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An Overview on Pipe Design using caesar II

Shweta Bisht* and Farheen Jahan*
**Assistant Professor, Department of Mechanical Engineering,*
Faculty of Engineering & Technology, MRIU, Faridabad, (HR), India

(Corresponding Author: Shweta Bisht)
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ABSTRACT: Design of piping system constitutes a major part of the design and engineering effort in the world of fluid conveyance. Stress analysis is a critical component of piping design through which important parameters such as piping safety, safety of related components and connected equipment and piping deflection can be checked and rectified timely. The objective of pipe stress analysis is to prevent premature failure of piping and piping components and ensuring that piping stresses are kept within allowable limits. This paper is designed for studying a wide range of abilities and backgrounds and will cover the fundamental principles and concepts used in pipe stress analysis. In addition to meeting the needs of design, the paper is structured to provide a deep understanding of the engineering principles involved in material selection, application of code criteria and the capabilities and tools incorporated in stress analysis software.

I. INTRODUCTION

Pipe Design mainly depends upon stress analysis. Process piping and power piping are typically checked by pipe stress engineers to verify that the routing, nozzle loads, hangers, and supports are properly placed and selected such that allowable pipe stress is not exceeded under different loads such as sustained loads, operating loads, pressure testing loads, etc., as stipulated by the ASME B31, EN 13480 or any other applicable codes and standards. It is necessary to evaluate the mechanical behavior of the piping under regular loads (internal pressure and thermal stresses) as well under occasional and intermittent loading cases such as earthquake, high wind or special vibration, and water hammer. This evaluation is usually performed with the assistance of a specialized (finite element) pipe stress analysis computer program.

CAESAR II is a complete pipe stress analysis software program that allows quick and accurate analysis of piping systems subjected to weight, pressure, thermal, seismic and other static and dynamic loads. It can analyze piping systems of any size or complexity.

CAESAR II is unique, incorporating calculation methods and analysis options not found in any other program. It provides for the static and dynamic analysis of piping systems. Calculation capabilities include:

(i) fiber reinforced plastic
(ii) buried piping
(iii) wind, wave and earthquake loading
(iv) expansion joints
(v) valves, flanges and vessel nozzles
(vi) piping components
(vii) nozzle flexibilities

Data Input: CAESAR II makes it easy to input and display all the data needed to accurately define a piping system analysis model. Input can be accessed or modified on an element-by-element basis, or datasets can be selected to make global changes.

Cutting-edge Graphics: The CAESAR II input graphics module makes quick work of developing analysis models while clearly indicating areas of concern and providing an excellent idea of the piping system's flexibility. Color-coded stress models and animated displacements for any stress load case are available.

Design Tools and Wizards: Tools and wizards for tasks such as creating expansion loops or viewing plant models in the analysis space help bridge the gap between knowledge and experience. Such tools take the guess work out of producing accurate analysis and recommending practical design changes. Nonlinear effects such as support lift off, gap closure and friction are also included. CAESAR II also selects the proper springs for supporting systems with large vertical deflections. Dynamic analysis capabilities include modal, harmonic, response spectrum and time history analysis.

Analysis Options: Besides the evaluation of a piping system's response to thermal, deadweight and pressure loads, CAESAR II analyzes the effects of wind, support settlement, seismic loads and wave loads.

Error Checking and Reports: The CAESAR II program includes an integrated error checker. This error checker analyzes the user input and checks for consistency from both a "finite element" and "piping" point of view. Reports are clear, accurate concise and fully user definable.

Material and Assemblies Databases: CAESAR II incorporates table look-ups for piping materials and components plus expansion joints, structural steel sections, spring hangers and material properties including allowable stress. This ensures correct datasets are used for each analysis. CAESAR II comes complete with major international piping codes.

Bi-directional Interface with Design: CAESAR II incorporates the industry's first and only seamless, bi-directional link between CAD plant design and engineering analysis.

A. Piping Code Options

o B31.1 and B31.1 (1967) - Power
o B31.3 - Process Piping
o B31.4 - Liquids Transportation
o B31.4 - Chapter IX - Offshore
o B31.5 - Refrigeration
o B31.8 - Gas Transportation
o B31.8 - Chapter VIII - Offshore
o ASNE Sec. III, Class 2&3 - Nuclear Power
o British Standard 806
o US Navy Spec. 505
o Z662 - Canadian Gas Transportation
o RCC-M Section C & D - French Nuclear Power
o BS 7159 - British Fiberglass Reinforced Plastic Pipe
o UKOOA - UK Offshore
o IGE/TD/12 - UK Gas

B. Design of pressure piping

Many decisions need be made in the design phase to achieve this successful operation, including:
(i) Required process fluid quantity
(ii) Optimum pressure-temperature
(iii) Piping material selection
(iv) Insulation selection (tracing)
(v) Stress & nozzle load determination
(vi) Pipe support standard

The codes provide minimal assistance with any of these decisions as the codes are not design manuals.

