GUIDE TO BETTER PIPE STRESS ANALYSIS

The Key to Increasing Accuracy

Bentley

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THE IMPORTANCE OF PIPING AND PIPELINES

The piping system is a key component of all process and power plants. As piping can handle greatly varying temperatures and pressures, it is probably the most efficient means of transporting a fluid from one point to another.

During its lifetime, a piping system is subject to multiple loads that generate displacements, deformations, and significant **stresses.** The failure of a single component within the piping system may lead to the shutdown of all or part of the system, or even cause serious safety issues.

A pipe stress engineer must ensure the **structural integrity** and **operability** of the piping system as it was routed by the piping designer.

Let's look at two case studies which illustrate the importance of accurate pipe stress analysis.

THE IMPACT OF INACCURATE DESIGN

Case Study 1: Solar Power Plant

First, we will consider a solar power plant project. Before connecting the piping to the turbine nozzle, springs were released, and the pipe dropped by more than 150mm. The manufacturer set a pipe drop limit of only 2mm.

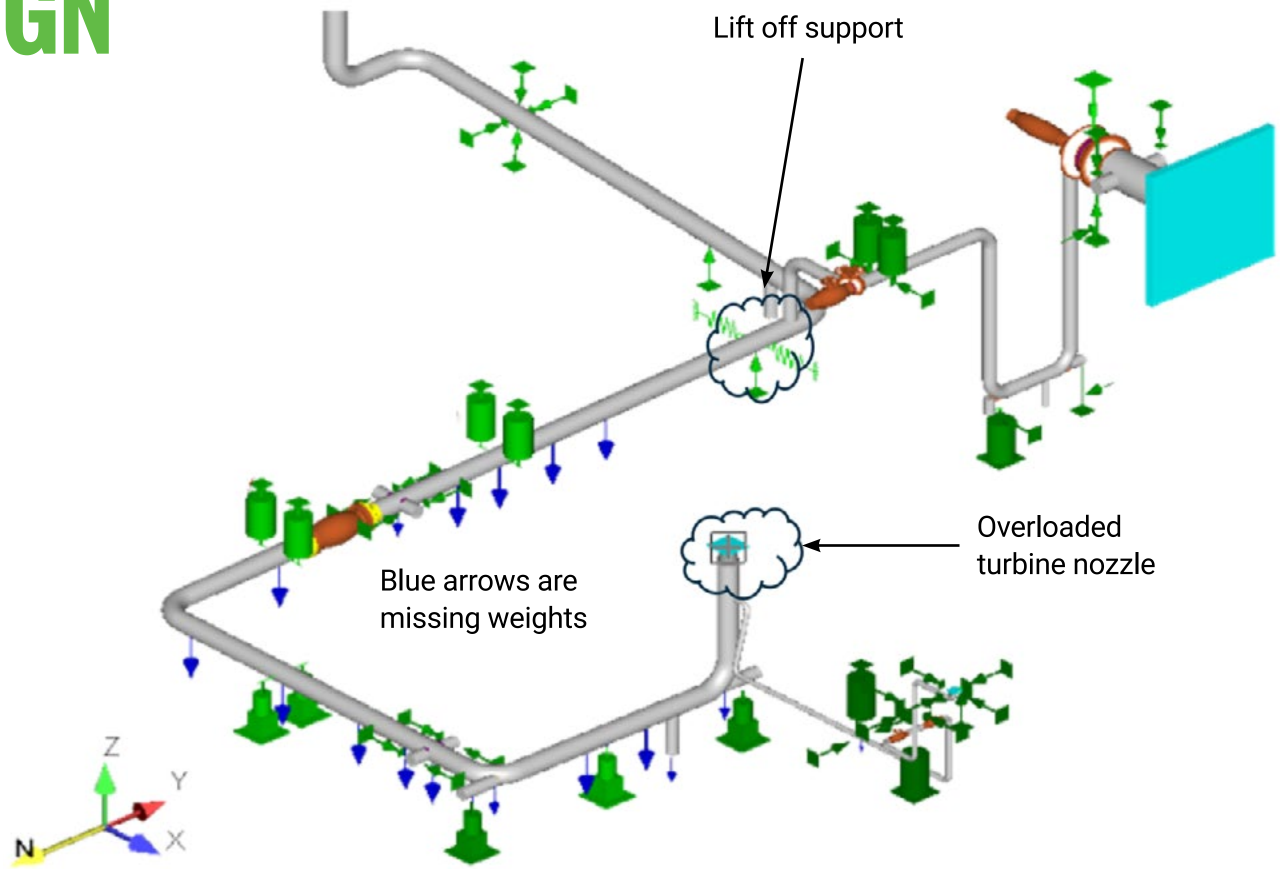
The problem was due to a cumulation of approximations on the dead loads. With the correct data, the simulation could match the behavior observed on site and the model could be used to evaluate new supporting configurations.

