Fluid Flow's Influence

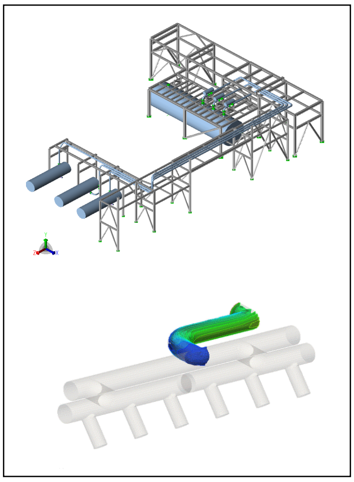
On the Structural Response of Piping Systems and their Analysis

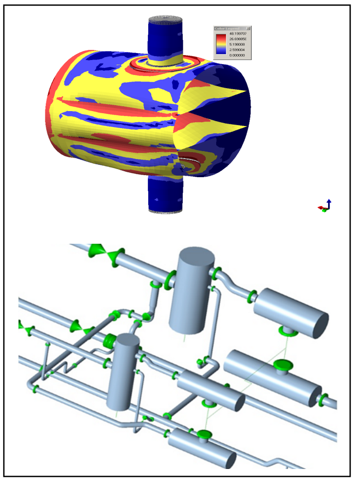
DRG
Dynaflow Research Group

INTERGRAPH

Dynaflow Research Group (DRG)

Consulting	Software	Training





DRG
Dynaflow Research Group

INTERGRAPH

Agenda

- **Case 1 – Vibration Assessment**
- Case 2 – Waterhammer Analysis
- Case 3 – Live demo

DRG
Dynaflow Research Group

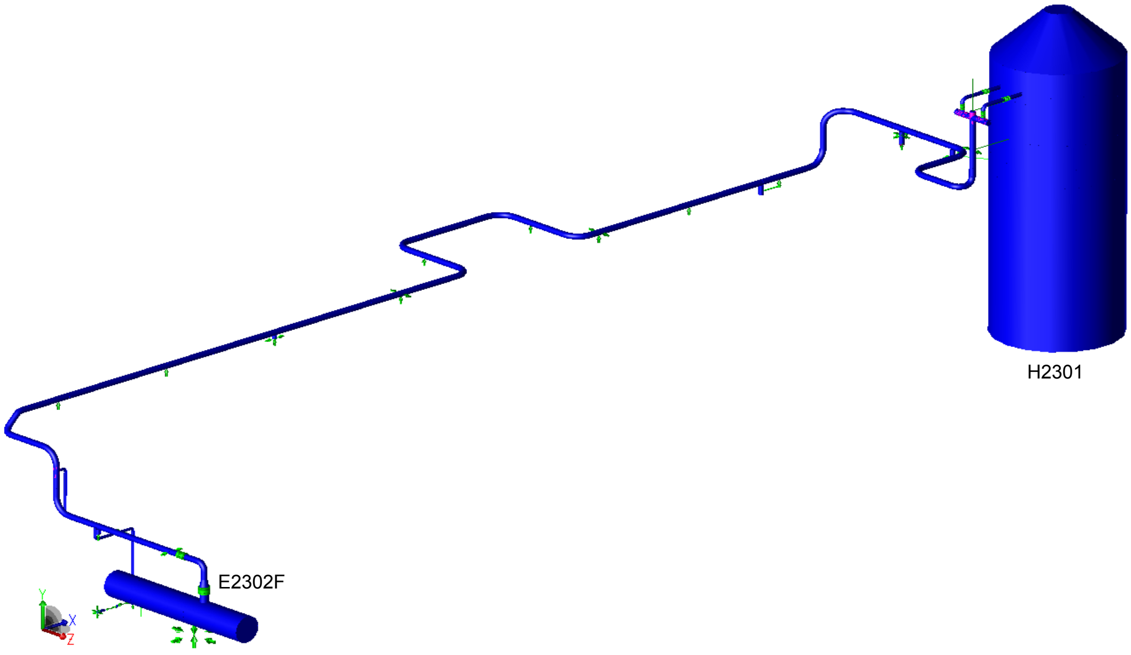
INTERGRAPH

Vibration Assessment of Gasoil Hydrofiner

DRG
Dynaflow Research Group

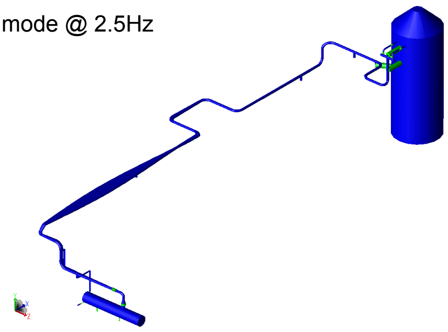
INTERGRAPH

C2 Model made for analysis of the system

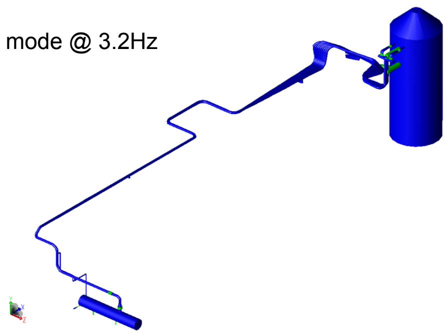


Overview of the first three eigen modes in this line determined using C2

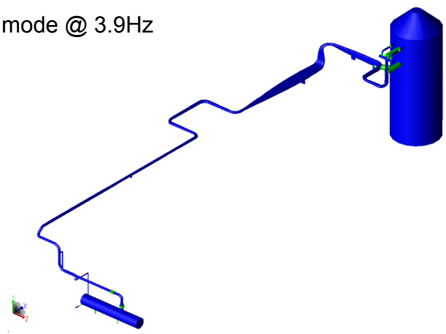
1st mode @ 2.5Hz



2nd mode @ 3.2Hz



3rd mode @ 3.9Hz



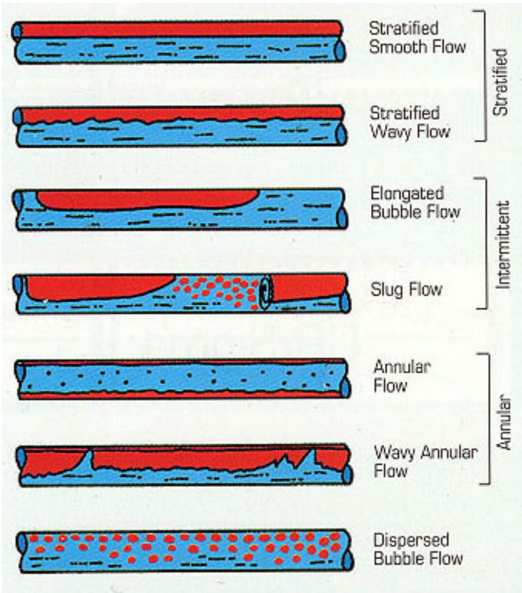
Mode 2 is the largest contributor to the maximum dynamic stress, therefore this mode has priority to be taken out or shifted up