II. PIPING DESIGN

A. Design procedure

The problem of design procedure is to find a pipeline configuration and size within the constraints, which is safe and economical. The steps in pipeline design are as follows:

I. The determination of the problem, which includes:
a. The characteristics of the fluid to be carried, including the flow rate and the allowable head loss;
b. The location of the pipelines: its source and destination, and the terrain over which it will pass, the location of separator station and the power plant;
c. The design code to be followed; and
d. The material to be used.
II. The determination of a preliminary pipe route, the line length and static head difference
III. Pipe diameter based on allowable head loss
IV. Structural analysis:
a. Pipe wall thickness; and
b. Stress analysis
V. The stress analysis is performed in pipe configuration until compliance with the code is achieved
VI. Support and anchor design based on reaction found in the structural analysis
VII. Preparation of drawings, specification and the design report.

B. Fluid characteristic

Important factors to be considered are the mass flow rate, pressure, temperature, saturation index and the allowable headloss over the pipeline length. Two phase piping:The steam and water flow patterns in the pipe vary from annular, slug to open channel flow; depending on the velocity and wetness of the steam. Slug flow generates high dynamic load and vibration that can damage the piping system. The preferred flow regime in the pipes is usually the annular flow. Pipes need to be sized correctly and run flat or on a downhill slope to achieve annular flow. The piping for two-phase fluids has to be designed for high pressure, dynamic load, possible slug flows, erosion, corrosion, minimum pressure loss (by running the pipe as short as possible), the desired flow regime (by selecting the correct fluid velocity and slope for the pipes), vibration prevention.

C. Codes Governing Piping Design and Stress Analysis

(i) ASME B31.3, ASME B31.4 and ASME B31.8
(ii) Other codes including applicable local codes
(iii) Role and scope of codes
(iv) Information available from codes
(v) Typical organization of code material

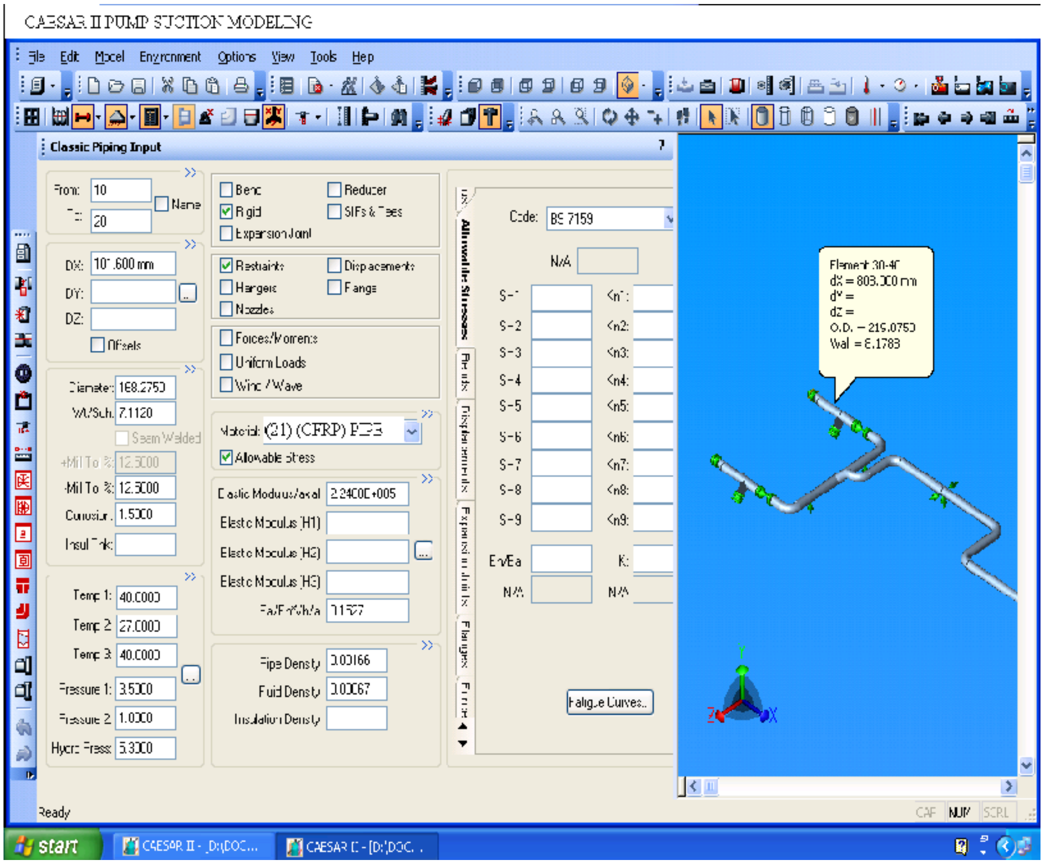

Fig.1. Pipe Modeling in CAESAR- II.

