DRG
Dynaflow Research Group

numikon®

BOSfluids

The Flow Simulation Tool of Choice

1

- *Introduction*
- *Input, Output, and Analysis Features*
- *Features and Example*
- *System and Training*

Introduction

BOSfluids® is an interactive computer simulation package that models steady state and transient flow in liquid or gas carrying piping systems.

The software package can be used to analyze fluid transients and to relate this information to the forces, pressures, flow rates and velocities experienced in the piping system with engineering accuracy.

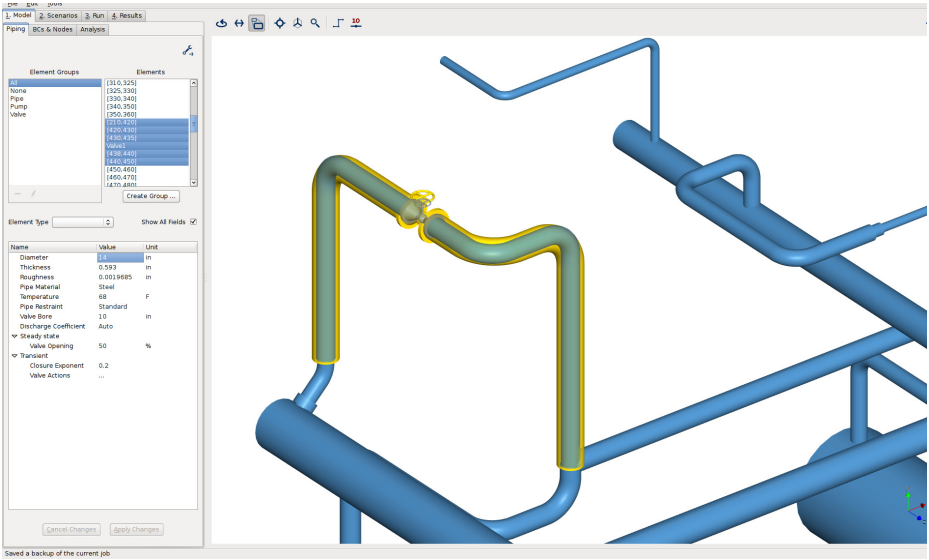
Transient Analysis

BOSfluids® is created to assist the needs of engineers in understanding the transient fluid behaviour, pressures, and reaction forces in their piping system. It is an effective tool to study transient effects including:

- Water hammer
- Slugs and flashing
- Pump start-up and shutdown
- Valve closure transients
- Relief valve gas transients
- Column separation
- Pipe evacuation
- Tube rupture
- Cavitation

BOSfluids® has a library of common valves and equipment that allows the users to create their specific piping system. The graphical user interface guides the users to easily construct their piping system, specify boundary conditions, visualize their 3-D piping network, and illustrate the transient results in either 2-D plots or 3-D views. Applications where BOSfluids® can be used are:

- Vessel blow down
- Sewage water system
- Oil transport lines
- Tanker loading and unloading
- High pressure heat exchanger tube rupture
- Water transmission and distribution systems
- Cooling water systems
- LNG systems
- And many more



Method of solving the governing equations

BOSfluids® uses a 1-D, single phase, flow solver. It assumes that the pipe system is axisymmetric, and that the wave and flow fronts are flat and perpendicular to the pipe centreline. BOSfluids® has the capability to solve multiphase problems involving cavitation and air inflow (air valves), and contains dedicated multi-phase elements.

BOSfluids® solves the governing equation of the system through the method of characteristics. The set of partial differential equations of the system describing the flow are reduced to a matrix of ordinary differential equations and solved by the initial boundary conditions specified by the user. The method allows the system to be solved quickly, with typical total simulation time scale of minutes.

Summary

BOSfluids® excels in the simple and guided model construction and includes a broad range of elements and equipment simulation options. It provides fast simulation of steady and transient state analyses, and animated 2-D plots and 3-D views of the results. These features makes BOSfluids® an intuitive software program able to assist the engineer with a broad range of problem.

BOSfluids® makes it simple to extract the required results of the simulation and displaying these in 2-D plots and 3-D views.

