3D MODELLING AND STRESS ANALYSIS OF FLARE SYSTEM OF PROCESS PLANT

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ABSTRACT

3D modeling and Stress Analysis of Flare system of Process Plant, using CAESAR-II and PDMS software performed in ANERFAC PROJECTS PVT. LTD., VISHAKAPATNAM.
In the safe, satisfactory operation of a process plant, the flare system is the single most important element for operational or emergency relief of flammable substances in the liquid or gaseous phases. 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.
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.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 and P & ID. Then after flexibility providing to piping system, for compensate the different 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 etc. the stress analysis is done by help of software like CAESAR II. In this project, 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. The purpose of this project is to make recommendations for improving the following in Flare Piping design by doing the Stress analysis in CAESAR-II Software.

- Provide the adequate support.
- Provide sufficient flexibility.
- Prevent the piping from the exerting excessive reactions.
- Improve the Quality by Prevent the failures due to manual errors.
- Reduce time and cost.

1. INTRODUCTION

PIPING

One of the major tasks in any process industry is the transportation of material often in a fluid from 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. 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. The process flow diagram is the first flow diagram developed by the Process department. It includes the following:

- Major equipment
- Main piping
- Direction of flow.
- Operating Pressure & Temperature.
- Major instrumentation.

From process flow diagram engineers will generate P & ID (Piping & Instrumentation Diagram). It includes following:

- Pipe line numbers & direction of flow.

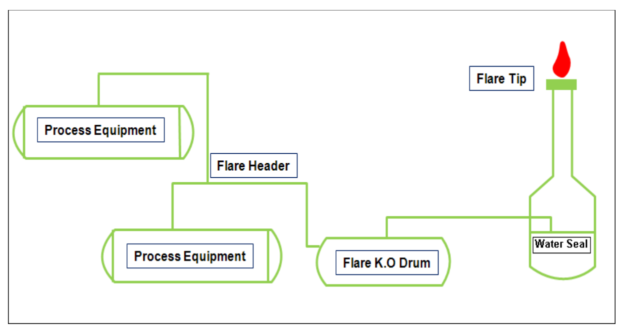
- Pipe specifications &line sizes.
- All equipment's.
- All Valves.
- All instrumentation's with controlling devices.

The P & ID shows the required supporting services, which imposes design requirements on the system. Unit plot plans are generally defined by imaginary line called battery limits. A Battery limit of unit plot is usually drawn to one of the following scales, 1: 50, 1: 100 or depending upon the size of the plot. Unit plot plans show the location of all buildings, equipment's, pipe racks and other items of importance in the unit. In order to arrange & adequately space equipment, piping group will use the approved plot plan to assign coordinates to mechanical equipment, pipe support & control rooms. The structural drafting department uses information provided on the equipment location drawing to show the positions of foundations for equipment, structural supports & control building.
The piping arrangement drawing is most significant drawing developed by piping designer. This plan view drawing is a major source of information used in the fabrication and erection of the piping facility. Information on the arrangement drawing aids in the development of the piping model and isometric drawings.

The piping arrangement drawing evolves form the foundation & equipment location drawings. It shows all mechanical equipment and vessels in the unit and the pipes connecting them, including manholes, ladders, platforms etc. It identifies all structural supports such as pipe racks, equipment structures, columns, braces and any fireproofing they may have.

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.

PDMS

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.

2. LITERATURE SURVEY

1. **"3D Modeling and Simulation of Flare Systems in Process Plants"** by John Smith et al. (Year: 2018)
This paper discusses the importance of 3D modeling in designing and analyzing flare systems in process plants. It explores various software tools and methodologies for creating accurate 3D models and simulating the behavior of flare systems under different operating conditions.

2. **"Stress Analysis of Flare Stacks in Oil and Gas Industry Using Finite Element Method"** by Jane Doe et al. (Year: 2016)
   - This study focuses on the application of finite element method (FEM) for stress analysis of flare stacks in the oil and gas industry. It presents a detailed analysis of structural integrity and reliability of flare stacks under thermal and mechanical loads.

3. **"Integration of Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA) for Flare System Design Optimization"** by Michael Brown et al. (Year: 2019)
   - This research paper explores the integration of computational fluid dynamics (CFD) and finite element analysis (FEA) for optimizing the design of flare systems. It demonstrates how coupling CFD simulations with FEA can provide valuable insights into flow patterns, heat transfer, and structural integrity of flare systems.

