Flexibility Analysis of Extraction Piping in Duplex Heater using CAESAR II

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Abstract:- This work is about flexibility analysis of extraction piping of duplex heater which is situated in the neck of surface condenser. Extraction piping is comprises of six pipelines. Flexibility analysis is carried out by using analysis software CAESAR II for all six pipelines, out of which analysis of one pipeline is presented here in this paper. Analysis is done as per ASME B31.1-2014 power piping code. Pipe lines are designed as per piping isometric drawings. Input data such as pressure, temperature and thermal expansions at junction is given by the different department of company. Bellow properties are given by the vendors. Pipe lines are analyzed for sixteen different load cases which are sustained, operational, occasional and expansion types of load cases. Different stresses obtained after analysis are compared with allowable stress to check for the safety. The design is said to be safe if all the stresses are in allowable range as per code.

***Keywords**:- Duplex heater; flexibity analysis; bellow; piping isometrics; thermal expansion.*

I. INTRODUCTION

A feed water heater is a component used in a power plant which increases the temperature of feed water delivered to generate steam. It increases the efficiency of the power plant. Heater uses the steam from the turbine to preheat feed water. Extraction piping is installed between turbine and feed water heater. One end of pipe is connected to turbine with flexible joint between them called as bellow and another end is connected to steam inlet nozzles of the heater of surface condenser. As name suggest purpose of extraction piping is to extract steam from the turbine and supply it to the heater. There are six such pipe lines for each steam inlet on which the flexibility analysis is carried out.

Duplex heater is placed in a neck of surface condenser as shown in fig 4. In operating condition, due to high temperature condenser tends to expand. To accommodate expansion of condenser in operating condition expansion joint which is also known as bellow provided to the extraction pipe as shown in fig 2 and 4.

The objective of piping flexibility analysis is to assure safety against failure of the piping material or anchor structure from overstress, against leakage at a joint, and against overstrain of connected equipment, without waste of material. Piping flexibility analysis resolve itself into the following:

1. The calculation of the forces, moments, and stresses (and desirably also displacements) at all significant location in a tubular structural frame under influence of thermal expansion.
2. Their comparison with allowable limit.

