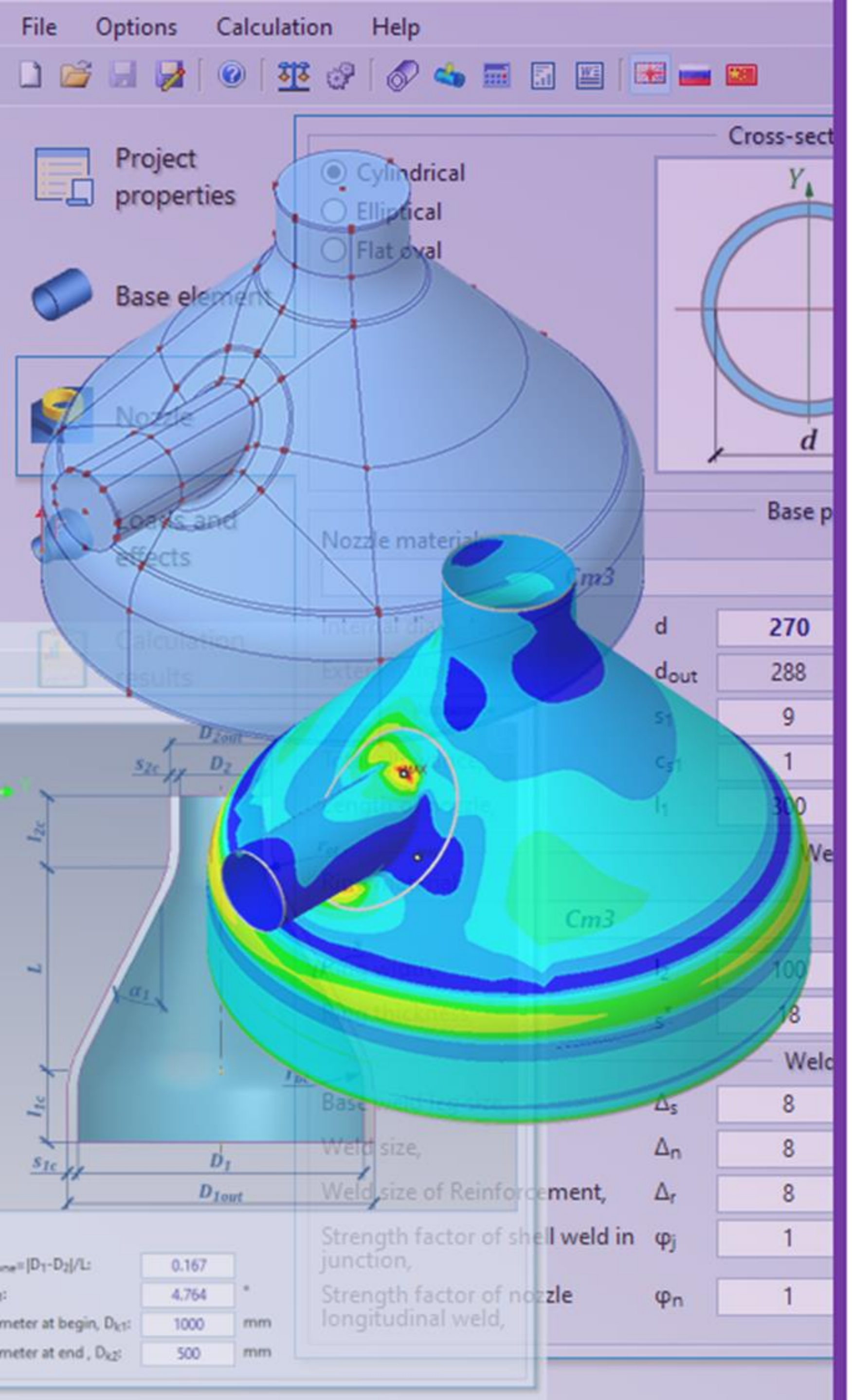


PASS/EQUIP Nozzle-FEM Overview Webinar

Powerful software for nozzle-to-shell junctions analysis

Roman Unesikhin,

Head of Product Development Group

PASS | PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

PASS Suite

The PASS software tools provide smart simulation & sizing tools for every piping and equipment engineer /designer

PASS

PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

Company Overview

- > 50 years history
- > 3,000 active users worldwide
- Best in class modern methods, algorithms and software libraries
- Embedded knowledge and support/training from industry experts
- User-friendly interface and flexible CAD integration
- Affordable price and flexible licensing

PASS Suite Users

- TRANSNEFT
- Caspian Pipeline Consortium
- C·A·C
- КазМунайГаз
- WorleyParsons resources & energy
- MCC CERI
- GAZPROM
- ROSNEFT
- Hitz Hitachi Zosen
- DAELIM
- THE LINDE GROUP
- SNC·LAVALIN
- NOVATEK
- SIBUR
- LUKOIL OIL COMPANY
- ŠKODA
- Severstal
- TechnipFMC
- MITSUBISHI
- KazTransOil
- 中国石油天然气股份有限公司 PetroChina Company Limited
- CEEC
- TECNICAS REUNIDAS

PASS/Nozzle-FEM

Powerful software for strength analysis of nozzle junction with wide capabilities

Why do you need Nozzle-FEM?

- You design pressure vessel, piping or something similar
- You need to specify allowable loads and stiffness (flexibility) of nozzle junction
- You are a good and responsible engineer
- You need to estimate strength of nozzle junctions
- You don’t know how to do it
- PASS/EQUIP Nozzle-FEM will help you and do most of the work

PASS
PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

Why do you need Nozzle-FEM?

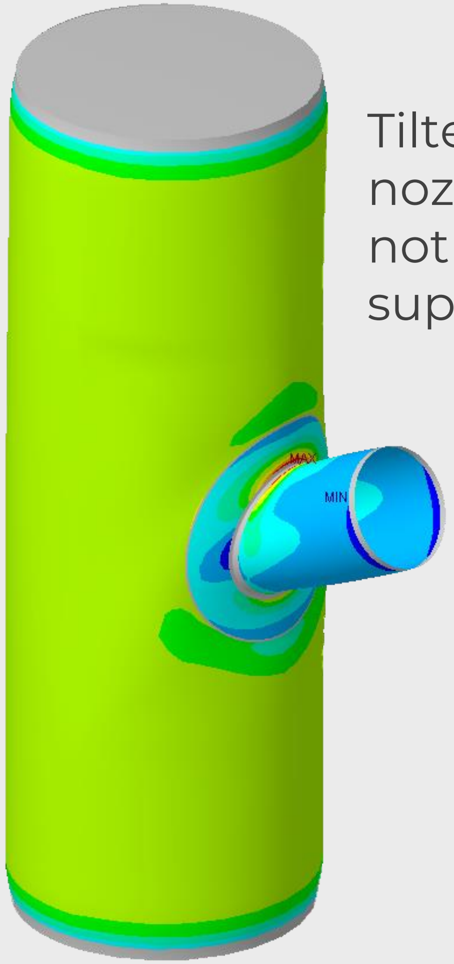
There are several methods to solve this problem:

- Using an analytical approach as per industry standards, like WRC 107(537).
- Using of a complex universal CAE software, like ANSYS, NASTRAN, COSMOS, Abaqus, etc.
- Using of specialized software like PASS/Equip Nozzle-FEM.

Options

1. Industry standards:
2. Universal CAE software:
3. Specialized software:

Option 1



Tilted nozzle is not supported

Analytical approach

- The most commonly used approach at present.
- Some analysis according to this approach is implemented in software like PASS/EQUIP Vessel.
- It has a number of disadvantages:
  - Limited variety of geometric shell shapes (mainly cylindrical and elliptical shells).
  - Considers only radial nozzles.
  - Provides very conservative results.

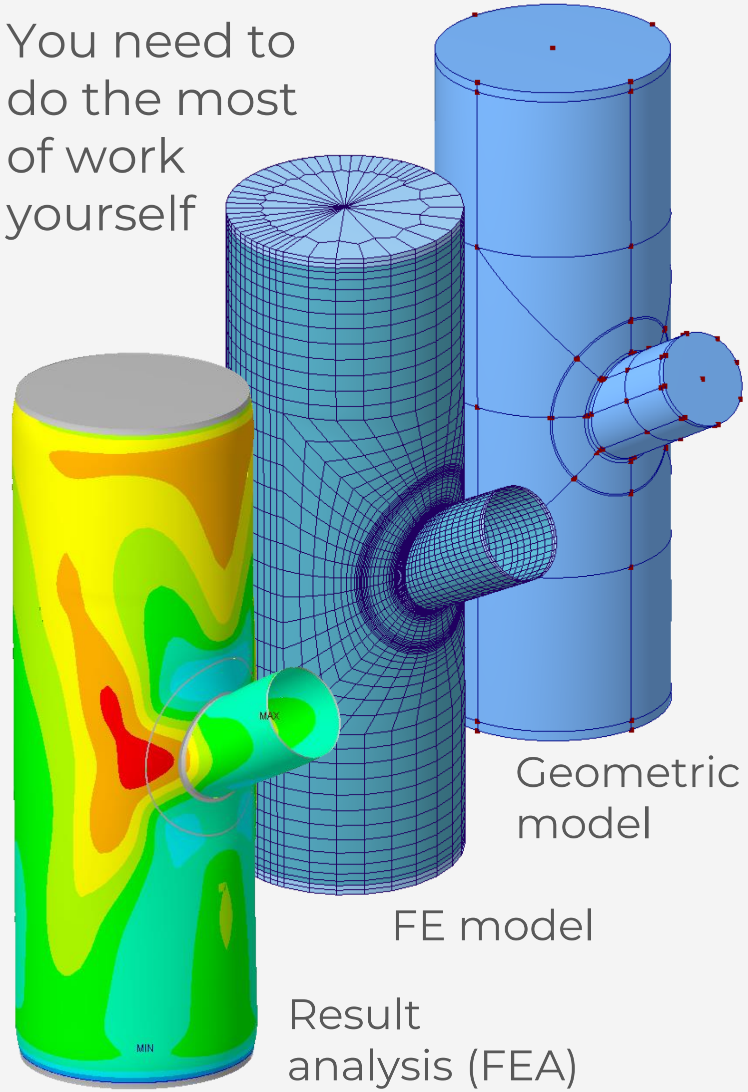
PASS PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

Universal CAE

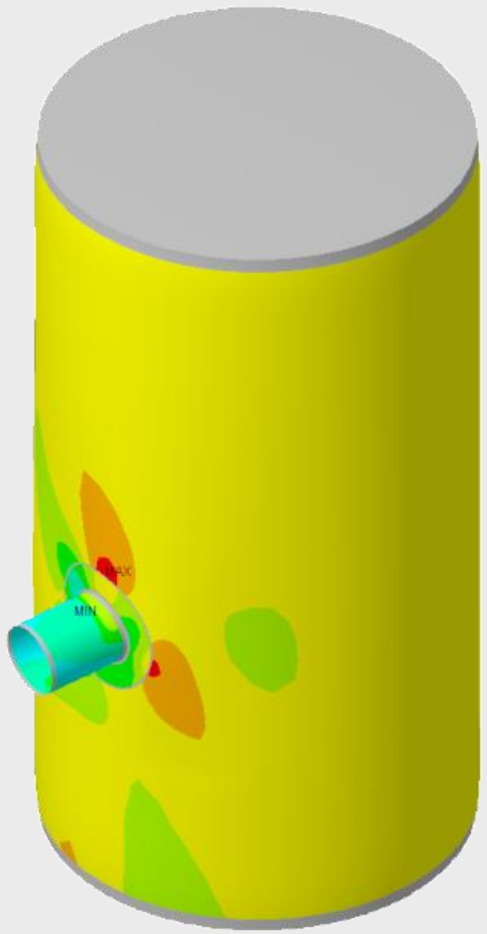
- It is great! But…
- Universal CAE software is very expensive
- You will have to do a lot of work yourself:
  - create a geometric model
  - create a finite-element model
  - handle calculation results
- Using of CAE software requires skills in different disciplines: surface and solid modeling, numerical methods (FEM) etc.

Option 2

You need to do the most of work yourself



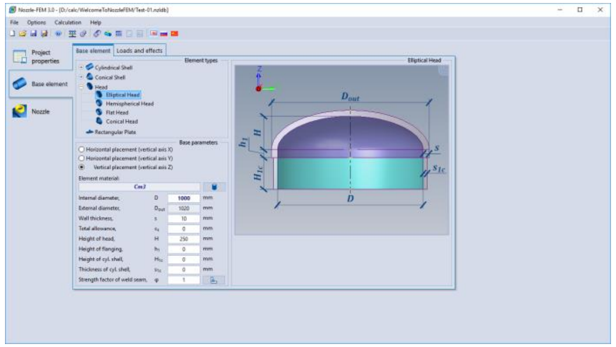
Option 3



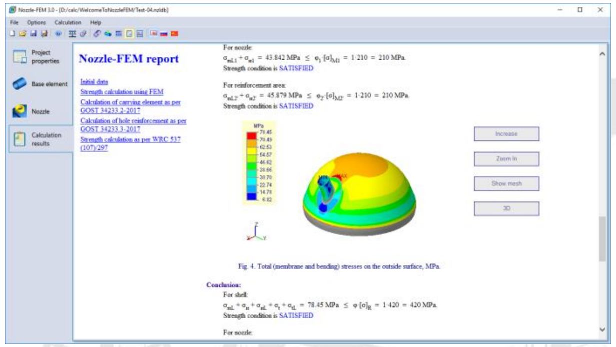
Specialized software

- Supports a wide variety of shell and nozzle configurations.
- Doesn't require special knowledge and skills.
- Less time for calculation and decision making.

