Modelling and Stress Analysis of Flare Piping

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Abstract - For transportation of fluid, steam or air piping system is widely used. For installing the piping system pipes, flanges, piping supports, valves, piping fittings etc. are used, which are piping elements. They are manufactured as per Codes and standards. A Flare pipe line is designed and 3D modeling is prepared in PDMS software. Attention is focused for stress analysis by Caesar-II software. So that various stress values, forces and deflections are analyzed at each node to make the design at safe operating conditions. Due to manual procedure of analysis in providing support location welded joints in flare pipes which are subjected to sustainable loads, occasional loads and thermal expansion will fail.

Keywords: Flare pipe, PDMS Software

I. INTRODUCTION

1.1 PIPING

One of the major tasks in any process industry is the transportation of material often in a fluid form one place to another. The most commonly adopted method for the same is to force the fluid through the piping subject to the same set of design condition. The piping system involves pipes but also the fitting, valves and other specialties. These items are known as piping components. Code specifies the piping components as mechanical elements suitable for joining or assembly in to pressure – tight fluid – containing piping system.[1,7]
Piping element is defined, as, material required installing the piping system. Elements of piping include design, specifications, materials, components, supports, fabrication, inspection and testing

1.2 PDMS

PDMS as it is known in the 3D CAD industry, is a customizable, multi-user and multi-discipline, engineer controlled design software package for engineering, design and construction projects in, but not limited to, offshore and onshore oil & gas industry, chemical & process plants, mining, pharmaceutical & food industry, power generation and paper industries.
PDMS enables both manager and engineers to take full advantage of unrivalled functionality, satisfying the demands of complex plant design, whilst maintaining the quality of the engineering deliverables. At any stage of project across all its discipline areas, PDMS enables, traditional deliverables, such as general arrangement and piping isometric drawings, reports and material take-offs to be extracted much earlier and for free from the data driven environment[2,4]

1.3. STRESS ANALYSIS

Piping Stress analysis is a term applied to calculations, which address the static and dynamic loading resulting from the effects of gravity, temperature changes, internal and external pressures, changes in fluid flow rate and seismic activity. A hot piping system will expand or elongate. A cold piping system will contract or shrink. Both these create stress problems. Stress analysis determines the forces exerted in the pipe, anchor points, restraints in piping system, stress induced in pipe must be checked against the allowable limits as per the respective codes and standards.[5,8]

II. FLARE PIPING

Flare is a combustion process through which hydrocarbon gases/VOC are burned either in open or in enclosed chambers. The primary advantage of flares is that they have high turndown ratios. With this feature they can be used for sudden and unexpected large discharge of hydrocarbons/VOCs such as safety valve discharges as well as venting process setups, non-environment friendly products or waste stream. The main advantage of flares is safe, effective disposal of gases at an affordable cost. [2,6]

The flare system probably is the least rewarding part of your plant. It is an expensive hole-in-the-pocket that has no economic redeeming features. But you must have one or all your combustible gaseous emissions from relief valves (and other sources that we won't make a big fuss about) will be emitted to pollute the atmosphere and, more importantly, is a major safety concern. [3,5]

2.1 STRESS

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III. CODES& STANDARDS

4.5 Codes & Standards

A group of general rules or systematic procedures for design, fabrication, and installation prepared in such a manner that it can be adopted by legal jurisdiction and mode into law.

Documents prepared by a professional group or committee, which are believed to be good and engineering practice and which contain mandatory requirements.