D. Static Analysis Input Listing

PIPE DATA
From 10 To 20 DX= 101.600 mm.
PIPE
Dia= 168.275 mm. Wall= 7.112 mm. Insul= .000 mm. Cor= 1.5000 mm.
GENERAL
T1= 40 C T2= 27 C T3= 40 C T4= 65 C T5= 27 C
P1= 344.7378 KPa
P2= 98.4965 KPaPHyd= 522.0316 KPa Mat= (21) PLASTIC PIPE(CFRP)
Ex= 22,063,222 KPaEa/Eh*Vh/a= .1527 Density= .0017 kg./cu.cm.
Fluid= .0006680 kg./cu.cm.
RIGID Weight= 191.27 N.
RESTRAINTS
Node 10 ANCCnode 420
ALLOWABLE STRESSES
BS 7159 (1989) Sy= 241,316 KPa

From 20 To 30 DX= 150.000 mm. DY= -25.000 mm.
REDUCER
Diam2= 219.075 mm. Wall2= 8.179 mm.

From 30 To 40 DX= 808.000 mm.
PIPE
Dia= 219.075 mm. Wall= 8.179 mm. Insul= .000 mm.
GENERAL
Mat= (21) PLASTIC PIPE(CFRP) Ex= 22,063,222 KPaEa/Eh*Vh/a= .1527
Density= .0017 kg./cu.cm.
SIF's & TEE's
Node 40 Welding Tee
ALLOWABLE STRESSES
BS 7159 (1989)

From 40 To 50 DX= 475.000 mm.

From 50 To 60 DX= 104.775 mm.
RIGID Weight= 177.93 N.

From 60 To 70 DX= 19.000 mm.
RIGID Weight= 78.38 N.

From 70 To 80 DX= 295.000 mm.
GENERAL
T1= 40 C T2= 40 C T3= 40 C T4= 65 C T5= 150 C P2= 49.2483 KPa
RIGID Weight= 1,378.95 N.

E. Principal Stresses and Failure Theories

(i) Longitudinal, circumferential and radial stresses
(ii) Principal axes and principal stresses.
(iii) Failure theories (maximum principal stress failure theory and shear stress failure theory)

