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SIMULATION EXPERTS

Piping Stress Analysis in Buildings

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Introduction

Pipes and piping systems are found in almost every building around us. They support essential services such as HVAC, firefighting, plumbing (domestic water and wastewater), and both potable and non-potable fluids flow within it. Each of these applications requires a specific type of pipe to meet the requirements of the applicable building codes, specifications, physical limitations, and best design practices.

These pipes can carry different types of fluids (typically water if it is a regular building) at different pressure and temperatures.

The objective of pipe stress analysis using simulation software is to check the piping or pipelines of various industries for operating and occasional loads. The piping network is then designed and validated as per codes that can withstand these loads and forces. The objective of pipe stress analysis is to determine the stresses, deflection, and forces in pipelines in the design stage as well as under operating conditions.

Based on the analysis results, various design modifications like the type of supports i.e., flexible connectors, rigid anchors, number of supports, and spring hangers are suggested. The analysis is conducted to come up with innovative design solutions that meet international code compliances like ASME.

In the case of reciprocating pumps and reciprocating compressors generally used in the Oil & Gas, Power, Chemical, and Process sectors, API 618 and API 674-based guidelines are followed.

The design of structural steel supports for various piping systems is done using FEM. These supports are designed using NBCC & ASCE.

Pipe Stress Analysis - Understanding

Pipe Stress Analysis - Understanding

Pipe stress analysis is an analytical method to determine how a piping system behaves based on its material, pressure, temperature, working fluid, and supports. The analytical method can be done by simple to complex hand calculations or computer simulations. The computer models can vary from 1-D beam elements to complex, finite element models.

Pipe stress analysis should be done primarily to provide safety to the public, when designing a building HVAC system, a high-pressure gas line in a refinery, a firefighting system, a water supply system, etc. A pipe stress analysis is also performed to increase the life of a piping system by maintaining structural integrity and system operability of the piping and its supporting system.

The basis of pipe stress analysis requires a complete understanding of the piping layout, process parameters, operating and occasional loading conditions faced by the piping network and site installation conditions based on the project requirements.

Pipe Stress Analysis-Competences

Major requirements in piping stress analysis are to provide adequate flexibility for absorbing thermal expansion and code compliance for stresses incurred in the piping system, safe nozzle loads, and displacement. The design is said to be safe if all of these are in the allowable range as per the codes.

Piping systems should have sufficient flexibility so that piping movements and movements of supports will not cause:

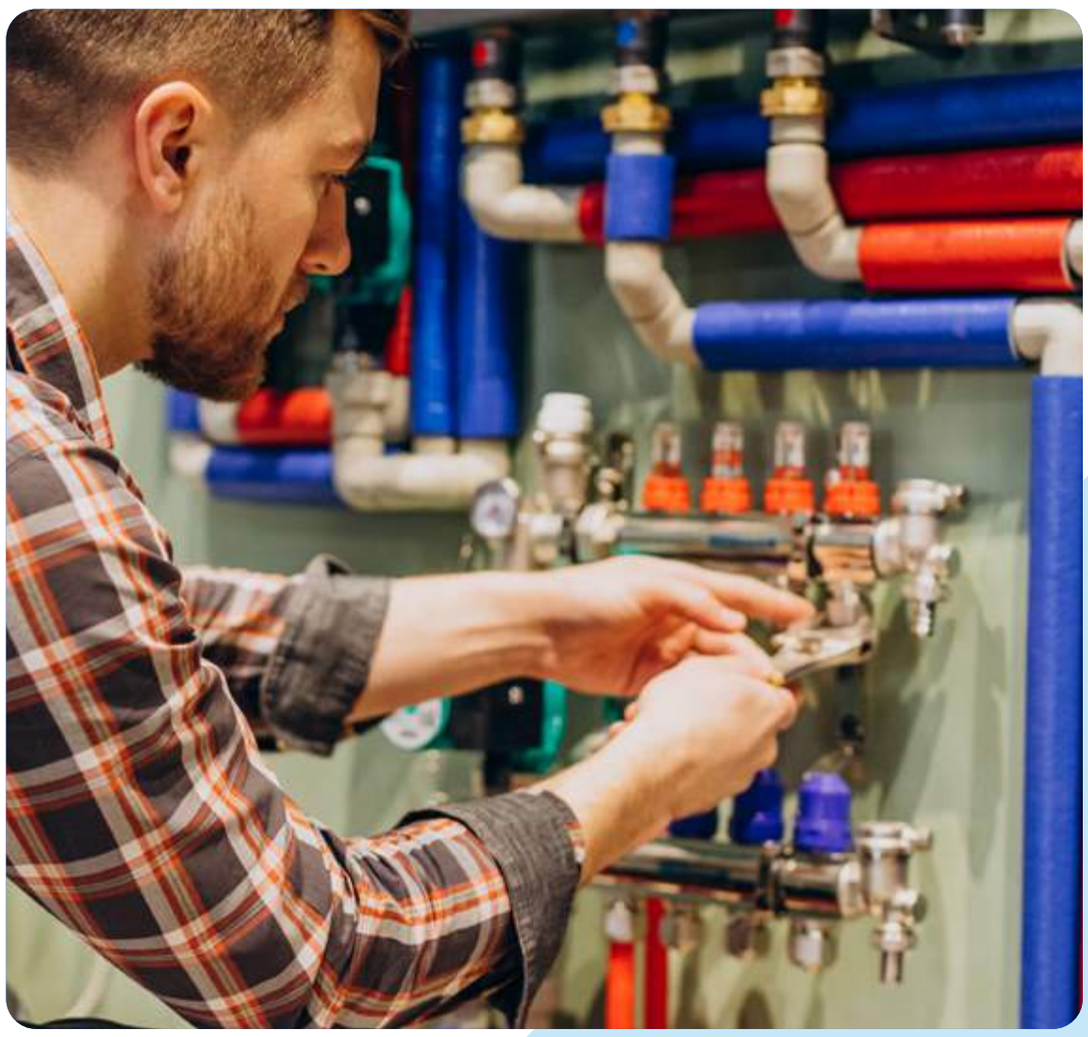
- Failure of piping from overstress/fatigue.
- Leak at joints.
- Detrimental loads on connecting equipment, resulting from excessive thrusts and movements in the pipes.
- Failure of pipe supports.

Flexibility analysis is concerned with the ability of the pipe to change its length and deform elastically. The piping system must be flexible enough to cater for excessive thermal expansion or movement of support or pipe endpoints, thus preventing the failure of pipe and support structure due to excessive stress. **Pipe stress analysis should be done:**

Pipe Stress Analysis - Understanding

- To keep stresses in the pipe and fittings within the code allowable levels.
- To keep nozzle loadings on attached equipment within the allowable limit of manufacturers or recognized standards (NEMA SM23, API 610, API 617, etc.).
- To calculate design loads for sizing supports and restraints.
- To determine piping displacements for interference checks.
- To solve dynamic problems in piping, such as those due to mechanical vibration, **acoustic vibration**, fluid hammer, pulsation, **transient flow**, and **relief valve** discharge.
- To help optimize the **piping design**.