3-D Views

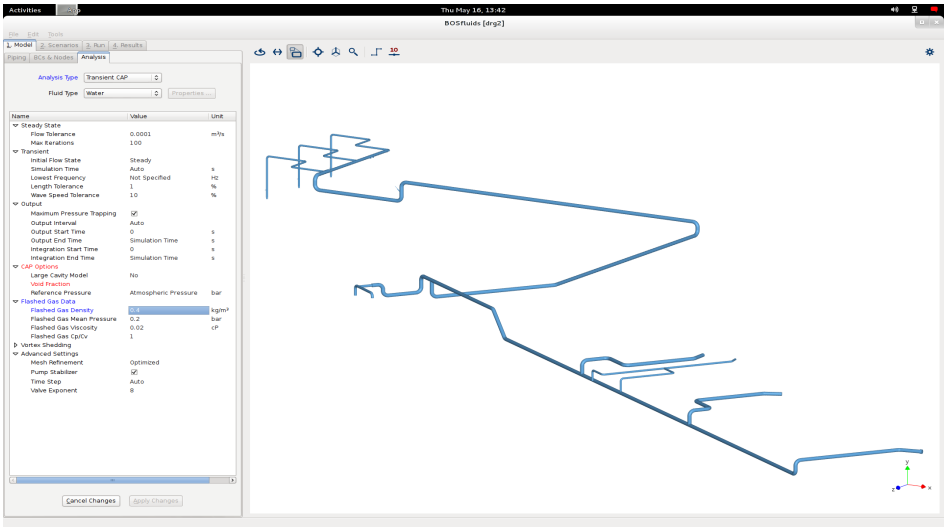
The 3-D views are a great feature in displaying the model to the user. Secondary, it is able

to demonstrate the transient development of flow parameters (pressure, flow rate, velocity, forces) in the piping system. This sees significant benefits when presenting results of the piping system to people less familiar with the system.

Scenarios

BOSfluids® makes use of 'scenario-based modeling'. A base model is built, after which variations of the model are built in separate scenarios. The whole set of scenarios is simulated with just one click, instead of running each model separately. Using different scenarios, one can investigate the impact of different valve types, closure rates, operating conditions, etc, in a very efficient way. For each of these variations, a scenario is created. Comparing the analysis results for the different scenarios provides insight in the impact of each variation.

Overall, BOSfluids® solves the needs of engineers in understanding the performance of their piping network, through an interactive and guided user interface, easy element-by-element model construction, interactive 2-D plots and 3-D views of the model and results,. It enables users to examine multiple scenarios in a single model file, and study a wide range of transient effects that occur in piping systems.

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5,5 m

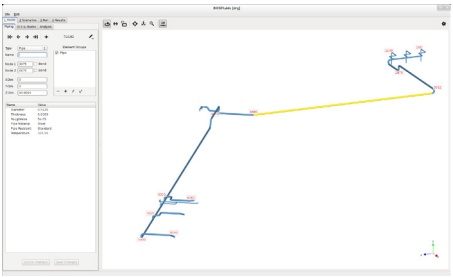
Input, Output and Analysis Features

Graphical userinterface, model construction, and post processing

The BOSfluids® graphical user interface is designed to create a streamlined procedure for the input, output and analysis of the piping network. An intuitive guidance through the analysis process is created through the use of named tabs. Functions that are commonly used in conjunction with each other are grouped for easy entry of data.

Building the piping system

BOSfluids® constructs the piping system through the user input of nodes and elements. The user selects the type of element from the dropdown list (i.e. pipe, valve, pump, etc.), inputs the required data relating to that element, with the element displayed in the 3-D viewer. When entering the data of the piping system, the user is indicated to the fields that require input, ensuring that the simulation contains all the required data. BOSfluids® is capable of simulating isotropic and orthotropic pipe material and a diverse range of valves and pumps, that users can select through the use of dropdown lists. The users continue the element-by-element building process to construct their entire piping system.



