DESIGN AND STRESS ANALYSIS OF FLARE PIPING IN CRUDE OIL PROCESSING INDUSTRIES

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Abstract

In a transportation of fluid, steam, air piping system is widely used. For installing the piping system pipes, flanges, piping supports, valves, piping fittings etc. are used, which are piping components. They are manufactured as per Codes and standards of ISO or DIN. Equipment and piping layout design as per process requirement and available space. Above layout made out by the help of General arrangement drawing, plant layout. Then after flexibility providing to piping system, for compensate the varios loads by the engineer. Stresses in pipe or piping systems are generated due to loads like expansion & contraction due to thermal load, seismic load, wind load, sustained load, reaction load and the other fatigue cycle load etc. the stress analysis is done by help of software like CAESAR II. In this paper, 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.

Keywords—: Caesar Model, Stress Isometrics 3D, Pipes, Flanges, Stress analysis part, Thickness Notch calculations.

I. Introduction

Piping element is defined as material required installing the piping system. Elements of piping include design specifications, materials, components, supports, fabrication, inspection and testing. Most of the operation in a process industry occurs at temperatures and pressure, which are different from normal atmospheric condition. These operation are often hazardous and do put the surroundings at risk. The job of the mechanical engineer is to confirm these risky operations within vessels and pipes, act as boundaries between these risky but necessary operations and the outer world. While protecting the outer world from risk, these structures suffer stress and stress themselves. They have their own limitations detected by their material of construction, method of designing and construction/ fabrication, schedule of maintenance and their physical age. Any flaw or shortcoming in any of these aspects would mean that these structures would be unable to do their protector's roll perfectly, and mishaps would occur. Mechanical designer have to make sure that the structure would guarantee reasonable safety for a reasonable period of time and not fail in spite of continuous or intermediate harsh condition faces by their design structure.

Stress analysis is a subject, which is more talked about and less understood. The objective of pipe stress analysis is to ensure safety against failure of the piping System by verifying structural integrity against the loading conditions, both external and internal, expected to occur during the lifetime of the system in the plant. This is to be undertaken with moist economic considerations. Modern conditions of

engineering technology, together with economics, demand that major plant items require minimum forces and moments acting upon them from outside sources such as pipe work. The result of this is an increased from outside sources such as pipe work. The result of this is an increased awareness of the importance of correctly calculating, and achieving in practice, the forces and moments applied to plant items by external pipe work systems.

Over the year, it has been a proactive to design and fabricate pipe work to a particular code or specification. These codes or specifications may be national, international, or the purchaser's own. The number of such codes, all varying in some way form one another, illustrates the complexity and the differing ideas, which exist on the subjects of pipe work design. The development of computer programs has reduced considerably the mundane effort which was previously required in the calculation of stress levels, terminal forces, and moments in complex piping systems.

The piping group to develop and layout the plot plan use flow diagram. The logical basis for the piping system design is the flow diagram. When developing the plot plan, the arrangement of equipment in the facility reflects the logical sequence of flow depicted on the flow diagram. Once the plot plan is finalized the piping designer routes the pipe between two vessels as indicated by the flow diagram using piping specifications and accepted design practices.

FLARE PIPING

Flare is a combustion process through which hydrocarbon gases are burned either in open or in enclosed chambers. The primary advantage of flares is that they have high turn down ratios. With this feature they can be used for sudden and unexpected large discharge of hydrocarbons 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. 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.

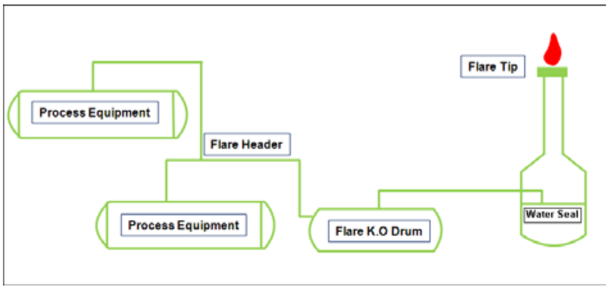


Fig.1 General Arrangement of Flare Piping

II. Designing And Analysis Tools

PDMS as it is known in the 3D CAD industry, is a customize, 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.

