STRESS DISTRIBUTIONS ON POWER PIPING LINES (ASME-B-31.1) USING CAESER-II

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***ABSTRACT*:** Piping system is one of the Transportation of Fluids, Steam/Air. The Piping elements such as pipes, elbows, flanges, fittings, valves, supports, gaskets, etc., are used in the piping system. These components are manufactured as per the codes and standards (ASME, EN). The power pipe lines are designed and 3D modelling is prepared and stress distributions are focussed by using the CAESER-II software. The main objective of pipe stress distribution is to prevent the failures occurring in piping & piping components and ensuring that piping stresses are operating within the allowable limits. This paper gives the clear information of engineering principles involved in material selection, application of different loads incorporated in stress analysis software, where as the manual procedure fails in providing the accurate results at different fittings and joints when they are subjected to "Operational loads, Sustained loads & Thermal Expansions".

Keywords: **CAESER-II, Power Piping, Piping Elements, Piping Stresses, pipe supports, code criteria, Operational loads, Sustained loads& Thermal Expansion.**

1.INTRODUCTION

Piping System is a network of Pipes consisting of Pipe Fittings and other 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 guidelines of International and Industrial Codes & Standards. Generally, Piping Engineering is applied among the following Industrial systems;

Building Services Piping System

Refrigeration and Heat Transfer Piping System
Liquid transportation and distribution piping (Pipelines) System
Gas Transmission and Distribution Piping System
Power Piping System
Process Piping System
Slurry Transportation Piping Systems

In this paper we discussed about the Power Piping system, which is a form of pipe work used to transport materials used in industrial processes and manufacturing. It is specially designed for particular applications to ensure that it will meet safety standards, in addition to suiting the needs of a given manufacturing process. In Automobile spare parts manufacturing, for example, process piping can be used to transport different parts of the automobiles (parts of the vehicles like engine, doors, wheels, seats, etc.,) to various points on the production line. Chemical manufacturing facilities use power piping to transport Temperatured components of their products along with materials like natural gas used in manufacturing. Refineries and similar facilities also utilize power piping to move chemical compounds.

The SIF calculations followed in Power Piping Plants referring to code ASME B31.1.And also explain the basic concept of flexibility such as flexibility characteristics and flexibility factor. CAD Packages like CAEPIPE,CAESER-II has been developed for the static & dynamic 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 in the piping layout. Compare the SIF results against the results obtained with CAESER-II 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 CAESER 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 power plant piping system by using CAESER software.

CODES AND STANDARDS:

A code is basically a standard that has been generally accepted by the government. The objective of each code is to ensure public and industry safety in a particular activity or equipment. Standardization can reduce cost, inconvenience and confusion that results from unnecessary and undesirable differences in systems, components and procedures.

Piping Codes
ASME B31.1 - Power Piping
ASME B31.2 - Fuel Gas Piping
ASME B31.3 - Process Piping

ASME B31.4 - Liquid Piping
ASME B31.5 - Refrigeration Piping
ASME B31.8-Gas Distribution and Transportation
ASME B31.9 - Building Service Piping
ASME B31.11-Slurry Piping

Materials classification

CLASSIFICATION OF PIPING MATERIALS			
PIPING MATERIALS			
	METALLIC	N ON- METALLIC	LINE D
FERROUS	NON -FERROUS	PVC	MS RUBBER LINED
CAST IRON	COPPER & ITS ALLOYS	HDPE	MS PTFE, MS PVDF
CARBON STEEL	A LUMINIUM & ITS ALLOYS	PTFE	MS LEAD LINED
ALLOY STEEL	NICKEL AND ITS ALLOYS	LDPE	MS CERAMIC LINED
STAIN LESS STEEL	LEAD AND ITS ALLOYS	GLASS	MS GLASS LINED
OTH ER SPECIAL A LLO YS		CERAMIC	FRPPP LINED
		CEMENT	