Engineering errors:

- Under-estimation of component weight
- Spring supports under-sized (consequence)
- Several stops and springs placed at incorrect locations

Overall impact:

The engineering team faced a delay of several weeks, which incurred penalties, plus the cost of rework.



Original calculated weight: 22.3 tons

- \+ Density correction: 558 Kg
- \+ Aluminum cladding: 450 Kg
- \+ Flange nuts and bolts: 1738 Kg
- \+ Supports, instrument, lines: 6954 Kg

New calculated weight: 32.0 tons

Missing weight: 9.7 tons or 43.5%!

THE IMPACT OF INACCURATE DESIGN

Case Study 2: 40 MW Power Plant

Next, let's consider a 40 MW heavy fuel power plant project. At startup of the line, the expansion joint failed and, consequently, further damages ensued in the engine, the valve, and the structure. The plant was shut down for 30 days.

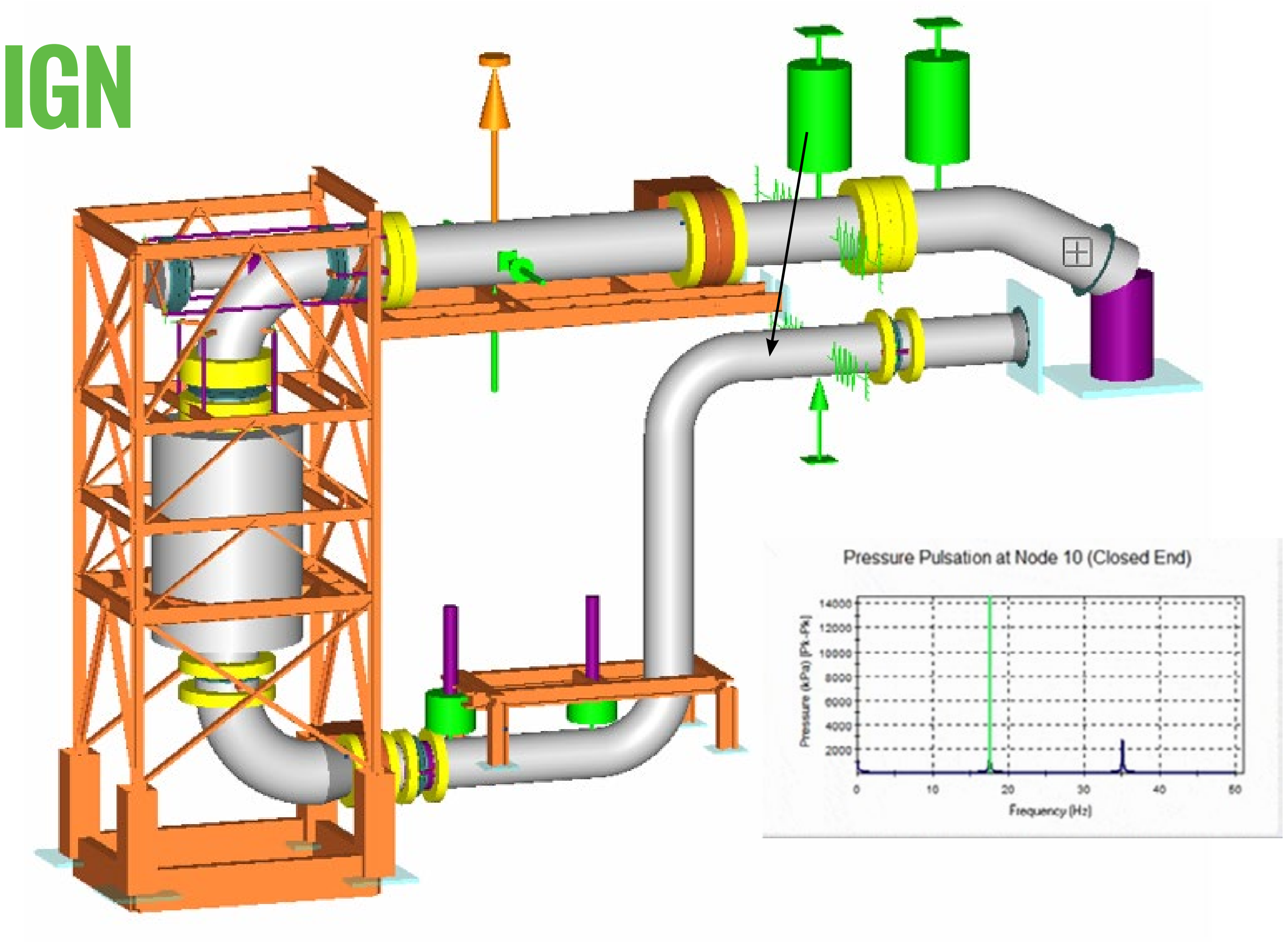
At the second startup, significant vibrations took place, resulting in another shutdown lasting 15 days. The modal analysis of the piping combined with the steel structure revealed a resonance problem. Without it, no problem was predicted.