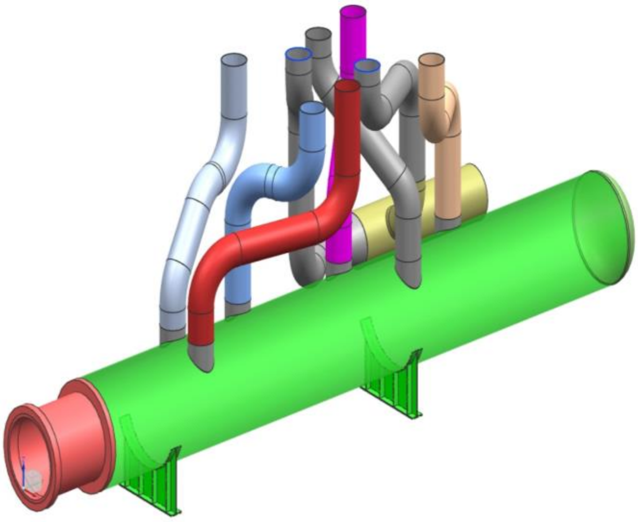

Fig 1:- LP Heater with extraction piping

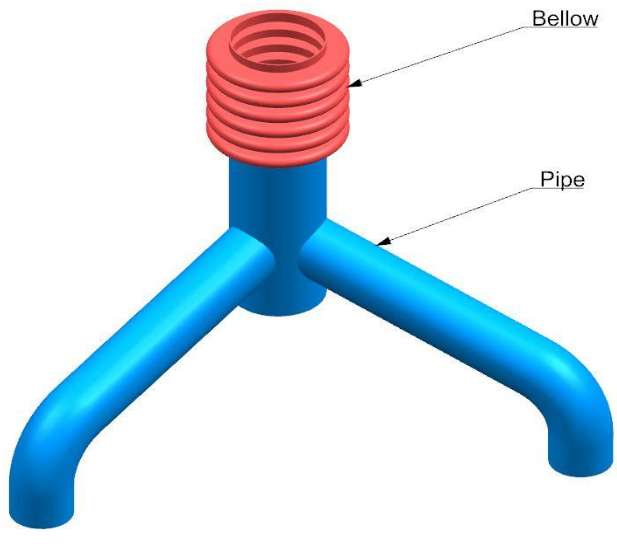

Fig 2:- Extraction piping with bellow

Flexibility analysis of extraction piping between duplex heaters of surface condenser & turbine for Power Plant is carried out. Each pipe line has been modelled as a separate system with displacement boundary conditions at turbine side and at LPH1/2 nozzles. The thermal growth at this mating point between turbine outlet and piping is provided by the customer, whereas thermal growth at nozzles of LHP1/2 is calculated by company. At both ends of pipe thermal growth is imposed as the displacement boundary conditions. Each extraction piping is analyzed for different load case combination using CAESAR II.

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II. CODES AND STANDARD USED

A. ASME B16.9

Factory-Made Wrought Steel Butt-welding Fittings. This Standard covers overall dimensions, tolerances, ratings, testing, and markings for wrought carbon and alloy steel factory-made butt-welding fittings of NPS 1/2 through 48. It covers fittings of any producible wall thickness. This standard does not cover low pressure corrosion resistant butt-welding fittings. [6]

B. ASME B31.1-2014 Power Piping Code

This code covers the minimum requirements for the design, materials, fabrication, erection, testing, and inspection of power and auxiliary service piping systems found in piping typically found in electric power generating stations, in industrial and institutional plants, geothermal heating systems, and central and district heating and cooling systems.[7]

C. Indian Standards, IS 1893 part 4

This standard describes the procedures for earthquake resistant design of industrial structures including stack like structures. It provides the estimates of earthquake loading for design of such structures.[8].

III. PIPE ROUTING

There are six pipe lines for supplying steam to the duplex low pressure feed water heater. Pipe routing of extraction piping can change project to project. Pipe routing for all the six pipelines is given in the piping isometric drawings. Isometric for one pipeline is shown in fig 3.