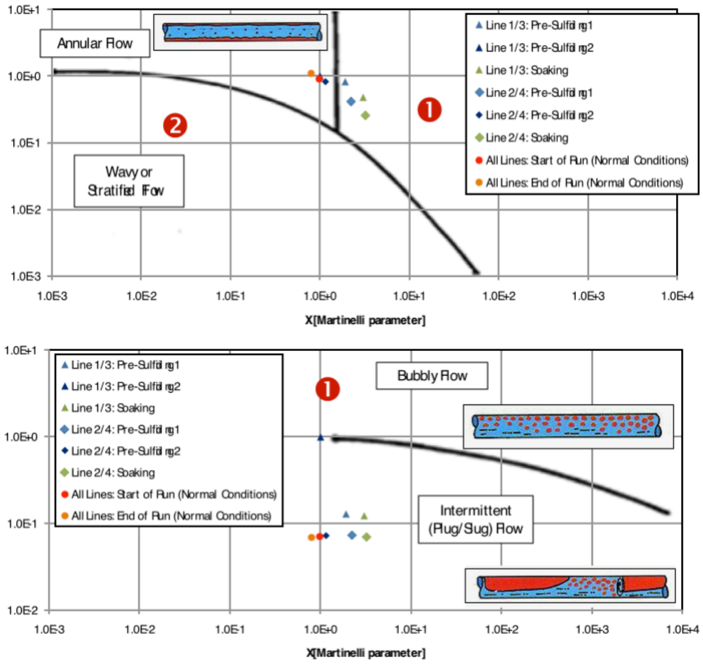
Mode 2 is also most observed in the field

© Intergraph 2014

Flow regime assessment of 2-phase flow

Slug Flow occurs during the start-up phase based on flow conditions



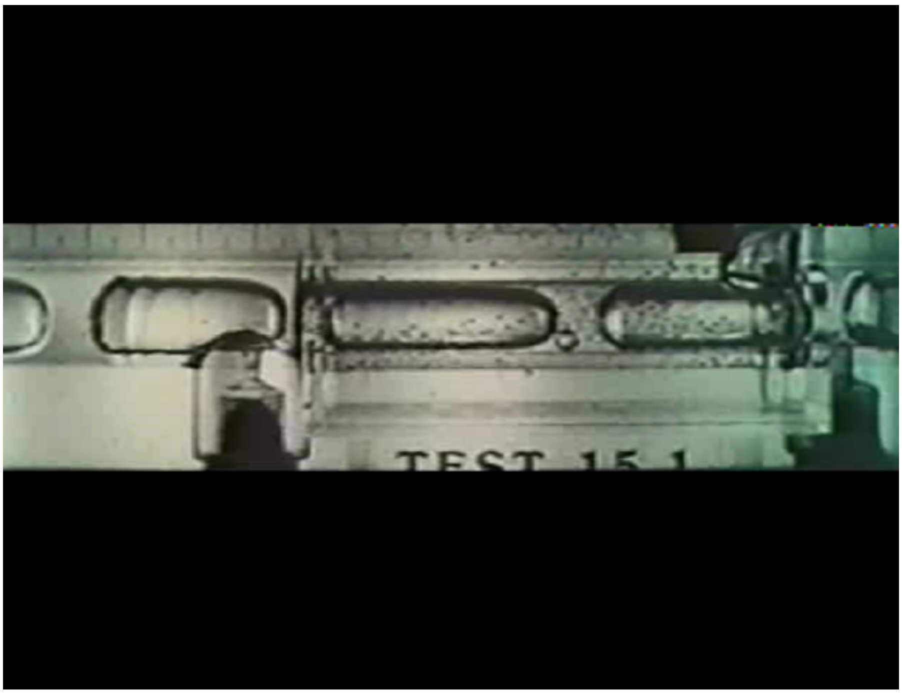


Map for horizontal flow, Taitel and Dulker (1976)