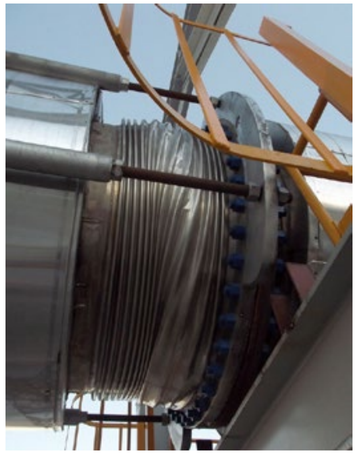
Engineering errors:

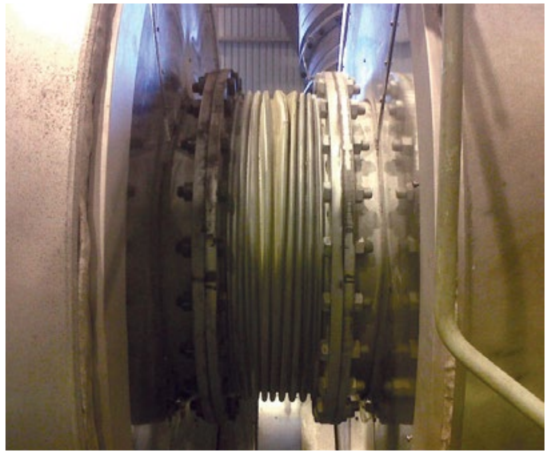
- Expansion joint thrust load not considered
- Incorrect modeling of the trunnions (supports)
- Flexibility of the structure ignored (vibration)

Overall impact:

The plant was shut down for a total of 45 days to perform structural and piping rework, resulting in a financial penalty.







THE STRESS ENGINEER'S COMPANION

As you can see, the impact of inaccurate pipe design carries significant costs and delays. To avoid these issues, many piping engineers around the world have chosen AutoPIPE, a pipe stress analysis and design application, to create high quality and cost-effective pipe designs.

With AutoPIPE, you can design and analyze piping systems for a variety of projects, including:

- Nuclear and fossil power plants
- Process and chemical plants
- Thermosolar plants
- Desalination plants
- Offshore FPSO platform and riser design
- Fire protection systems
- Oil refineries
- Cross-country gas and oil pipelines
- Building services

Piping material can be metallic or non-metallic (HDPE, GRP/FRP, PVC, PP, PE, etc.)

AutoPIPE is audited by NUPIC, NIAC, and NRC nuclear users.

Multiple loading conditions can be simulated:

Static Loads	Dynamic Loads
• Temperature	• Response spectrum
• Pressure	• Relief valve opening
• Earthquake	• Seismic anchor movement
• Wind	• Harmonic
• Hydrotest	• Water/steam hammer
• Wave	• Time history load
• Snow	• Thermal transient
• Imposed displacements	• Fatigue for nuclear
• Buoyancy	
• Fault crossing	
• Soil liquefaction	

Quality Assurance You Can Trust

- ASME NQA-1
- ASME N45.2
- 10CFR50 Appendix B

COMPLY WITH GLOBAL STANDARDS

AutoPIPE offers many global standards so you can ensure your pipe stress analysis complies with various guidelines.

Piping Codes

- ASME B31.1, B31.3, B31.4, B31.8, B31.12
- EN13480, BS806, SPC-2, TBK5-6, CSA-Z662, Stoomwezen, Miti501, KHK, General Code
- Offshore: CSA-Z662, DNV, B31.4 Ch IX, B31.8 Ch VIII
- BS7159 (GRP), ISO14692 (GRP)
- Nuclear: ASME NB/NC/ND, RCC-M, JSME PPC

Rotating Equipment Loads

- Centrifugal pumps: API 610
- Centrifugal compressors: API 617
- Steam turbines: NEMA SM 23

Vessel Local Stresses

- API 650, PD5500, WRC107, WRC297, KHK

Nozzle Flexibility Calculation

- ASME, API 650, Bijlaard, WRC297, Spherical, User

Flange Check

- ASME Section VIII, Division 1
- ASME Section VIII, Division 2
- ASME Section III, Appendix XI
- ANSI Check

AutoPIPE maintains ASME codes going back to 2004 and nuclear codes as early as 1972.