Object data
(structural dimensions)



Result report

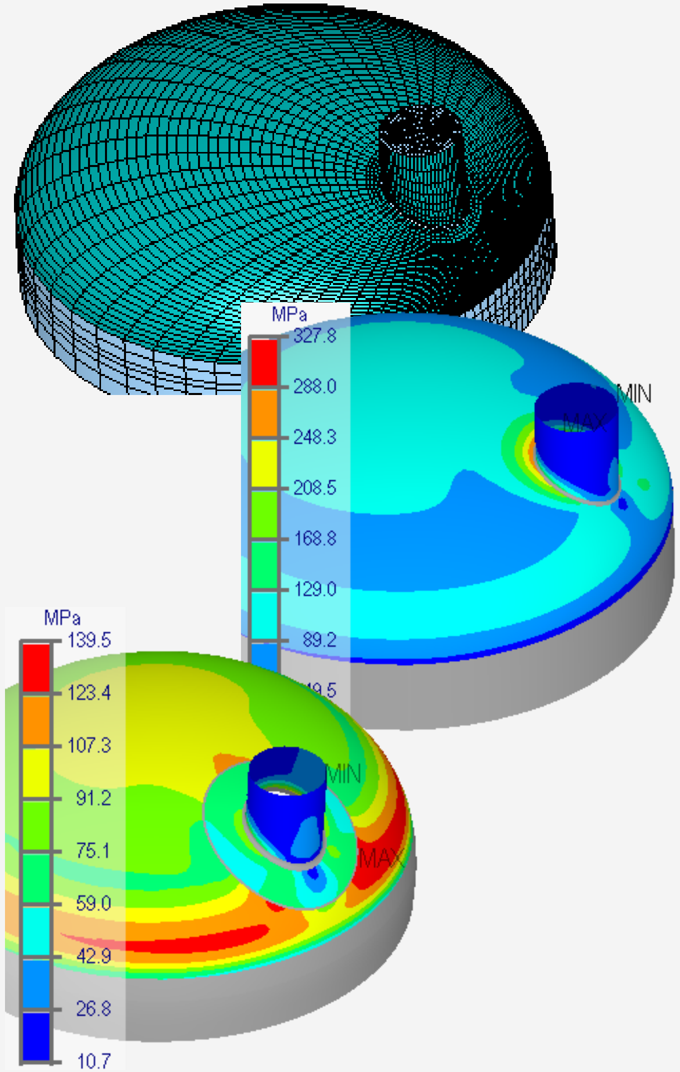


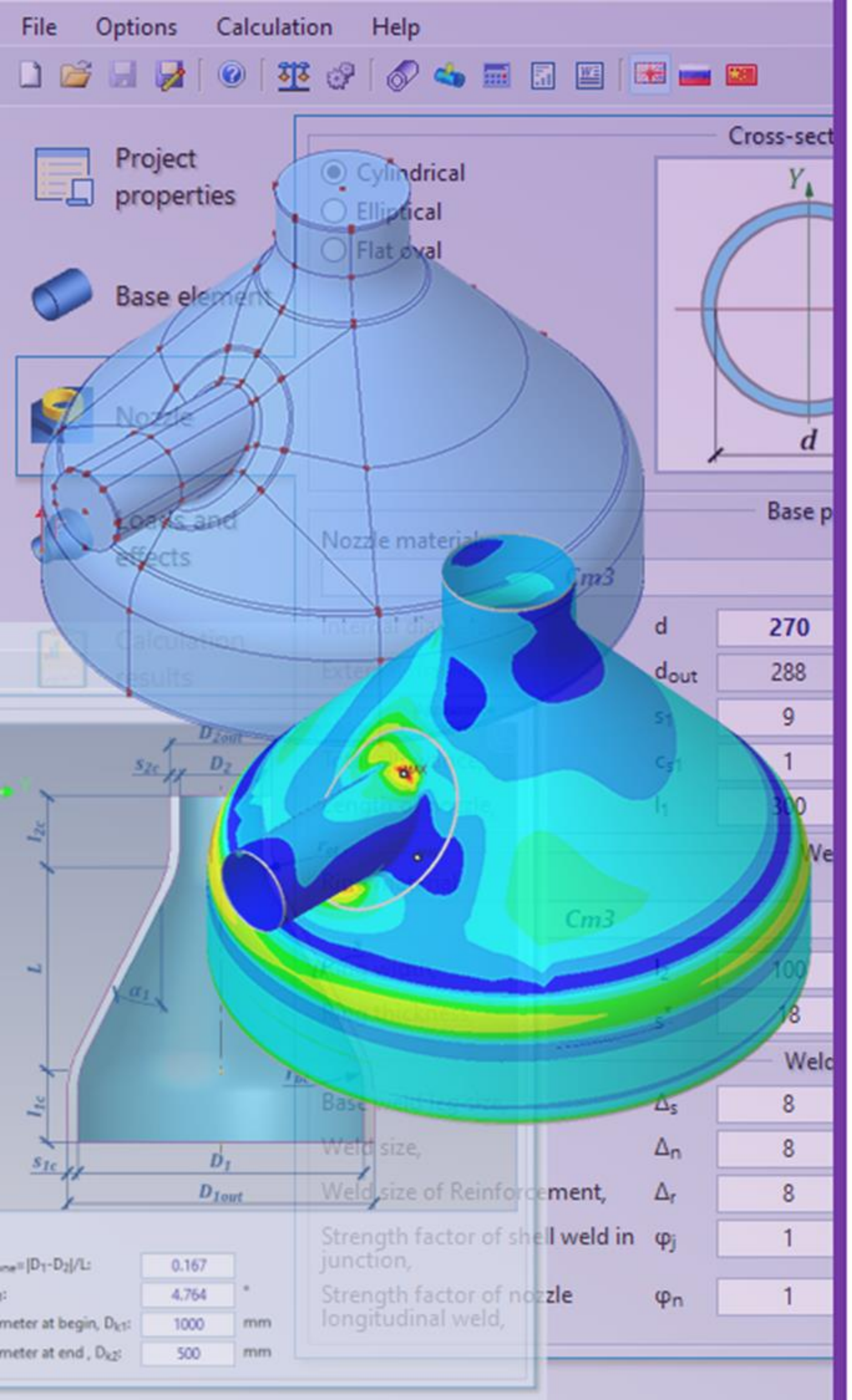
PIPING AND EQUIPMENT
ANALYSIS & SIZING SUITE

Main features

- Stresses and flexibility calculation of nozzle-shell junctions, tees, skirt support, using Finite Element Method (FEM)
- Allowable loads
- Stiffness/flexibilities of junction
- Stress Intensification Factors (SIF)
- In addition to external loads and pressure hydrostatic pressure and temperature loads can be taken into account
- Fatigue analysis (GOST 34233.3)
- Strength and stiffness calculation as per WRC537(107/297)
- Automatically generating HTML and RTF reports

Nozzle-FEM





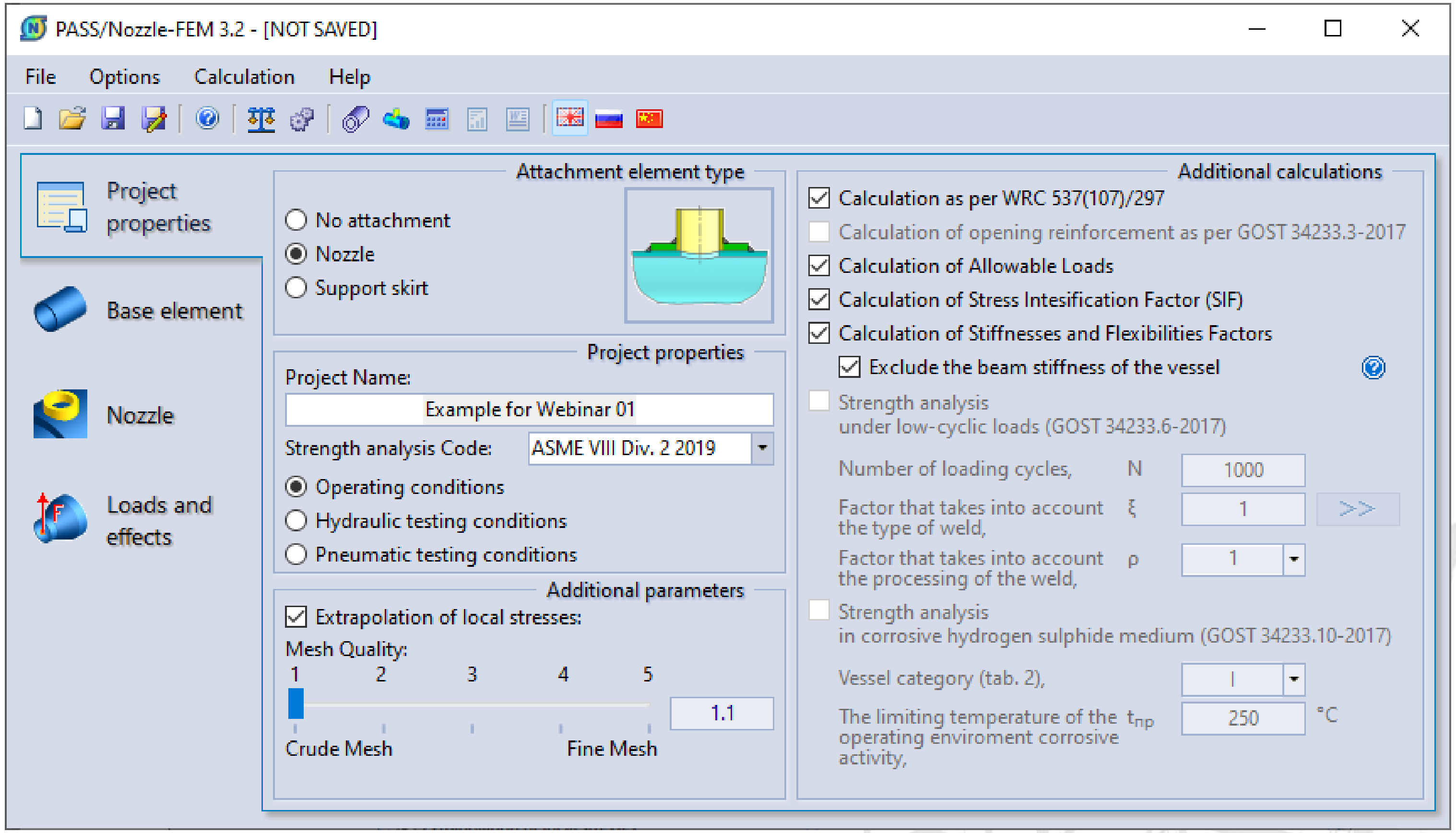
PASS/Equip Nozzle-FEM Capabilities

PASS

PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

Project properties

PASS/Equip Nozzle-FEM workspace is divided into several tabs for step-by-step setting of the input data.



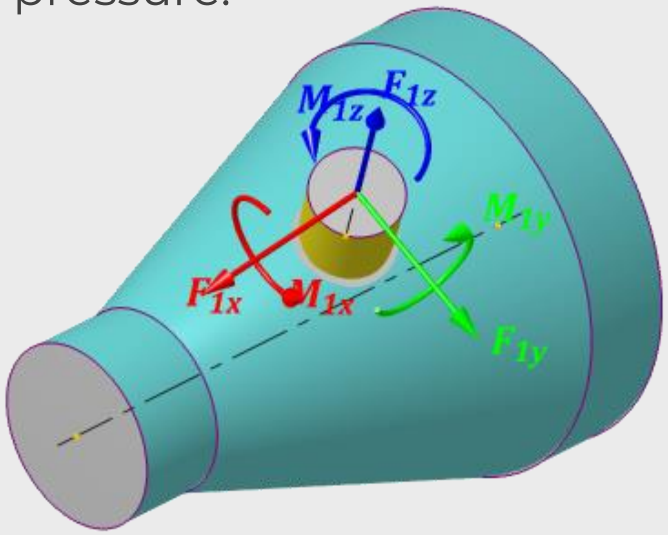
Nozzle-FEM

- Select an attachment element type.
- Select a code for stress analysis.
- Select additional FE-calculations (allowable loads, stiffness, SIF) and some analytical methods (like WRC).
- Set parameters to control calculation accuracy.

PASS PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

Nozzle-FEM

PASS/Equip Nozzle-FEM uses codes for estimating of membrane, bending, and total stresses in nozzle junction caused by external loads and pressure.



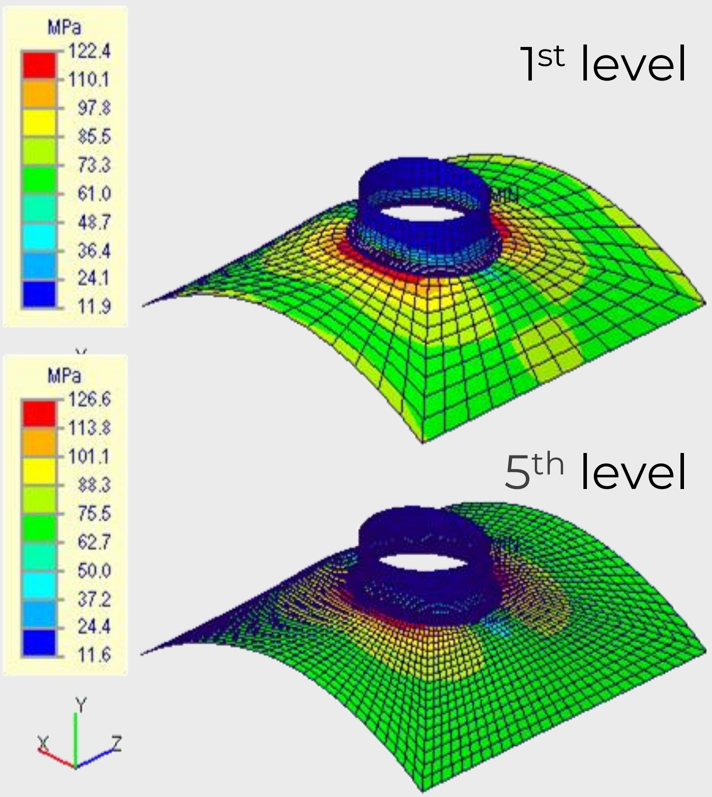
PASS | PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

Supported codes

- ASME VIII–Division 1 2019 (USA)
- ASME VIII–Division 2 2019 (USA)
- EN 13445-3 2017 (European)
- JB 4732 (Chinese)
- GOST 34233.1,2,3-2017 (Russia)
- GOST 34233.6-2017 (calculation of strength under low-cyclic loads)
- GOST 34233.10-2017 (calculation of strength in corrosive hydrogen sulphide medium)
- PNAE G-7-002-86 (Russia)