- ASME B 31.3 : Process Piping
- ASME B 16.5 : Steel Pipe Flanges and Flanged Fittings
- ASME B 16.11 : Forged Steel Fittings, Socket Welded and Threaded
- ASME B 16.9 : Wrought Steel Butt Welding Fittings
- ASME B 36.10 : Welded and Seamless Wrought Steel Pipe
- ASME B 16.20 : Ring Joint Gasket and Grooves for Pipe Flange
- ASME B 18.2.1 : Square and Hex. Bolts and Screws
- ASME B 18.2.1 : Square and Hex. Nuts
- API 602 : Compact Steel Gate Valves
- API 600 : Bolted Bonnet Steel Gate Valves
- BS 5352 : Check Valves – Socket Welded & Threaded
- BS 1873 : Steel Globe Valves – Flanged & Butt Welded
- BS 1868 : Steel Check Valves – Flanged & Butt Welded
- BS 5351 : Steel Ball Valves – Flanged & Socket Welded

IV. CLASIFICATION OF PIPING MATERIALS

4.1 Purpose of piping stress analysis

- Safety of piping and piping components.

- Safety of connected equipment and supporting structure.
- Piping deflections are within the limits
- Interrelated with piping layout and support design
- Layout should take care of sufficient flexibility for thermal expansion, and simplified supports
- Pipe section properties to be suitable for intended service, temperatures, and pressures and anticipated loadings.

Support locations and types to satisfy nozzle loads, valves accelerations and piping movements
How Piping and Components Fail (Modes of Failures);
There are various failure modes, which could affect a piping system. The piping engineers can provide protection against some of these failure modes by performing stress analysis according to piping codes.
Failure by general yielding: Failure is due to excessive plastic deformation. Yielding at Sub Elevated temperature Body undergoes plastic deformation under slip action of grains.
Yielding at Elevated temperature: After slippage, material recrystallizes and hence yielding continues without increasing load. This phenomenon is known as creep.
Failure by fracture: Body fails without undergoing yielding.
Brittle fracture: Occurs in brittle materials.
Fatigue: Due to cyclic loading initially a small crack is developed which grows after each cycle and results in sudden failure.