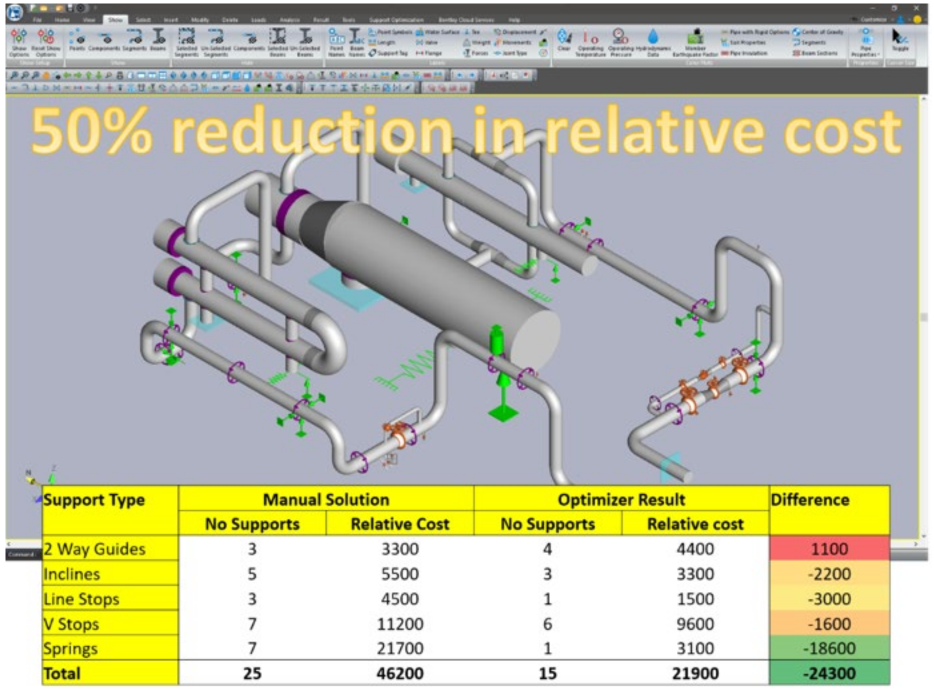
OPTIMIZE YOUR SUPPORT CONFIGURATION

A stress engineer is responsible for determining the optimal support location based on multiple criteria.

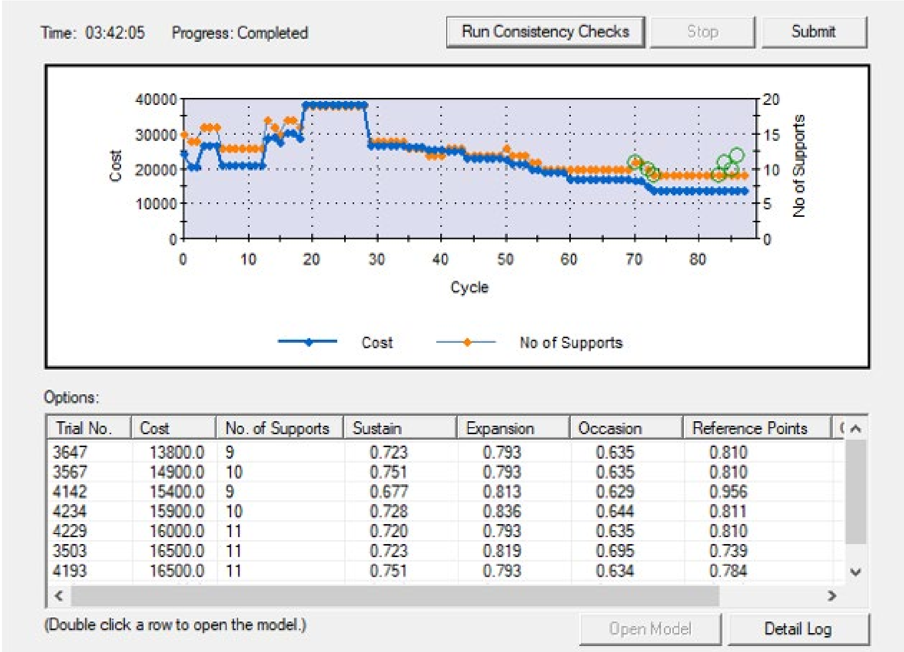
Experienced stress engineers can find a satisfactory solution more quickly. But even so, they still lack the time to go further in their search for an optimized solution. Evaluating several support configurations can take hours or days.

Is it worth the effort? Absolutely! With hundreds or thousands of supports in a project, the cost savings can be huge and the design can be very competitive.