CAESAR: Present day process plant piping systems use various fluids at various conditions of pressure and temperature. The piping engineer has to design the systems to ensure reliability and safety throughout designed plant life. The piping systems are subjected to combined effects of fluid internal pressure, it s own weight and restrained thermal expansion. The elevated temperature also affects the pipe strength adversely. The stress engineer of a piping design department performs the necessary calculations to ascertain that the various Requirements due to internal pressure, thermal expansion and external weight are satisfied. Various computer packages are available in the market, which perform the required rigorous analysis. These analyses are basically static analyses. There are situations where stresses are introduced into the piping systems due to dynamic loading situations like reciprocating compressor vibration, safety valve discharge etc. However it is the static analysis which most of the pipe stress engineers perform and are acquainted with.

Now the present day computer packages that are being used (CEASAR-II, CAEPIPE, PIPEPLUS etc.) are quite comprehensive and if the piping configuration and pipe data are fed properly, comprehensive analysis are done through the computer packages. This has improved pipe stress analysis job productivity immensely. However sometimes this has led to a decline in the knowledge about the basics of pipe stress analysis especially in situation where the stress analysis engineer after acquiring some sort of skill in the use of the analysis package does not make effort to learn about the basics of pipe stress. Some of the ideas about the basics of pipe stress have been enumerated herein. CAESAR II is a PC-based pipe stress analysis software program developed, marketed and sold by INTERGRAPH Engineering Software. This software package is an engineering tool used in the mechanical design and analysis of piping systems. The CAESAR II user creates a model of the piping system using simple beam elements and defines the loading Conditions imposed on the system. With this input, CAESAR II produces results in the form of displacements, loads, and stresses throughout the system. Additionally, compares these results to limits specified by recognized codes and standards. The popularity of CAESAR II is a reflection of Code's expertise in programming and CAESAR II gingering, as well as CAESAR II dedication to Service and quality.

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. For a given a piping system the type of analysis to be carried out depends upon the size of the pipe, temperature and connected equipment.

III. Material Selection

The Below figure shows various alternatives of materials, which can be used for Flare Piping.

Fig.2 Classification of Materials

A. FERROUS MATERIALS

i. CARBON STEELS ..Carbon Steels Is an alloy of Iron and Carbon Contains 0.1 % to 1.5 % of Carbon

Based on Carbon Content it can be classified into 1. Mild steel - 0.05 % - 0.30 %

2. Medium Carbon steel – 0.30 % - 0.70 %

3. High carbon Steel – 0.70 % - 1.5 %

4. It can withstand up to a temperature of 450 C

General chemical composition of CS is C - 0.07, 1.56 %, Mn – 1.6 %,

Si – 0.6 %, S – 0.1%, P – 0.1%.

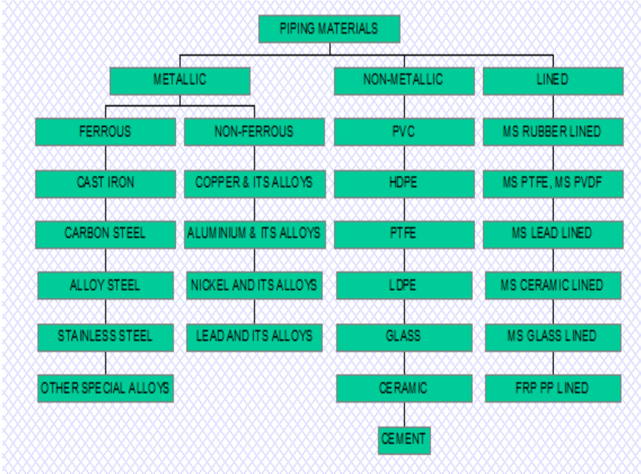
CARBON STEEL – MATERIAL COMPOSITION

MATERIAL	CHEMICAL COMPOSTION				
	C	Mn	Si	P	S
A106 GrB (1/2"-14")	0.3	0.29 - 1.06	0.1	0.035	0.035
API 5L GrB (1/2"-14")	0.27	1.15	-	0.04	0.05
A53 GrB (1/2"-14")		0.9	0.15 - 04	0.035	0.035
A105 (S.W.) (1/2"-1½")	0.35	0.9	0.35	0.05	0.05
A216GrWCB 2" & above	0.3	1	0.6	0.04	0.045

Table 1 Carbon Steel Material Composition

ii. ALLOY STEELS

When Alloy Steels are generally considered to be steels to which one or more alloying elements, other than carbon, have been added to give them special properties that are different than those of straight carbon steels. From the standpoint of composition, steel is considered to be an alloy steel when amounts of manganese, silicon, or copper exceed the maximum limits for the carbon steels, or when purposeful addition of minimum quantities of other alloying elements are added. These could be chromium, molybdenum, nickel, copper, cobalt, niobium, vanadium, or others......