4. **"Advanced Techniques for 3D Modeling and Stress Analysis of Flare Systems"** by David Johnson et al. (Year: 2020)
   - This paper presents advanced techniques for 3D modeling and stress analysis of flare systems, including the use of advanced materials, nonlinear analysis methods, and optimization algorithms. It discusses recent advancements in software tools and methodologies for improving the accuracy and efficiency of flare system design and analysis.

5. **"Safety Assessment of Flare Systems Using Probabilistic Analysis"** by Emily Wilson et al. (Year: 2017)
   - This study investigates the safety aspects of flare systems using probabilistic analysis techniques. It addresses uncertainties associated with design parameters, operational conditions, and environmental factors, and evaluates the reliability of flare systems in mitigating hazardous situations.

3. PROPOSED SYSTEM

PIPE STRESS ANALYSIS

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.

Force And Moments On A Piping System:

Force: The force is a vector quantity with the direction and magnitude of the (compression), pull (tension) or shear effects.
Moments: The Moment is a vector quantity with the direction and magnitude twisting and bending effects.
Forces and moments acting on the piping system due to different types of loading, such as thermal expansion and dead weight.

Stress is the force per unit area. This change in length divided by the original length is called strain.

Stress-Strain Curve for Ductile and Non ductile Material:

For a ductile material such as ASTM A53 Grade B, the stress –strain curve is given in figure. Until the proportional limit is reached , variation of stress in the material with respect to strain follows a straight line. Hooke's law defines the Young's modulus of elasticity E. Ultimate tensile stress is the highest stress the material can withstand.
Yield strength is the point on
the curve at which any further strain will cause permanent deformation to stressed elements. Allowable stress is the yield strength divided by factor of safety.

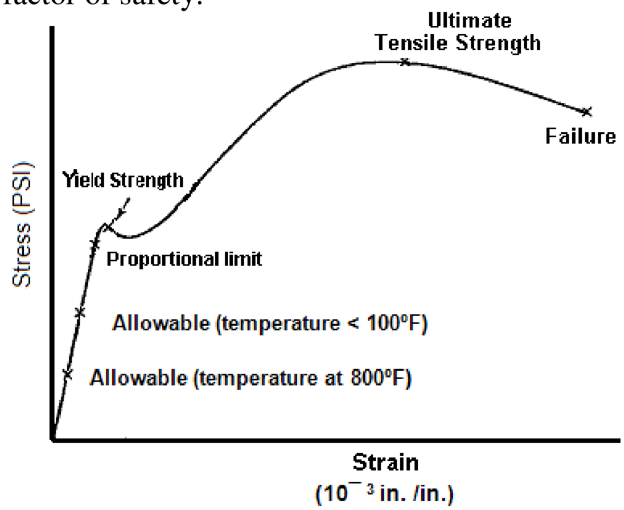


Fig.1 Typical Stress-Strain Curve for Ductile Material (ASTM A 53 Grade B)

A typical stress-strain curve for a non ductile material like cast iron is given in figure. The stress-strain diagram for a given piping material shows the limitations on stress to avoid permanent deformation or rupture.

Fig 5.2 Typical Stress-Strain Curve for Non ductile Material (cast iron)

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. When Piping and Components Fail (Theories of Failure) Various theories of failure have been proposed, their purpose being to establish the point at which failure will occur any type of combined loading. The failure theories most commonly used in describing the strength of piping systems are:

Maximum principal stress theory

This theory states that yielding in a piping component occurs when the magnitude of any of the three mutually perpendicular principle stresses exceeds the yield point strength of the material.

Maximum shear stress theory

This theory states that failure of a piping component occurs when the maximum shear stress exceeds the shear stress at the yield point in a tensile test.

In the tensile test, at yield, S1=Sy (yield stress), S2=S3=0.So yielding in the components occurs when

Maximum Shear stress =τmax=S1-S2 / 2=Sy / 2

The maximum principal stress theory forms the basis for piping systems governed by ASME B31.3.

Note: maximum or minimum normal stress is called principal stress.

Fig .2 Representing Fatigue Failure of Pipe

When the ends of the pipe ends are closed and pipe is subjected to an internal pressure 'P' following stresses would act on each element of the pipe.