The 3-D viewer allows users to visually inspect their piping network as they are constructing it. It assists the user to observe any potential errors during the building process. Likewise, the user can interact with the 3-D viewer by rotating and panning the model, viewing node numbers,

labels, and different element types. The 3-D viewer also allows users to select groups of elements and modify their input parameters. An included feature in BOSfluids® is the grouping and labelling of elements. It allows users to create custom groups and sections within their piping system. This provides significant benefits when modifying the input parameters at a group-level and creating different scenarios during model simulation.

Boundary conditions and Analysis

The user proceeds by specifying the known boundary conditions and type of analysis. Boundary conditions define the steady state and transient conditions that the solver needs to evaluate. Boundary conditions are specified on the nodes of elements, with a range of conditions able to be defined within BOSfluids®. Boundary conditions that are able to be defined include:

- Fixed/time/harmonic flow rate
- Fixed/time/harmonic pressure
- Reciprocating pump or compressor
- Slug/sonic/steady pressure
- Long pipe

The user is able to select two types of analyses, either steady state or transient. Transient analyses requires the initial steady state solution to be solved, and therefore is often selected as default.

Cavitation

BOSfluids® allows the user to study cavitation in the piping system during the transient simulation by providing two cavitation models: CAP (concentrated air pockets) and VCM (vapour cavity model). The cavitation models are commonly used in the analysis of column separation associated with entrained gas, voids forming in the pipe section and slug flow or deluge fill loads when valves are instantly opened or when pumps are starting up.

BOSfluids® has a large library of standard fluid properties that the user can select, including:

- Water
- Steam
- Crude oil
- Refrigerants (Freon 11, 12, 113, 114)
- Fuels (LNG, gasoline, kerosene)
- Variety of gases (CO2, NaOH, SO2, Octane)

Users can also define their own fluid properties in the model.

Scenarios

BOSfluids® allows the user to simulate multiple scenarios within the one file using the scenario feature. The user is able to change input parameters in the piping system to examine and evaluate different scenarios in a very efficient way. Comparing the analysis results for the different scenarios provides

insight in the impact of each variation. Parameters that can be modified include:

- Pipe diameter and/or thickness
- Element type
- Boundary conditions
- Analyses type and fluid properties

With the scenario-based approach it is not necessary anymore to maintain a separate model file for each variation of the model. This means that an update to the base model does not require one to update and re-run each separate model one-by-one.

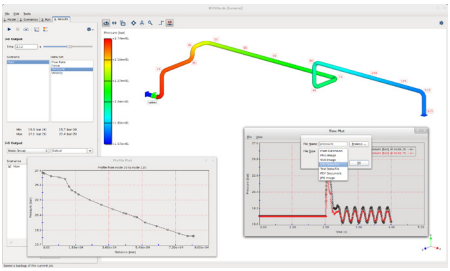
Post Processing

BOSfluids® produces animated 2-D plots and 3-D transient views of the simulation results. 2-D profile plots can be created displaying, flow rates, pressures, velocities or forces along a pipe branch, illustrating the development of the flow in the piping system.

The 2-D profile plot is updated as the time position is changed. Similar to the 2-D profile plots, the 3-D viewer displays the results of the entire piping system and updates as the time position is changed. The 3-D viewer provides a clear oversight of what is occurring in the entire piping system. The user can select to sequence through the transient simulation, producing a video display in the 3-D viewer of the piping system solution, and animated 2-D profile plots.

2-D time plots can be created at specific nodes or elements (valves, pumps, etc.), observing the flow rate, pressure, velocity and/or force variation over time. 2-D time plots can be produced alongside other scenarios simulated, to compare with ease the performance of the piping system. These features combined allow the user to quickly and simply extract, assess and evaluate the performance of their piping system. The 2-D plot graphics and tabulated results can be exported to a variety of different formats.

BOSfluids® includes the feature to import/



export models to and from CAESAR II. This is commonly done when examining the piping system for mechanical resonance in CAESAR II, due to the unbalanced forces calculated in BOSfluids®. User do not require recreating the model geometry within either BOSfluids® or CAESAR II, allowing them to effortlessly continue their analyses.

Features and Example

Features and illustrated example of BOSfluids

Unique features that are included in the BOSfluids® package are:

Intuitive guidance of the analyses process, including indicating the required input parameters for each type of element. Many functions have been reorganised and regrouped for easy data entry.