AutoPIPE Advanced gives you next-level capabilities and offers Support Optimizer functionality. Take advantage of artificial intelligence algorithms and multiple core processing to analyze thousands of configurations and converge toward the most economical options.



Support Type	Manual Solution		Optimizer Result		Difference
	No Supports	Relative Cost	No Supports	Relative cost	
2 Way Guides	3	3300	4	4400	1100
Inclines	5	5500	3	3300	-2200
Line Stops	3	4500	1	1500	-3000
V Stops	7	11200	6	9600	-1600
Springs	7	21700	1	3100	-18600
Total	25	46200	15	21900	-24300



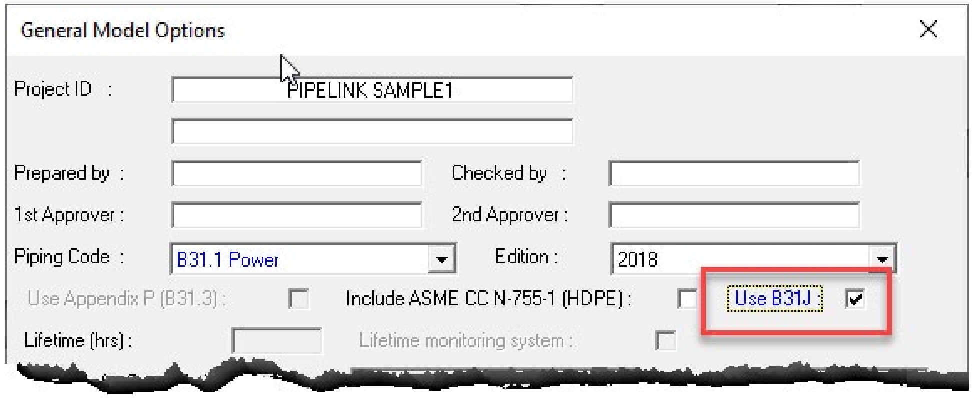
Trial No.	Cost	No. of Supports	Sustain	Expansion	Occasion	Reference Points
3647	13800.0	9	0.723	0.793	0.635	0.810
3567	14900.0	10	0.751	0.793	0.635	0.810
4142	15400.0	9	0.677	0.813	0.629	0.956
4234	15900.0	10	0.728	0.836	0.644	0.811
4229	16000.0	11	0.720	0.793	0.635	0.810
3503	16500.0	11	0.723	0.819	0.695	0.739
4193	16500.0	11	0.751	0.793	0.634	0.784

INCREASE ACCURACY **WITH ASME B31J**

The beam theory idealization of the piping fails to capture the local stresses in bends, intersections, and joints. The problem is addressed by the introduction of **Flexibility & Stress Intensification Factors (SIF).**

Piping codes provide simple formulas to calculate those stress intensification factors for standard components. In their 2020 Edition, B31.1 and B31.3 codes adopted the modern and more accurate approach of ASME B31J.

ASME B31J aims to provide a standardized method to develop the stress intensification factors and determine the flexibility factors for metallic piping components, and sustained stress factors used in B31 piping analysis.



AutoPIPE has implemented B31J as an internal module. It can be activated with a simple click.

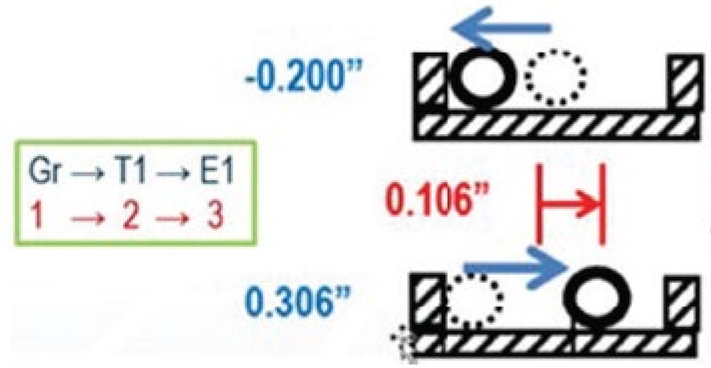
SIMULATE REAL BEHAVIORS

Load Path-dependent

In the real world, gravity load is applied first, then temperature, pressure, or other loads. The sequencing doesn't matter in a linear analysis.

Gaps, friction, or soil require nonlinear analysis. Each load is applied considering the initial state of the supports from the previous load step. Here, the sequencing does matter.

The load sequencing approach is recommended by ASME to capture the real behavior of the piping under operating conditions.