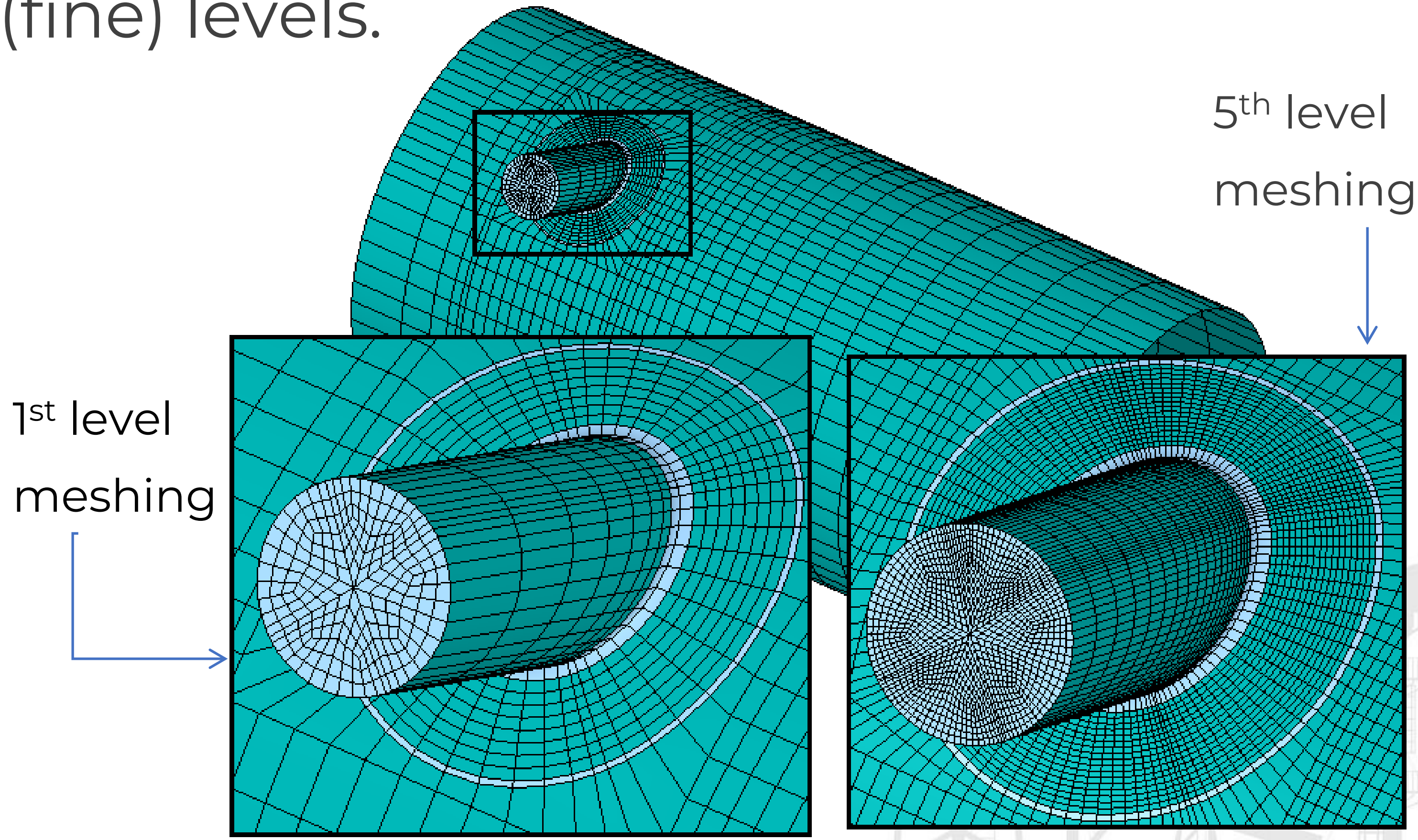
Nozzle-FEM

How finite element size affects the results:

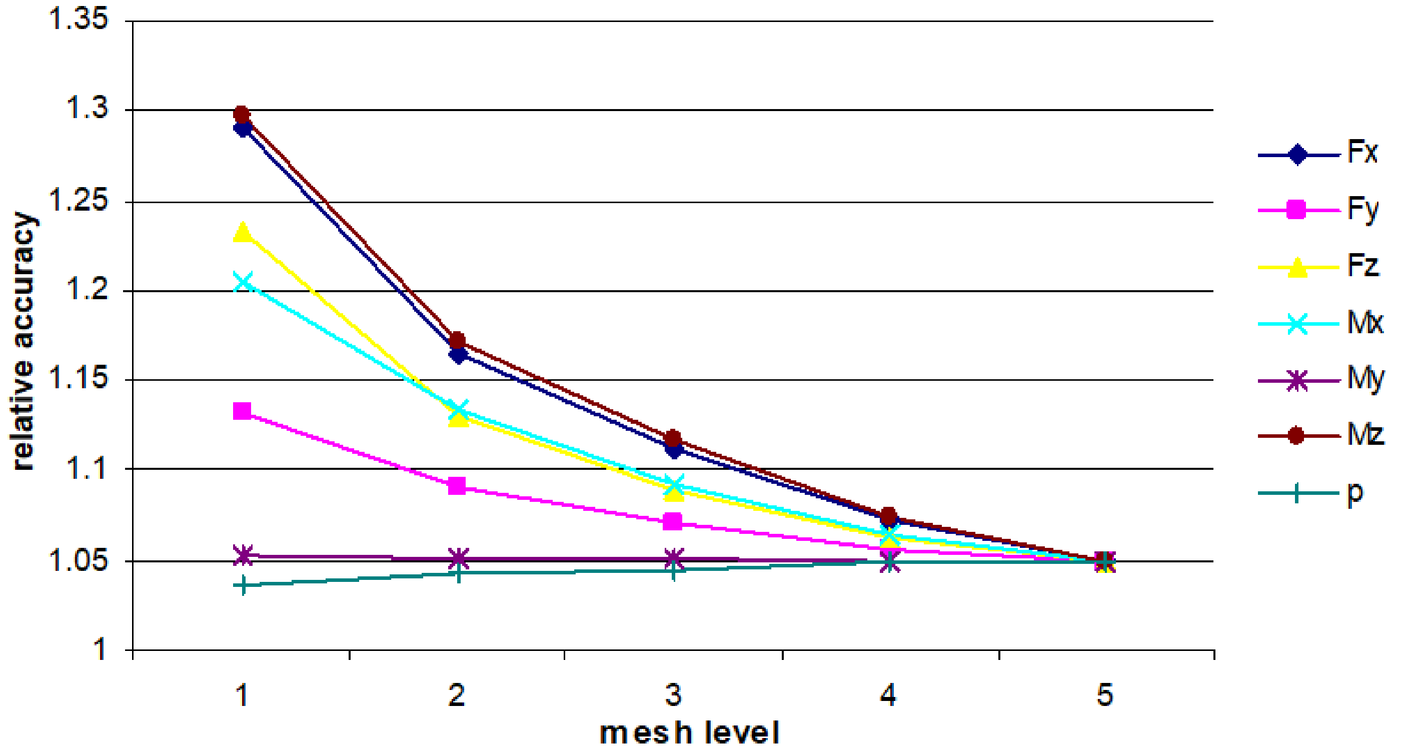


Accuracy of results

Results accuracy is achieved by mesh quality controlling: from 1st (crude) to 5th (fine) levels.



Accuracy of results



Stress factor values for nozzle junction, Km

Level	1	2	3	4	5
K_m	1.30	1.20	1.14	1.09	1.05

Nozzle-FEM

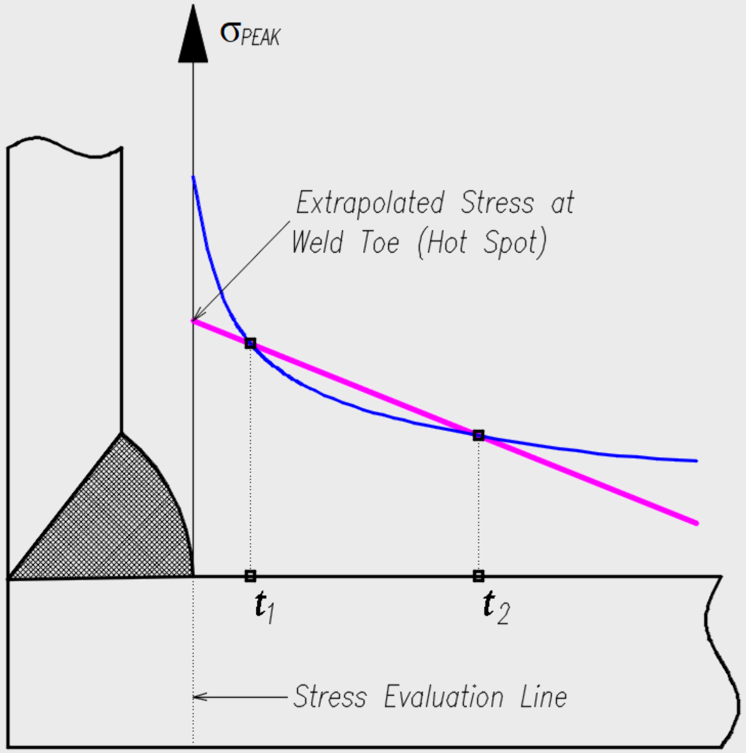
Lots of numerical tests allowed us:

- to define stress dependencies on mesh levels for various loads
- to define stress factor Km used by the program in stress analysis

PASS PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

Nozzle-FEM

Hot Spot Stress (HSS) method [1-4]:



PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

Convergence of results

To refine str
extrapolatic
problems:

- It allows t
concentra
additiona
- It increase
refining le
skip calcu

HSS uses a l
calculate st
t2 by LSE de

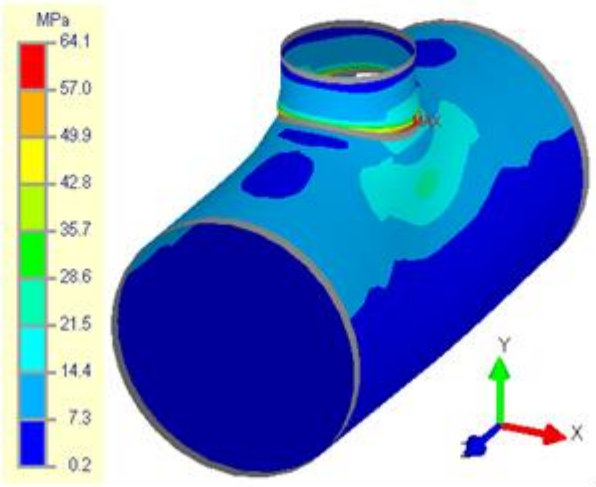
This approa
around con
results at di

Reference list for Hot Spot Stress method:

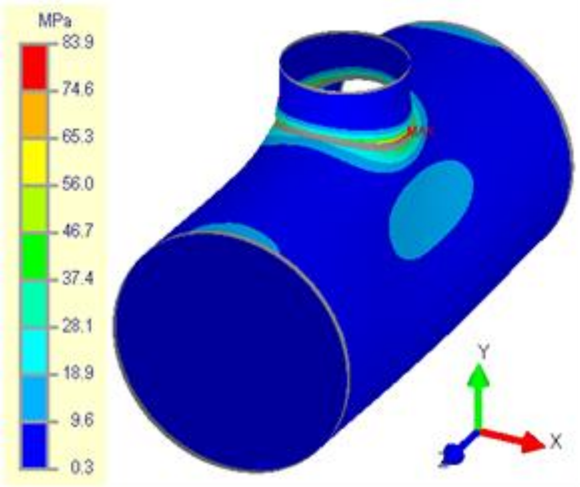
1. Fricke, W. Recommended Hot-Spot Analysis Procedure for Structural Details of Ships and FPSOs Based on Round-Robin FE Analysis [Electron. resource] / W. Fricke // Int'l J. of Offshore and Polar Engineering. – 2002. – Vol. 12, No. 1. – CD-R.
2. Maddox, C. J. Hot-Spot Stress Design Curves for Fatigue Assessment of Welded Structures [Electron. resource] / C. J. Maddox // Int'l J. of Offshore and Polar Engineering. – 2002. – Vol. 12, No 2. – CD-R.
3. Nazari, A. Application of the Hot Spot Stress Method to the Fatigue Assessment of Hollow Section Shiploader Boom Connections [Electron. resource] / A. Nazari, J. Durack // Proc. of 5th Australasian Congr. on Appl. Mechanics ACAM– 2007. – Brisbane, 2007. – CD-R.
4. Bard, W. T. Fatigue Assessment of Aluminum Ship Details by Hot-Spot Stress Approach [Text] / W. T. Bard, W. Xiaozhi, B. Stig // ABS Technical Papers, 2007. – P. 255-271.

Convergence of results

Total stress without extrapolation stress procedure:

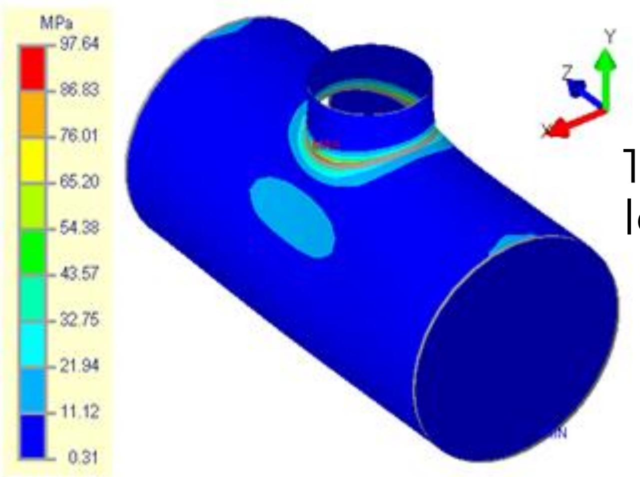


1st level

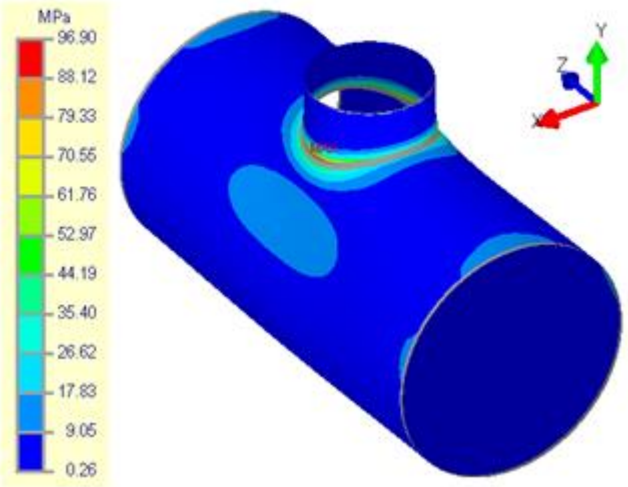


5th level

Total stress with **extrapolation stress** procedure:



1st level



5th level

Nozzle-FEM

This example demonstrates that the maximum value of total stresses at 1st level did not reach the value of 5th level.

The figure below shows that the maximum peak values are not obtained even at 5th level of the mesh.