Labelling and grouping of element to create distinct sections of the piping system.

An interactive 3-D view of the piping system as it is being built, allowing users to visually inspect for errors, display node numbers and labels, and select (group of) elements from and change their properties.

library of valves and elments, including:

- Air valve
- Ball valve
- Butterfly valve
- Check valve
- Control valve
- Gate valve
- Globe valve
- Orifice
- Pump
- Regulator valve
- Relief valve
- Rupture valve
- Surge Vessel

Isotropic and orthotropic pipe material, including:

- Fibreglass
- Asbestos cement
- Concrete (high or low strength)
- Metals (Steel, aluminium, copper-nickel, ductile iron)
- Plastics (PE, PVC, uPVC)

Buried and above ground piping systems.

Scenario builder allowing multiple scenarios

to be simulated at once with different settings, transient conditions, valves, etc. These results can be quickly compared in the assessment of the piping system performance.

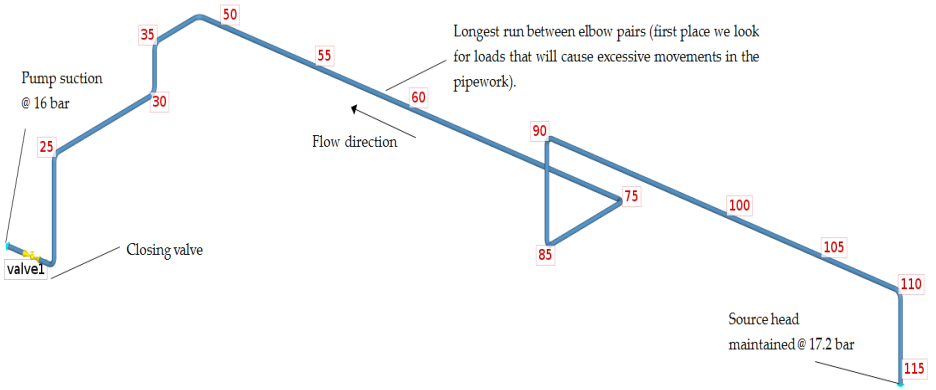
Improved post-processing, with 3-D views and animated 2-D plots for easy assessment of the piping system performance. This includes improved scale settings and improved reporting.

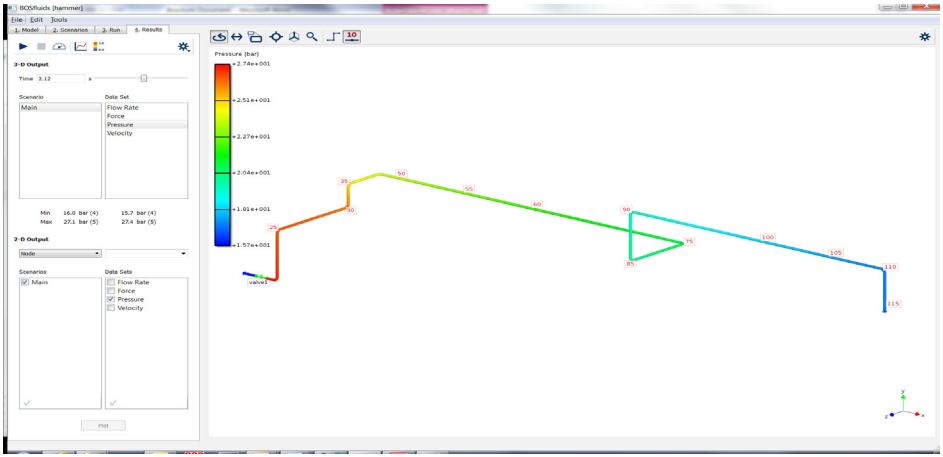
Interface system with CAESAR II allowing current models and results to be imported and exported to BOSfluids® and vice-versa.

Example - Water Hammer

BOSfluids® is well suited for solving water hammer analyses in piping systems. The piping system below describes the sudden valve closure at the pump suction and the resulting water hammer event. BOSfluids® will be used to calculate the pressure rise and the unbalanced forces that result from the valve closure. For the water hammer system, pulling liquid from a supply tank, node 125 will be at an open end. At this location the pressure will be assumed to stay constant. The system will behave like a closed-open system whose natural period is 4L/c where "L" is the length from node 5 to node 125, and "c" is the speed of sound in the fluid. Reflections from a closed end pipe will cause a pressure maximum and a corresponding velocity minimum. Reflections from an open end will result in a velocity maximum and a pressure minimum.