4.2 PROCEDURE OF ANALYSIS

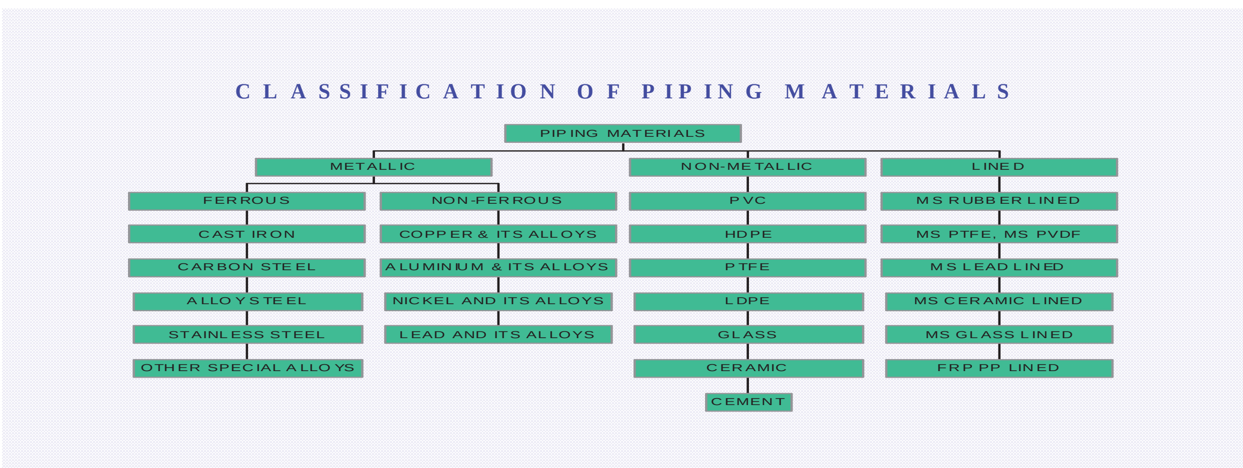


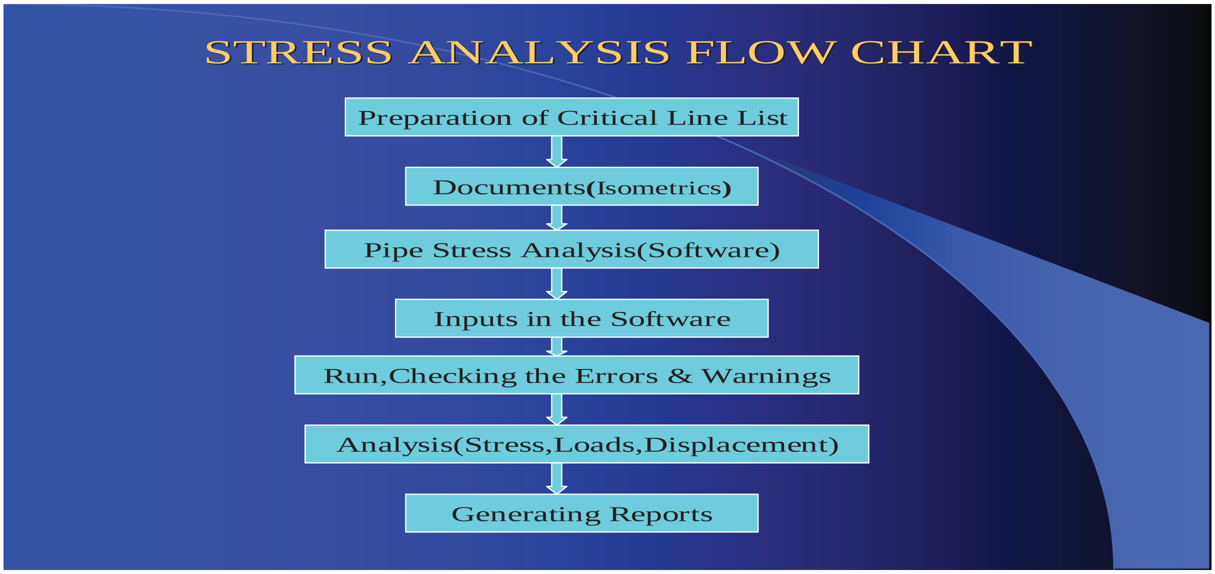
FIG.A

4.3 PROCEDURE FOR STRESS ANALYSIS

- Identify the possible loads that the piping system would encounter during the life of the plant. (Self weight, wind, seismic etc.)
- Relate each of these loads to the stresses developed.
- Get the cumulative effect of the possible loads in the system.
- Find end connection displacement to the equipment (Nozzle) with thermal displacement or other critical load. As per allowable load at end connection find the stress and for compensate the effect place supports & loops if required.
- As per allowable limits find the deformation (using Caesar) and place the supports as per requirements.
- After the system is designed, to ensure that the stresses are within the safe limits.

Several loadings are experienced by the piping systems during their service life. However, not all the loadings produce the same kind of effect and hence their design treatment cannot be the same.
Input:

- Preparation of Critical Line List
- Documents (Isometrics)
- Pipe Stress Analysis (Software)



- Inputs in the Software

Analysis:

- Run, Checking the Errors & Warnings
- Analysis (Stress, Loads, Displacement)

Output:

- Generating Reports

4.4 Preparation of Critical Line List

The first step in the stress analysis work process is to identify the lines on the critical lines list. The critical lines list is a list of line numbers that are likely to receive formal calculations by the stress engineer. This list of lines is important to the designer. It identifies those lines that have the most potential for layout revision requests. The revision requests typically come from the stress engineer on the project.

4.5 Documents (Isometrics)

The stress engineer uses the stress isometrics to serve as the basis for a formal calculation. The piping layout designer draws the preliminary isometrics.

4.5 Inputs in the Software

By using this isometrics to input properties in to the Caesar software. Inputs are like material, temperature, pressure, density etc

4.5 Run, Checking the Errors & Warning

After completion of input, check the errors by using error check button in the software. After completion of the error

	THICKNESS CALCULATIONS AS PER ASME B 31.3	REV	0
DOCUMENT NO.			