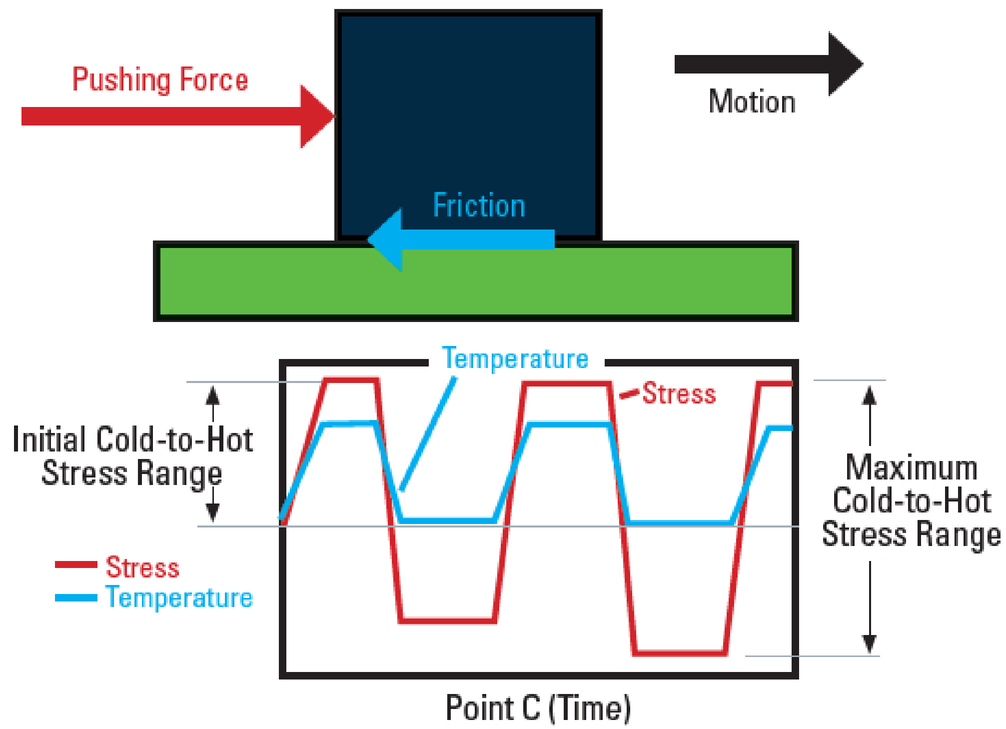


Result of load sequencing

Friction Case

When the pipe system returns to ambient conditions after an operating cycle, friction forces reverse sign but maintain magnitude, possibly doubling the stress and load ranges during cooldown.

AutoPIPE load sequencing can simulate the full load cycle and evaluate the true stress range.



Incremental analysis approach

EVALUATE MULTIPLE SCENARIOS

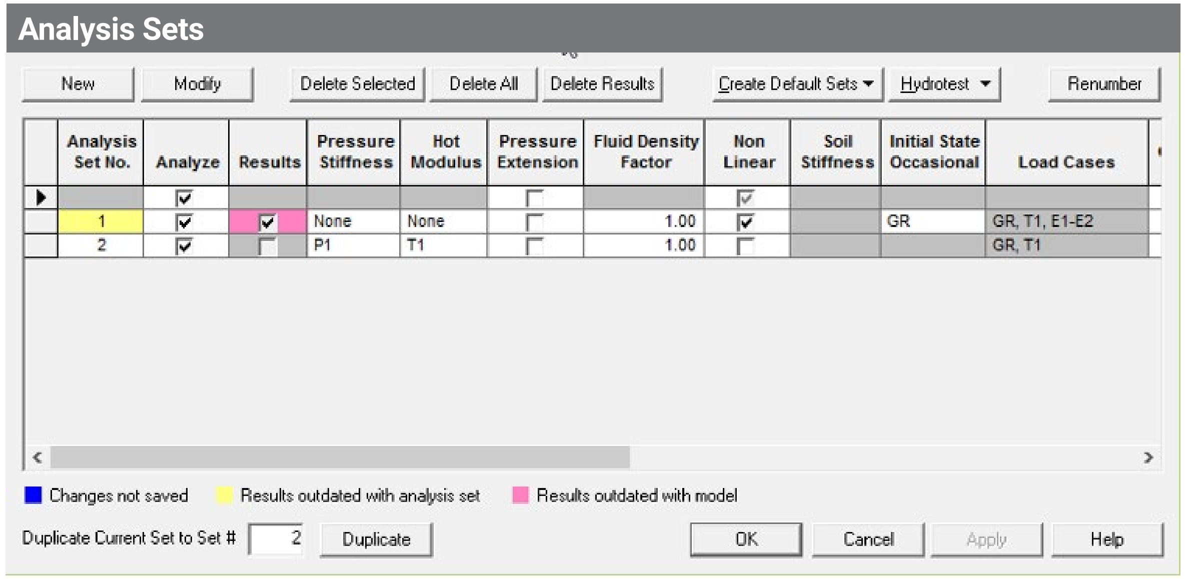
In plant design, it is vital to perform pipe stress analyses to examine various loading conditions.