When using the stress extrapolation procedure, 1st and 5th levels of the mesh produce similar results which exceed calculation results done without applying of stresses extrapolation.

PASS
PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

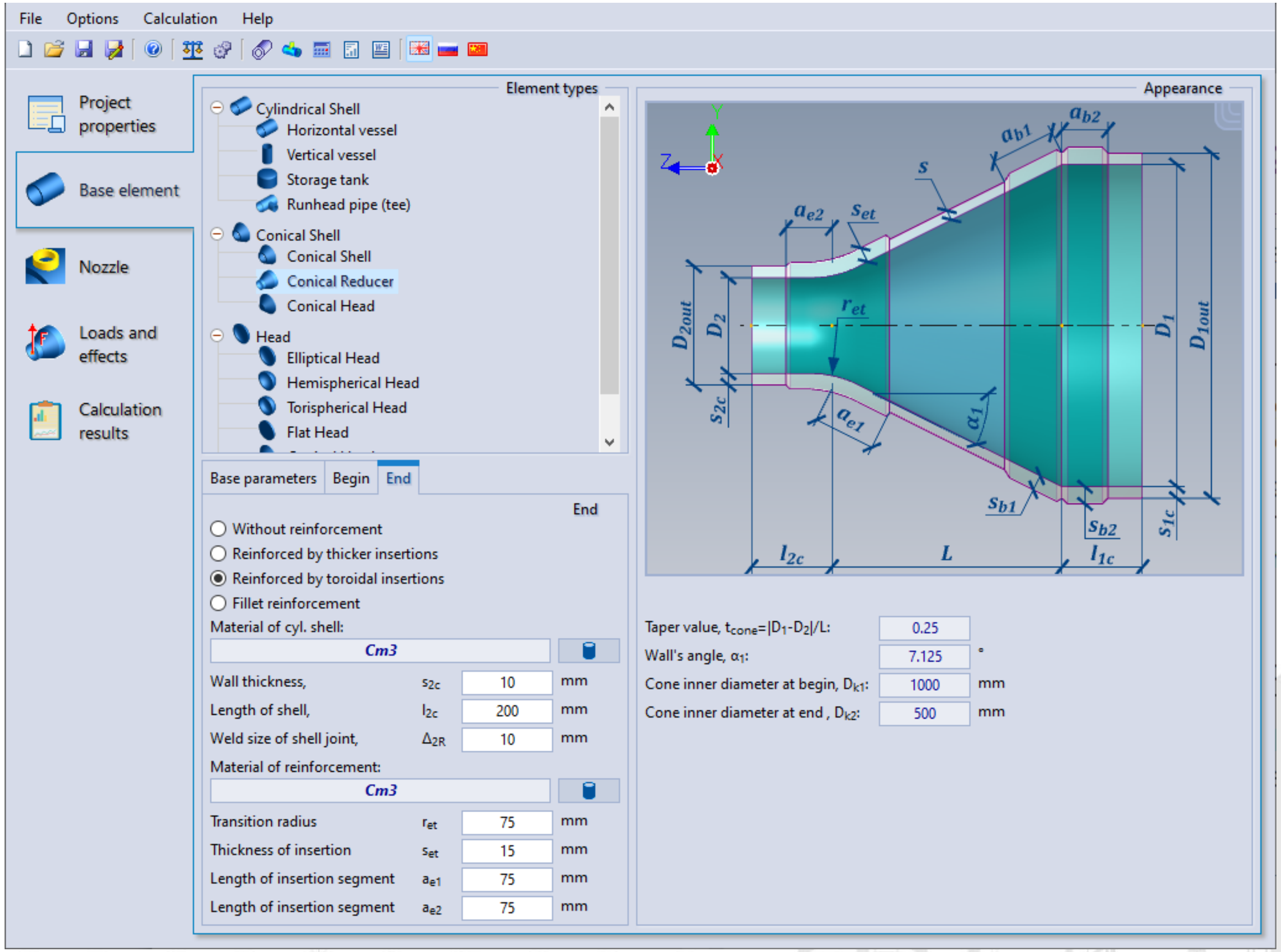
Nozzle-FEM

Comprehensive type set:

- Cylindrical shell
- Conical shell
- Storage tank (lowest course).
- Conical reducer
- Elliptical head
- Hemispherical head
- Torispherical (dished) head
- Flat head
- Cone head
- Rectangle plate (box)

Shell element

Shell tab allows to set its parameters:

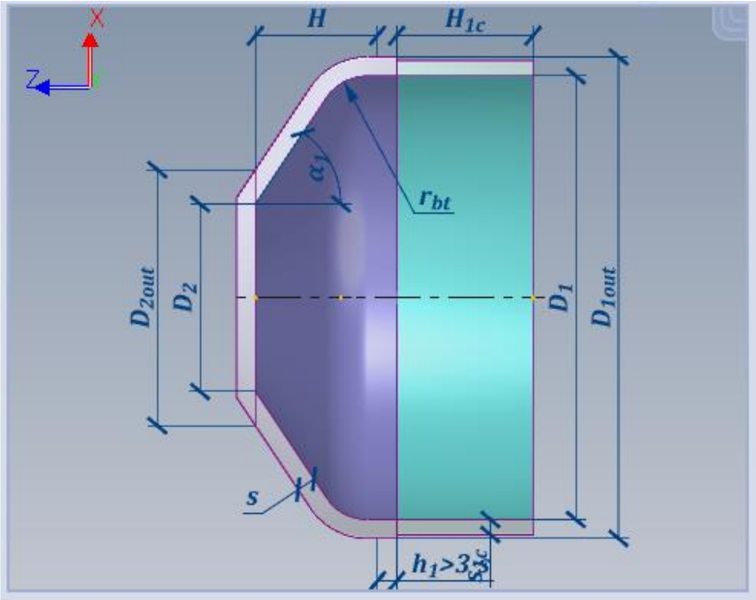


PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

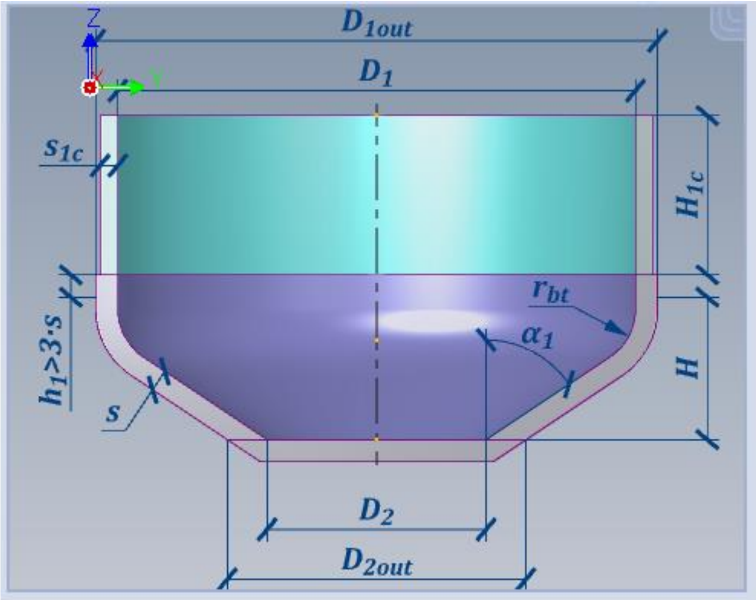
Shell orientation features

- PASS/Equip Nozzle-FEM allows to easily change space orientation of shell
- This is important for true setting of hydrostatic pressure

Horizontal position

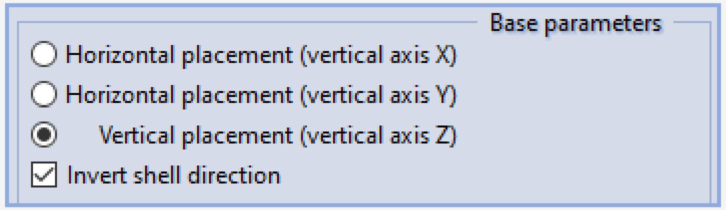


Invert vertical position



Nozzle-FEM

To define space orientation, select the proper radio button:



Nozzle-FEM

Comprehensive nozzle junction set:

- With Reinforcing Pads
- With Nozzle Inserts
- With Barrel
- Trunnion connections
- Junctions in pipeline
- Storage tank nozzles (including nozzles with tombstone shape reinforcing plate)
- With beading
- With weld-in toroidal insertion

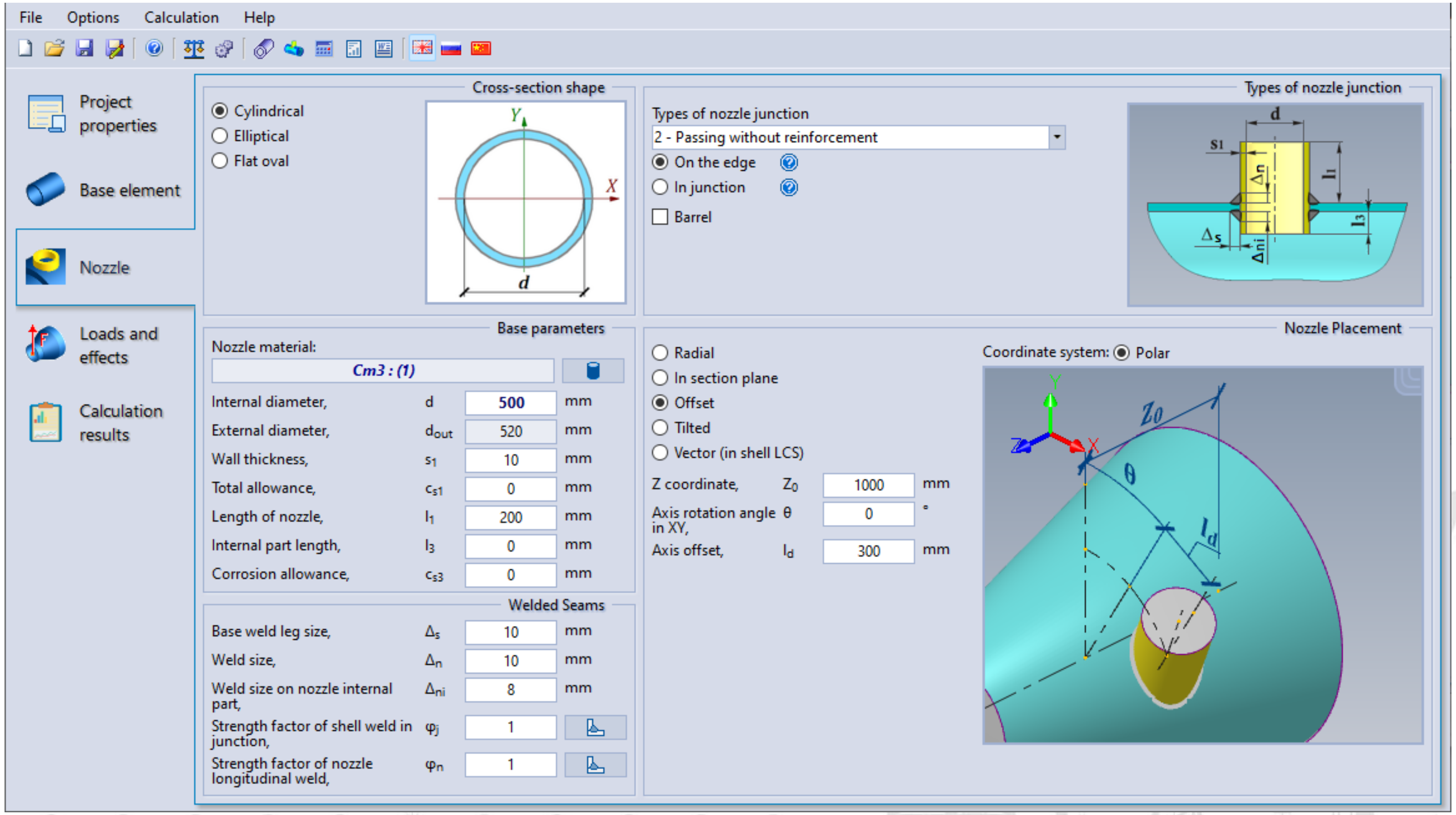
PASS

PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

Nozzle tab

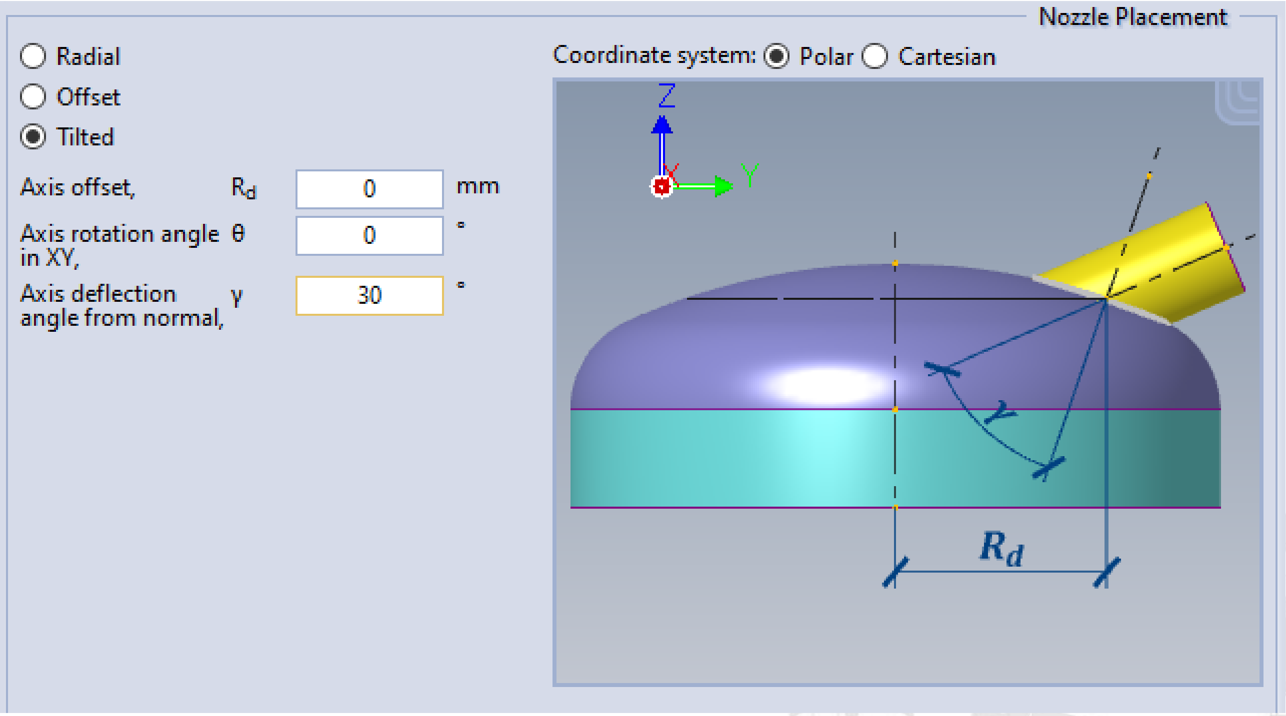
Nozzle tab allows to set nozzle parameters:

- Cross-section shapes
- Nozzle and reinforcement data
- Junction type
- Nozzle placement



Nozzle placement features

- There is a big set of nozzle orientation ways
- Different view is provided for each dimension field



Nozzle-FEM

Comprehensive orientation set:

- Radial
- Hillside Offset
- Tilted
- Polar and Cartesian coordinates placement
- Tilted in section plane
- Vector

PASS PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

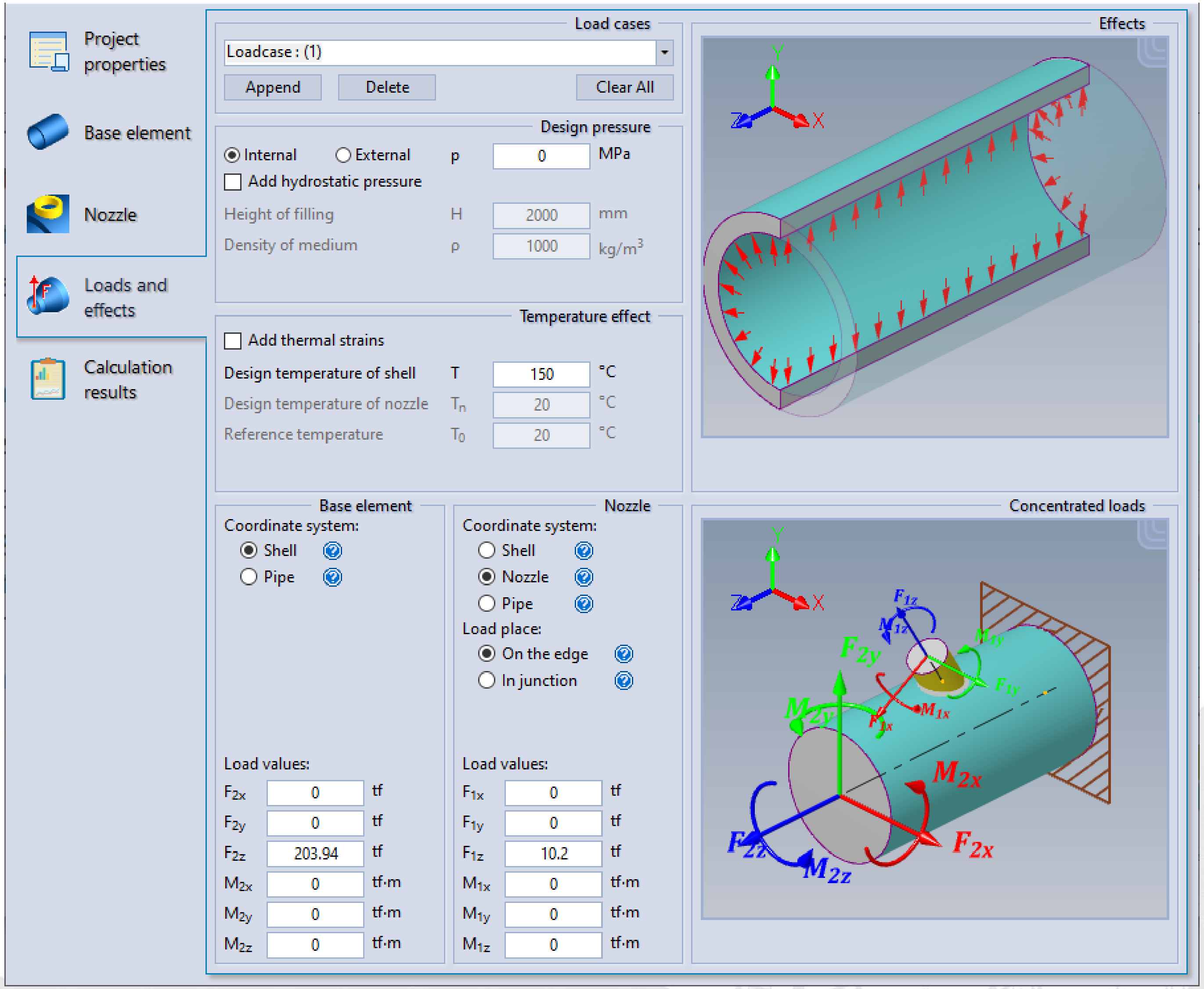
Nozzle-FEM

Loads and effects

Key features:

- Load cases adding
- Concentrated loads (in global, local and pipe CS)
- Thermal strains
- Inner/outer pressure
- Hydrostatic pressure

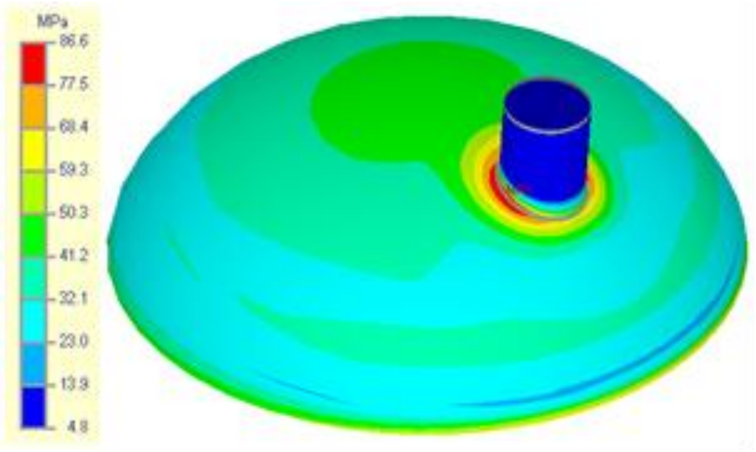
Loads can be automatically converted when switching between different coordinate systems.



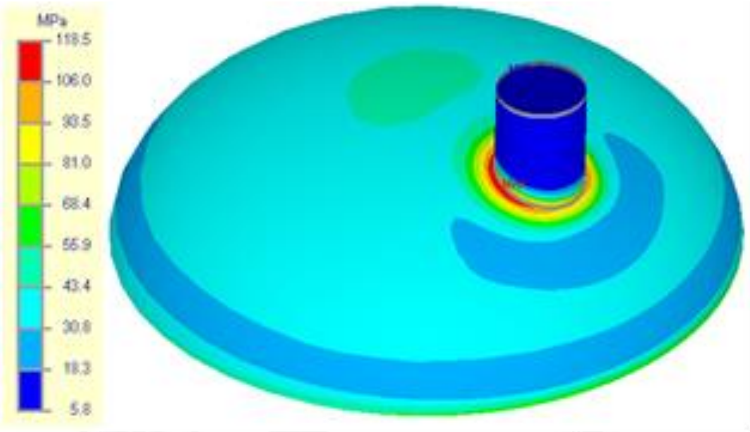
Thermal strains

PASS/Equip Nozzle-FEM considers thermal expansion (deformation) of structure element materials that causes additional stresses by constrained deformations (different linear expansion coefficients, temperatures, etc.)

Without thermal strains



With thermal strains



Nozzle-FEM

Difference between shell and nozzle material thermal expansion factors leads to a constrained thermal deformation and additional stresses.

Stresses can drastically increase in the nozzle junction area.

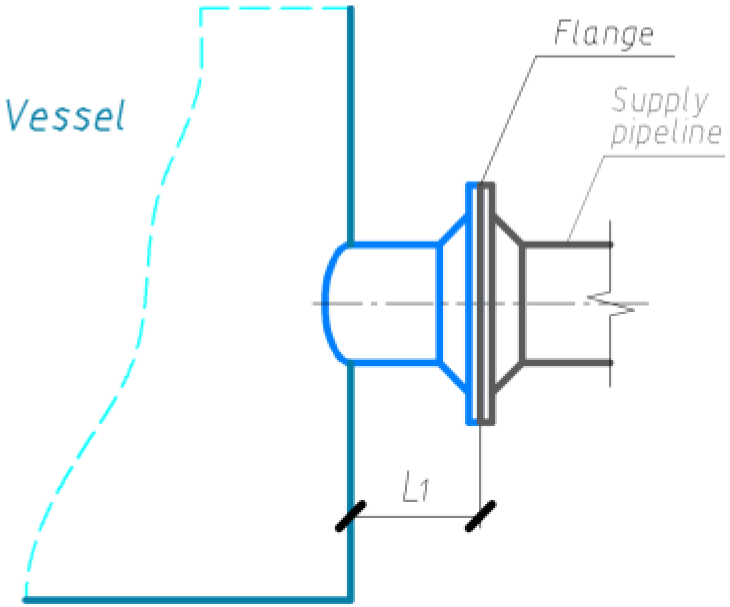
In the example, it increases by 32MPa (37%).

PASS
PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

Loads setting

Nozzle-FEM provides two ways to set loads on nozzle: «On the edge» and «In junction», that are different in definition of nozzle length.

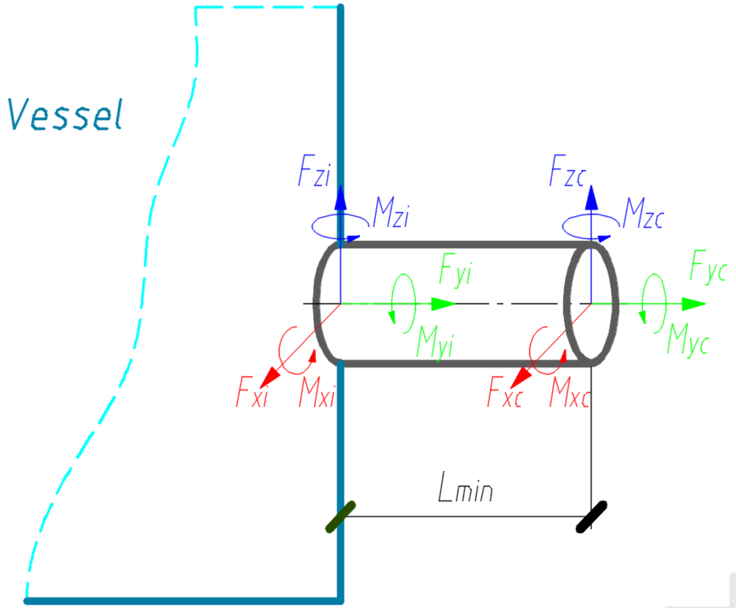
On the edge – a typical case when the nozzle and supply pipelines are connected by flange. In this case, the design scheme, including the supply pipelines, ends on a flange connection, and the design loads on the nozzle are obtained at this point.



Nozzle length is calculated as:

$$L_1 \geq \max\{\delta, \delta_2, r\} + \min\{s, s_1\}.$$

In junction – a case when the supply pipeline ends at the place of junction into the shell. In this case, the design scheme, including the supply pipelines, usually ends on the outer surface of the shell, and the design loads on the nozzle are obtained at this point.



Nozzle length is calculated as [see ASME B31J-2017]:

$$L_{min} = \min\left\{0.5 d_{cp}^{1.4} s_1^{-0.4}, d\right\}.$$

PASS
PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

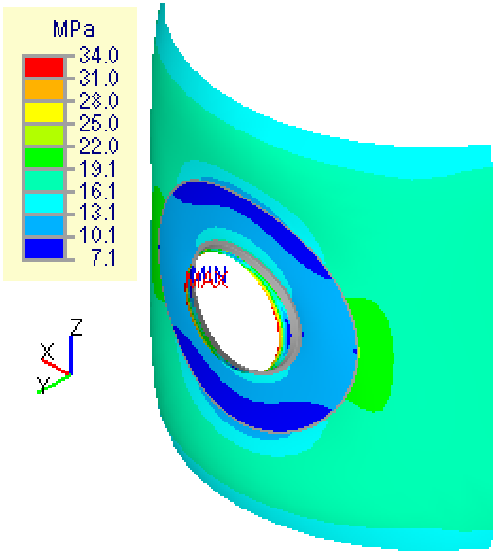
Nozzle-FEM

Calculation **“in Junction”** corresponds to the "flexible" connection between the pipeline and the shell, and has been obtained based on numerous field tests [ASME B31J-2017].

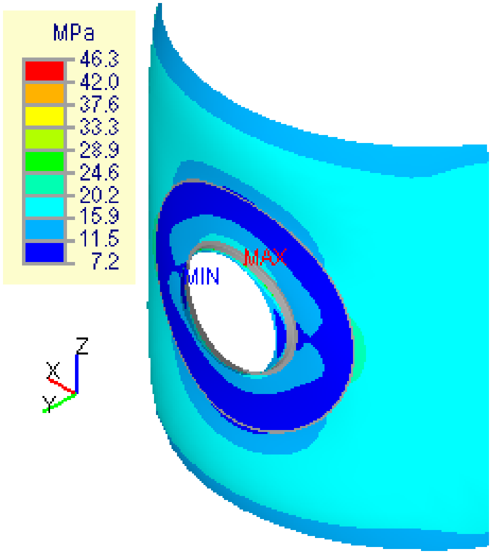
It allows engineers to consider an ovalization of the section at the junction area that corresponds to the "flexible" connection between the pipeline and the shell.