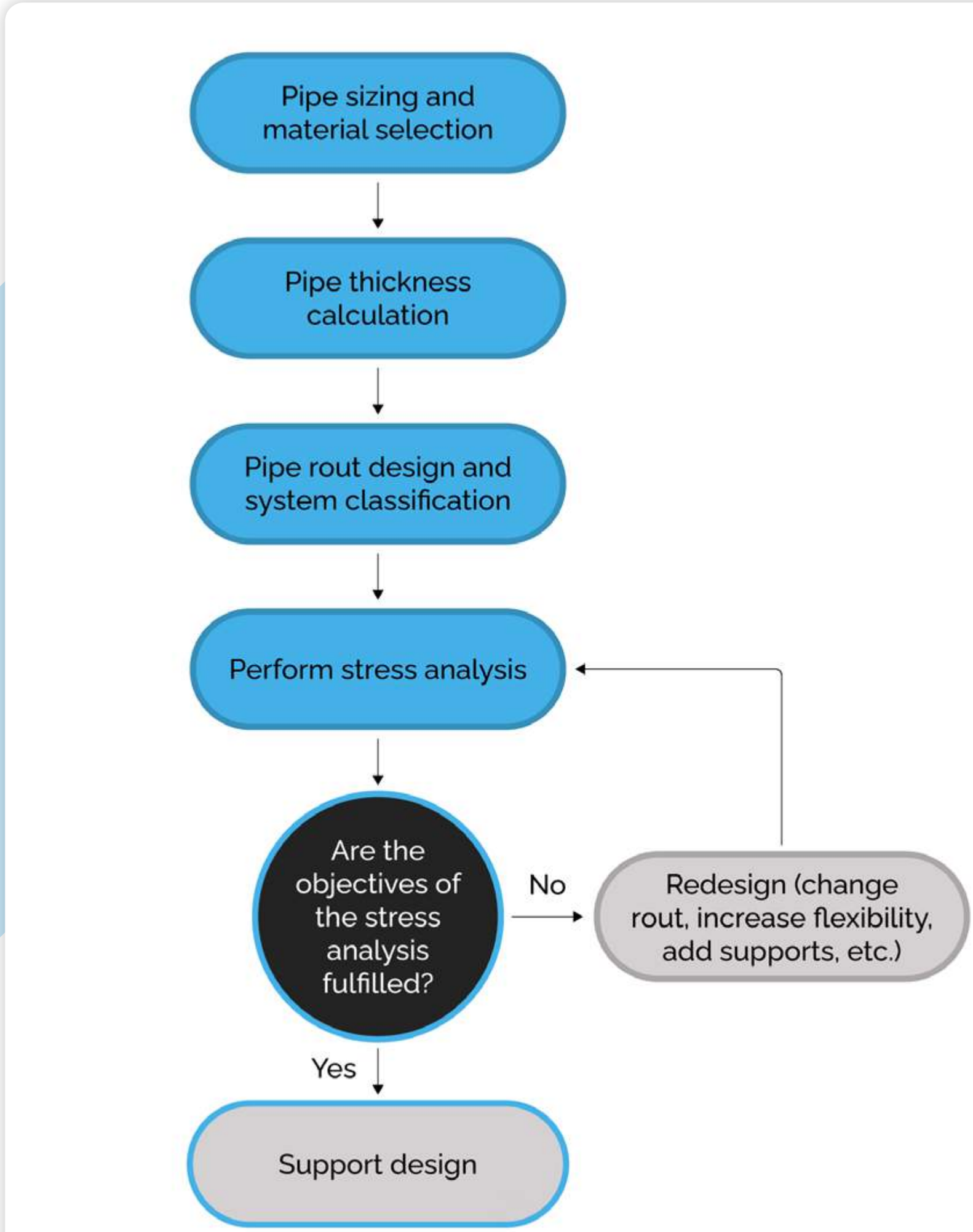
Pipe stress analysis is used to protect the equipment because a pipe is nothing more than a big lever arm connected to a delicate piece of equipment. If not properly supported and designed, it can have devastating effects on that equipment.



