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Analytical Calculations for Piping Thickness and Stress

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Abstract

Piping systems are important means of fluid transportation and we can find their use in several industrial and commercial applications. Some of the typical situations where pipes are used are: power plants, oil refineries, steel industry, oil and gas transportation, commercial heating etc. Hence, sustainability and durability of piping system is of keen importance. Failure in piping deign can cause severe accidents and shortage of many other essential resources like electricity, water, gas, fuel for transportation etc. Pipe failure is typically caused by increased stresses beyond allowable limits which are caused due to thermal expansion, fatigue, creep, sustained loading, wind, seismic loading, snow etc. Although with the advent of computers we have resorted to computations methods of piping design, the manual analytical methods still find their utility. Hence in this paper, we present the analytical method of calculating two important components of piping design i.e piping thickness and stress under sustained loading.

Keywords: *Piping design, piping thickness, sustained loading, analytical method*

1. Introduction

(John J. McKetta, 1992; Shah Rahman, 2004; Erik Oberg et al., 2000) Piping design is the most lengthy and complex part of the entire design procedure and is always on the critical path of the project plan. Each pipeline must be treated individually and be put through the universal engineering design assessment. In order to properly design piping system, we must understand both the system's behaviour under potential loading, as well as the regulatory requirements imposed upon it by the governing codes. There are a number of reasons for performing stress analysis on a piping system. A few of these follows:

- In order to keep stresses in the pipe and fittings within code allowable levels
- In order to keep nozzle loadings on attached equipments within allowable of manufacturers or recognised standards
- In order to keep vessel stresses at piping connections within ASME allowable levels.
- In order to keep design loads for sizing supports and restrains.
- In order to determine piping displacements for interference checks
- In order to solve dynamic problems in piping such as those due to Mechanical vibrations, acoustic vibration, fluid hammer, transient flow and relief valve discharge.
- In order to help optimize piping design

The objective of pipe stress analysis is to ensure safety against failure of the Piping System by verifying the 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 the most economic considerations.

Some of the causes of stress in a piping system are (Engineering and Design, 1999):

- Thermal expansion
- Fatigue
- Creep
- Sustain loading
- Wind
- Seismic loading
- Ratcheting
- Snow

The steps involved in the stress analysis can be listed as:

1. Identify the potential loads that the piping system would encounter during the life of the plant.
2. Relate each of these loads to the stresses and strains developed.
3. Get the cumulative effect of the potential loads in the system.
4. Decide the allowable limits. The system can withstand without failure.
5. After the system is designed, to ensure that the stresses are within the safe limits.

Pipe routed in straight lines cost the least. Normally, pipe cannot be routed straight because of thermal expansion

(Shah Rahman, 2007). Stretching a pipe even a small amount takes a very large force. Preventing pipe from expanding thermally takes an equally large force.

Allowable stress varies with material and temperature but are on an order of magnitude of:

(a) Pressure = 1,000 to 10,000 psi
(b) Dead load = 1,000 to 10,000 psi
(c) Thermal = upto 20,000 psi

The material engineer checks pressure stresses when calculating wall thicknesses.

Dead load stresses are controlled by proper use of the pipe span charts and checked by the stress engineer when required. Thermal expansion stresses are roughly determined by piping during the pipe study and finally checked by the stress engineer.

The literature of piping design is vast and procedure of piping design is complex, however, amongst others there are two important components of piping design i.e piping thickness calculations and piping sustained load calculations. Here we explain the procedure of calculating these two.

2. Determination of the piping wall thickness

(ASME, 2004; ASTM, 1996; ASTM, 2007; P. E. Nayyar and L. Mohinder, 2000) The determination of the piping wall thickness is one of the most important calculations of the piping system design process. In arriving at the final specification of the piping wall thickness, the number of factors to be considered:

- Pressure integrity
- Allowances for Mechanical strength, corrosion, erosion, wear, threading, grooving or other joining processes.
- Manufacturing variations (tolerance) in the wall thickness of commercial pipe
- Wall thickness reduction due to butt-welding of end preparation (counter boring)
- While a number of different pipe wall thickness design formulas have been proposed over the years, the ASME piping codes have adopted one or the other of the following formulas for pressure-integrity design: $t = \frac{PD}{2(SE+Py)}$

Where

t :design minimum wall thickness required to ensure pressure integrity, in

P:design pressure, psig

D: outside diameter of pipe, in

S: allowable stress, psi

E: weld joint efficiency factor (some codes also specify a casting quality factor F for cast piping materials

y: dimensionless factor which varies with temperature

Most construction codes require the provision of additional wall thickness, over and above that intended to ensure pressure integrity. This additional material allowance is provided by the following formulae:

$$t_m = t + c$$

Where

t_m : minimum wall thickness required to satisfy the design rules of the code,in

t : wall thickness required to provide pressure integrity

c : additional material allowance, in

**The additional material allowance *c* is made up of a number of individual allowances that are provided to address different loads or conditions the piping system will see during fabrication, installation, and operation. Each allowance is figured separately, and their sum is added to the pressure-integrity wall thickness to arrive at the final design minimum wall thickness. The major constituents of *c* include:

- Wall thickness added to account for progressive deterioration or thinning of the pipe wall in service due to the effects of corrosion, erosion, and wear.
- Wall thickness added to account for material removed to facilitate joining of the various segments of the piping system. Typical joining methods include threading, grooving, and swaging. If a machining tolerance is required as a part of the joint manufacture, this tolerance must be accounted for in the most conservative manner.
- Wall thickness added to provide mechanical strength. This additional strength might be required to resist external operating loads or loads associated with shipping and handling.