Loads setting in junction

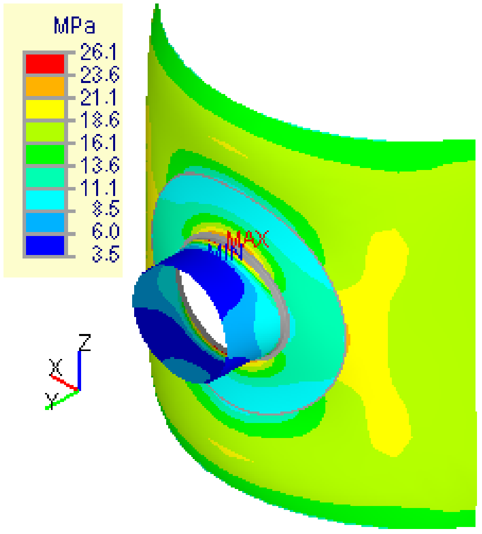
The influence of edge effect on results in junction:



L=30мм – well-defined edge effect from the load application



L=50мм – short length of the nozzle, falls within the area of the edge effect of the load application



At the nozzle length obtained by formula

$$L_{min} = \min\left\{0.5 d_{cp}^{1.4} s_1^{-0.4}, d\right\}.$$

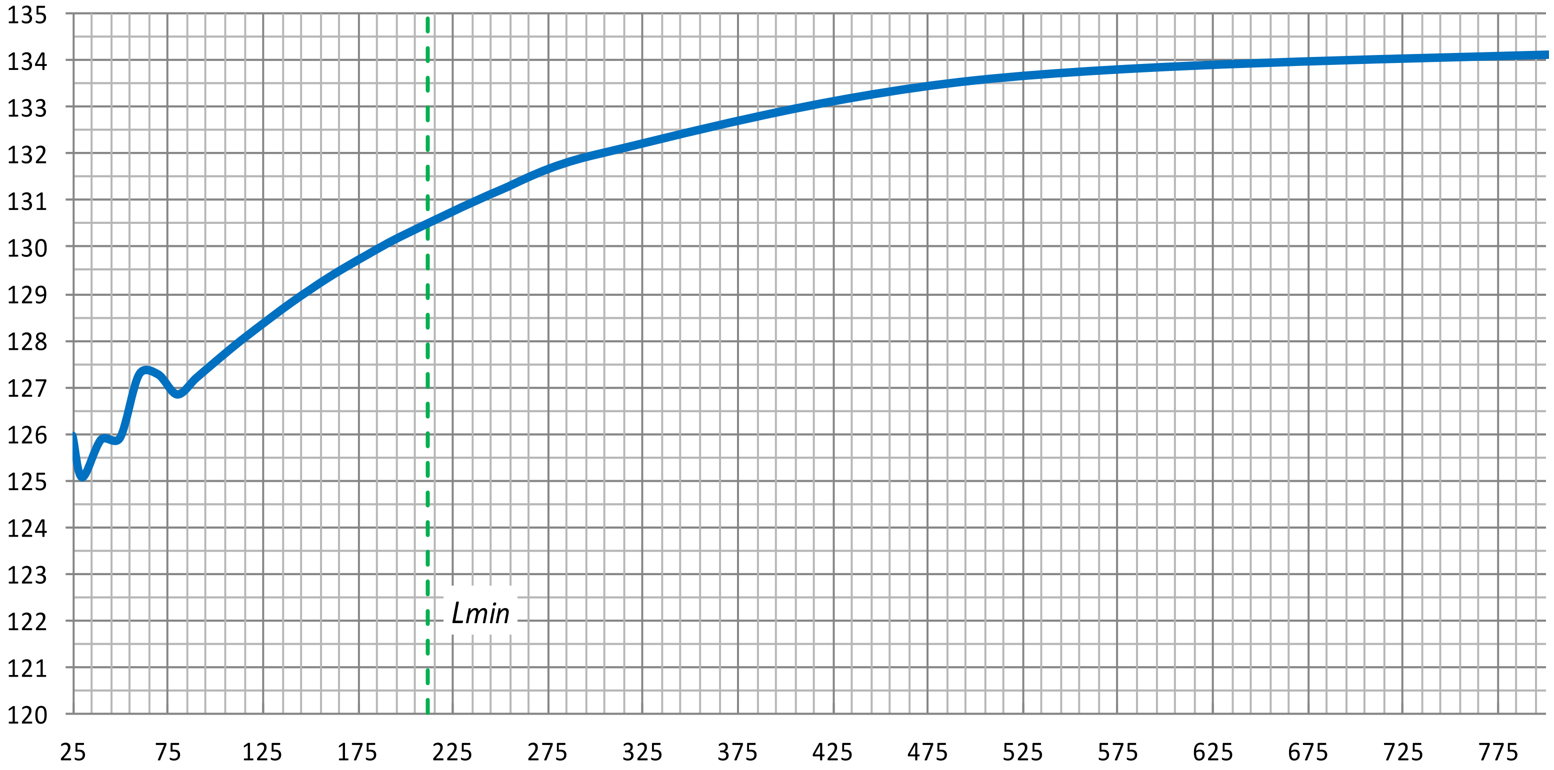
PIPING AND EQUIPMENT
ANALYSIS & SIZING SUITE

Nozzle-FEM

When calculating the strength, PASS/Equip Nozzle-FEM software automatically converts the loads specified by the user at the junction point into statically equivalent loads

Loads setting in junction

The plot represents the change curve in the allowable axial force depending on the nozzle length, which shows that, in the junction area, at a distance less than 100 mm, edge effects from the load application point appear (D=2000mm, s=12mm, d=203, s1=6 mm).



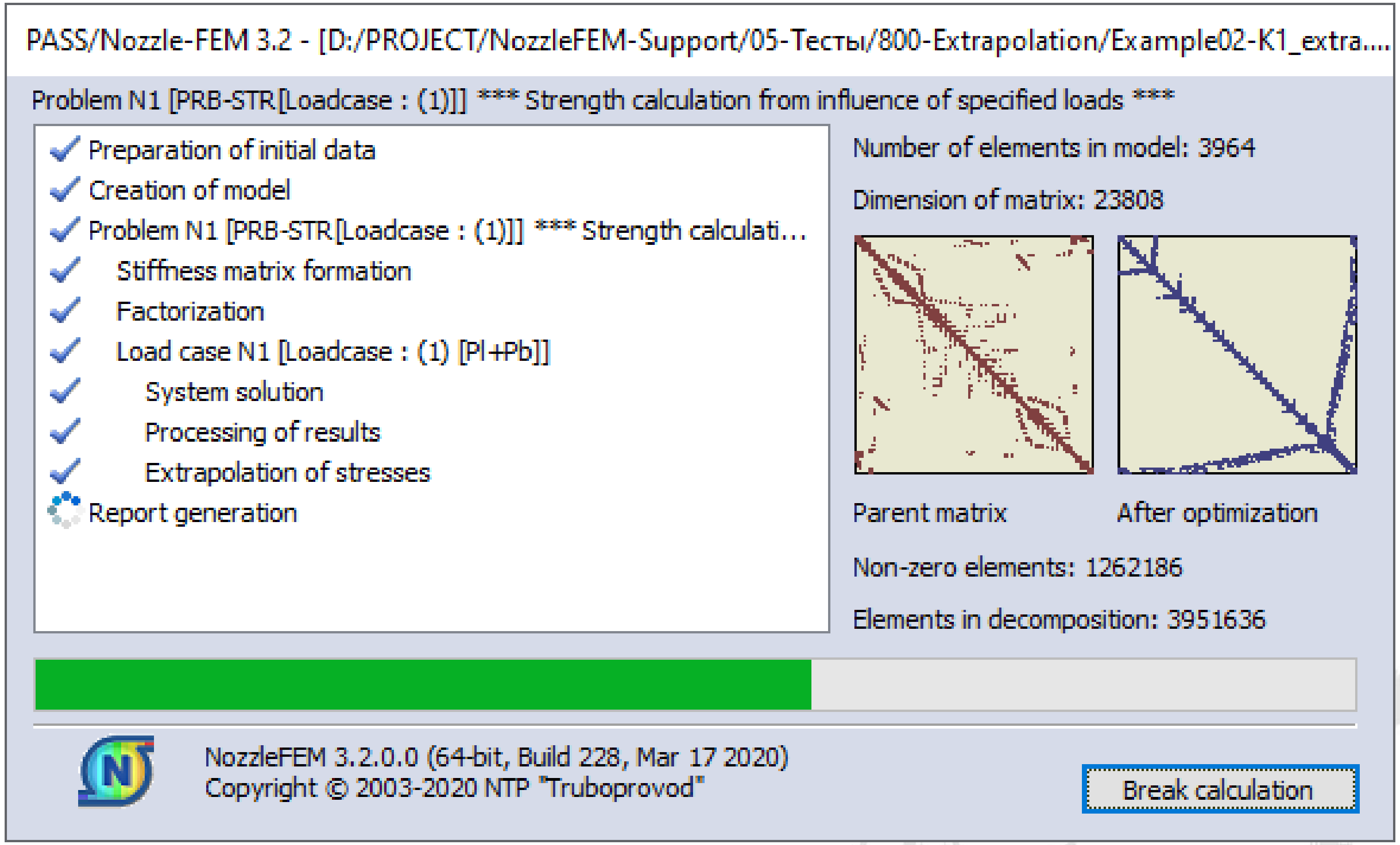
PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

Nozzle-FEM

Steps:

- Checking data Input
- Creation of models (geometric, finite-element)
- Solution
- Results/stress analysis
- Html report generation

Calculation stage



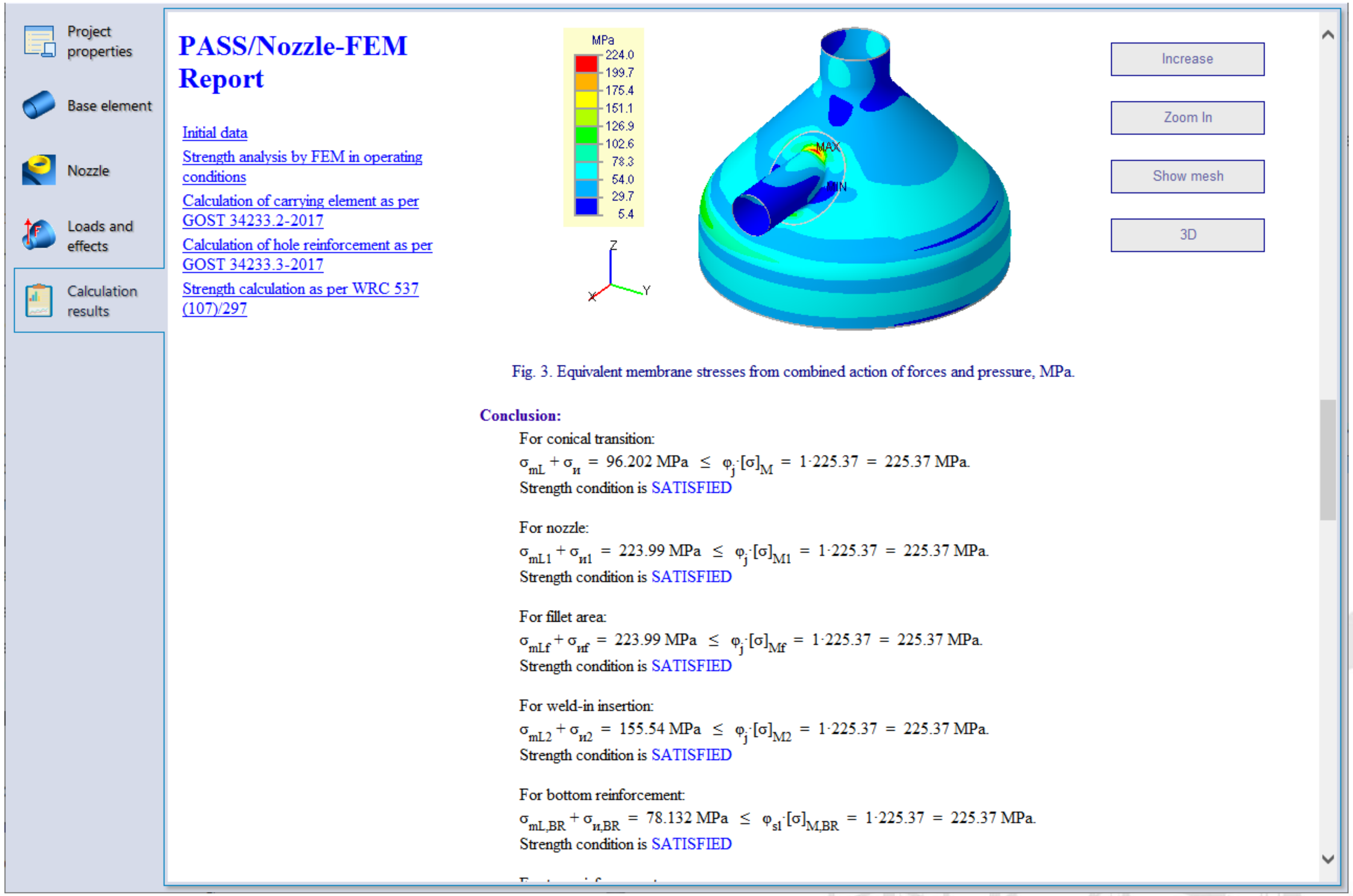
PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

Nozzle-FEM

- General report is provided in HTML.
- It contains input data, strength analysis, etc.
- RTF format can be generated.
- 3D-postprocessor from the report.