WHAT ARE THE EFFECTS OF ALLOYING?

- Improved Corrosion resistance
- Better Hardenability
- Improved Machinability
- High or low temperature Stability
- Ductility
- Toughness
- Better Wear resistance

DESCRIPTION	CHEMICAL COMPOSTION				
	C	Mn	Si	Cr	Mo
Ferritic alloy steel pipe for high Temp services	0.05 - 0.15	0.3 - 0.6	0.5	1.9 - 2.6	0.87 - 1.13
	0.08 - 0.12	0.3 - 0.6	0.2 - 0.5	8 - 9.5	0.85 - 1.05
Pipe fitting alloy steel for moderate and elevated Temp	0.05 - 0.15	0.3 - 0.6	0.5	1.9 - 2.6	0.87 - 1.13
Alloy steel castings for Pr containing parts suitable for high Temp services	0.18	0.4 - 0.7	0.6	2 - 2.75	0.9 - 1.2

Table 2 Alloy Steel Material Composition

iii. STAINLESS STEEL

When sufficient nickel is added to iron-chromium alloys, an austenitic (FCC) structure is retained at room temperature. Austenitic stainless steels possess an excellent combination of strength, ductility, and corrosion resistance. These steels cannot be hardened by quenching, since the austenite does not transform to martensite. A stronger type of stainless steel has been developed which takes advantage of precipitation reactions within the metal matrix made possible by addition of elements such as aluminum, titanium, copper, and nitrogen. These materials are referred to as precipitation— hardenable stainless steels. Both martensitic and austenitic stainless steels can be enhanced in this manner.

Posses greater percentage of chromium which forms a chromium oxide film exposed to air that prevents chemical attack of moist air on the material surface

Nickel retains the austenitic structure of steelGreater resistance to corrosion than all types of steels Classified into three types based on its micro structure

1. Austenitic stainless steel
2. Ferritic stainless steel
3. Martensitic stainless steel

MATERIAL	CHEMICAL				
	C	Mn	Cr	Mo	Ni
A312	0.036	2.01	19-21	-	9 -10
Gr.TP316L	0.26	1.16	15-17	2-3	10 -13
A403	0.07	2	18-20	-	8 -10
A351	0.08	1.5	18-20	-	8 -10
A182	0.06	2	18-20	-	8 -10

Table 3 Stainless Steel Material Composition

B. NON-FERROUS MATERIALS

i. NICKEL AND ITS ALLOYS

- Easy Machinability and weldability
- Chloromet and Hastelloy are widely used other than Monel 400
- Not resistant to oxidising environments
- Monel 400 is used to handle dilute sulphuric acid and hydrochloric acid
- Alkalis and sea water do not affect Nickel

ii. ALUMINIUM AND ITS ALLOYS

- Good thermal conductivity
- Most workable metal
- Highly resistant to atmospheric conditions, industrial fumes, fresh brackish or salt water
- Not resistant to corrosion
- Loses strength rapidly at 1750C.

iii. TITANIUM

- Strong and medium weight
- Titanium Oxide is formed which prevents corrosion
- Resistant to Nitric acid of all concentrations except fuming nitric acid
- Welding requires inert atmosphere
- Loses strength above 4000C
- Provides good resistance to hydrochloric acid when alloyed with 30%

iV. MOLYBDENUM

- Not affected by impingement and crevice corrosion

IV. Designing Issues

Piping in a particular plant can be compared with arteries & veins in our body. There are mainly two types of pipes from manufacturing

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point of view. The first is Seamless pipes & second is Welded pipes.

Various attributes of pipe are described below.

A) End Preparation: There are three types of end preparation of pipes.

- ☐ Plain End (PE)
- ☐ Butt weld or Beveled End (BW/BE)
- ☐ Threaded End

B) Design & Dimension Standard:This will provide the following information.

Nominal Bore (NB), Thickness, Outside Diameter (OD), Tolerance & Weight.

The Dimension Standard for pipe is as follows.