Piping design code

The basic design code for engineers working with topside offshore projects is the ASME B31.1 Power Piping Code. The ASME B31.1 Power Piping Code is originally a design code for power plants to be placed on land. It is however the most used piping code for power piping on oil and gas platforms and has been widely used for subsea installation. (D. N. Veritas, 2008)

Abbreviations and Acronyms

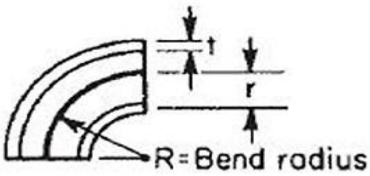


FIG.1 sketch for pipe bend

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

FLEXIBILITY

Flexibility analysis is done on a piping system to study its behaviour when its temperature changes from ambient to operating; 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.

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,

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

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

Allowable displacement stress,

$\sigma a = f\,(1.25\sigma c+0.25\sigma h)$ as defined in ASME B31.1, code for power piping.

Where,

σc = Basic allowable stress at minimum metal temperature expected during the displacement cycle during operation.
σh = Basic allowable stress at maximum metal temperature expected during the life time of the piping.
f = stress range reduction factor for cyclic conditions for total number of full temperature cycles during the life time of the plant.

The computed stress, $\sigma c = \sqrt{\sigma b^2 + 4\sigma t^2}$
Where, σb = Resultant bending stress
σt = Torsional stress = $M/2Z$
M = Torsional movement
Z = Section modulus of pipe
The resultant bending stress for elbows, bends and full size outlet branch connections shall be calculated as:
$\sigma_b = \sqrt{(IiMi)^2 + (IoMo)^2/Z}$
Where, I_i = In-plane stress intensification factor
Io= Out-planestress intensification factor
M_i= In-plane bending moment
Mo= Out-plane bending moment

Piping Inputs & Outputs

INPUTS	OUTPUTS
P&ID	ISOMETRICS
MDS (MECHANICAL DATA SHEET)	GAD (GENERAL ARRANGEMENT DRAWING)
LINE LIST	3D MODEL
PMS (PIPING MATERIAL SPECIFICATIONS)	
STRUCTURAL MODEL	

Load Cases Considered During Stress Analysis:

Operating: Weight of pipe and fluid weight, Temperature, Pressure, Support Loads (Hangers) are considered during operating condition.

Sustained: Sustained loads are the sum of dead weight loads, axial loads caused by internal pressure and other applied axial loads that are not caused from temperature and accelerations etc.

Thermal Expansion loads: For the given diameter of pipe containing fluid the temperature is applied and the variations are observed.

SPECIFICATIONS OF STRESS ANALYSIS:

i. To ensure that the stresses in the pipeline in both cold and hot conditions are within the allowable limits.
ii. Flexibility analysis calculations carried out in case of pipelines subjected to restrained thermal expansion or contraction.
iii. To avoid vibration and leakage.
iv. The calculation of the forces, moments and stresses at all the significant locations of the piping system and their influence on the thermal expansion are calculated.
v. To check the piping configuration for safe operation from the design point of view (Pressure and Temperature).
vi. To comply with the applicable codes (IBR, ASME, EN, etc.)
Vii.To ensures the piping is well supported and does not sag or deflect in an unsighted way under its own weight, the weight of content and thermal insulation.
viii. To ensure that the deflections, when thermal and other loads are applied do not cause interference with adjacent piping, structures and components.

Inputs in the Software

By using this isometrics to input properties in to the Caesar software. Inputs are like material, temperature, pressure, elastic modulus, Poisson's ratio, fluid density etc.,

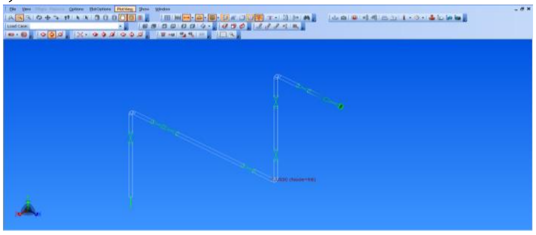


Fig-1: Input data and modelling diagram.