- Circumferential (hoop) stress σH
- Longitudinal Stress σL
- Redial Stress σR

CIRCUMFERENTIAL (HOOP) STRESS: σH:

The effect of this may split the pipe into two halves as shown in fig.2. The failure of the pipe in two halves in fact is possible across any plane, which contains diameter and axis of the pipe. Elements resisting this type of failure would be subjected to stress and direction of this stress is along the circumference. Hence the above stress is called Circumferential or Hoop Stress.

If -

D = Diameter of the pipe L = Length of the pipe

t = thickness of the pipe.

Then

Bursting force, FB = Pressure Area

= P XD XL

Resisting force, FR = Resisting metal area Stress, σH

Equating FB & FR

P X D XL = 2t X L X σH

t = (P X D) / (2 X σH)

or

σH = (P XD) / 2t

This equation is used for calculating the thickness of pipe so as to withstand pressure 'P' where σH is allowable circumferential stress.

LONGITUDINAL STRESS: σr

Considering that the pipe ends are chased and pipe is subjected to an internal pressure 'P' the pipe may fail as shown in Fig.3. Elements resisting this type of failure would be subjected to stress and direction of this stress is parallel to the longitudinal direction of the pipe. Hence this stress is called longitudinal stress.Then

Bursting force, FB = Pressure X Area

= P x Π D2 / 4

Resisting force, FR = Resisting metal area X Stress, σL

= π D t X σL (when t is significantly small as compared to D) Equating FB & FR

P X (Π/4) D2 = π D t X σL

t = PD / (4 x σL)

Or

σL = PD / (4 t)

NOTES:

1) On comparing equations 1 & 2, it is clear that when a pipe having diameter ‘D’ and thickness ‘t’ is subjected to an internal pressure ‘P’, the induced circumferential tress is double the induced longitudinal stress.
2) Normally, the pipe is considered as a thin wall cylinder i.e. $t \leq D/6$
3) Usually D is substituted by Do (outside diameter) in order to have higher safely margin.

RADIAL STRESS: σ R

Each element of the pipe is subjected to radial stress which acts in radial direction. σR = P

If a pipe designed for a certain pressure experiences a much higher pressure, the pipe would rupture even if such load (pressure) were applied only once. The failure or rupture is sudden and complete. Such a failure is called catastrophic failure. It takes place only when the load exceeds far beyond the load for which design was carried out. Over the year s, it has been realized that systems, especially piping systems can fail even when the loads are always under the limits considered safe but the load application is cyclic (e.g. high pressure ,low pressure , high pressure.). Such a failure is not guarded against by conventional pressure design formula or compliance with failure theories. Once this was realizes and it was seen than systems may fail after prolonged use under the load they could withstand till that time, it became clear that system design must comply with at least two different types of loads causing two different types of failures. For piping system design, it is now well established that one must treat these two types of loads separately and together guard against catastrophicand fatigue failure.

STRESS CATEGORIES

The major stress categories are primary, Secondary and peak.

Primary Stress:

These are developed by the imposed loading and are necessary to satisfy the equilibrium between external and internal forces and moments of the piping system. Primary stresses are not self-limiting.
These are typically steady or sustained types of loads such as internal fluid pressure, external pressure, gravitational forces acting on the pipe such as weight of pipe and fluid, forces due to relief or blow down . pressure waves generated due to water hammer effects. The last two loads are not necessarily sustained loads. All these loads occur because of forces created and acting on the pipe. In fact, primary loads have their origin in some force
Acting on the pipe causing tension, compression, torsion etc leading to normal and shear stresses. Too large a load of this type leads to deformation, often plastic. The deformation is limited only if the material shows strain hardening characteristics. If it has no strain hardening property or if the load is so excessive that the plastic instability sets in, the system would continue to deform till rupture. One says that primary loads are not self-limiting. It means that the stresses continue to exist as long as the load persists and deformation does not stop because the system has deformed into a no-stress condition but because strain hardening has come into play.

Secondary Stress:

These are developed by the constraint of displacements of a structure. These displacements can be caused either by thermal expansion or by outwardly imposed restraint and anchor point movements. Secondary stresses are self-limiting.