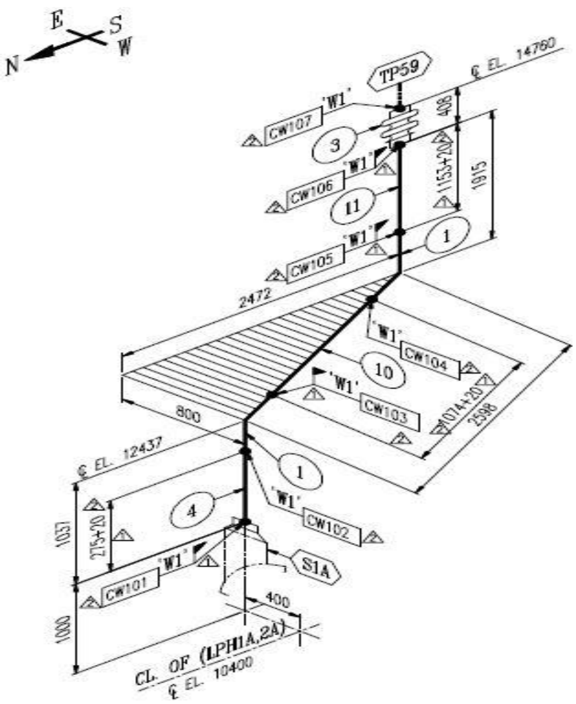

Fig 3:- Piping isometric between nozzle S1A and turbine

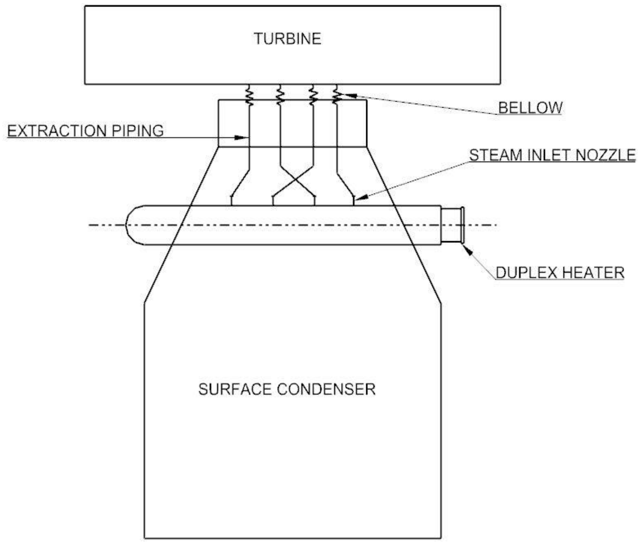

Fig 4:- Placement of Duplex Heater

Part no.	Description	Material	Size
1	90 deg. LR elbow	ASTM A-234 GR WPB	20" NB x SCH. STD. ASME B16.9
3	Metallic expansion bellow	ASTM A-240 GR 304	450
4	Pipe 1 for nozzle S1A	ASTM A-106 GR B (SEAMLESS)	20" NB x SCH. STD.
10	Pipe 2 for nozzle S1A	ASTM A-106 GR B (SEAMLESS)	20" NB x SCH. STD.
11	Pipe 3 for nozzle S1A	ASTM A-106 GR B (SEAMLESS)	20" NB x SCH. STD.

Table 1. Component of Pipeline

IV. OPERATING CONDITION DATA

A. Temperature

Shell side and tube side data of temperature is given in the table below. Shell side data is temperature of steam entering and coming out respectively. While tube side data is temperature of feed water entering and coming out respectively.

Equipment	Operating Temperature (°C) (In/Out)	
	Shell Side	Tube Side
LPH 1	62.2/62.2	48.4/59.4
LPH 2	82.8/82.8	59.4/80.0

Table 2. Temperature Data

B. Pressure

The extraction piping is analyzed for two different operating Cases.

Case 1: Condenser Operating Pressure and LP heater at Operating Pressure

Case 2: Condenser Operating Pressure and LP heater at Full Vacuumed (FV) Condition.

The extraction piping is analyzed for each mentioned case using effective pressure calculated in above tables and operating temperatures. The Fig 5 shows the condenser pressure and LP heater Pressure conditions for extraction piping whereas Fig 6 shows the effective pressure for extraction piping. Based on effective pressure for case 1 and Case 2 following load cases are defined.

Load Case 1:	Weight +Effective Pressure 1 (W+P1)
Load Case 2:	Weight +effective Pressure 2 (W+P2)
Load Case 1	Weight + Effective Pressure 1 + Operating Temperature + Displacement (W+P1+T1+D)
Load Case 2	Weight + effective Pressure 2 + Operating temperature + Displacement (W+P2+T2+D)

Table 3. Load Cases

The seismic loads also used in combination with above load cases. Detailed load case combinations are discussed in section VIII.

Conditions		Condenser Pressure		Turbine Pressure		Effective Pressure for Extraction Piping (External) (g)	Effective Pressure for Extraction Piping (Internal) (g)
		Bar (abs)	Bar (g)	Bar (abs)	Bar (g)		
100% TMCR	Case 1	0.0694	-0.9306	0.22	-0.78	-0.1506	0.1506
	Case 2	0.0694	-0.9306	FV	-1	0.0694	-0.0694

Table 4. For Pipes Between Turbine And Lph1

Conditions		Condenser Pressure		Turbine Pressure		Effective Pressure for Extraction Piping (External) (g)	Effective Pressure for Extraction Piping (Internal) (g)
		Bar (abs)	Bar (g)	Bar (abs)	Bar (g)		
100% TMCR	Case 1	0.0694	-0.9306	0.53	-0.46	-0.4621	0.4621
	Case 2	0.0694	-0.9306	FV	-1	0.0694	-0.0694

Table 5. For Pipes Between Turbine And Lph2

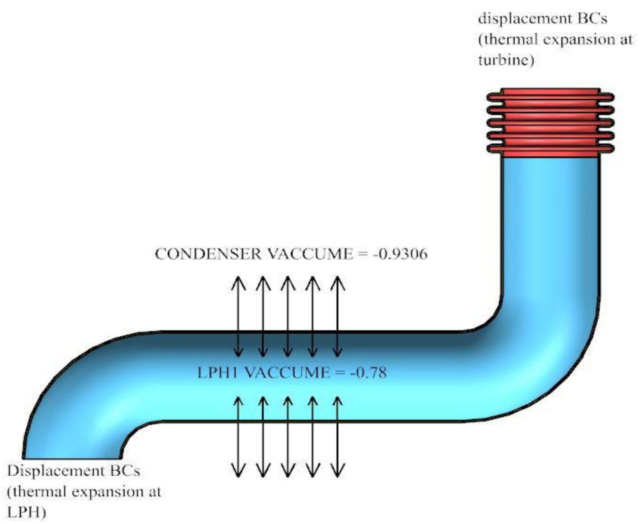

Fig 5:- Condenser Pressure (act externally) and LPH Pressure (act internally) for extraction Piping.