DRG
Dynaflow Research Group

INTERGRAPH

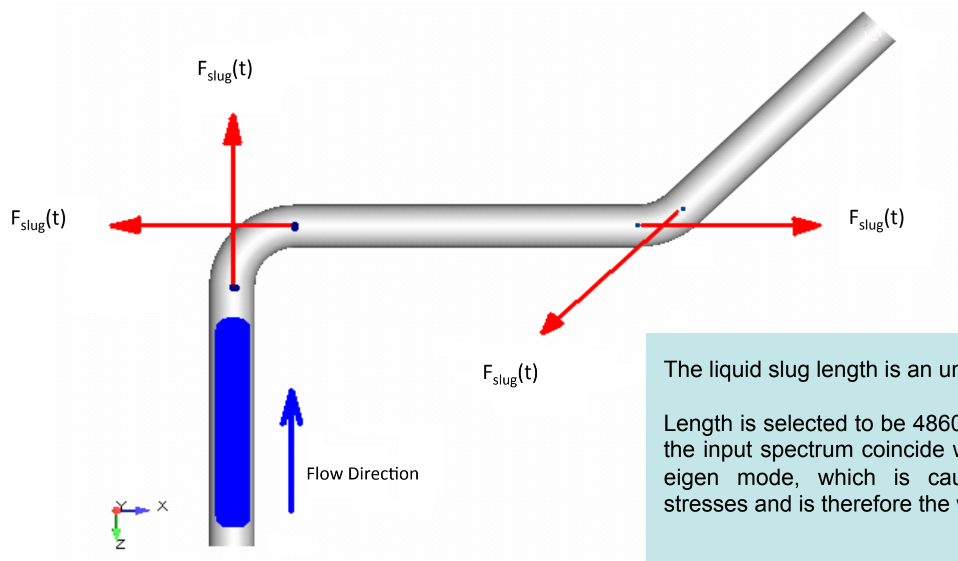
Example of slug flow



DRG
Dynaflow Research Group

INTERGRAPH

Unbalanced Slug forces act on elbows



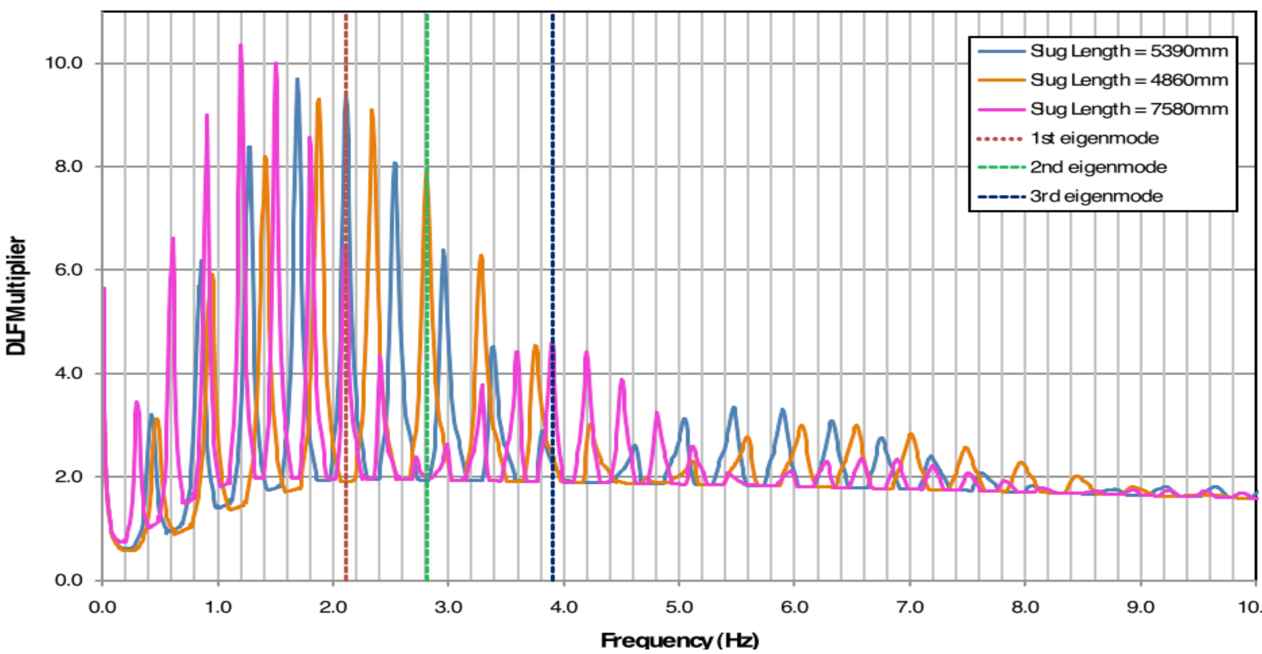
The liquid slug length is an unknown

Length is selected to be 4860mm in order to let a peak of the input spectrum coincide with the frequency of the 2nd eigen mode, which is causing the largest dynamic stresses and is therefore the worst case scenario

DRG
Dynaflow Research Group

INTERGRAPH

Slug length selected based on worst case (2nd eigen mode)

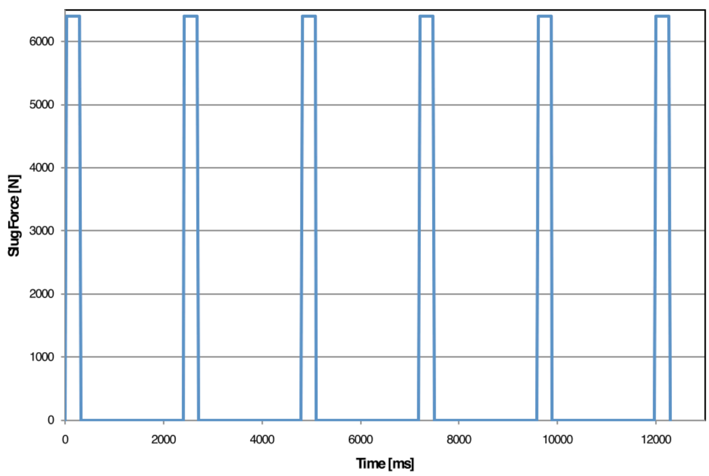


DRG
Dynaflow Research Group

INTERGRAPH

Time history of slugs used to assess stresses in the system

TIME DEPENDENT SLUG LOAD CONSTRUCTED



Slug loads added to the various bends in the model

Dynamic CAESAR II run analyzed using time history of slugs

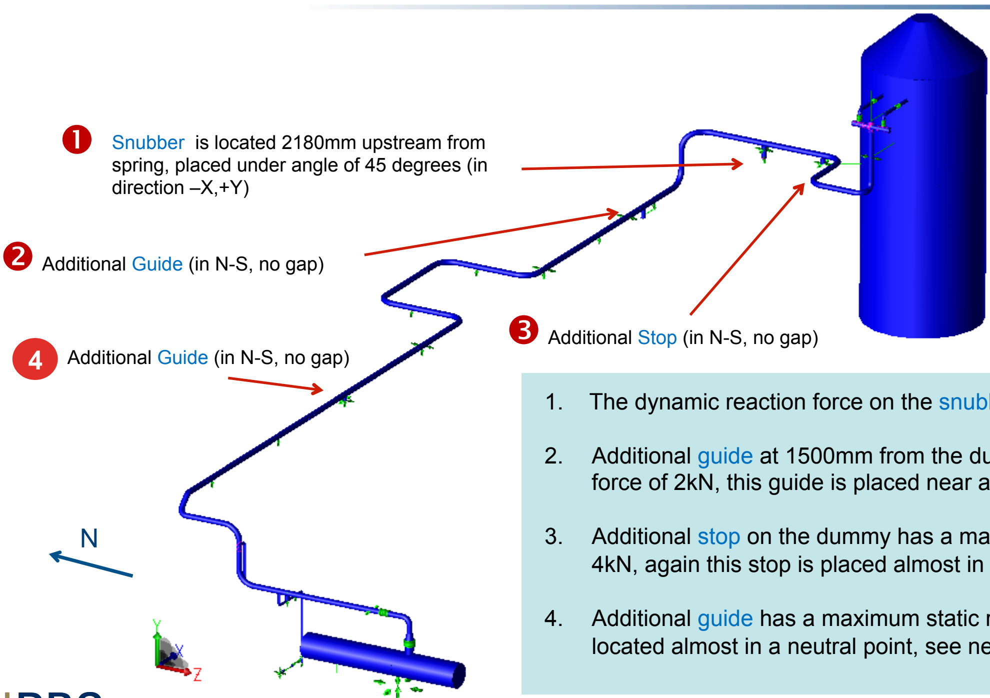
High dynamic stresses found of 16.7MPa

Highest stresses at the piping just upstream of the nozzle of the furnace

The maximum dynamic displacements of 10mm

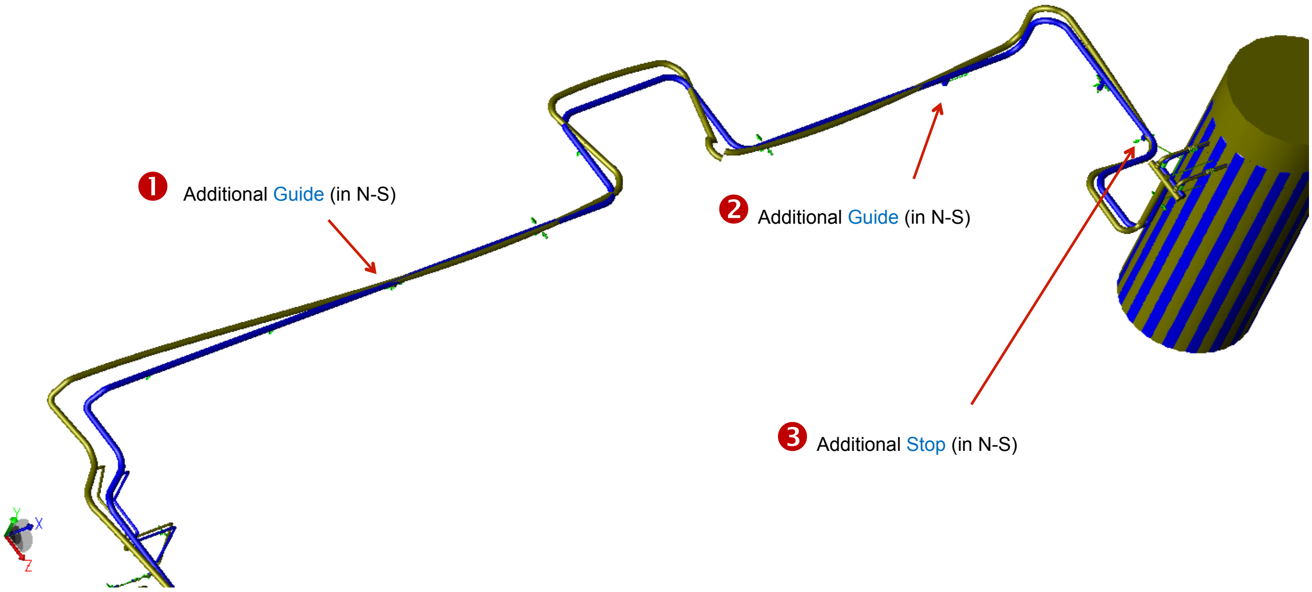
High support loads found

3 additional rigid restraints and one snubber are proposed



1. The dynamic reaction force on the snubber is 10kN
2. Additional guide at 1500mm from the dummy has a maximum reaction force of 2kN, this guide is placed near a neutral point
3. Additional stop on the dummy has a maximum static reaction force of 4kN, again this stop is placed almost in a neutral point
4. Additional guide has a maximum static reaction force of 1kN, as it is located almost in a neutral point, see next slide for neutral points