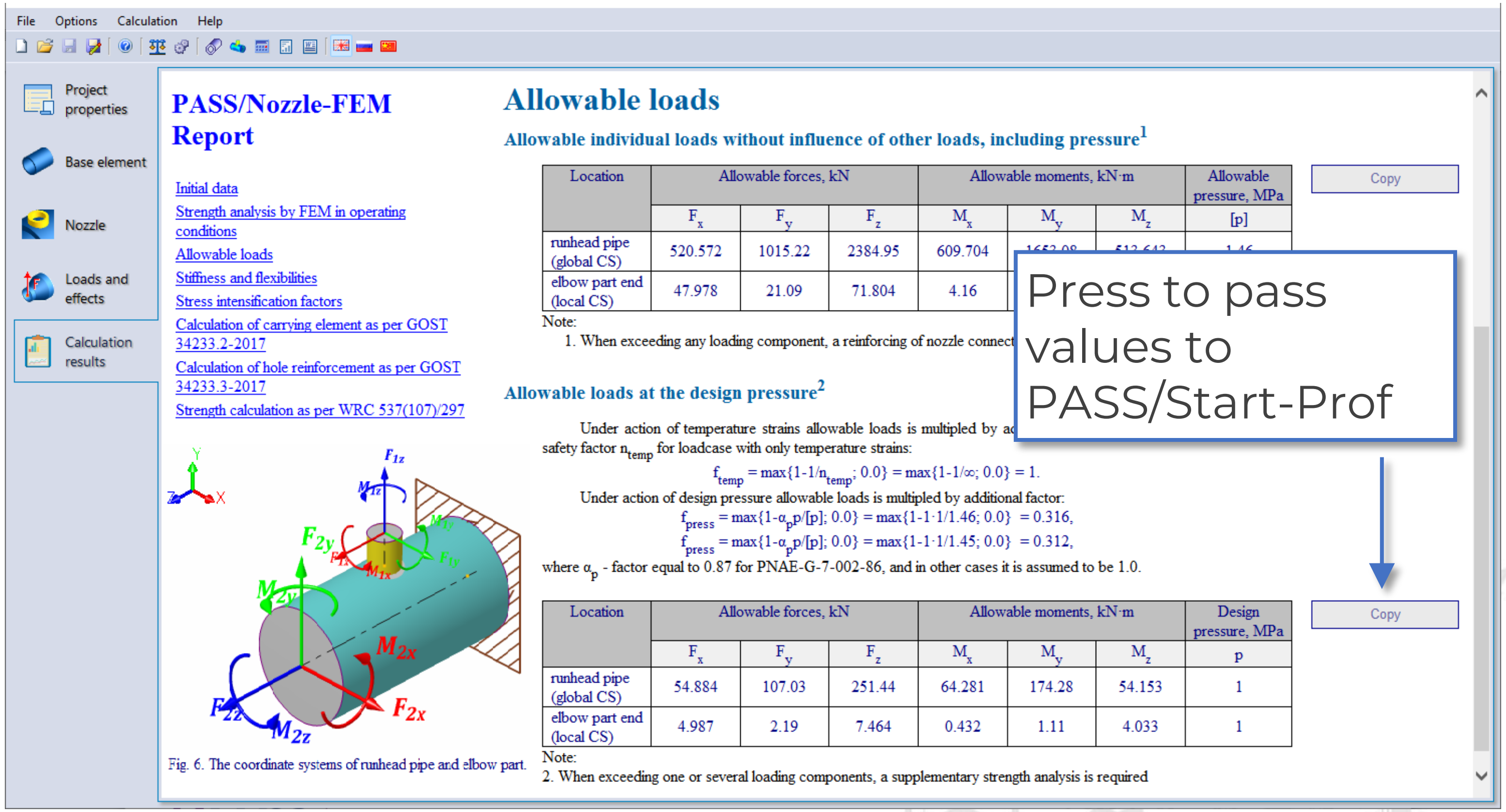
Comprehensive report content

Intuitive report



Report with allowable loads

Allowable loads on nozzle junction are presented:



Allowable loads

Allowable individual loads without influence of other loads, including pressure[1]

Location	Allowable forces, kN			Allowable moments, kN·m			Allowable pressure, MPa
	F_x	F_y	F_z	M_x	M_y	M_z	[p]
runhead pipe (global CS)	520.572	1015.22	2384.95	609.704	[illegible]	[illegible]	[illegible]
elbow part end (local CS)	47.978	21.09	71.804	4.16	[illegible]	[illegible]	[illegible]

Note:

1. When exceeding any loading component, a reinforcing of nozzle connect

Allowable loads at the design pressure[2]

Under action of temperature strains allowable loads is multipled by ad safety factor n_{temp} for loadcase with only temperature strains:

$$f_{temp} = \max\{1-1/n_{temp}; 0.0\} = \max\{1-1/\infty; 0.0\} = 1.$$

Under action of design pressure allowable loads is multipled by additional factor:

$$f_{press} = \max\{1-\alpha_p p/[p]; 0.0\} = \max\{1-1\cdot1/1.46; 0.0\} = 0.316,$$

$$f_{press} = \max\{1-\alpha_p p/[p]; 0.0\} = \max\{1-1\cdot1/1.45; 0.0\} = 0.312,$$

where α_p - factor equal to 0.87 for PNAE-G-7-002-86, and in other cases it is assumed to be 1.0.

Location	Allowable forces, kN			Allowable moments, kN·m			Design pressure, MPa
	F_x	F_y	F_z	M_x	M_y	M_z	p
runhead pipe (global CS)	54.884	107.03	251.44	64.281	174.28	54.153	1
elbow part end (local CS)	4.987	2.19	7.464	0.432	1.11	4.033	1

Note:

2. When exceeding one or several loading components, a supplementary strength analysis is required

Nozzle-FEM

- 1st table: for individual allowable loads without influence of other loads
- 2st table: for allowable loads that take into account their combined action

PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

Nozzle-FEM

Report with stiffness/flexibilities

If option “Exclude beam stiffness” is enabled, then it additionally displays a table of flexibilities factors for programs like PASS/Start-Prof.

Table of flexibility factors

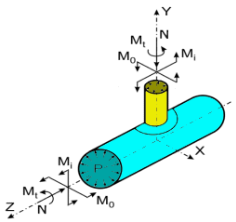


Fig. 8. The coordinate system for determining the flexibility factors.

Description		Main part	Branch part
From axial force N	k_a	0.012	5.919
From inplane bending moment M_i	k_i	0.036	7.352
From outplane bending moment M_o	k_o	$9.493\cdot10^{-12}$	19.11
From torsion moment M_t	k_t	0.034	0.221

PASS/Nozzle-FEM 3.2 - [D:/PROJECT/EPOSV7-OUT64/test/Tee-01.nzldb]

File Options Calculation Help

Project properties
Base element
Nozzle
Loads and effects
Calculation results

PASS/Nozzle-FEM Report

Stiffness and flexibilities

The nozzle junction stiffnesses and flexibilities was calculated with parent shell fixed at both ends.

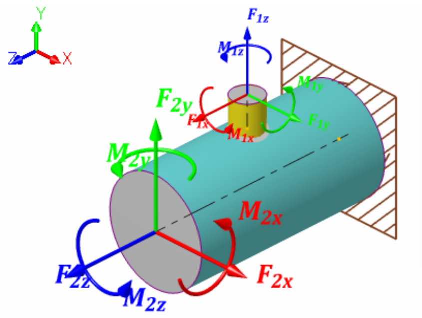


Fig. 7. The coordinate systems of runhead pipe and elbow part.

Press to pass values to PASS/Start-Prof

The stiffness table

The calculated stiffness values are shown in the table below:

Location	Linear, kN/m			Angular, kN·m/deg		
	KL_x	KL_y	KL_z	KR_x	KR_y	KR_z
runhead pipe (global CS)	$3.286\cdot10^{7}$	$2.633\cdot10^{8}$	$6.413\cdot10^{8}$	$4.574\cdot10^{5}$	$1.745\cdot10^{15}$	$3.772\cdot10^{5}$
elbow part end (local CS)	$7.674\cdot10^{4}$	$3.924\cdot10^{4}$	$1.758\cdot10^{5}$	23.83	61.92	1586.86

Copy

The flexibilities table

The calculated flexibilities values are shown in the table below:

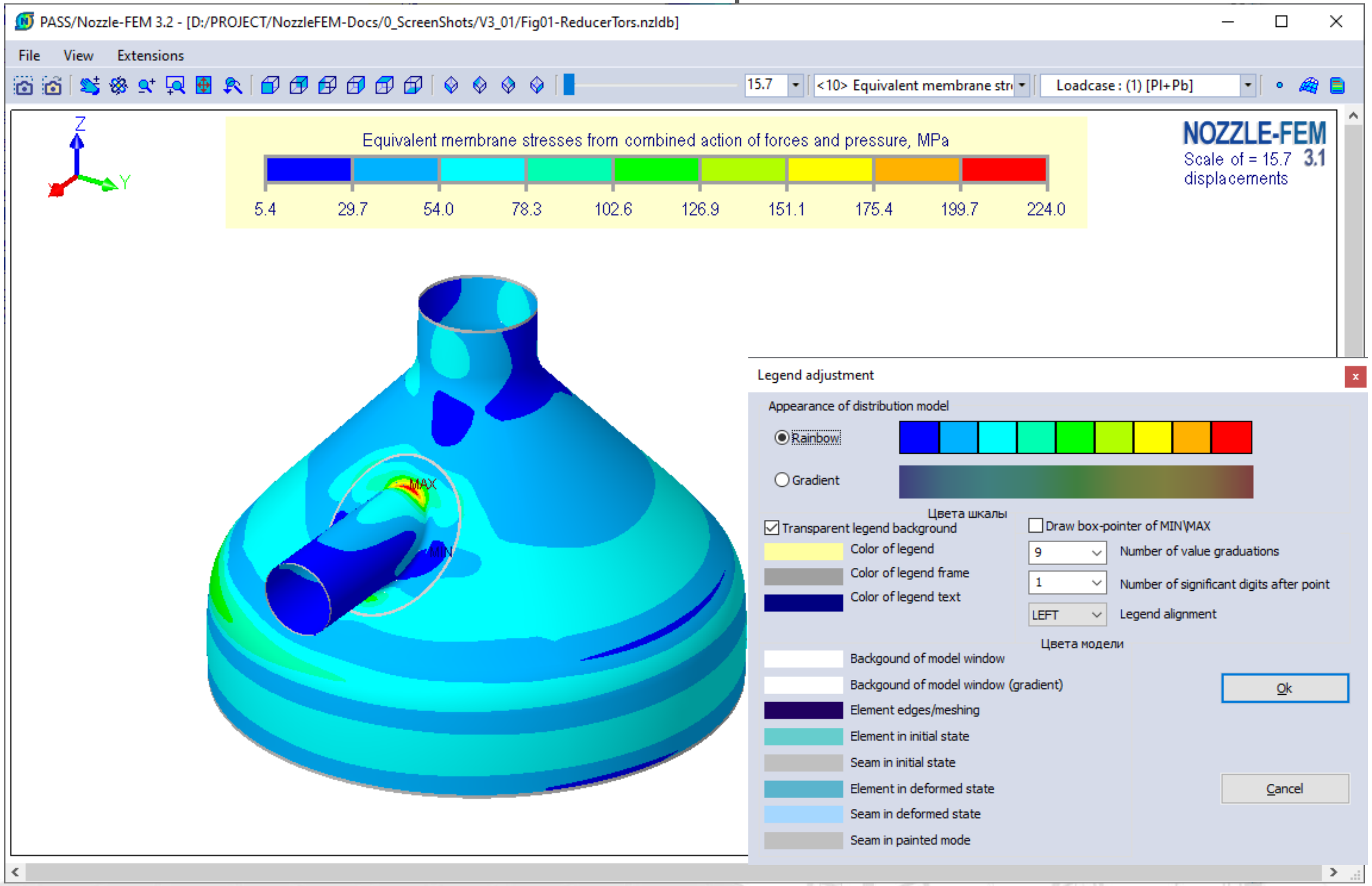
Location	Linear, $(kN/m)^{-1}$			Angular, $(kN\cdot m/deg)^{-1}$		
	FL_x	FL_y	FL_z	FR_x	FR_y	FR_z
runhead pipe (global CS)	$3.043\cdot10^{-8}$	$3.798\cdot10^{-9}$	$1.559\cdot10^{-9}$	$2.186\cdot10^{-6}$	$5.730\cdot10^{-16}$	$2.651\cdot10^{-6}$
elbow part end (local CS)	$1.303\cdot10^{-5}$	$2.549\cdot10^{-5}$	$5.690\cdot10^{-6}$	0.042	0.016	$6.302\cdot10^{-4}$

Copy

PASS
PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

3D processor features

Launched from Html report



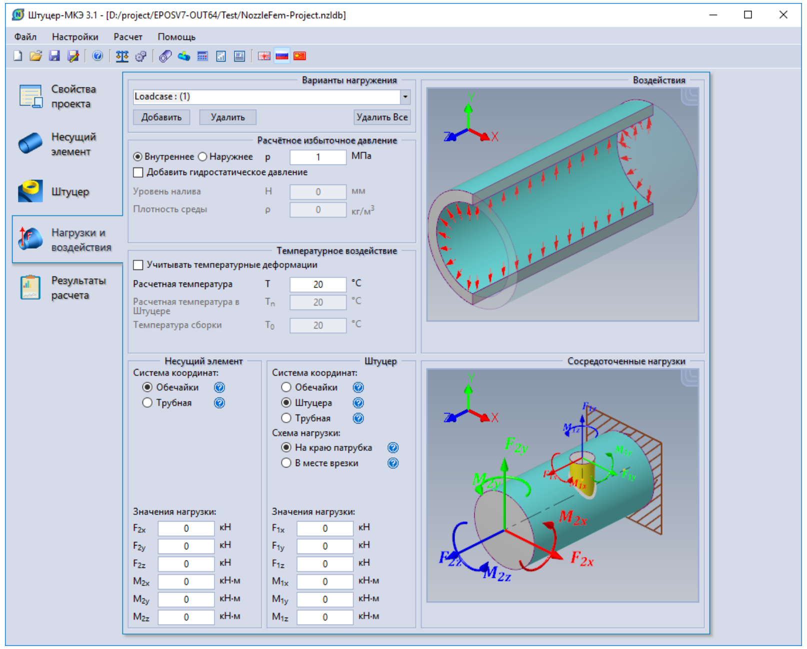
Nozzle-FEM

Capabilities:

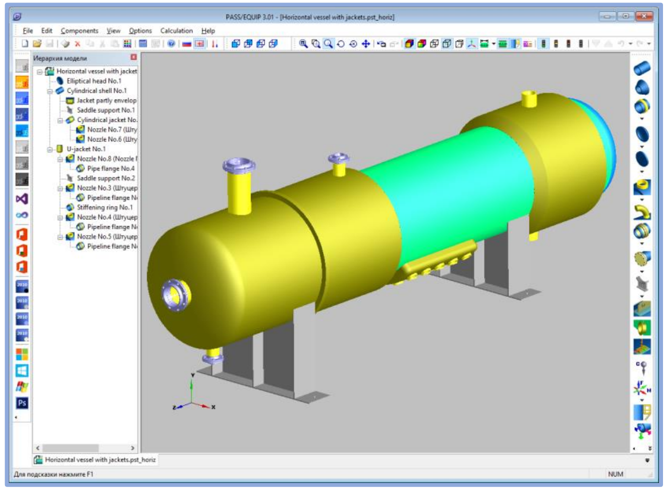
- Change view
- Make screenshots
- Choose different paint modes
- Change load case
- Change color set
- Etc.