Design code ASME B31.3

Pipe thickness

Minimum thickness of pipe selected, $\bar{T}$ >= t_m + manufacturer's minus tolerance(12.5%)
Minimum required thickness, t_m = t + c
Pressure design thickness, t = $\frac{PD}{2(SEW+PY)}$

Piping spec

Pipe details

Pipe material		ASTM A 106 Gr B	Welded ASME B 36.10
Pipe size (outside diameter)	D	32	NPS
Design Pressure	P	285	psig
Design Temperature	T	176	°F
Basic allowable stress in tension at design temperature (from Table A-1)	S	20000	psig
Corrosion allowance	c	1.6	MM
Longitudinal weld joint factor (form Table A-1B)	E	0.85	(E = 1, for seamless pipes)
Coefficient (from Table 304.1.1)	Y	0.4	(Y = 0.4, for temperatures at 900°F and below)
Weld joint strength reduction factor, per para 302.3.5 (e)	W	1	(W = 1, for Temperatures at 950°F and below)

Pipe size (NPS)	Outside diameter (MM)	t (MM)	c (MM)	t_m (MM)	t_m + (negative mill tolerance of 12.50 %)	Selected thickness, $\bar{T}$ (MM)	(Note 7)	
1/2	21.3	0.18	1.60	1.78	2.03	N A	N A	N A
3/4	26.7	0.22	1.60	1.82	2.08	N A	N A	N A
1	33.4	0.28	1.60	1.88	2.15	N A	N A	N A
1 1/4	42.2	0.35	1.60	1.95	2.23	N A	N A	N A
1 1/2	48.3	0.40	1.60	2.00	2.29	N A	N A	N A
2	60.3	0.50	1.60	2.10	2.40	N A	N A	N A
3	88.9	0.74	1.60	2.34	2.68	N A	N A	N A
4	114.3	0.95	1.60	2.55	2.92	N A	N A	N A
6	168.3	1.41	1.60	3.01	3.44	3.58	...	...
8	219.1	1.83	1.60	3.43	3.92	3.96	...	...
10	273	2.28	1.60	3.88	4.44	4.78	...	...
12	323.8	2.71	1.60	4.31	4.92	5.16	...	...
14	355.6	2.97	1.60	4.57	5.22	5.33	...	...
16	406.4	3.40	1.60	5.00	5.71	6.35	Sch 10	...
18	457.2	3.82	1.60	5.42	6.19	6.35	Sch 10	...
20	508	4.24	1.60	5.84	6.68	7.14	...	...
32	812.8	6.79	1.60	8.39	9.59	10.31	...	...

check to run the input by using run button[2,8]

4.6 Results of analysed flare piping nozzle loads

Nozzle	Load	Force		
Node No.	condition	Fx (N)	Fy (N)	Fz (N)
160	Oper.	4379	-2317	9669
	Sus	-36	-2456	-61
	Allow.	15000	15000	15000
320	Oper.	788	-1236	2440
	Sus	0	-613	-11
	Allow.	2500	2500	2500
540	Oper.	48	-1896	-1421
	Sus	-2	-939	-52
	Allow.	3750	3750	3750
720	Oper.	27	3589	3096
	Sus	7	-1177	-62
	Allow.	3750	3750	3750

TABLE.1

Max. Allow. Stress Of Given System Is **343155.5** Kpa
Actual Stress Max. At Node 260 Is **295349.0** Kpa
Stress Ratio Of Given System Is Ratio Of Actual Loads Per Max.To Allow. Loads.

STRESS RATIO = <u>ACTUAL LOADS PER MAX.</u> X 100
ALLOW.LOADS

4.7 PIPE THICKNESS CALCULATIONS

Analysis:

After completion of the run, to check the coad stress check, nozzle loadings, restraints loadings, displacements and etc.