ANSI/ASME B 36.10 For Carbon Steel (CS), Low Temperature Carbon Steel (LTCS), Low Alloy Steel (LAS) Pipes

ANSI/ASME B 36.19 For Stainless Steel (SS) Pipes

C) Material

CS: It is used for temperature range from (–) 290C to 4270C.Most commonly used CS materials are as follows:

ASTM A 106 Gr. B (Seamless pipes) API 5L Gr. B (Seamless & Welded) ASTM A 53 Gr. B (Seamless & Welded) IS 1239 (Upto 6” & ERW)

IS 3589 (Above 6”)

LTCS: It is used for low temperature i.e. from (–) 460C to 3430C. The most commonly used LTCS materials are as follows:

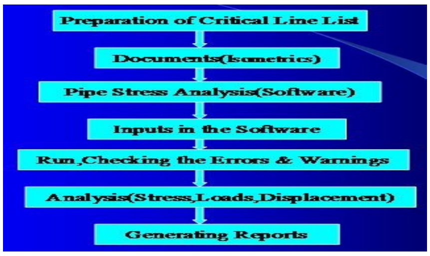
ASTM A 333 Gr. 6(Seamless pipes) ASME A 671 (Welded pipes)

LAS: It is used for high temperature i.e. (-) 290C to 3430C. The most commonly used LAS materials are as follows:

ASTM A 335 Gr. P11, P12, P9 (Seamless pipes) ASTM A 691 Gr.C60, C65, C70 (Welded pipes)

SS:It is used for cryogenic temperature range i.e. from (-) 1960C to 5380C. Most commonly used SS materials are as follows:

ASTM A 312 TP 304 / ASTM A 312 TP 304L
ASTM A 312 TP 316 / ASTM A 312 TP 316L



ASTM A 312 TP 321

FLANGES

Flanges are used to make a joint that is required to be dismantled. Various attributes of Flanges are described below:

1) Type: There are five types of Flanges.

A) Weld Neck Flange: It has Butt Weld End Connection. Radiography Test (RT) is possible.

B) Socket Weld Flange: Here Fillet welding is done from outside only. Die Penetration Test (DP) is possible.

C) Slip On Flange: Here Fillet welding is done from inside as well as from outside. DP Test is possible.

D) Threaded Flange: It is mainly used in Galvanized pipes.

2) Facing: There are four types of facing.

A) Raised Face: It is specified up to 600 (psi) rating pipe class.

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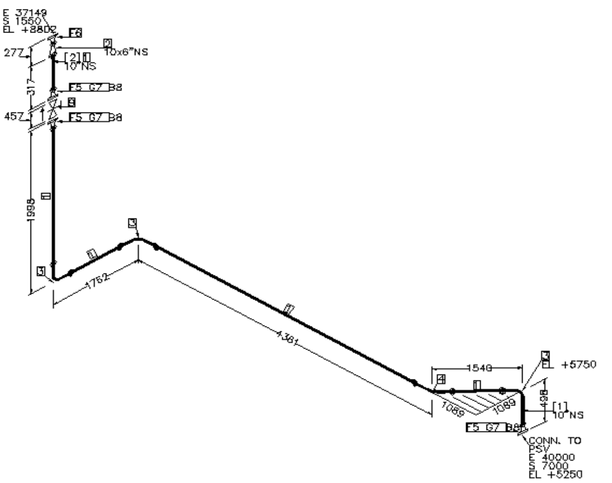
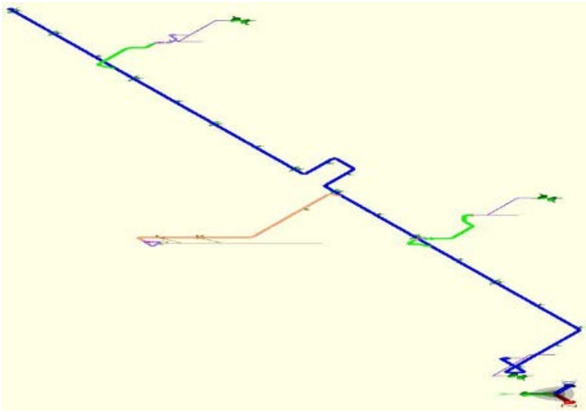


B) Ring Joint: It is specified from 900 rating (psi) & above pipe class.