Just as the primary loads have their origin in some forces; secondary loads are caused by displacement of some kind. For example, the pipe connected to a storage tank may be under load if the tank nozzle to which it is connected moves down due to tank settlement. Similarly, pipe connected to a vessel is pulled upwards because the vessel nozzle moves up due to vessel expansion. Also, a pipe may vibrate due to vibrations

in the rotating equipment it is attached to. A pipe may experience expansion or contraction once it is subjected to temperatures higher or lower respectively as compared to temperature at which it was assembled. The secondary loads are often cyclic but not always. For example load due to tank settlement is not cyclic. The load due to vessel nozzle movement during operation is cyclic because the displacement is withdrawn during shut down and resurfaces again after fresh start-up. A pipe subjected to a cycle of hot and cold fluid similarly undergoes cyclic loads and deformation. Failure under such loads is often due to fatigue and not catastrophic in nature. Broadly speaking, catastrophic failure is because individual crystals or grains were subjected to stresses, which the chemistry and the physics of the solid neither could nor withstand. Fatigue failure is often because the grains collectively failed because their collective characteristics (for example entanglement with each other act.) changed due to cyclic load. Incremental damage done by each cycle to their collective texture accumulated to such level that the system failed. In other words, catastrophic failure is more at microscopic level, where as fatigue failure is at macroscopic level if not at macroscopic level.

Peak Stress:

Unlike loading condition of secondary stress which causes distortion, peak stresses cause no significant distortion. Peak stresses are the highest stresses in the region under consideration and are responsible for causing fatigue failure.

Peak stresses are those stresses, which are caused by local discontinuities or abrupt changes in a pipe wall thickness when a pipe is subjected to a primary or secondary stress loading. Peak stresses are stress concentration points, which can cause crack initiation contributing to a fatigue failure.

ALLOWABLE STRESS AS PER ASME B31.3

The allowable stress for piping system or a piping component material is based on a function of the yield or tensile strength if the material at cold to moderate temperature, or is based on creep rated or stress for rupture in elevated temperature service.

Cold Allowable Stress (Sc):-

The term Sc is the allowable stress at cold condition, which includes cryogenic service, or ambient installed temperature for elevated temperature service.

Hot Allowable Stress (Sh):-

Sh is the allowable stress for material in the hot operating condition which would be the design temperature for elevated temperature service or ambient for cold or cryogenic service. The values of Sc & Sh are tabulated in Appendix A Table A_1 of the 31.3.

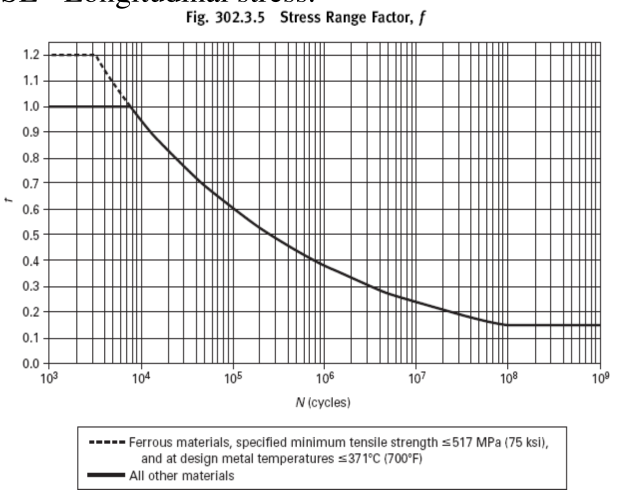
B31.3 establish maximum allowable stress limits that can be safely accommodated by piping system before failure will commence for two separate stress loading condition These limits are stress level that can cause a failure from single loading condition . These limits are for stress level that can cause a failure from a single loading, Sh and those that can cause failure from repeated cyclic loading Sa.

Allowable stress range (Sa):-

Allowable stress range is the stress limit for those stresses that are repeated and cyclic in nature, or simply, it is the allowable stress o be compared to the calculated displacement stress range, SE (a secondary stress).

SA = f(1.25 Sc +0.25Sh) or SA = f[1.25(Sc+Sh)-SL]

SL= Longitudinal stress.



F = stress range reduction factor presented in B31.3

Fig.3 Stress Range Factor under Life Cycles

Stress due to sustained loads:

Sustained loads are expected to be present throughout the plant operation e.g. pressure and weight.

SL<=SA

S L= (PD/4t)+Sb

P=Pressure D=diameter. T=thickness

S b is given below

S h = Basic allowable stress at maximum metal temperature.

The thickness of the pipe used in calculating S L shall be nominal thickness minus mechanical corrosion and erosion allowance.

