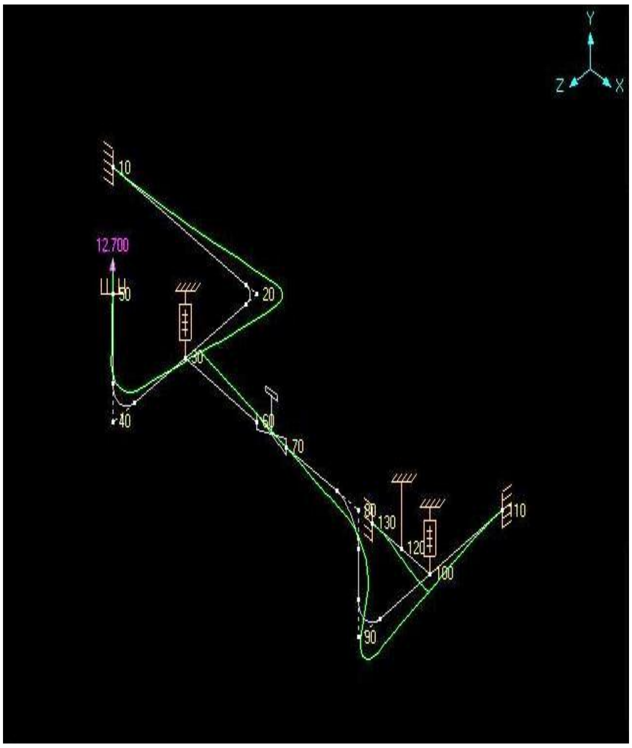

Fig. 8. Displacement layout of piping system (operating)

Table 12. Displacement value at all nodes (operating)

Caepipe : Displacements: Operating (W+P1+T1) - [process

#	Node	Displacements (global) X (mm)	Y (mm)	Z (mm)	XX (deg)	YY (deg)	ZZ (deg)
1	10	0.000	0.000	0.000	0.0000	0.0000	0.0000
2	20A	10.777	0.776	-8.781	-0.0711	0.1678	0.0318
3	20B	11.521	1.278	-8.135	-0.0986	-0.1475	0.0503
4	30	6.698	3.686	-3.188	-0.1095	-0.2447	0.0592
5	40A	2.323	5.781	0.885	-0.1210	-0.2132	0.0716
6	40B	0.504	8.613	1.515	-0.1261	-0.1082	0.0421
7	50	0.000	12.700	0.000	0.0000	0.0000	0.0000
8	60	12.521	4.800	3.773	-0.1071	-0.2589	0.0150
9	70	14.854	4.916	6.500	-0.1069	-0.2525	0.0056
10	80A	18.930	4.069	10.500	-0.1053	-0.1667	-0.1109
11	80B	18.076	0.432	11.659	-0.0325	0.0306	-0.4240
12	90A	13.383	-1.901	11.908	-0.0099	0.1313	-0.4390
13	90B	8.559	-3.082	9.862	0.1085	0.2268	-0.3392
14	100	4.639	-1.074	5.777	0.0844	0.1492	-0.1602
15	110	0.000	0.000	0.000	0.0000	0.0000	0.0000
16	120	2.319	0.000	3.285	0.0422	-0.4144	-0.0382
17	130	0.000	0.000	0.000	0.0000	0.0000	0.0000

Table 13. Maximum and minimum displacements during operating

Direction	Type	Value	Node
X	Minimum	0.000	10
(mm)	Maximum	18.930	80A
Y	Minimum	-3.082	90B
(mm)	Maximum	12.700	50
Z	Minimum	-8.781	20A
(mm)	Maximum	11.908	90A
XX	Minimum	-0.1261	40B
(deg)	Maximum	0.1085	90B
YY	Minimum	-0.4144	120
(deg)	Maximum	0.2268	90B
ZZ	Minimum	-0.4390	90A
(deg)	Maximum	0.0716	40A

8. Conclusion

The experimental results confirm the prior design and analysis of a Process Plant Piping System using CAEPIPE. This CAD package provides a systematic and efficient methodology for designing and analysis with far less effort. Compare the SIF results against the results obtained with CAEPIPE by using some observations on SIF equations are found to be same. So, the analysis of a piping system using CAEPIPE gives more accurate and precise results. The stress ratio SE/SA at Node 100 and 130 exceeds, 1. In this particular case, the high thermal stresses may be induced and the pipe will fail at these two nodes. There are some advantages for using CAEPIPE software on this research papers:

1) The formulas used in this research is easy to check for pipe configurations. The formula gives results in conformance to CAEPIPE results in most of the simple standard configurations.
2) The stress ratio in CAEPIPE may changewhen the number of bends are high. So, there are multiple combinations possible with other factors remaining same.
3) The piping engineer may have to carry out analysis once more on that software CAEPIPE.

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