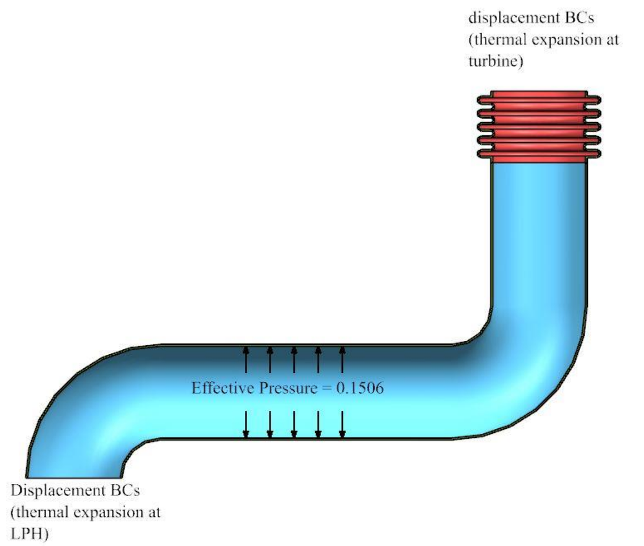

Fig 6:- Resultant Pressure (Effective) act as internal pressure for Extraction Piping.

V. EXPANSION BELLOW PROPERTIES

Bellow data required for the analysis is axial stiffness, lateral stiffness, angular stiffness and effective diameter. We get axial stiffness for bellow from the vendor. Lateral stiffness can be calculated from EJMA as follow.

$d_e = id_{con} + h_c$ (1)

Where d_e = Effective diameter of bellow.
Id_{con} = Inner diameter of convolution of bellow.
h_c = Height of convolution.
$d_e = 457 + 21$

$d_e = 478$ mm

l_e = length of convolutions = 300 mm

Axial stiffness = K_a = 21.5 Kg/mm

Lateral stiffness = $K_l = (3/2) \times K_a \times (d_e/l_e)^2$ (2)

Lateral stiffness = $K_l = (3/2) \times 21.5 \times (478/300)^2$

Lateral stiffness = 81.8734 Kg/mm

Size	MOC	Axial Stiffness (Kg/mm)	Lat. Stiffness (Kg/mm)	Ang. Stiffness (Kg/rad)	Effective Diameter (mm)
450	ASTM A-240 GR 304	21.5	81.87	0	478

Table 6. Bellow Properties

VI. LOADING AND BOUNDARY CONDITIONS

- Operating pressure and temperatures mentioned in section IV are used.
- The expansion below properties are used mentioned in section V.
- Thermal growth at mating point of pipe from turbine (as input from Customer) and at junction between pipe and feed water heater.
- Seismic Loading: Horizontal seismic coefficients in X Z direction are considered as 0.1166. The vertical seismic coefficients are considered as 0.66 time's horizontal seismic coefficient. Seismic coefficient can be calculated as per IS 1893 part 4.

A. Seismic Coefficient Calculation

Seismic coefficient can be calculated from the equation-

$A_h = ((Z/2) \times (S_a/g)) / (R / I)$ (3)
Where
A_h = Seismic coefficient
Z = Zone factor = 0.16
S_a/g = Spectral acceleration coefficient for rock and soil = 2.5
I = Importance factor = 1.75
R = Response reduction factor = 3

Values of all the above parameters can be calculated from IS 1893 part 4. Putting all values in equation (3) we get value of A_h as 0.1166

B. Thermal Expansion

Line Connection between LP1 to LPH1/2	Thermal growth at mating point of pipe from turbine (mm)			Thermal growth at junction between pipe and feed water heaters (mm)		
	ΔX	ΔY	ΔZ	ΔX	ΔY	ΔZ
TP59 of Turbine to S1A of heater	-1.1	-1.3	0.6	11.76	-0.7	-0.59

Table 7. Thermal Expansion Data

Thermal expansion given in the following table for thermal growth at mating point of pipe turbine are according to coordinate system of turbine and thermal expansion for junction between pipe and feed water heater are according to heater coordinate system. During analysis these imposed thermal displacement boundary condition are taken as per CAESAR II coordinate system.