Generating Reports: After completion of Analysis to create a output report in text format

4.8 PDMS MODELS

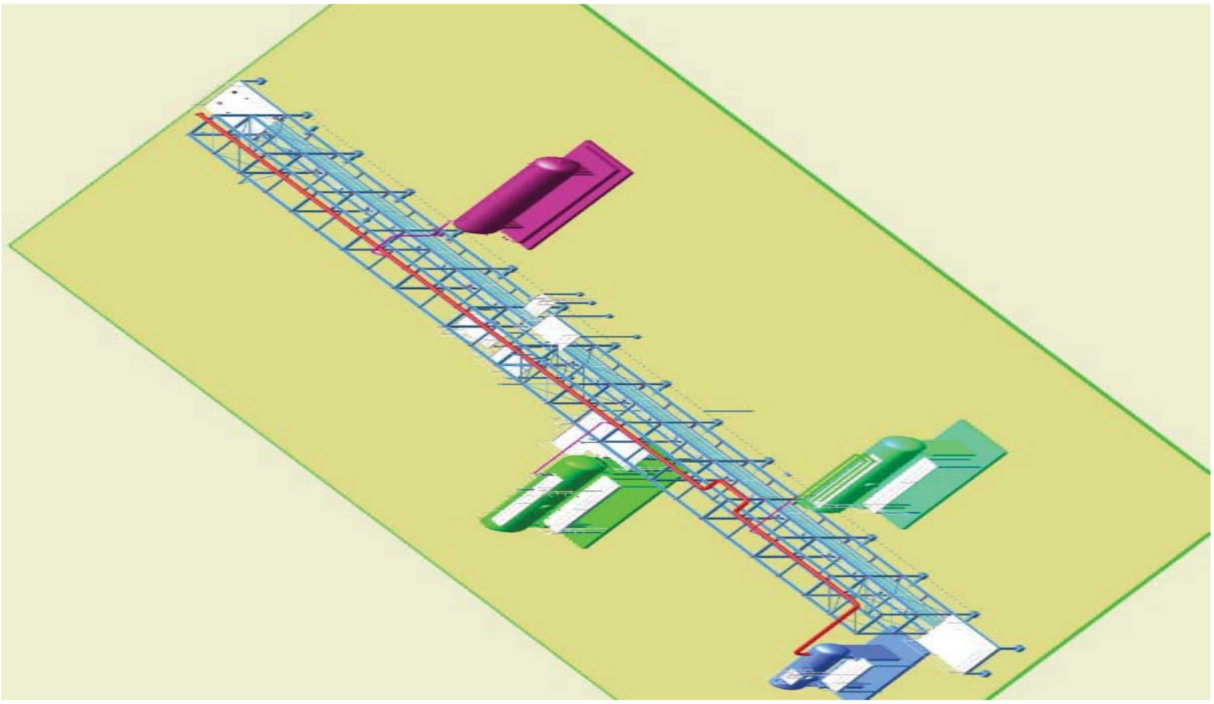


FIG.C

V. FUTURE WORK

1. The material used for the blades in this turbine is aluminum, in further study alternate material like synthetic fibers, composite material can be used to reduce weight and increase strength of the blade.
2. The design of turbine blades in a project is a semi circular bucket with constant thickness in further study the blade can be made aerofoil instead of constant thickness.
3. The wind speed in site report is presented only in hourly basis, in future work the wind speed can be recorded monthly and yearly basis.
4. Analysis of stress developed in the blades using the packages like ANSYS.
5. Study of the airflow over the wind turbine blade in order to reduce eddy loses and friction loses.

IV. CONCLUSION

Stress Analysis of Flare line between equipments to knock out Drum is made as safe by providing an expansion loop. As per ASME 31.3. Equipments and knock out Drum nozzles are within then Allowable. Stress, Nozzle loads, Restraint loads, all are within the limit after providing an expansion loop as per Standards

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