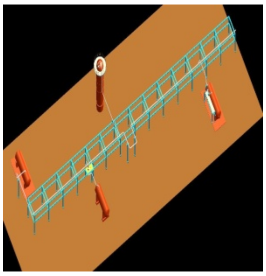
C) Flat Face: It is only used for 150 (psi) rating pipe class. It is specified for utility fluids like Cooling Water and Low Pressure Nitrogen.

D) Tongue & Groove: Its use is mainly dependent upon the nature of fluid to be handled.It is specified to handle extremely hazardous fluids like Liquid Ammonia.

V. Results and discussions.

Pipe Stress analysis provides the necessary technique for engineers to design piping systems without over stressing and overloading the piping components and connected equipment. The following terms from applied mechanics are briefly discussed (not defined) here to familiarize the engineer with them.

Fig.3 Flow chart for Stress analysis



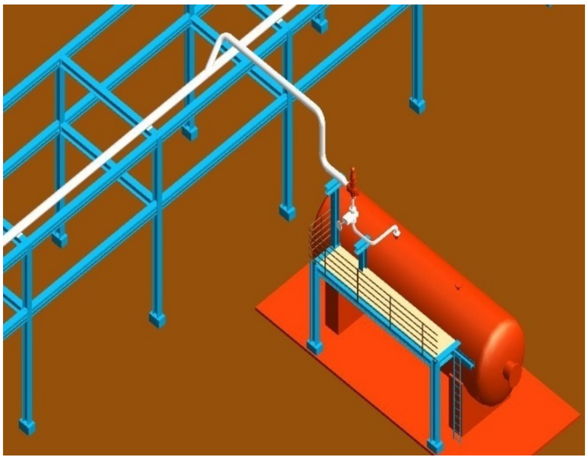


Fig.4 PDMS Model

Fig.5 PDMS Isometric Model

Fig.6 CEASER Model

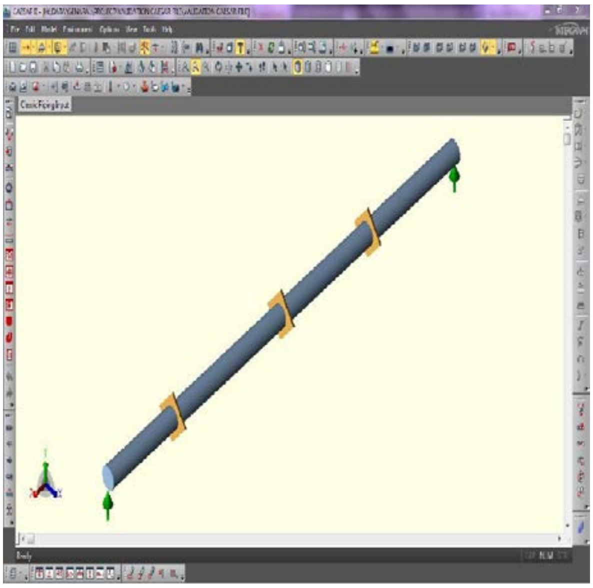


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Fig.7 CEASER Model Snapshot

Table-4 Error between Caesar Software and manual Calculations

S.NO	LOAD CASE	TYPEOF LOAD/STRESS	CAESAR CALCULATED VALUE	HAND CALCULACTION VALUE	% ERROR
1	SUSTAIN	Shear Force	10000 N	10000 N	0
2		Bending Moment	15000 N-m	15000 N-m	0
3		Axial Stress	993.3 KPa	993.27 KPa	0.003
4		Bending Stress	30609.8 KPa	30609.777 KPa	0.000075
5		Torsion Stress	0 KPa	0 KPa	0
6		Hoop Stress	2058.9 KPa	2136 KPa	3.6095
7		Code Stress	31603.0 KPa	31603.047 Kpa	0.000487
8		Code Stress Ratio	26.8 %	26.8 %	0

After comparing the values derived from manual calculations and the ones obtained from Caesar 2014 software, it was observed that the software's results are identical to the manual calculations. Only in one case did the software deviate from the expected value. However, that deviation was only 3.6%. As per industrial norms, a deviation of 10% is allowed. The 3.6% deviation observed here is well within that allowed deviation. Therefore, it can be concluded that software generates expected results and is free of any errors.

Stress Analysis of Flare pipeline between equipment's to knock out Drum is safe. As per ASME 31.3. Equipment's and knock out Drum nozzles are within the Allowable Range. Stress, Nozzle loads, Restraint loads, all are within the limits after providing an expansion loop as per Standards.

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