The maximum magnitude of the unbalanced water hammer load will be smaller than that predicted by the Joukowski equation: pcdv. Water hammer and steam hammer waves reflect from both closed and open ends, as well as from changes in diameter. Only five reflections are needed to produce a resonant level response in an undamped piping system. This means that even low magnitude pressure waves can produce large displacements if they move in the system at a speed



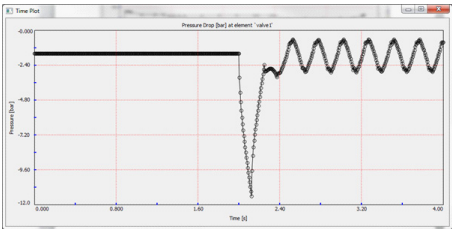


that corresponds to a mechanical natural frequency. It is for this reason that some systems are particularly susceptible to acoustic excitation.

The piping system is easily constructed in the user interface with 3 boundary conditions specified in the model, pump suction pressure, the source head, and the transient valve closure of 0.4 seconds. Having completed a transient simulation of the model, pressure rise and force plots of the valve can be examined quickly and plotted in 2-D plots and 3-D views. These results can be evaluated to the rating of the pipe and valve to ensure that the system is operated safely.

The magnitude and frequency of the impulse and sinusoidal force need to be examined such that it does not excite a mode of vibration of the mechanical system. Mechanical vibration can occur in the system during water hammering event and precautions needs to be taken to ensure that water hammers are quickly damped out of the system, through either restraints or reducing the water hammer force.

Examining whether this is going to occur in our current piping system, the model needs



to be exported to software capable of examining such phenomena. BOSfluids® can easily export data and model to CAESAR II, which is capable of analysing stresses and mechanical vibrations in the system.


TRAINING

System and Training

System requirements and surge analyses traininig using BOSfluids®

System Requirements

BOSfluids® is currently available for the Windows operating system (Windows XP or newer). In the near future, BOSfluids® will be available for Linux-based operating systems. For smooth visualisation of the 3-D model, a basic Nvidea or AMD graphics card should be used.

Training and Support

Training and support are offered by Dynaflow Research Group, who has extensive experience and expertise in the software. The training course is usually 2 days covering the topic of surge analysis, including:

- Creating awareness of surge and water hammer problems encountered in industry
- Increase knowledge of common transient flow response phenomena in piping
- Improve capability to perform a surge analysis using BOSFluids® in order to improve the performance of the piping system

The basic theoretical knowledge behind the software will be described to perform a surge analysis and assess the transient flow behaviour of the piping system.

Maintenance and updates

Dynaflow provides updates and maintenance of the software and are able to assist users if problems are encountered. Users will be notified when updates are available and can be downloaded directly from the website.

Dynaflow Reseach Group

At Dynaflow Research Group (DRG) we support our clients, solve their most complex and critical technical issues

Consulting services

We provide engineering consulting services in all aspects of design and analysis for the Petro- chemical industry. Our work often requires a multi-disciplinary approach where we combine expertise in fluid flow behaviour, dynamic oscillations, FEM and stress analysis with sophisticated analysis software to predict system performances.

Training

DRG offers a wide range of training courses such as software training, fiberglass training, dynamics and stress training. Most of these training courses are offered on a regular basis during the year. We also develop customised training programs with our customers fit to their specific needs.

Products

DRG has been developing software for many years, which has resulted in several commercially available software packages such as BOSfluids, BOSpulse, Jive and Hades. We also provide technical consulting services, and develop numerical software that can be used in computer simulations and other types of scientific computations.

Research

DRG conducts research on different aspects of pipe-system design and pressure vessels. Most of this research is done in close collaboration with Paulin Research Group and their Houston test facilities (www.paulin.com). Dynaflow Research Group provides support to clients with their R&D to help them continuously improve their products.

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