Fig.4 Representing Sustain Loads

Stress due to occasional loads.

Occasional loads.

These loads are present at infrequent intervals during plant operation e.g. earthquake wind etc. The sum of the longitudinal loads due to pressure, weight and other sustained loads and of stresses produced by occasional loads such as earthquake or wind shall not exceed 1.33Sh

Fig.5 Representing Occasional Loads

Expansion loads

These are loads due to displacements of pipe example Thermal expansion, seismic anchor movements, and Building settlements.

The displacement stress range SE shall not exceed SA. S E<=SA

Where

SE = (Sb2 + 4St2) 1/2

Sb = resultant bending stress Psi

= [(Ii Mi)2+Io Mo)] / Z.
Mi =in –plane bending moment, in .lb Mo = out plane bending moment in lb
Ii = in plane stress intensification factor obtained from appendix of ASME B31.3 Io =out plane stress intensification factor obtained from appendix of ASME B31.3 St = Tensional stress, Psi
=Mt /2Z
Mt =Tensional moment in lb

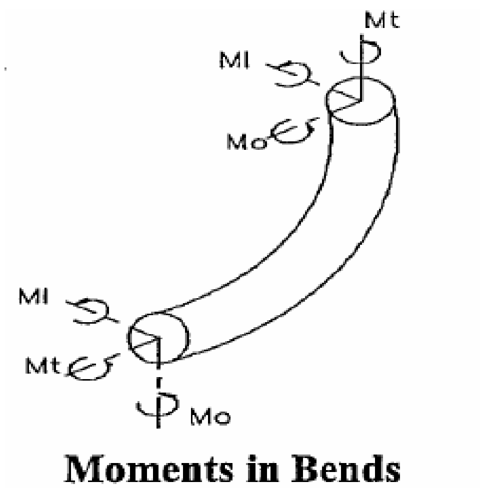


Fig.6 Representing Moments in Bends

The ratio of flexibility of a bend to that of a straight pipe having the same length and cross section is known as its “Flexibility Factor “usually denoted by ‘k’. The factor by which the circumferential stress exceeds the longitudinal stress in the bend is called the “stress identification factor “.

Appendix D of ASME B31.3 & 31.1 tabulated the expressions top be used for calculating the Flexibility factor &S.I.F. the parameter used for the calculation of this factor is called the “Flexibility characteristic “denoted by the letter ‘h’.
Flexibility characteristic h=TR1 /r2 T = wall thickness
R1 = mean radius of bend r2 = mean radius pipe

Using this parameter code indicates that the flexibility factor =k =1.65/h In plane S.I.F = Ii =0.9/h2/3
Out plane S.I.F = Io =0.75/h2/3
CLASSIFICATION OF LOADS STATIC AND DYNAMIC LOADS
Loading affecting the piping system can be classified as primary and secondary loads. Primary loading occurs from sustained loads like dead weight. Primary loads are called non self limiting loads. An example of a secondary loading (self limiting) is a thermal expansion load. Because different piping codes define the piping qualification criteria in slightly different way, each code will be addressed separately later.
Static loading includes:

- Weight effect (live loads and dead loads)
- Thermal expansion and contraction effects
- Effects of support, anchor, and terminal movements
- Internal or external pressure loading

Live loads under weight effect include weight of content, snow, and ice loads. Dead loads consist of weight of piping valves, flanges, insulation, and other superimposed permanent loads.

Dynamic loading includes:

- Impact forces

- Wind
- Seismic loads (earthquake)
- Vibration
- Discharge loads

Primary Loads:
This is a normal or shear stress due to imposed loading like dead weight, pressure, occasional loads, wind and earth quake. The sum of the longitudinal stresses due to pressure and other sustained loads in the piping system shall not exceed the allowable stress (Sh) in the hot condition.

- Sustained Loads (Pressure & Weight)
- Occasional Loads (Earthquake & Wind)

Secondary Loads:
This is a normal or shear stress developed due to imposed restraints on the free thermal expansion in a piping system. The secondary expansion stress (SE) due to bending and torsion is self limiting and local yielding, or distortion that can usually satisfy the conditions causing the stress. The stresses are computed over an allowable stress range (SA) from hot to cold.