Pipe Stress Analysis - Procedure

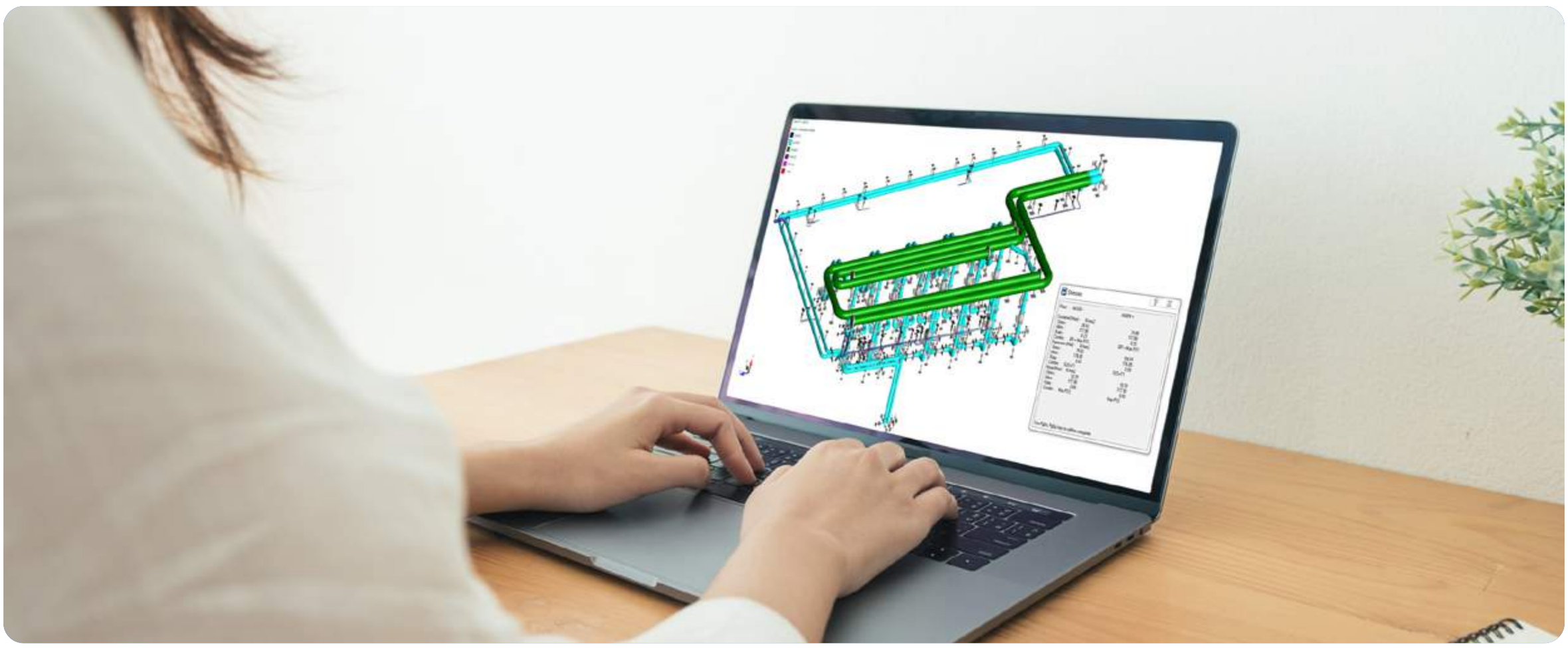
Pipe Stress Analysis - Procedure

The following analysis and calculation steps can be performed **in the global design process of the system in order to achieve an optimal and safe piping system**.



Pipe Stress Analysis - Procedure

1. Review the input piping layout drawings and other technical data.
2. Develop a 3D model of the complete piping system.
3. Develop loads and their load combinations as per applicable codes.
4. Apply constraints of equipment, supports, etc., as per site installation conditions.
5. Perform pipe stress analysis
    a. Are the objectives of the analysis fulfilled?
    b. If Yes, perform support design.
    c. If No, suggest adequate design modifications to meet the code requirements.



Pipe Stress Analysis - Procedure

The complete piping system model will be done using a piping layout and other technical data. The possible loads that occur in piping systems during the life of the plant (self-weight, wind, seismic, etc.) will be identified and correlated to the stresses developed to get the cumulative effect of the possible loads in the system. It should be ensured that the allowable load, deformation, and stresses at connections should be within the acceptance criteria as per the applicable codes.