VII. CAESAR MODEL

Model according to piping isometric is modeled in the CAESAR II. Materials assigned to the different component as given in the bill of materials. All the conditions such as pressure, temperature and thermal growth are imposed to the model. Bellow properties are assigned to bellow. ASME B31.1 is selected for analysis.

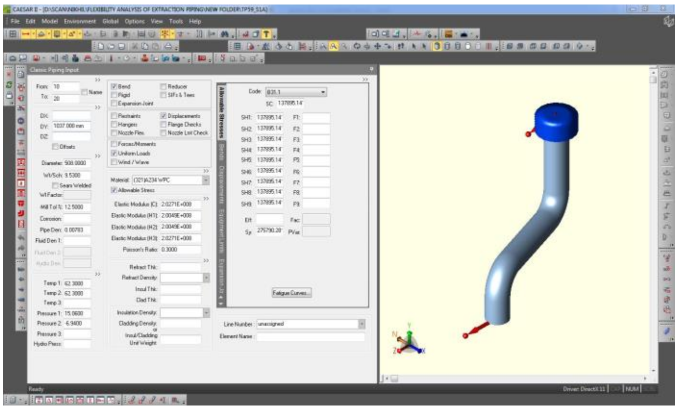

Fig 7:- Modelled Extraction Pipeline for Nozzle S1A.

VIII. LOAD CASES

There are four types of load cases that we consider in the analysis i.e. sustained, operating, occasional and expansion.

Sustained: In sustained load cases we consider only weight and pressure. This condition occurs when plant is in standby condition and hence there will be no thermal expansion.

Operating: This case occurs when the plant is in operating condition. During operation there will be thermal expansion due to high temperature.

Occasional: This case occurs when wind or earthquake occurs which can affect the structures. Seismic and wind loadings are considered in this case.

Expansion: This situation occurs when effect of only temperature and displacement are considered. List of all the load cases are given in the table below.

Load Case No	Type of Load Case	Load Case	Description
L1	SUSTAINED	W+P1	Weight + Effective Operating Pressure 1
L2	SUSTAINED	W+P2	Weight + effective Operating Pressure 2
L3	OPERATING	W+D1+T1+P1	Weight + Displacement + Operating Temp.+ Effective Operating Pressure 1
L4	OPERATING	W+D1+T2+P2	Weight + Displacement + Operating Temp.+ Effective Operating Pressure 2
L5	OPERATING	W+D1+T1+P1+U1	Weight + Displacement + Operating Temp.+ Effective Operating Pressure 1 + Seismic (+X)
L6	OPERATING	W+D1+T1+P1-U1	Weight + Displacement + Operating Temp.+ Effective Operating Pressure 1 + Seismic (-X)
L7	OPERATING	W+D1+T1+P1-U2	Weight + Displacement + Operating Temp.+ Effective Operating Pressure 1 + Seismic (-Y)
L8	OPERATING	W+D1+T1+P1+U3	Weight + Displacement + Operating Temp.+ Effective Operating Pressure 1 + Seismic (+Z)
L9	OPERATING	W+D1+T1+P1-U3	Weight + Displacement + Operating Temp.+ Effective Operating Pressure 1 + Seismic (-Z)
L10	OPERATING	W+D1+T2+P2+U1	Weight + Displacement + Operating Temp.+ Effective Operating Pressure 2 + Seismic (+X)
L11	OPERATING	W+D1+T2+P2-U1	Weight + Displacement + Operating Temp.+ Effective Operating Pressure 2 + Seismic (-X)
L12	OPERATING	W+D1+T2+P2-U2	Weight + Displacement + Operating Temp.+ Effective Operating Pressure 2 + Seismic (-Y)
L13	OPERATING	W+D1+T2+P2+U3	Weight + displacement + Operating Temp.+ Effective Operating Pressure 2 + Seismic (+Z)
L14	OPERATING	W+D1+T2+P2-U3	Weight + Displacement + Operating Temp.+ Effective Operating Pressure 2 + Seismic (-Z)
L15	EXPANSION	L3-L1	Expansion Case 1
L16	EXPANSION	L4-L2	Expansion Case 2