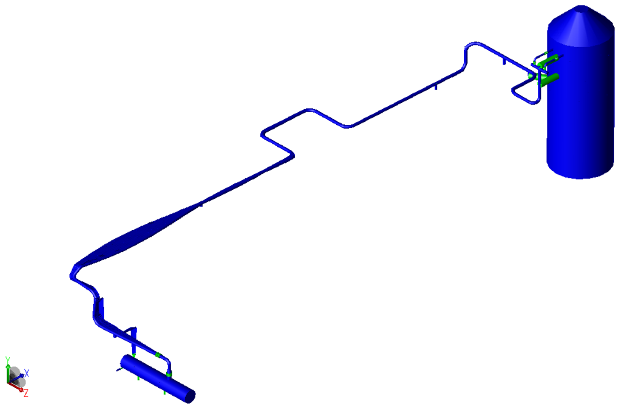
Three additional rigid restraints are all placed at neutral points



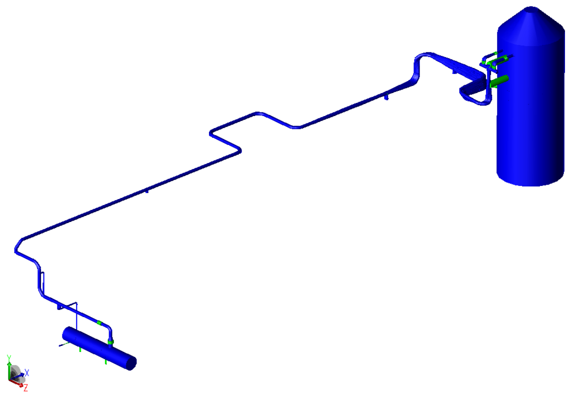
Reduction of maximum dynamic stresses

First eigen modes at higher frequencies; stiffness has increased

1st mode form 2.5 to 3.9Hz



2nd mode from 3.2 to 5.2Hz



Conclusions

Slug flow very likely to occur and almost certainly the cause of the vibrations

Slug impact analyzed for worst case scenario: slug length such that it resonates with 2nd eigen mode of the system

Additional supporting resulted in higher eigen modes

- First eigen mode occurs now at 3.9Hz instead of 2.5Hz, second eigen mode is at 5.2Hz instead of 3.2Hz

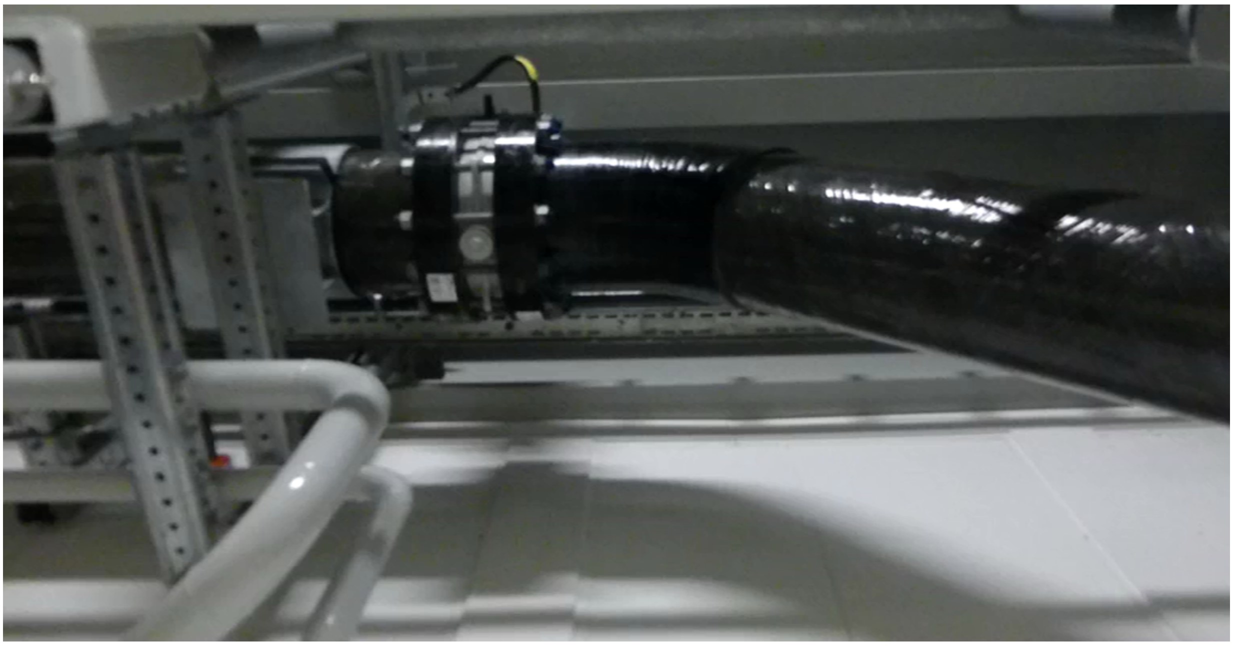
Resulting in lower stresses and smaller displacements

- Maximum dynamic stress went down from 16.7MPa to 10.1MPa; this is at the piping just upstream of the nozzle of the furnace
- The maximum dynamic displacement went down from 10mm to 4mm

Agenda

- Case 1 – Vibration Assessment
- **Case 2 – Waterhammer analysis**
- Case 3 – Live Demo

The problem



Introduction

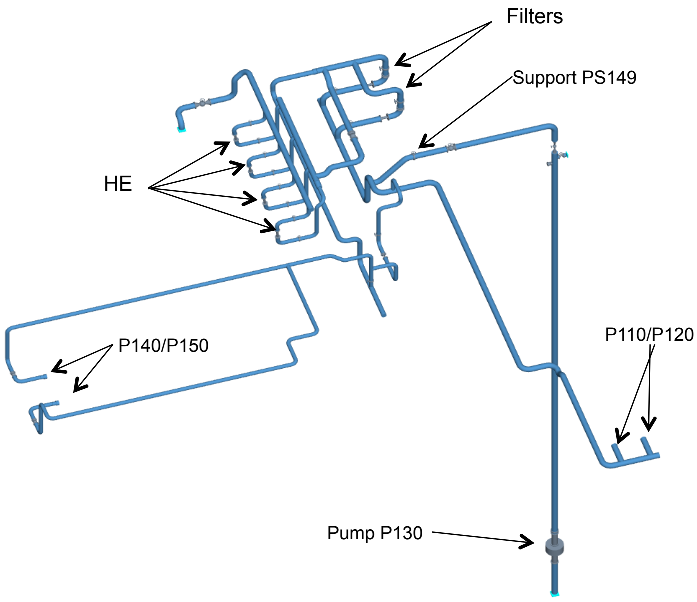
During the commissioning of Sea Water System 50, uncontrolled displacement of the pipework has been observed as a result of hydraulic hammering during ESD of sea water lift pump 50-P-130.