If stresses exceed the allowable range then suitable design modifications, i.e., changes in support types, additional expansion joints, U loops, pipe loops, rigid supports, and flexibility at equipment connection will be suggested to achieve code compliances after the system is designed, to ensure that the stresses are within the safe limits.

Pipe Stress Analysis - Procedure

Piping Codes

- ASME B31.1 - Power Piping
- ASME B31.2 - Fuel Gas Piping
- ASME B31.3 - Process Piping
- ASME B31.4 - Liquid Piping
- ASME B31.5 - Refrigeration Piping
- ASME B31.8 - Gas Distribution and Transportation
- ASME B31.9 - Building Service Piping
- ASME B31.11 - Slurry Piping
- ASME B31.12 - Hydrogen Piping

Pipe stress analysis software

- CAESAR II
- Bentley Autopipe

Pipe Stress Analysis - Objectives

Pipe Stress Analysis - Objectives

Pipe stress analysis is done and suitable design modifications will be suggested to meet the acceptance criteria of applicable codes. Following outcomes will be achieved based on pipe stress analysis results.

- To keep nozzle loading on attached equipment within the allowable limit by manufacturers or standards like (API 610, API 617, the Hydraulic Institute, etc.)
- Determine the loads on structural supports, anchors and foundations.
- Evaluate the effects of sustain and operational loads on the piping system, pipe supports, anchors & attached equipment including:
    - Dead weight of pipe, and accessories
    - Operating and hydro test pressure
    - Operating temperatures
- Evaluate the effects of occasional loads on the piping system, pipe supports, anchors & attached equipment including:
    - Wind
    - Seismic

Pipe Stress Analysis - Objectives

- Evaluate the effects of support friction on piping system movements and stresses.
- Evaluate the effects of expansion joints on piping system movements and stresses.
- Evaluate the effects of changes in temperature, pressure and weight on flanged connections to identify possible locations where leakage may occur.

Critical Challenges /Failure in Piping

Critical Challenges/Failure in Piping

Thumb rules are easy, timesaving, and sometimes cost-effective methods often practiced by experienced professionals.

But things do turn wary, and problems like the pipe blast issue (image shown in next page, it was observed in a Domestic Water Supply Risers: uPVC pipes sch 80 in one of the high rise residential projects in North India) become a regular phenomenon. When the adequate number of pipe supports and flexible connectors to accommodate the pipe movement are not taken into consideration, things like pipe blast and pipe breakage happen.

These issues can be a source of discomfort not just to the building occupants, but also to the building contractors, project management and the service team.

In an age of social media, to prevent negative publicity, concerned parties should take proactive measures to not let these types of failures happen.

Things can be avoided at the design stage by using expert consultancy services from companies like Mechartes, who have been providing these pipe stress analysis and support design services for the last 15+ years.

Critical Challenges/Failure in Piping

Branch pipe failure. Pipe sheared at this location.