Table 8. Load Cases

IX. RESULTS AND DISCUSSION

A. *Displacement Report*

LOAD CASE DEFINITION KEY
CASE 1 (SUS) W+P1
CASE 2 (SUS) W+P2
CASE 3 (OPE) W+P1+T1+D1
CASE 4 (OPE) W+P2+T2+D1
CASE 15 (EXP) L15=L3-L1
CASE 16 (EXP) L16=L4-L2

Node	DX mm.	DY mm.	DZ mm.	RX deg.	RY deg.	RZ deg.
10	0	0	0	0	0	0
18	-0.003	-0.001	-0.01	-0.0025	0	0.0008
19	-0.05	-0.087	-0.153	-0.0453	0	0.0147
20	-0.099	-0.522	-0.306	-0.082	0	0.0265
28	-0.099	-2.961	-0.305	-0.0837	0	0.0271
29	-0.162	-3.475	-0.5	-0.0699	0	0.0226
30	-0.286	-3.651	-0.883	-0.0533	0	0.0172
40	-0.7	-3.652	-2.164	-0.0518	0	0.0168
50	0	0	0	0	0	0

Table 9. Displacements Report: Nodal Movements Case 1 (Sus) W+P1

Node	DX mm.	DY mm.	DZ mm.	RX deg.	RY deg.	RZ deg.
10	0	0	0	0	0	0
18	-0.001	-0.001	-0.004	-0.0009	0	0.0003
19	-0.018	-0.032	-0.057	-0.0166	0	0.0054
20	-0.036	-0.189	-0.112	-0.0289	0	0.0093
28	-0.036	-1.042	-0.112	-0.0291	0	0.0094
29	-0.057	-1.216	-0.178	-0.0232	0	0.0075
30	-0.098	-1.274	-0.303	-0.0175	0	0.0057
40	-0.234	-1.273	-0.723	-0.017	0	0.0055
50	0	0	0	0	0	0

Table 10. Displacements Report: Nodal Movements Case 2 (Sus) W+P2

Node	DX mm.	DY mm.	DZ mm.	RX deg.	RY deg.	RZ deg.
10	-0.7	-0.59	11.76	0	0	0
18	-0.704	-0.334	11.733	-0.0054	-0.0009	0.0009
19	-0.762	-0.317	11.379	-0.0873	-0.0066	0.0142
20	-0.792	-1.039	10.895	-0.1569	-0.0173	0.0312
28	-0.559	-5.57	10.009	-0.1653	-0.0181	0.0314
29	-0.587	-6.609	9.34	-0.1845	-0.0212	0.0353
30	-0.77	-6.931	8.048	-0.1983	-0.0235	0.0329
40	-1.571	-6.247	3.157	-0.1994	-0.0232	0.0325
50	-1.1	-1.3	0.6	0	0	0

Table 11. Displacements Report: Nodal Movements Case 3 (Ope) W+D1+T1+P1

Node	DX mm.	DY mm.	DZ mm.	RX deg.	RY deg.	RZ deg.
10	-0.7	-0.59	11.76	0	0	0
18	-0.702	-0.333	11.739	-0.0039	-0.0009	0.0004
19	-0.73	-0.262	11.475	-0.0586	-0.0066	0.0049
20	-0.729	-0.706	11.089	-0.1038	-0.0173	0.014
28	-0.497	-3.651	10.202	-0.1107	-0.0181	0.0137
29	-0.483	-4.35	9.663	-0.1378	-0.0212	0.0202
30	-0.583	-4.554	8.627	-0.1625	-0.0235	0.0213
40	-1.105	-3.868	4.598	-0.1646	-0.0232	0.0213
50	-1.1	-1.3	0.6	0	0	0

Table 12. Displacements Report: Nodal Movements Case 4 (Ope) W+D1+T2+P2

Node	DX mm.	DY mm.	DZ mm.	RX deg.	RY deg.	RZ deg.
10	-0.7	-0.59	11.76	0	0	0
18	-0.7	-0.332	11.743	-0.0029	-0.0009	0.0001
19	-0.712	-0.23	11.532	-0.042	-0.0066	-0.0005
20	-0.693	-0.517	11.201	-0.0749	-0.0173	0.0047
28	-0.46	-2.609	10.314	-0.0816	-0.0181	0.0043
29	-0.425	-3.134	9.841	-0.1146	-0.0212	0.0127
30	-0.484	-3.28	8.931	-0.145	-0.0235	0.0157
40	-0.871	-2.595	5.321	-0.1476	-0.0232	0.0158
50	-1.1	-1.3	0.6	0	0	0