Due to the hammering support no. PS-149 failed to restrain the pipe in lateral direction.

Preliminary results of the water hammer analysis performed by DRG is presented here.

An overview of possible scenarios which could have led to the support displacement is included.

Model Geometry



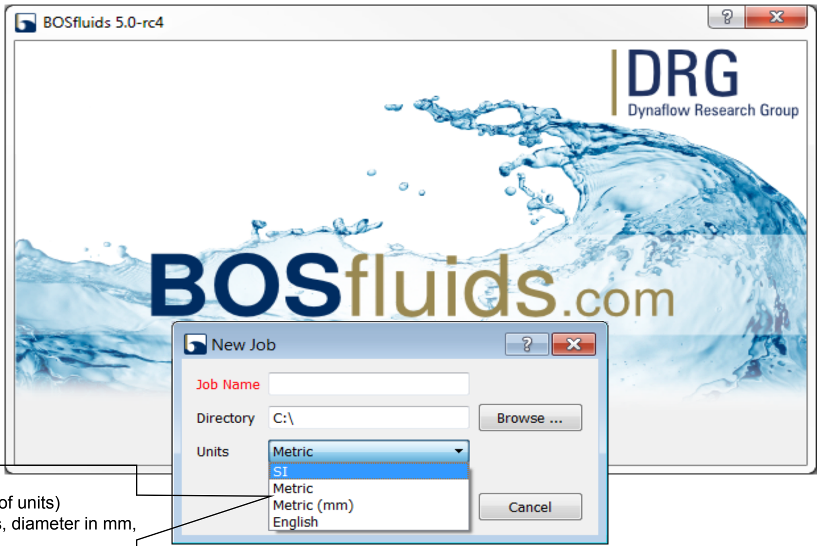
Based on the received isometrics the piping is modeled in the transient software package BOSfluids.

The heat exchangers (HE) and filters (F) are included as orifices.

A 40m riser pipe is included

Initially all lines > 3” are modeled

Opening BOSfluids

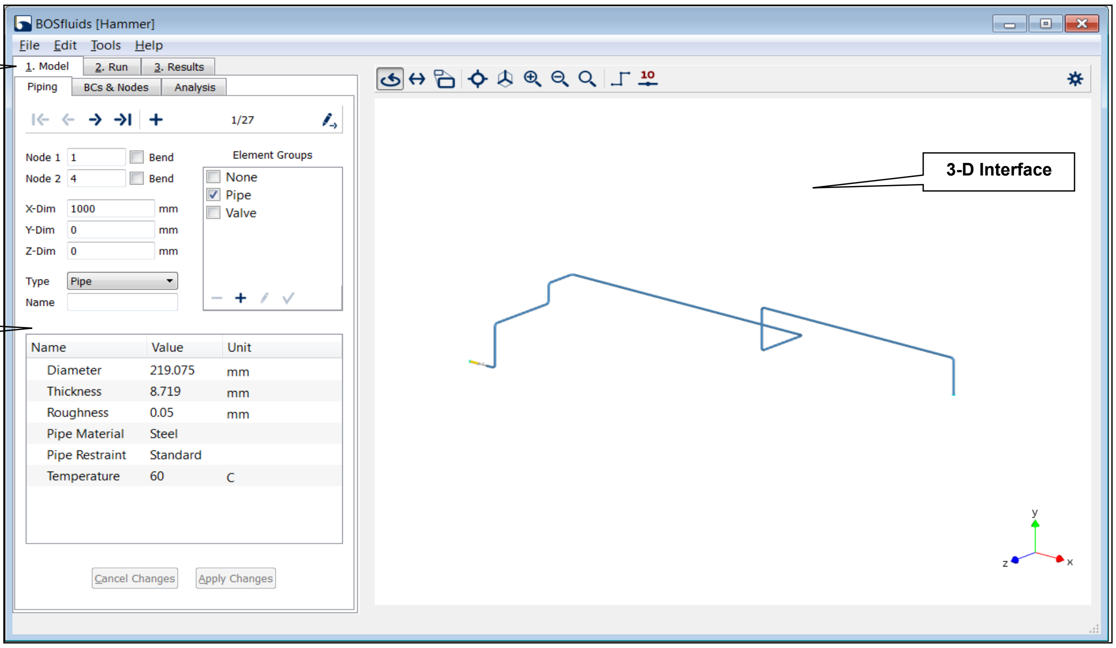


Units

- **SI** (International system of units)
- **Metric** (Length in meters, diameter in mm, pressure in bar)
- **Metric** (mm) (Length mm, diameter in mm, pressure in bar
- **English** (Length and diameter in inches, pressure in psi)

3D model similar to CAESAR II

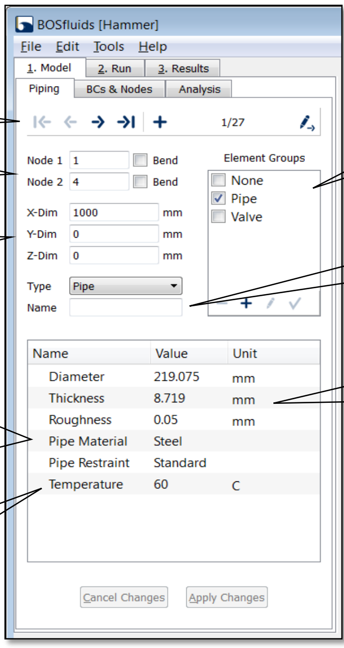
Tab system



Input window

3-D Interface

Creating a piping model is simple



Navigation Toolbar

Node numbers
Bend (Default = 1.5D)

X, Y, Z Dim
Vector between nodes

Pipe material
- STEEL
- GRE55
- GRE63
- GRE73
- GRP00
- FUJIK GRP
- UPVCO
- PVC

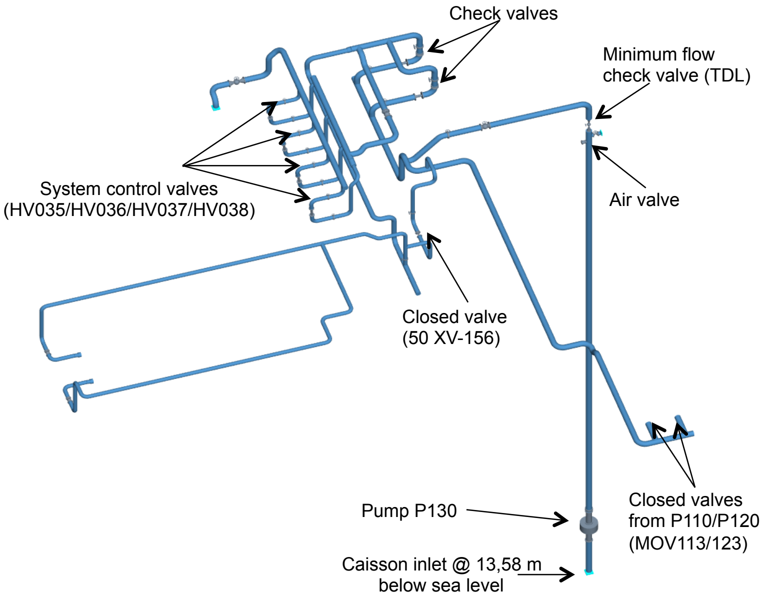
Temperature
Temperature is used for fluid properties