Case Study

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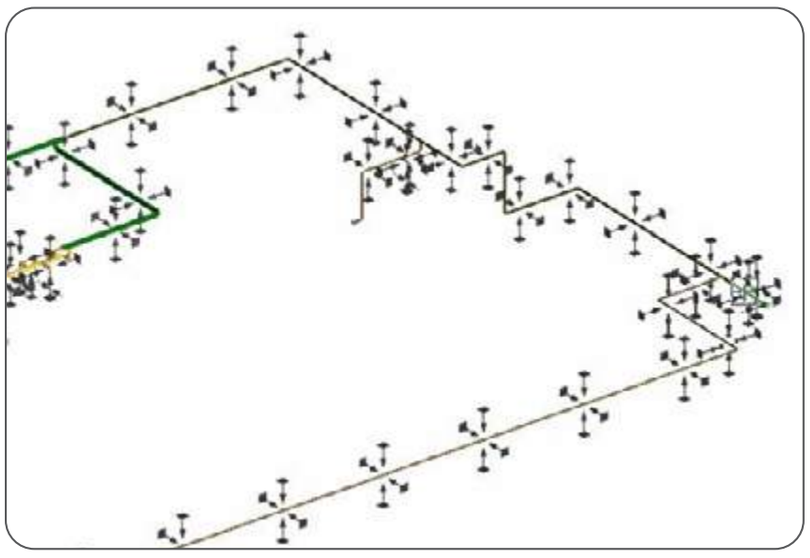
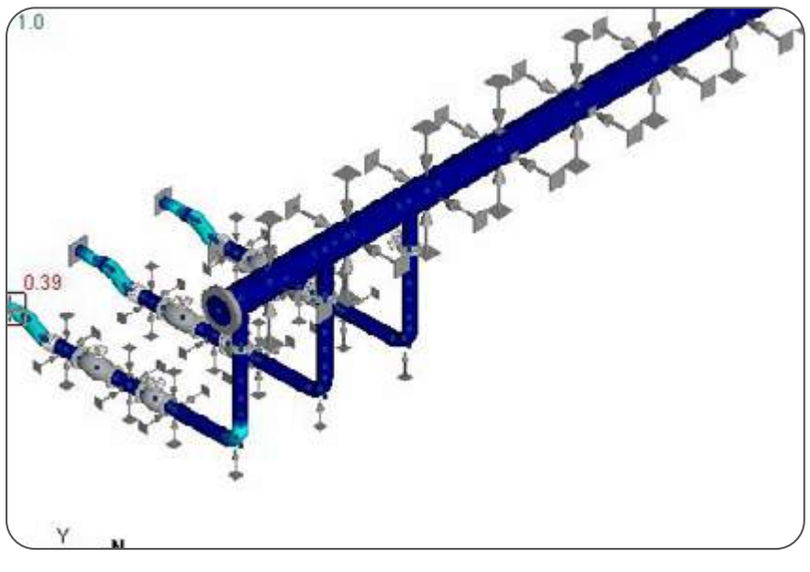
Stress Analysis & Support Design for Pipelines

Objective:

The objective is to check the pipelines for operating & occasional loads. The piping network are then designed, that can withstand these loads & forces. Purpose of analysis is to determine the stresses, deflection & forces in pipelines in design as well as operating condition. Based on results, various design modifications like flexible connectors, rigid anchors, additional supports, spring hangers etc. Stress analysis is conducted to come up with innovative design solutions that meet international codes like IBC, UBC, BS, ASME, FEMA, and API. Design of structural steel supports for piping systems are design using BS 5950 & ASCE.



General Piping Network



Stress Contour

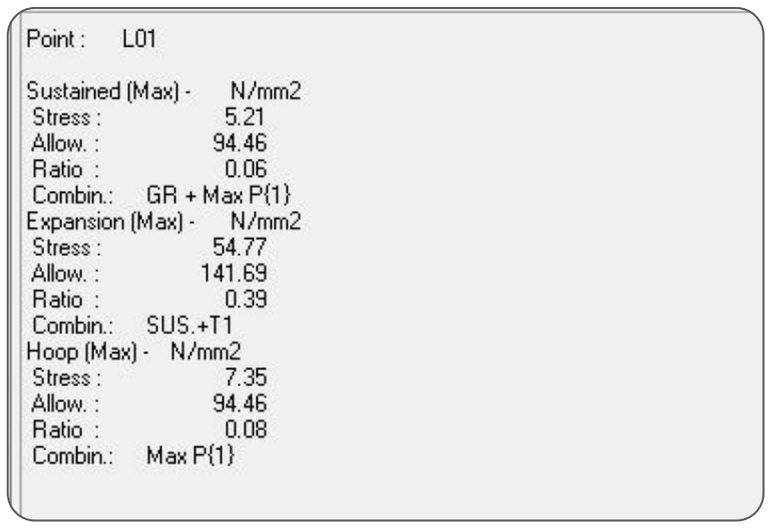
Modeling & Analysis:

The 3D modeling for the entire pipeline network with all the bends and runs along with initial support locations are captured and modeled using pipe stress analysis software Bentley-AutoPIPE. The piping system are appropriately modeled accounting for their loss coefficient and elevation. The analysis shows the displacement for the pipes at different locations and also the stresses caused due to operating & occasional loads. Various combinations of loading on the pipeline are provided as per applicable standards, which includes:

i) Dead load
ii) Pressure Load
iii) Thermal Load
iv) Seismic loads

Outputs:

- The stress ratio for the different load combinations.
- Forces & Moments acting on each support in all 3 directions.
- Stress Isometrics for Piping network.
- Structural steel support for Piping system to sustain various loads.
- Design modifications like additional supports & their types, if required in piping network, to reduce the stresses.



Stress Contour Plots

Selected List of Similar Projects:

- Doha Festival City.
- Muscat, Salalah & Delhi International Airports.
- Maliha Hospital, Dubai.

Reference List of Selected Building Projects

Reference List of Selected Building Projects

No.	Description of Project - Pipe Stress and Support Design	Details of Services
1	Barwa commercial Avenue	Piping stress Analysis for chilled water network inside the buildings
2	Supreme Education Council	Piping stress Analysis & support design for chilled water network inside the buildings
3	Hamad Medical City	Piping stress Analysis for chilled water & domestic water network inside the buildings
4	Dubai World Trade Centre (DWTC)	Piping stress Analysis & support design for chilled water network inside the building
5	Raban Palace	Piping stress Analysis & support design for chilled water network
6	Education City CP 5	Piping stress Analysis for chilled water network
7	Souq Waqif - Car Park	Piping stress Analysis for chilled water network

Reference List of Selected Building Projects

No.	Description of Project - Pipe Stress and Support Design	Details of Services
8	Muscat and Salalah Airport – Oman	Pipe Stress/Seismic analysis, Support Design, Hydraulic and Surge Analysis for Various Piping
9	GIFT City – Gujarat	Pipe Stress & Surge Analysis for CHW Pipelines
10	Opus Tower	Piping stress Analysis & support design
11	Lusail Marina Tower	Piping stress Analysis for chilled water & domestic water network, firefighting including Risers inside the buildings.
12	World Crest Tower, Mumbai	Piping Seismic/Stress Analysis for firefighting, plumbing network inside the buildings. (60 Floors)
13	Kempinski Hotel	Piping stress Analysis for chilled water & domestic water network inside the buildings

Reference List of Selected Building Projects

No.	Description of Project - Pipe Stress and Support Design	Details of Services
14	Al -Ain Hospital	Piping Seismic/Stress Analysis for chilled water, drainage, firefighting, plumbing network inside the buildings
15	Maliha Hospital	Seismic Calculations for chilled water, drainage, firefighting, plumbing network inside the buildings
16	EMAL AL TAWEELAH	Expansion and Contraction Analysis for Buried Chilled Water Pipe
17	National Rehabilitation Center	Expansion and Contraction Analysis for Buried Chilled Water Pipe
18	Delhi Airport – T3	Piping stress Analysis & support design for HVAC piping
19	Doha Festival City	Piping stress Analysis & support design

Team Capabilities

Team Capabilities

We at Mechatres are focussed on providing accurate simulation results with a professional and engineering approach. Our simulations represent the system closely and physics correctly at each parameter and step. With expertise in advanced numerical tools like Computational Fluid Dynamics (CFD) and Finite Element Method (FEM), our Team members are having experience of more than 12+ years and have been successfully delivering projects in

Piping analysis: we offer the following services in the Building sector:

- Piping Stress Analysis & Support design
- Surge / Water hammer Analysis
- API based Pulsation and Mechanical Vibration Study.
- Acoustic Modelling
- Root Cause Analysis
- Seismic & Vibration Analysis
- Finite Element analysis
- Flow Induced Vibration (FIV)/ Flow Induced Turbulence (FIT)
- Acoustic Induced Vibration (AIV)
- Structural stress analysis
- CFD Modelling

You can find more case studies and other resources on our website.

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That was...

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