AutoPIPE enables engineers to define multiple analysis sets and provide references to these results from separate analyses during post-processing.

Some piping codes, like nuclear class NB, make it a requirement that different hot moduli be applied to different thermal analysis sets.

A hot modulus static analysis enables the user to calculate hot stresses corrected to an ambient or cold modulus condition while support and equipment loads are calculated with a hot modulus, i.e., a hot operating condition.

This means that linear vs. nonlinear scenarios, hot vs. cold modulus, pressure vs. no-pressure stiffening, and a wide range of soil properties can be examined all at the same time.



PERFORM FLANGE CHECKS

Flanges are an example of components for which failure could result in serious problems in the plant.

As an illustration, a heat exchanger with a certain type of flange can be fabricated well in advance before actually knowing the loads from the piping assembly on that flanged joint. This can lead to excessive loads on the flanged joint, causing it to fail.

Both leak tightness and strength need to be checked.

The AutoPIPE flange check module is fully integrated in the pipe stress workflow. The checks are updated with any change in the system.

AutoPIPE supports various methods for flange design:

- ANSI Check (Equivalent Pressure Method)
- ASME VIII, Div. 1 & 2; ASME III, Appendix XI
- EN1591-1 (under development)

IMPLEMENT ROTATING EQUIPMENT CHECKS

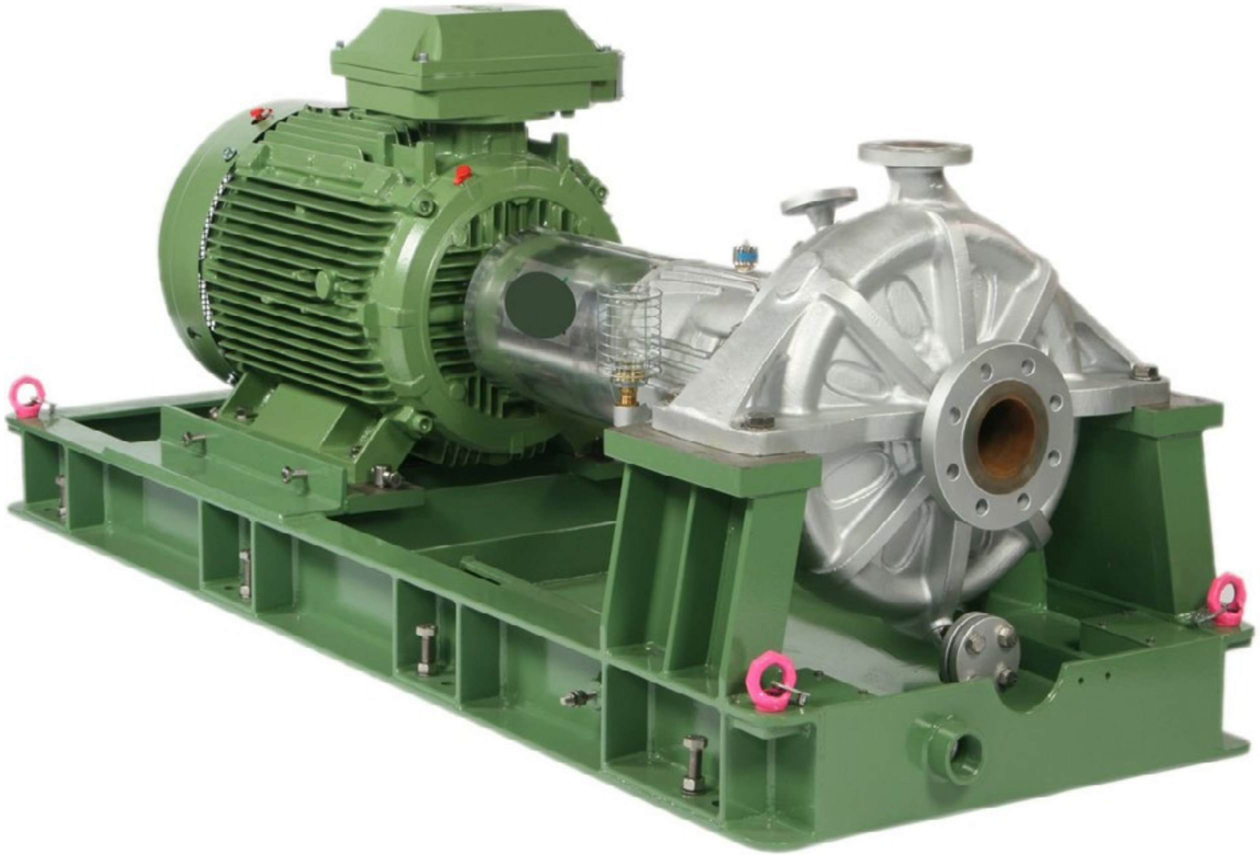
Rotating equipment involves sensitive elements. Excessive loads imposed by the piping on the equipment can deform machine parts and impact its operability. The stress engineer must ensure that the piping loads never exceed the allowable values.