RESULTS WITH CAESER-II SOFTWARE IN DIFFERENT CONDITIONS AS FOLLOWS:

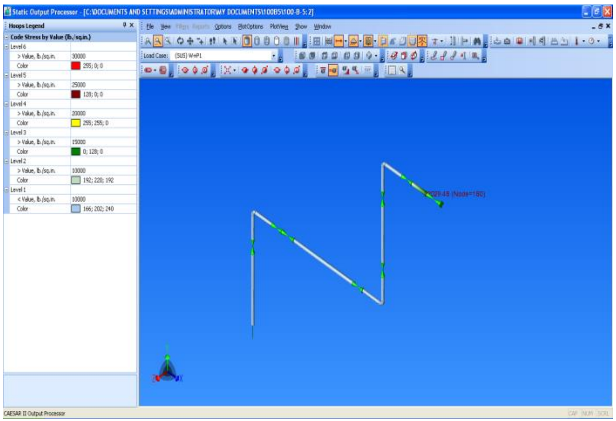


Fig-2: Stress distribution diagram after analysis.

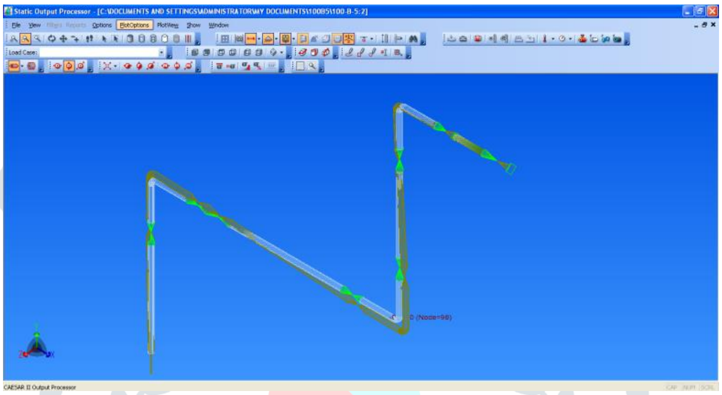


Fig-3: Stress distribution diagram after analysis.

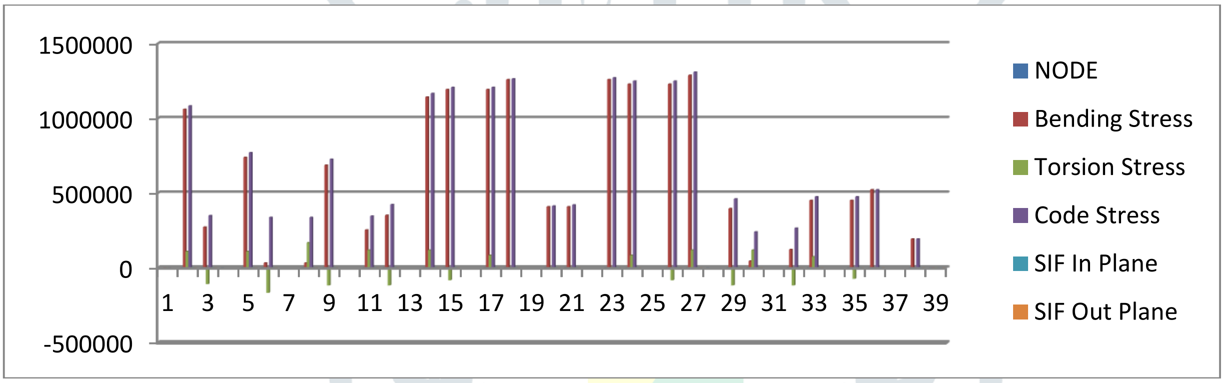
STRESSES REPORT IN EXPERIMENTAL CONDITION:

CAESAR II Ver.5.10.00, (Build 070917)					
STRESSES REPORT: Stresses on Elements					
STRESS CHECK PROCESSED: LOADCASE (SUS)					
Piping Code: B31.1 = B31.1					
NODE	Bending Stress lb/sq.in	Torsion Stress. lb/sq.in	Code Stress lb/sq.in	SIF In Plane	SIF Out Plane
20	6537.3	0	6725.9	1	1
30	2962.5	0	3093.5	1	1
40	2247.5	0	2361.7	1	1
50	1032	0	1126.7	1	1
60	3408.2	0	3439.1	1	0
70	0	0	713.2	1	1
80	3728.2	0	3759.1	1	1
90	2240.5	0	2271.4	1	1
100	1069.7	0	1623	1	1
110	312.7	0	427.1	0	0
120	402.3	0	533.6	1	1
130	3262.1	0	3439.4	1	1
140	3977.1	0	4171.3	1	1
150	3782.6	0	5406.3	1	1
160	5926.4	0	5045.9	0	1
170	0	0	3813.4	1	0
180	21998	0	22029	0	1

STRESSES REPORT IN OPERATING CONDITION:

CAESAR II Ver.5.10.00, (Build 070917)					
STRESSES REPORT: Stresses on Elements					
STRESS CHECK PROCESSED: LOADCASE 6 (OPE) W+T1+P1					
ASME-B31.1 = power piping					
N	Bending Stress (Kpa)	Torsion Stress (Kpa)	Code Stress Kpa	SIF In Plane	SIF Out Plane
10	1059872.4	108849.9	1082037.4	1	1
18	737832.1	108849.9	769316.6	3.257	2.714
19	32057	-167499.5	336567.4	3.257	2.714
20	685722.8	-117534.3	724933.1	3.257	2.714
28	350478.6	-117534.3	422048.1	1	1
29	1192336.5	-83109.3	1206491.3	3.257	2.714
30	1258876.4	0	1263294.4	3.257	2.714
38	407735	0	419626.8	1	1
39	1228293.4	-83109.3	1248375.1	3.257	2.714
40	395201.7	-117534.3	459865.8	1	1
48	121397.9	-117534.3	264603.1	3.257	2.714
49	449909	74036.2	473687.3	3.257	2.714
50	521643.2	0	521681.3	3.257	2.714
60	0	0	38	1	1

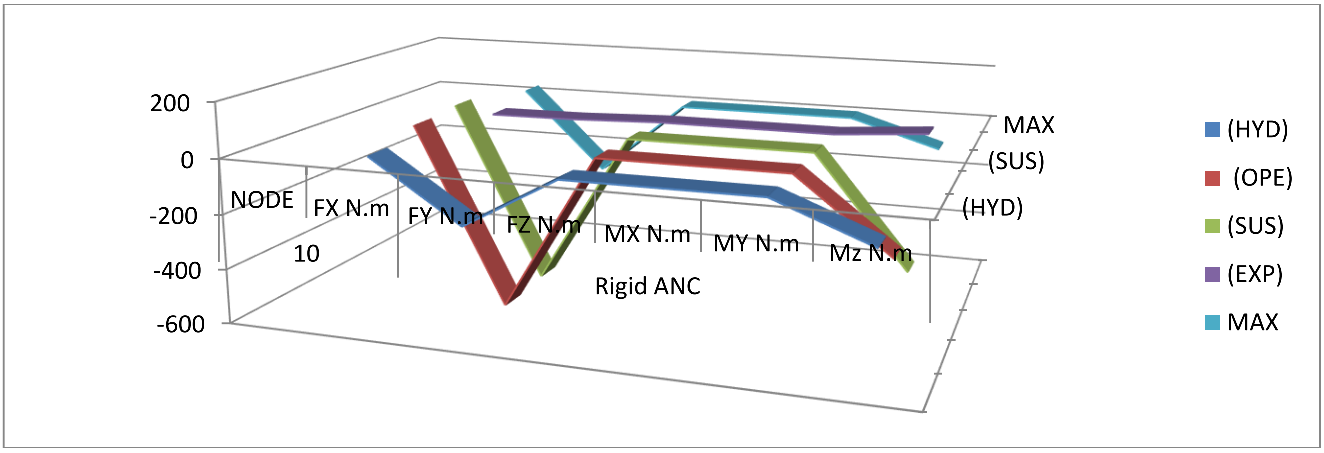
SIFGRAPHYCAL REPRESENTATIONS:

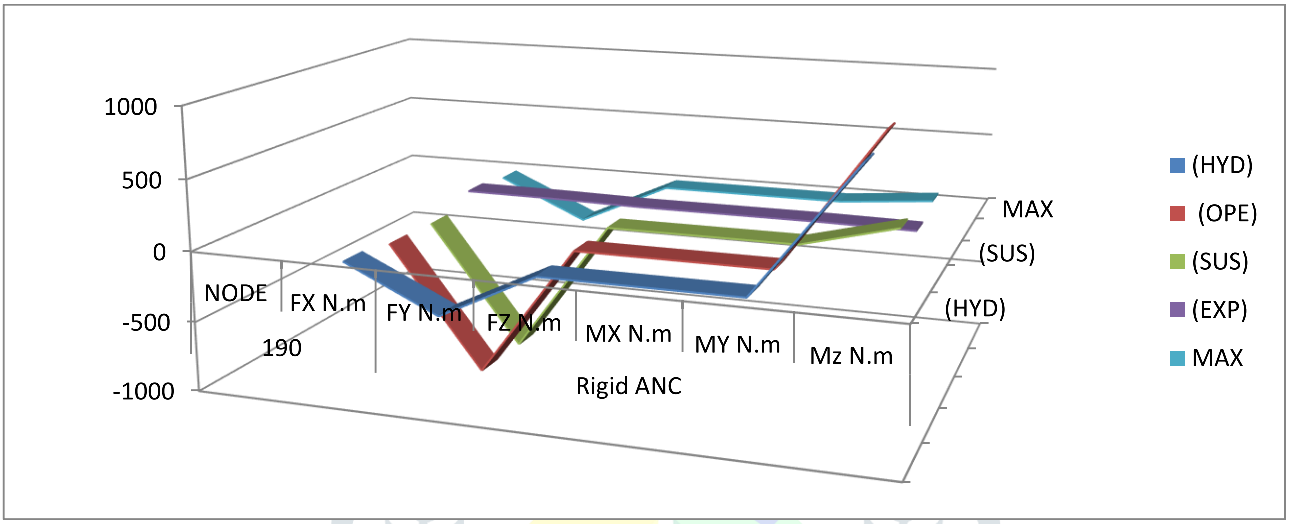


RESTRAINT SUMMARY:

CASE (OPE) W+T1+P1				
CASE (SUS) W+P1				
CASE (EXP) L6=L2-L4				
10		Rigid ANC		
NODE	FX N.m	FY N.m	FZ N.m	Mz N.m
(HYD)	26	-190	0	-130.9
(OPE)	70	-574	0	-260
(SUS)	83	-563	0	-405.5
(EXP)	-14	-11	0	25.1
MAX	27.6	-287	0	-101.833
190		Rigid ANC		
NODE	FX N.m	FY N.m	FZ N.m	Mz N.m
(HYD)	-26	-336	0	902
(OPE)	-70	-935	0	967.1
(SUS)	-83	-947	0	174.9
(EXP)	14	11	0	-7.8
MAX	-20.75	-315.667	0	58.3

GRAPHYCAL ANALYSIS:





CONCLUSIONS

The experimental results confirm the prior design and analysis of a Power Plant Piping System using CAESER-II software. This software allows the accurate modelling of piping system which is statically indeterminate. The colour diagram of stress distribution can be obtained after analysis and as per the colour definition at the top left corner, the red colour indicates the points of higher stresses, blue colour indicates the points of intermediate stresses and green colour indicates the lower stresses. The stress range factor shall be ideally less than or equal to one. The red zone area indicates for closer supervision during inspection.

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