Table 13. Displacements Report: Nodal Movements Case 15 (Sus) L15=L3-L1

Node	DX mm.	DY mm.	DZ mm.	RX deg.	RY deg.	RZ deg.
10	-0.7	-0.59	11.76	0	0	0
18	-0.7	-0.332	11.743	-0.0029	-0.0009	0.0001
19	-0.712	-0.23	11.532	-0.042	-0.0066	-0.0005
20	-0.693	-0.517	11.201	-0.0749	-0.0173	0.0047
28	-0.46	-2.609	10.314	-0.0816	-0.0181	0.0043
29	-0.425	-3.134	9.841	-0.1146	-0.0212	0.0127
30	-0.484	-3.28	8.931	-0.145	-0.0235	0.0157
40	-0.871	-2.595	5.321	-0.1476	-0.0232	0.0158
50	-1.1	-1.3	0.6	0	0	0

Table 14. Displacements Report: Nodal Movements Case 16 (Sus) L16=L4-L2

B. Stress Summary

LOAD CASE DEFINITION KEY
CASE 1 (SUS) W+P1
CASE 2 (SUS) W+P2
CASE 15 (EXP) L15=L3-L1
CASE 16 (EXP) L16=L4-L2

Piping Code: B31.1 = B31.1 -2016, June 30, 2016

CODE STRESS CHECK PASSED: LOADCASE 1 (SUS) W+P1

Highest Stresses: (KPa) LOADCASE 1 (SUS) W+P1
Ratio (%): 12.9 @Node 18
Code Stress: 17849.3 Allowable Stress: 137895.1
Axial Stress: 332.9 @Node 10
Bending Stress: 23546.5 @Node 18
Torsion Stress: 0.0 @Node 28
Hoop Stress: 386.3 @Node 18
Max Stress Intensity: 24217.6 @Node 18

CODE STRESS CHECK PASSED: LOADCASE 2 (SUS) W+P2

Highest Stresses: (KPa) LOADCASE 2 (SUS) W+P2
Ratio (%): 4.8 @Node 18
Code Stress: 6662.5 Allowable Stress: 137895.1
Axial Stress: 378.7 @Node 10
Bending Stress: 8767.0 @Node 18
Torsion Stress: 0.0 @Node 28
Hoop Stress: 178.0 @Node 18
Max Stress Intensity: 9105.1 @Node 18

CODE STRESS CHECK PASSED: LOADCASE 15 (SUS) L15=L3-L1

Highest Stresses: (KPa) LOADCASE 15 (SUS) L15=L3-L1
Ratio (%): 12.3 @Node 18
Code Stress: 17026.6 Allowable Stress: 137895.1
Axial Stress: 217.7 @Node 20
Bending Stress: 21990.1 @Node 18
Torsion Stress: 572.6 @Node 18
Hoop Stress: 0.0 @Node 18
Max Stress Intensity: 22038.2 @Node 18

CODE STRESS CHECK PASSED: LOADCASE 16 (SUS) L16=L4-L2

Highest Stresses: (KPa) LOADCASE 16 (SUS) L16=L4-L2
Ratio (%): 12.3 @Node 18
Code Stress: 17026.6 Allowable Stress: 137895.1
Axial Stress: 217.7 @Node 20
Bending Stress: 21990.1 @Node 18
Torsion Stress: 572.6 @Node 18
Hoop Stress: 0.0 @Node 18
Max Stress Intensity: 22038.2 @Node 18

C. Code Compliance Extended Summary

CASE 15 (SUS) L15=L3-L1
CASE 16 (SUS) L16=L4-L2

Piping Code: B31.1 = B31.1 -2016, June 30, 2016

*** CODE COMPLIANCE EVALUATION PASSED ***

Highest Stresses: (KPa)
Ratio (%): 12.9 @Node 18 LOADCASE: 1 (SUS) W+P1
Code Stress: 17849.3 Allowable Stress: 137895.1
Axial Stress: 388.8 @Node10 LOADCASE: 12 (OPE) W+D1+T2+P2-U2
Bending Stress: 46078.2 @Node 18 LOADCASE: 7 (OPE) W+D1+T1+P1-U2
Torsion Stress: 733.8 @Node 18 LOADCASE: 5 (OPE) W+D1+T1+P1+U1
Hoop Stress: 386.3 @Node 18 LOADCASE: 1 (SUS) W+P1
Max Stress Intensity: 46770.4 @Node 18 LOADCASE: 7 (OPE) W+D1+T1+P1-U2