- Expansion Loads

Sustained Load:

- Design load on piping supports will include
- Live loads: weight of medium transported or for test
- Dead loads: weight of piping, fittings, insulation, valves, flanges etc.
- When a gas or steam piping is to be hydro tested, its effects also need to be considered.
- If pipe supports are not designed for this load, temporary supports may be needed,

Occasional Loads

Piping Seismic analysis, if required, may be performed by one of the three methods eg

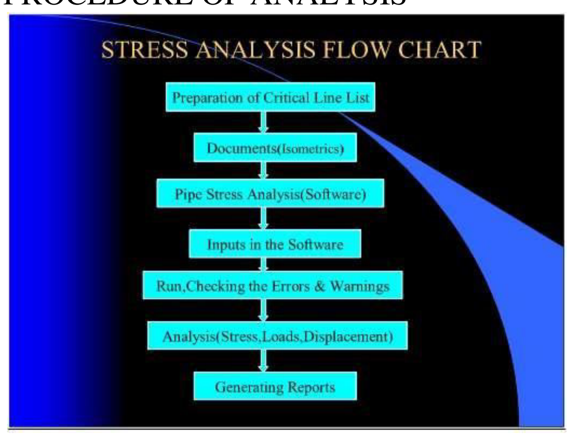
- Time history analysis
- Modal response spectrum analysis
- Static analysis.

A basic equation of motion for any piping system subjected to seismic excitation is M d2x/dt2 + C dx/dt + kx = f
Where M mass matrix of system C damping matrix
K stiffness matrix
d2x/dt2 acceleration vector dx/dt velocity vector
x displacement vector
f external loading vector, function of time

THERMAL EXPANSION LOADS

- Piping systems are to be analyzed for maximum operating temperature.
- Free thermal analysis may be performed considering terminal points and anchors and equipment nozzles. A thermal stress < 10,000 psi means adequate flexibility in piping system.
- Equipment nozzle displacements due to thermal expansions need to be considered
- The thermal stresses developed in the pipe are in fact “stress range” i.e. difference between thermal expansion and highest and lowest temperatures.
- Loads due to differences in expansion characteristics as in bimetallic, lined, jacketed or metallic-non metallic piping also need to be considered.

PROCEDURE OF ANALYSIS



Stress Analysis Procedure Flow Chart

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 eachssss 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.

Several loading s are experienced by the piping systems during their service life. However, not all the loading s 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

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.

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.

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

Run, Checking the Errors & Warnings

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

Analysis:

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

Generating Reports:

After completion of Analysis to create a output report in text format.