Element Groups

Name
Name element to cross-reference in post-processing

Input parameters
Pipe dimensions
Roughness (default = 0.05mm)

Dynamic elements are added to model geometry



Check valves downstream filters

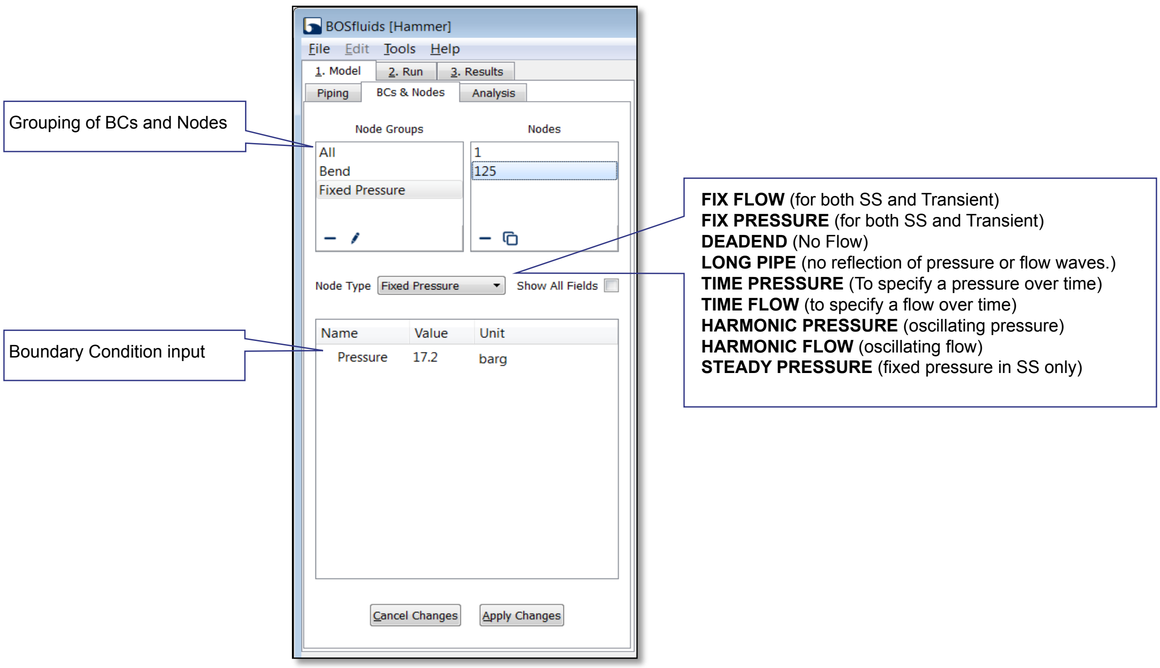
Valves: 50 XV-156 and MOV 113/123 are closed

Pump inlet is assumed to be located 11m below sea level

DRG
Dynaflow Research Group

INTERGRAPH

Boundary conditions are added in a separate tab



DRG
Dynaflow Research Group

INTERGRAPH

3 mechanisms identified as possible sources of high loads

Pressure drop caused by the ESD of the pump.

- The rapid reduction of discharge pressure caused by the pump shut down can result in unbalanced forces in the order of tens of kN. Depending on the pump inertia.

Cavitation

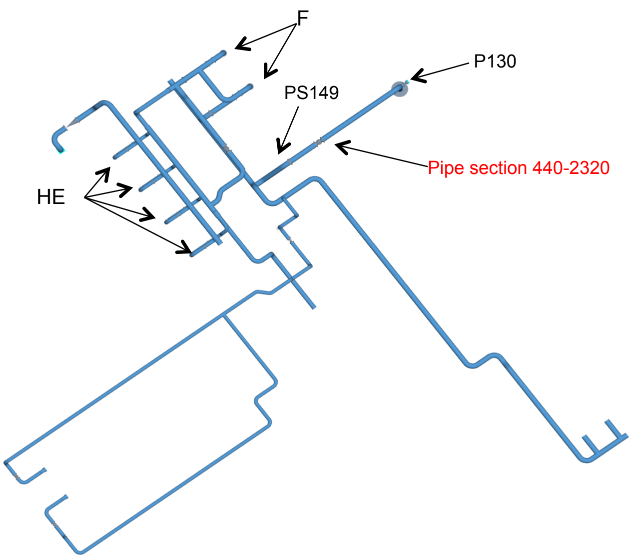
- Due to the rapid deceleration of the large fluid column by an upstream event, cavitation may occur in the upper pipe sections, where the hydrostatic pressure is the lowest. When these cavity pockets collapse they may be cause high pressure spikes and unbalanced loads.

Backflow through check valve

- When the check valve does not close fast enough backflow might occur. When the check valve closes during backflow, forces proportional to the speed of the backflow occur in the system.
- This mechanism is unlikely since the check valve contains a spring that should close the valve before backflow occurs.