When provided by the manufacturer, the allowable values can be entered as user-defined values.

Alternatively, AutoPIPE can check the equipment loads to relevant standards:

- API 610 for centrifugal pumps
- API 617 for centrifugal compressors
- NEMA SM 23 for steam turbines

A detailed report lists all intermediate calculation and the summary of the check result.



The AutoPIPE rotating equipment module is fully integrated in the pipe stress workflow. The checks are updated with any change in the system.

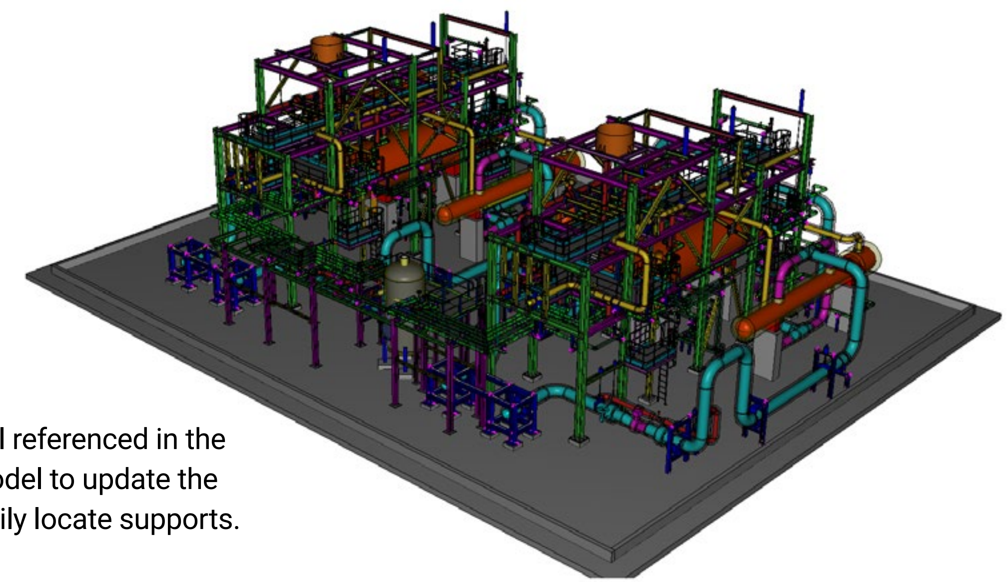
CLOSE THE COLLABORATION GAP

Many projects involve interdependent disciplines. Accurate and up-to-date information reduces the risk of errors and helps you make better decisions.

AutoPIPE provides tools to optimize project workflows, including:

- Standard formats to exchange data with CAD systems like OpenPlant, PDMS/E3D, SmartPlant 3D, and Plant 3D.
- Bidirectional link with STAAD/SACS models to transfer pipe loads and include the flexibility of the structure.
- Export/import with CAESAR II input files (*.xml, *.C2, *.cii).
- 3D export to include the stress model in the CAD model.
- Spreadsheet format to import pipe routing coordinates.
- Exchange data with PIPENET or AFT IMPULSE for pressure surge transient analysis.
- Export nozzle loads to AutoPIPE Vessel for the design of pressure vessels and heat exchangers.

Standard Formats	Specific Applications
Import: • CAESAR II • PCF • PXF • PDS neutral file • ADLPipe **Export:** • CAESAR II • DXF • PDMS XML • DGN for hot clash detection • SQLite and MDB database files	• STAAD and SACS • PipeNet, AFT Impulse • CAESAR II • MicroStation • OpenPlant and AutoPLANT • AutoPIPE Vessel • AutoCAD • Revit • PDMS/E3D • PDS • SmartPlant 3D • Inventor • SolidWorks • LICAD



A stress model referenced in the global CAD model to update the piping and easily locate supports.

BETTER PIPE STRESS ANALYSIS STARTS HERE

Choose AutoPIPE to increase the accuracy of your pipe design projects. Save time with easy-to-use software that helps you perform advanced analysis and design.

Learn More >