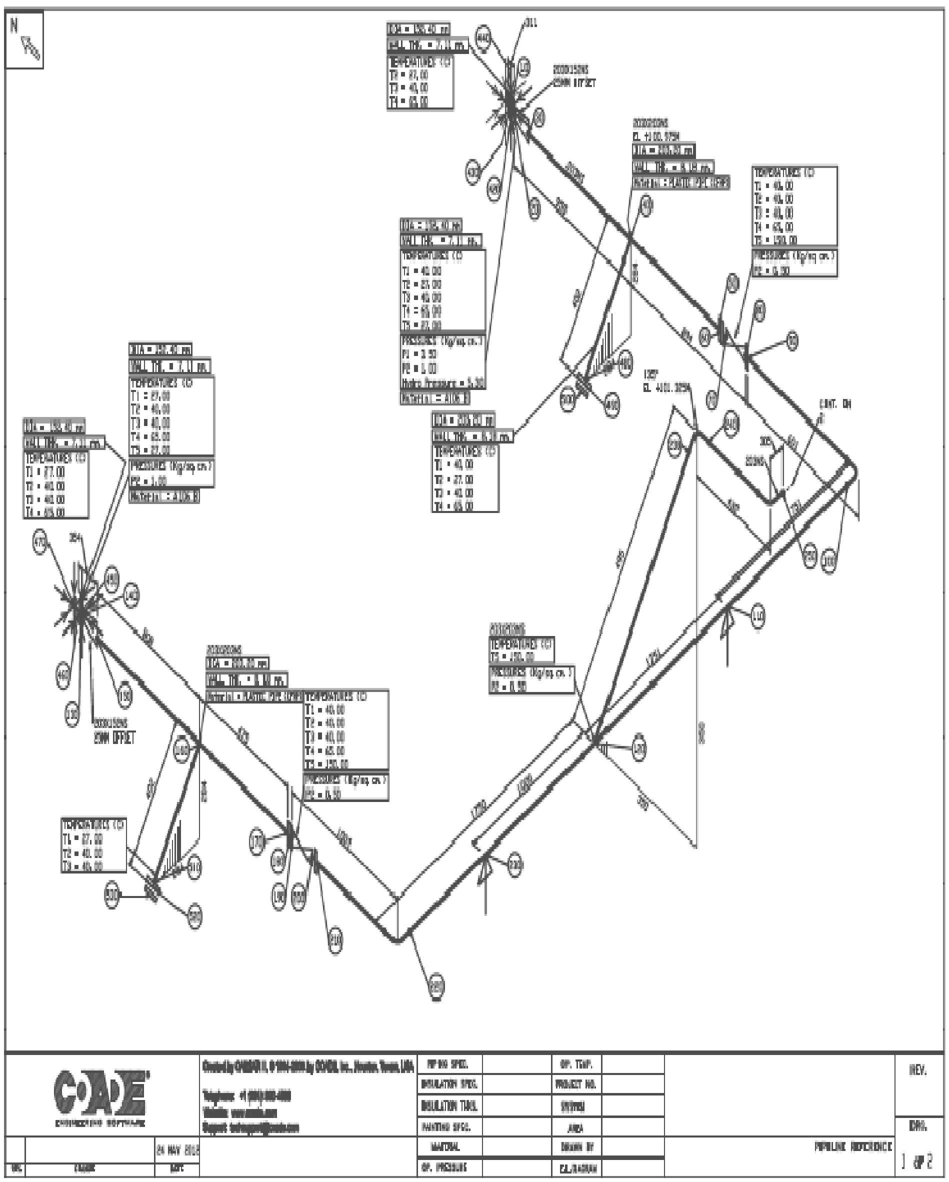

Fig. 2. Stress Isometrics of Pump Suction.

F. Design Pressure, Design Temperature and Allowable Stress
(i) Definition of design pressure and design temperature
(ii) Basis for allowable stress
(iii) Allowable at "hot" and "cold" conditions, that is, Sh and Sc
(iv) Code tables for allowable stresses.

G. Design of Pipe Wall Thickness for Internal Pressure
(i) Wall thickness design equations - ASME B31.3, ASME B31.4 and ASME B31.8
(ii) Calculation of Maximum Allowable Working Pressure (MAWP)
(iii) Pressure - temperature class ratings for flanges
(iv) Determining appropriate flange pressure class.

H. Loads on Piping Systems
(i) Primary and secondary loads
(ii) Self - limiting and non-self - limiting characteristics of loads
(iii) Sustained and occasional loads
(iv) Static and dynamic loads
(v) Bending stresses in pipes
(vi) Longitudinal stress and torsional stress
(vii) Code criteria for design.

I. Thermal Stresses in Piping Systems
(i) Thermal expansion/contraction of materials
(ii) Stresses due to thermal expansion/contraction
(iii) Thermal fatigue and cyclic stress reduction factor
(iv) Design criteria for thermal stresses - Stress Intensification Factors (SIFs), allowable stress range for thermal expansion and calculation of expansion stress range

III. PIPE STRESS ANALYSIS SOFTWARE

Introduction to CAESAR II stress analysis software:
(i) Overview of CAESAR II software
(ii) Piping input and creation of model
(iii) Navigation and toolbars
(iv) Static analysis and output
(v) Checking for code compliance.

A. P & IDs
Piping specification, General arrangement drawings, 3D equipments & structural model are some of basic inputs for piping engineering & modeling.
(i) Pipe size calculation for piping network for single phase, 2 phase flow.
(ii) Utility piping network calculations.
(iii) Piping stress analysis.

B. Piping design
For high vacuum system (less than 1 Torr)
(i) High temperature condition
(ii) High pressure condition.

(iii) Conceptual Piping routing.
Generating 3D plant layout drawing showing details of structural design & process equipments:
(i) Piping material selection, process material tracking and review. Piping routing & module design is accomplished using P&ID.
(ii) G.A drawings, 3D piping routing produced on the plant model. Clash detection test performed on the model for any overlap in piping routing.
(iii) Our engineers generate piping isometric drawings for every pipeline in the plant. The isometric includes all pipe lengths and all necessary datum's identifying the pipe location in the region where it is to be installed. The isometric is the pipe manufacturing drawing and includes a part list identifying all component parts of the pipe being detailed.
(iv) Preparation of advance bill of material.

IV. FUTURE SCOPE

(i) Design of pressure components.
(ii) Pipe Span calculations.
(iii) Design of pipe supports & hangers.
(iv) Stiffness & flexibility.
(v) Expansion & stresses.
(vi) Line expansion & flexibility.
(vii) Supports & anchorage of piping.

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