Unbalanced forces expected to be largest in pipe section 440-2320

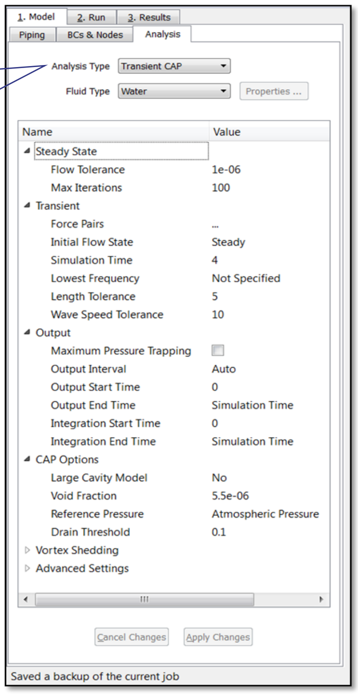
TOP VIEW



DRG
Dynaflow Research Group
© Intergraph 2014
INTERGRAPH

Defining the analysis type

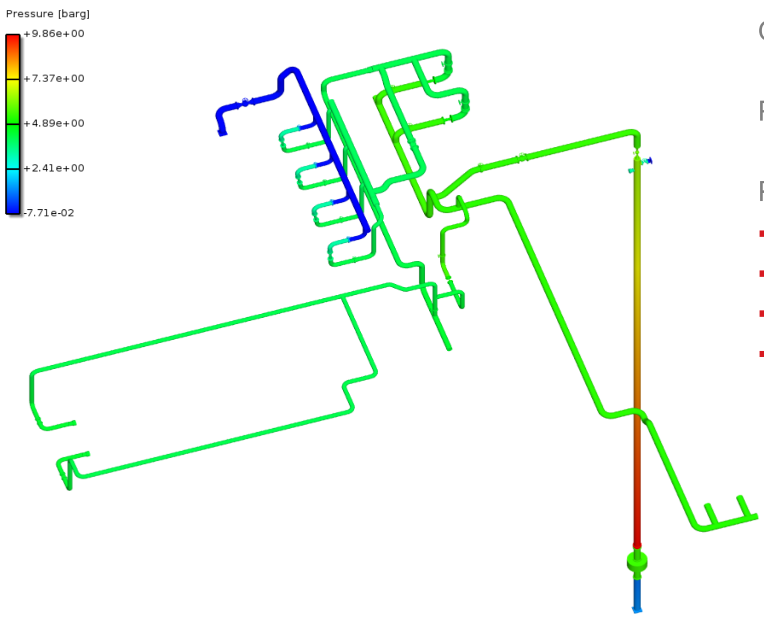
Analysis Type
- **Steady State** (sizing of the pipeline and flow)
- **Transient** (capturing transient phenomenon due to valve closure or pump shutdown or start up
- **Transient with cavitation** (when entrained gas, or full voids are present/ formed in the pipe section. Vapor Cavity Model(VCM) or Concentrated Air Pocket (CAP))



DRG
Dynaflow Research Group

INTERGRAPH

Steady state – Rated flow



Q = 1015 m3/hr

Pump head = 90 m

Pressure drops:
- Filters = 0,99 bar
- Heat exchangers = 0,85 bar
- Control valves = 3,2 bar
- Minimum flow check valve = 0,5 bar

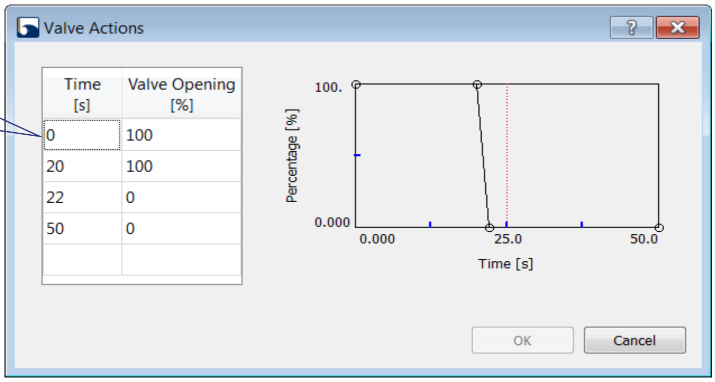
DRG
Dynaflow Research Group

© Intergraph 2014

INTERGRAPH

Action widgets for input of transient phenomena

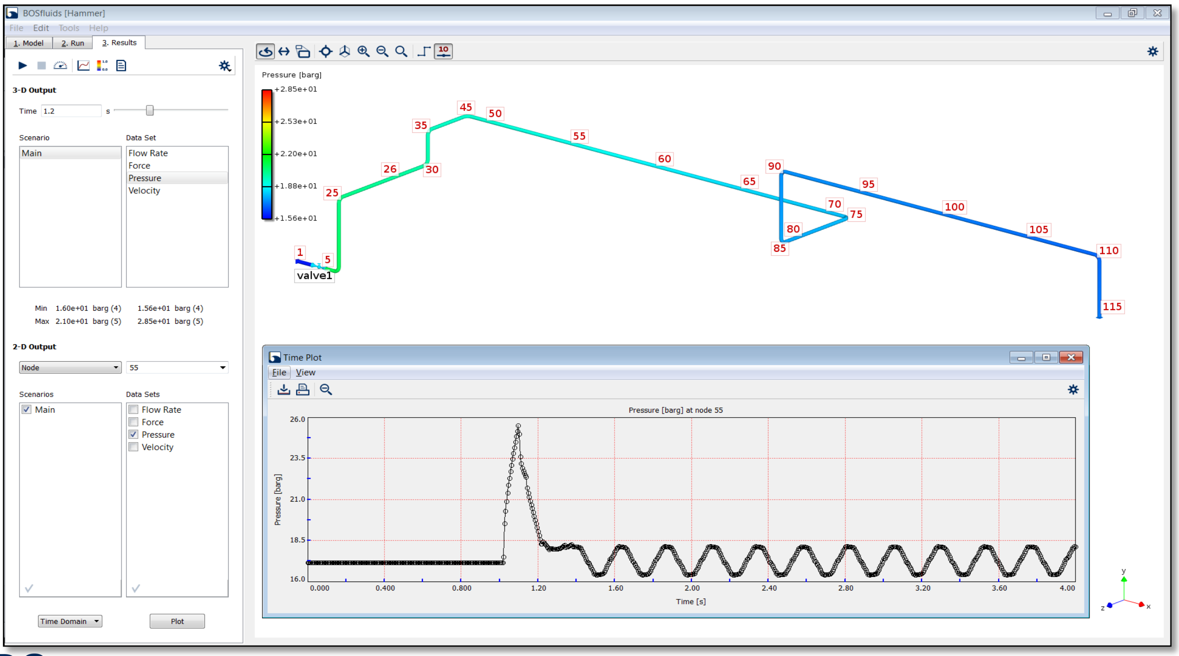
Valve Actions
Used to open and close valves in the transient analysis. Valves may be opened and closed all or part-way.



DRG
Dynaflow Research Group

INTERGRAPH

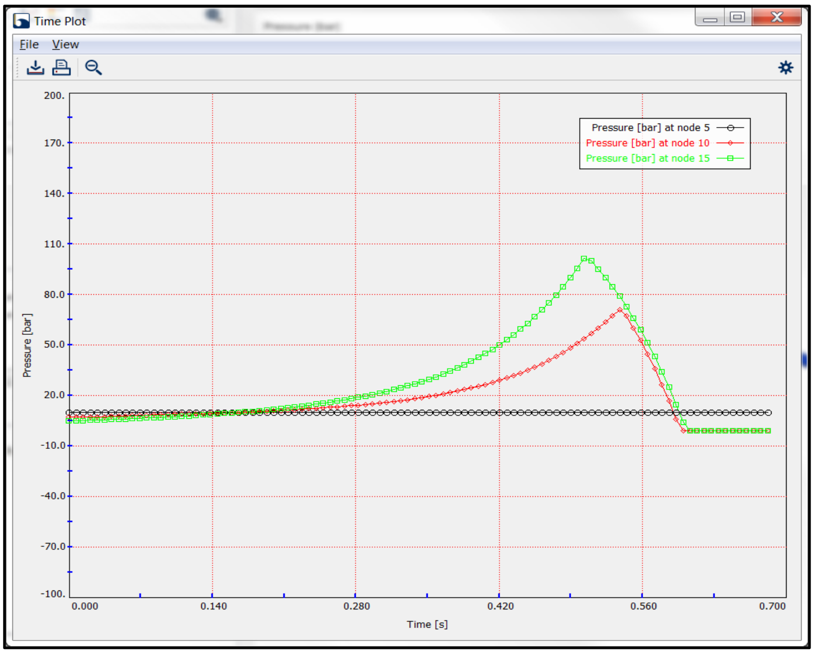
Graphic post processing for rapid review of calculations