4. RESULTS

PDMS MODEL AND PDMS ISOMETRICS

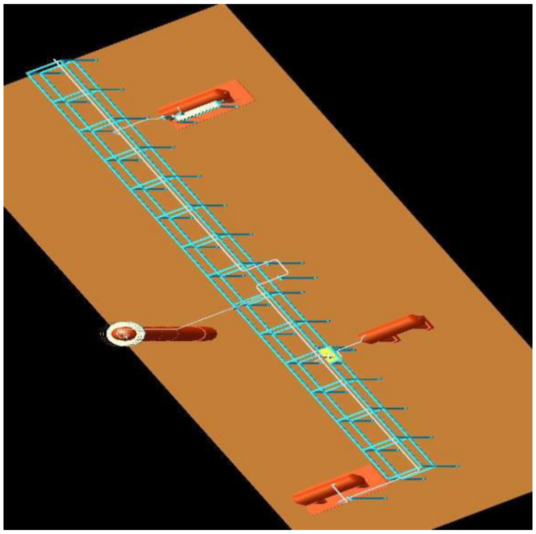


Fig 7PDMS Model

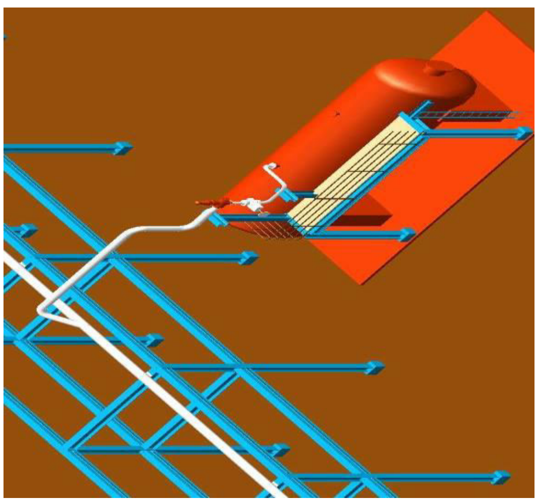


Fig 8 PDMS Model

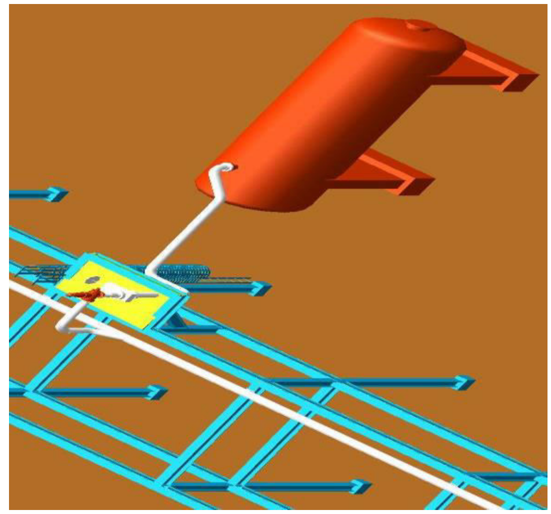


Fig 9 PDMS Model

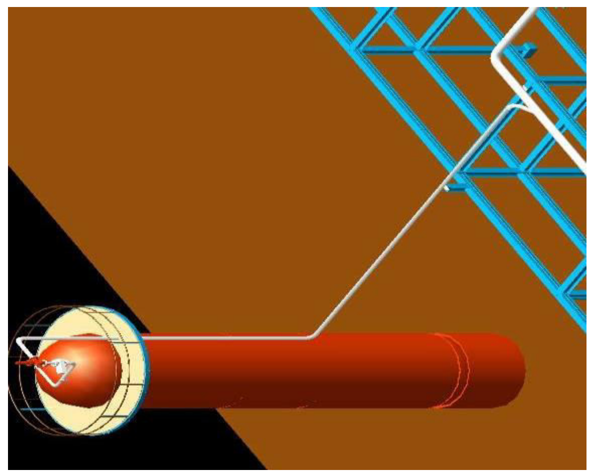


Fig 10PDMS Model

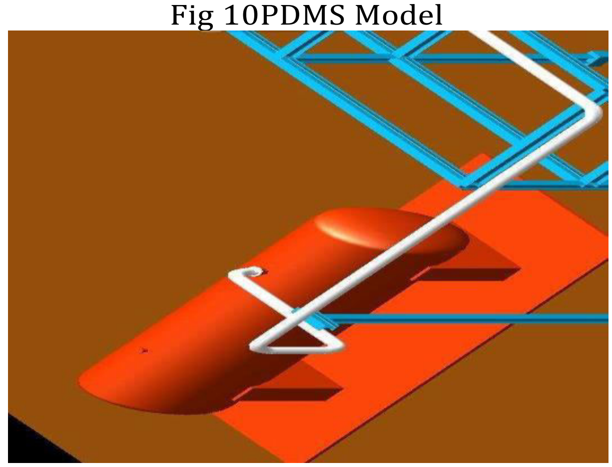


Fig 11 PDMS Model

Table 12.1 Analyzed System Nozzle Loads For Flare Piping

Nozzle Node No.	Load condition	Force		
		Fx (N)	Fy (N)	Fz (N)
320	Oper.	2763	7876	2884
	Sus	381	4969	149
	Allow.	15000	15000	15000
720	Oper.	2714	4686	1543
	Sus	2095	426	676
	Allow.	7500	7500	7500
1240	Oper.	1994	1993	1068
	Sus	83	103	713
	Allow.	7500	7500	7500
1720	Oper.	8747	7300	2971
	Sus	290	4865	16
	Allow.	12500	12500	12500

Max. Allow. Stress Of Given System Is 107702.6 Kpa Actual Stress Max. At Node 1580 Is182556.9 Kpa

Stress Ratio Of Given System Is Ratio Of Actual Loads Per Max.To Allow. Loads.

Stress Ratio = Allow.Stress X 100
Developed Stress

= 107702.6 X 100
182556.9

= 58.996 %

5. CONCLUSION

1) Stress Analysis of Flare pipeline between equipment's to knock out Drum is safe.

2) As per ASME 31.3. Equipment's and knock out Drum nozzles are within the Allowable. Stress, Nozzle loads, Restraint loads, all are within the limits after providing an expansion loop as per Standards.
3) There is good agreement between numerical results and analytical results.

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