D. Restraint Report

LOAD CASE DEFINITION KEY

CASE 1 (SUS) W+P1
CASE 2 (SUS) W+P2
CASE 3 (OPE) W+D1+T1+P1
CASE 4 (OPE) W+D1+T2+P2
CASE 5 (OPE) W+D1+T1+P1+U1
CASE 6 (OPE) W+D1+T1+P1-U1
CASE 7 (OPE) W+D1+T1+P1-U2
CASE 8 (OPE) W+D1+T1+P1+U3
CASE 9 (OPE) W+D1+T1+P1-U3
CASE 10 (OPE) W+D1+T2+P2+U1
CASE 11 (OPE) W+D1+T2+P2-U1
CASE 12 (OPE) W+D1+T2+P2-U2
CASE 13 (OPE) W+D1+T2+P2+U3
CASE 14 (OPE) W+D1+T2+P2-U3
CASE 15 (SUS) L15=L3-L1
CASE 16 (SUS) L16=L4-L2

Node	Load Case	FX N.	FY N.	FZ N.	MX N.m.	MY N.m.	MZ N.m.
10	TYPE=Displ. Reaction;						
	1(SUS)	610	-7795	1886	-7304	0	2364
	2(SUS)	204	-4349	630	-2758	0	893
	3(OPE)	472	-7522	-1483	-17235	-2091	2580
	4(OPE)	65	-4076	-2740	-12689	-2091	1109
	5(OPE)	1014	-7527	-1461	-17176	-2679	2154
	6(OPE)	-70	-7517	-1506	-17295	-1502	3006
	7(OPE)	498	-7946	-1403	-17562	-2091	2686
	8(OPE)	494	-7537	-879	10	-1900	2521
	9(OPE)	449	-7507	-2088	-17826	-2281	2640
	10(OPE)	607	-4081	-2717	-12629	-2679	682
	11(OPE)	-477	-4071	-2763	-12748	-1502	1535
	12(OPE)	91	-4500	-2660	-13016	-2091	1215
	13(OPE)	88	-4091	-2136	-12098	-1900	1049
	14(OPE)	42	-4061	-3345	-13280	-2281	1168
	15(SUS)	-139	273	-3370	-9931	-2091	216
	16(SUS)	-139	273	-3370	-9931	-2091	216
	MAX	1014/L5	-7946/L7	-3370/L15	-17826/L9	-2679/L5	3006/L6
50	TYPE=Displ. Reaction;						
	1(SUS)	-610	1932	-1886	375	0	-121
	2(SUS)	-204	-1514	-630	125	0	-40
	3(OPE)	-472	1659	1483	-341	-262	-90
	4(OPE)	-65	-1787	2740	-591	-262	-9
	5(OPE)	-328	1664	1461	-337	-293	-61
	6(OPE)	-616	1654	1506	-346	-232	-119
	7(OPE)	-498	1626	1403	-325	-262	-95
	8(OPE)	-494	1674	1565	-358	-252	-95
	9(OPE)	-449	1644	1402	-325	-272	-85
	10(OPE)	79	-1782	2717	-586	-293	20
	11(OPE)	-209	-1792	2763	-596	-232	-38
	12(OPE)	-91	-1820	2660	-575	-262	-14
	13(OPE)	-88	-1772	2821	-607	-252	-14
	14(OPE)	-42	-1802	2659	-575	-272	-4
	15(SUS)	139	-273	3370	-716	-262	31
	16(SUS)	139	-273	3370	-716	-262	31
	MAX	-616/L6	1932/L1	3370/L15	-716/L15	-293/L5	-121/L1

X. CONCLUSION

We calculated axial stress, hoop stress, bending stress and maximum stress intensity by using CAESAR II. We found that all the stress values are below allowable stress. Hence we can conclude that pipeline is safe.

We also found the displacements of all the nodes and reaction at starting node and end node.

Finally we can conclude that piping system is flexible enough to sustain all four cases i.e. sustained, operating, occasional and expansion.

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