3. Calculating stress under sustained loading

(ASME, 2004; ASTM, 1996; ASTM, 2007; P. E. Nayyar and L. Mohinder, 2000)

3.1 Basic concepts

There are 3 basic conditions under which stresses can be developed in a piping system. These are:

- Sustained conditions
- Thermal conditions
- Occasional conditions

3.2 Sustain conditions

CAUSE: It includes all the stresses that develop in a piping system due to the dead weight of the pipe as well as the internal pressure exerted by the static fluid in the pipe. It doesn't include the forces exerted due to the fluid in motion.

EFFECT: These stresses can cause sagging in the pipe.

PREVEVTION: These stresses can be minimized by giving vertical resting supports to the piping system.

Formula for calculating the stress:

$S_{SUS} = (pd/4t) + (F/A) + (M/Z)$

Where

p= internal pressure
d= outside diameter
M= bending moment
Z= section modulus
F= force
A= area of contact

Formula for allowable stress:

S_{All}=w X S_h

Where

S_{All} =allowable stress
S_h = basic allowable stress at maximum temperature
w= weld factor

3.3 Thermal conditions

CAUSE: If the temperature of the piping system is increased from the ambient or installed temperature to the operating temperature then the various components of the piping system tend to expand. If the expansion is not allowed due to presence of anchors or guides or anchors then stresses are generated. These are called as thermal stresses.

EFFECT: Thermal stresses in the piping system can cause cracks in the pipe which in turn may lead to failure of the pipe.

PREVENTION: thermal stresses can be avoided by giving minimum number of anchors and guides in the piping lay out.

Formula for calculating thermal stresses:

$S_{thermal} = (S_b^2+4S_t^2)^{1/2}$

Where, $S_{thermal}$ = thermal stress

S_b^2 = bending stress
S_t^2 = torsion stress

Formula for allowable stress:

$S_{Allowable} = f^* (1.25\, S_c + 0.25\, S_h)$

Where, $S_{allowable}$= thermal stress

S_h=basic allowable stress atmaximum temperature
S_c=basic allowable stress at minimum temperature
f= friction factor = $6(N)^{-0.2} \leq 1$

CYCLES N	FACTOR f
7000 OR LESS	1
OVER 7000 TO 14000	0.9
OVER 14000 TO 22000	0.8
OVER 22000 TO 45000	0.7
OVER 45000 TO 100000	0.6
OVER 100000 TO 200000	0.5
OVER 200000 TO 700000	0.4
OVER 700000 TO 2000000	0.3

3.4 Occasional conditions

CAUSE: These include all those factors which are not present throughout the year and occur only occasionally, under special circumstances. These include factors such as wind, snow, earthquakes, etc.
EFFECT: These stresses lead to both formations of cracks as well as sagging in the pipe.
PREVENTION: These stresses can be minimized by providing axial stops in the piping layout.

Formula used for calculating occasional stresses:

$S_{occ} = (pd/4t) + (F_o/A) + (M_o/Z)$

Where,

p= internal pressure
d= outside diameter
M= occasional bending moment
Z= section modulus
F= occasional load
A= area of contact

Formula for allowable stress:
$S_{Allowable} = 1.33S_h$

Where,

$S_{allowable}$= thermal stress
S_h = basic allowable stress at maximum temperature

Conclusion

The applications of piping design are widely accepted and procedure for designing piping is very complex. A simplified and handy procedure is there for needed. Hence, here in this paper we presented the analytical method of calculating two important components of piping design i.e piping thickness and stress under sustained loading.

References

[1]. ASME B31.3 Process Piping Guide, Revision 1, (2004), from *Los Alamos National Laboratory Engineering Standards Manual* OST220-03-01-ESM

[2]. ASTM D2513-09a Standard, (1996), Specification for Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings, *ASTM International*, West Conshohocken, PA
[3]. ASTM Standard F2389 (2007), Standard Specification for Pressure-rated Polypropylene (PP) Piping Systems, *ASTM International*, West Conshohocken, PA
[4]. Engineering and Design, (1999), Liquid Process Piping, *U.S. Army Corps of Engineers*, EM 1110-l-4008
[5]. Erik Oberg, Franklin D. Jones, Holbrook L. Horton, and Henry H. Ryffel, (2000), *Machinery's Handbook* (26th ed.), Industrial Press Inc.
[6]. John J. McKetta, (1992), Piping Design Handbook,
[7]. P. E. Nayyar and L. Mohinder (2000), "A1". In Mohinder L. Nayyar, P.E., *Piping Handbook* (7th ed.), McGraw-Hill, New York.
[8]. Shah Rahman (2004), Thermoplastics at Work: A Comprehensive Review of Municipal PVC Piping Products, *Underground Construction*: 56–61.
[9]. Shah Rahman, (2007), Sealing Our Buried Lifelines, *Opflow Magazine, American Water Works Association*: 12–17.