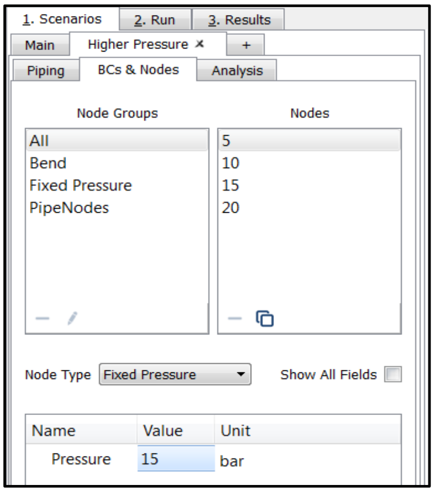
DRG
Dynaflow Research Group

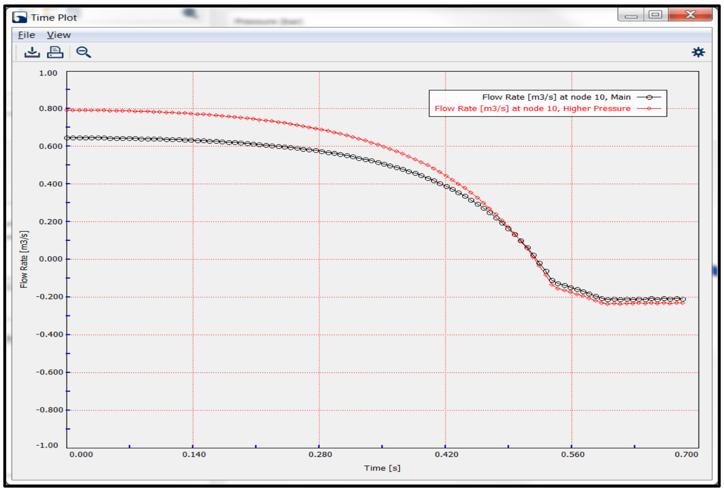
INTERGRAPH

Pressure versus Time Plot at multiple node locations

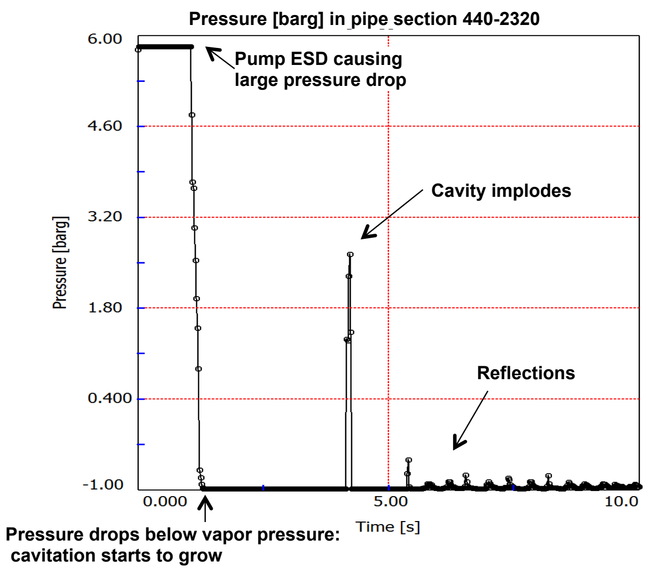


Several scenario's can be analyzed and results compared





Transient analysis shows several pressure pieks



Pump trip at t = 1 s

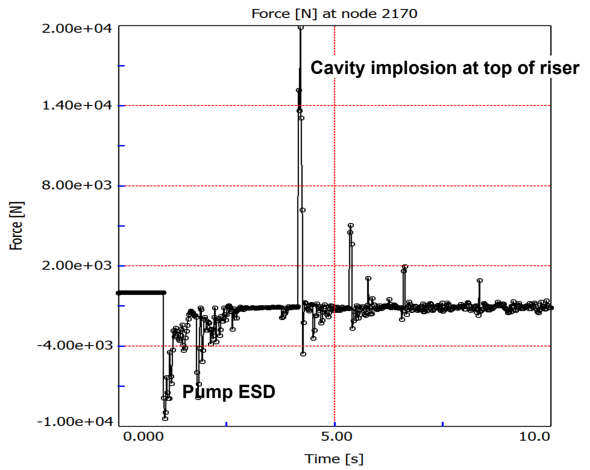
Min. flow check valve starts to close at t = 1,33s and is fully closed at t = 1,9s

Cavity starts to grow in horizontal pipe section downstream sea water pump upon min. flow check valve closure

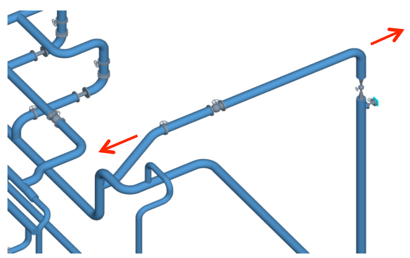
Cavitation may occur in horizontal pipe above heat exchangers outlet, an unbalanced load results from the collapse of this cavity

Pressure pieks result in high unbalanced loads

Force [N] on pipe section 440-2320



Unbalanced load location on pipe section 440-2320



Here two mechanism of unbalanced forces may be observed:

- 9,5 kN due to pump ESD at t = 1,07s
- 20 kN due to cavitation at t = 4,21s. This cavity is greatly influenced by air from the air valve that might find its way downstream of the check valve

Summary

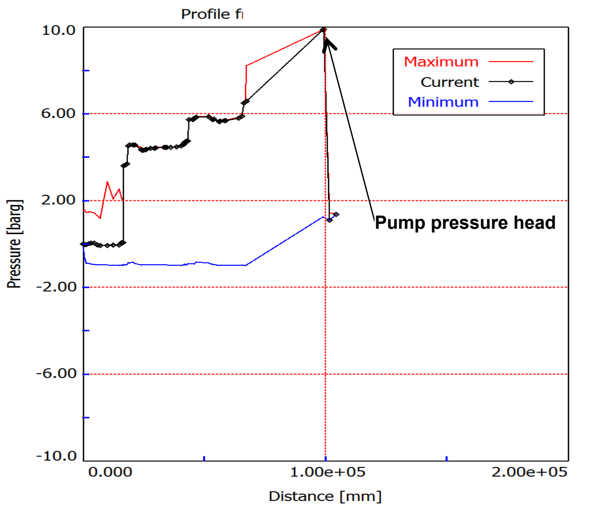


Figure showing the maximum and minimum pressure along the flow path during the simulation. The current line is the steady–state condition

Two mechanisms are identified that may have caused high unbalanced loads near the support PS149 in the lateral direction: ESD of the pump and cavitation

Unbalanced forces in the order of 10 to 20 kN may be observed during ESD

Cavitation forces might possibly be large enough to also move PS150 or PS148. Caesar analysis will determine that

No pressure peaks above the operational pump head are observed during the entire simulation.

NB. Cavity might not collapse (not creating any unbalanced forces) if the TDL valve is allowed to open again and let air into the system through the air valve.

Agenda

- Case 1 – Vibration Assessment
- Case 2 – Waterhammer analysis
- **Case 3 – Live demo**

DRG Dynaflow Research Group
© Intergraph 2014
INTERGRAPH

DRG
Dynaflow Research Group

Houtsingel 95
2719 EB Zoetermeer
The Netherlands
Reg nr. 27320315

T +31 79 361 5150
F +31 79 361 5149
E info@dynaflow.com
W www.dynaflow.com