PASS PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

Integration capabilities

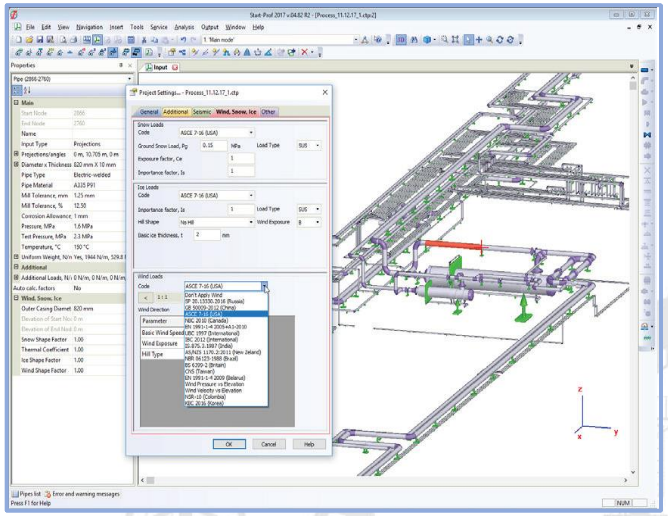


- PASS/EQUIP vessel allows to pass and to export (nzl-files) any part of model



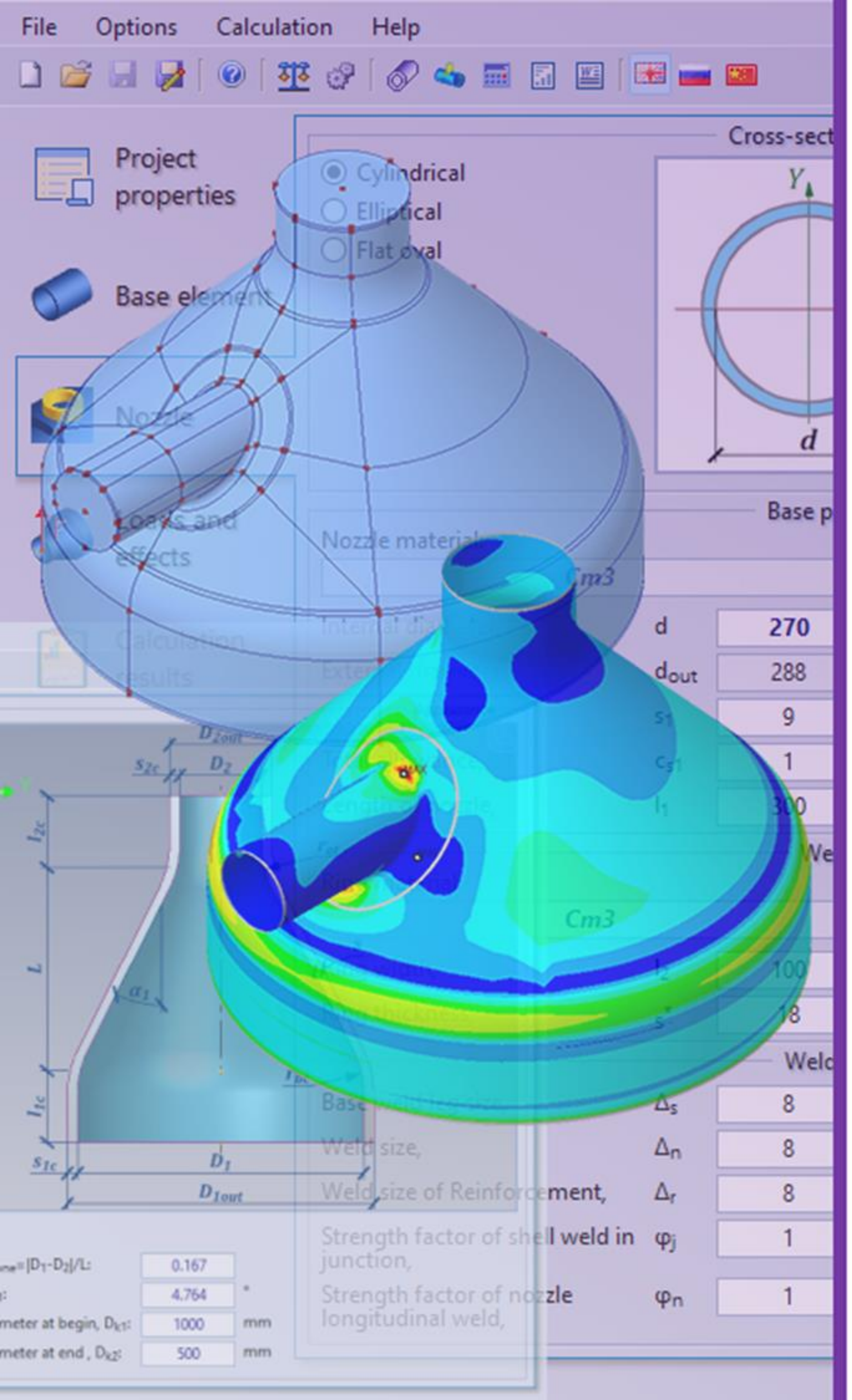
PASS/EQUIP Vessel

PASS/Start-Prof



- Export calculated values from report to PASS/Start-Prof
- Calculation module as per WRC107(537)/297 and GOST 34233.3
- Future plans of full integration: Start-Prof will run Nozzle-FEM for numerical calculation (FEM) of nozzle junctions, nozzle-to-shell stiffness/flexibilities, allowable loads, stress intensification factors etc.

PASS
PIPING AND EQUIPMENT
ANALYSIS & SIZING SUITE



PASS/Equip Nozzle-FEM Advantages

PASS

PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

Advantages

Key PASS/Equip Nozzle-FEM advantages:

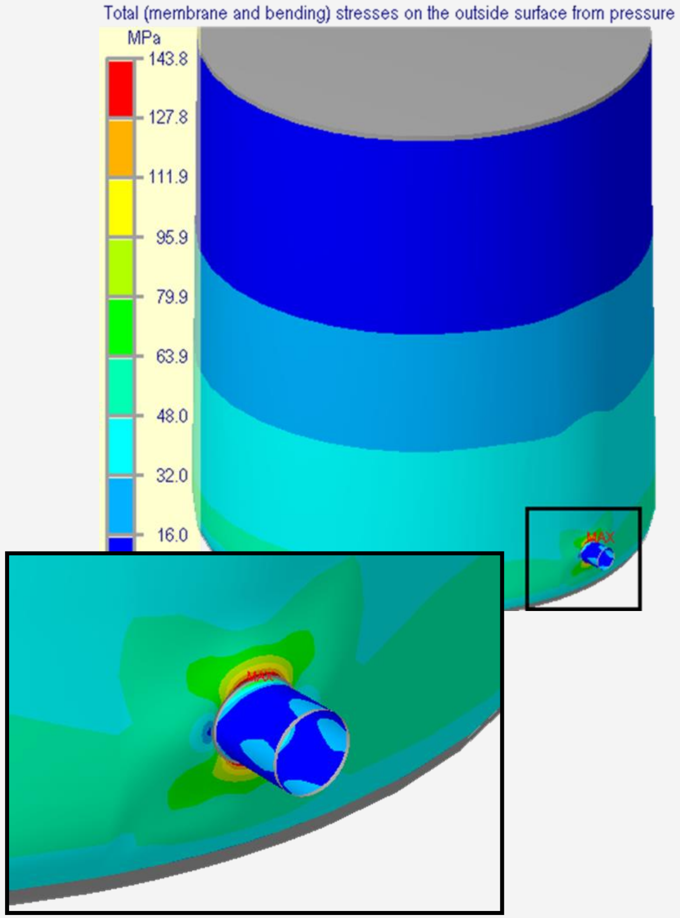
- User friendly modern interface
- Wide range of shell types
- Wide range of nozzle junction types and nozzle placement capabilities
- Different nozzle cross-section shapes
- Affordable price

PASS

PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

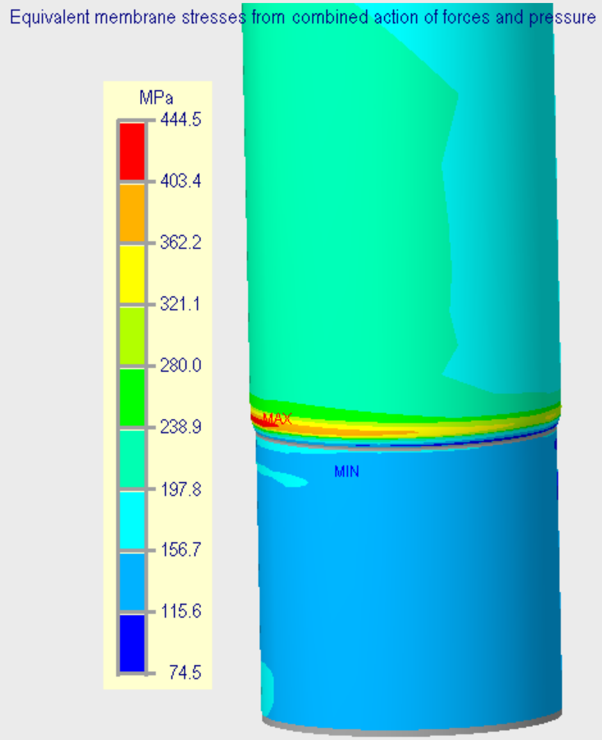
Nozzle-FEM

Adding of hydrostatic pressure



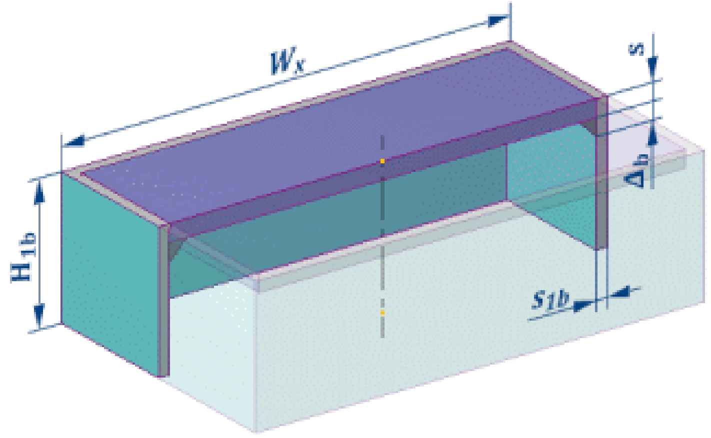
Nozzle-FEM

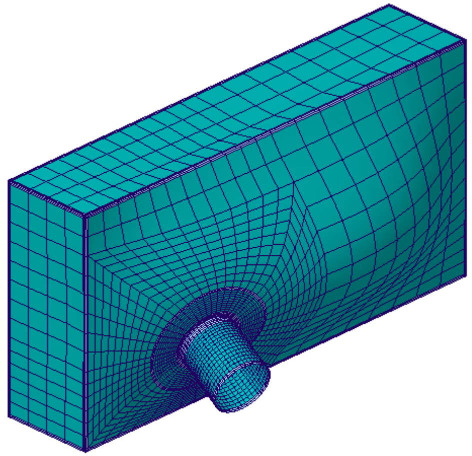
Connection between skirt and vessel (including thermal stresses)

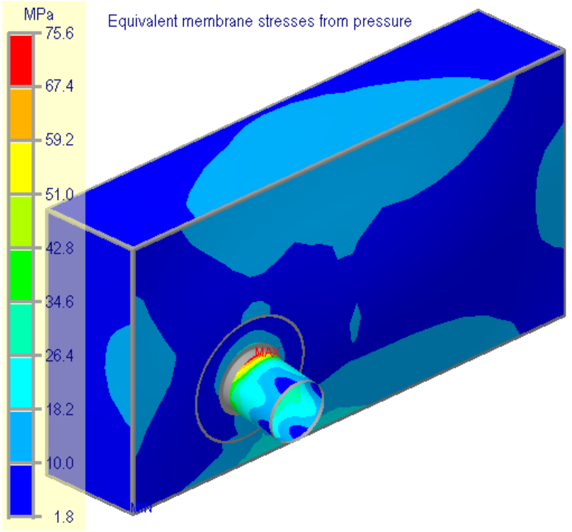


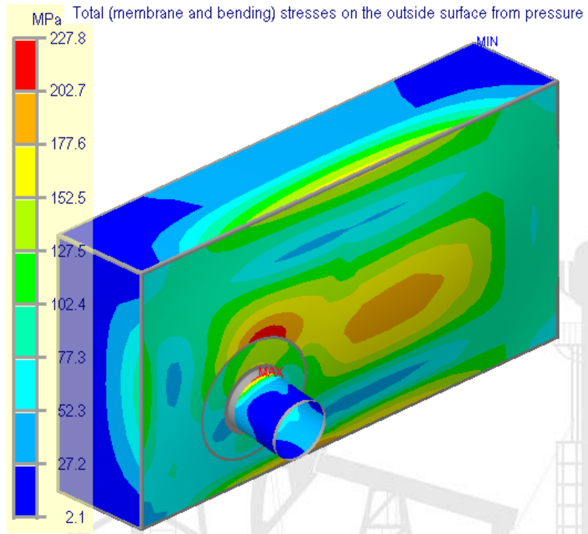
Examples of advantages

Nozzle in Rectangular Plate









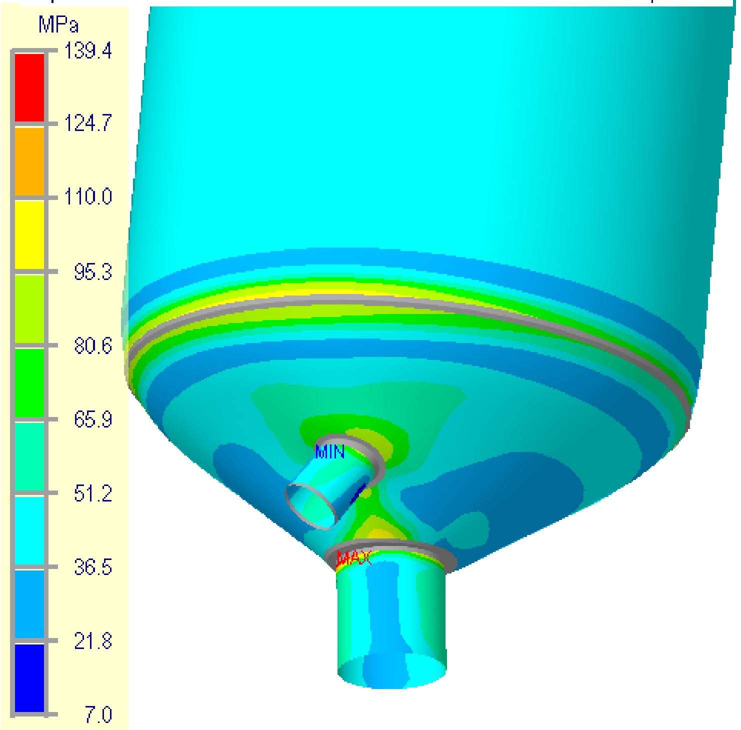
PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

Examples of advantages | PASS/EQUIP Nozzle-FEM

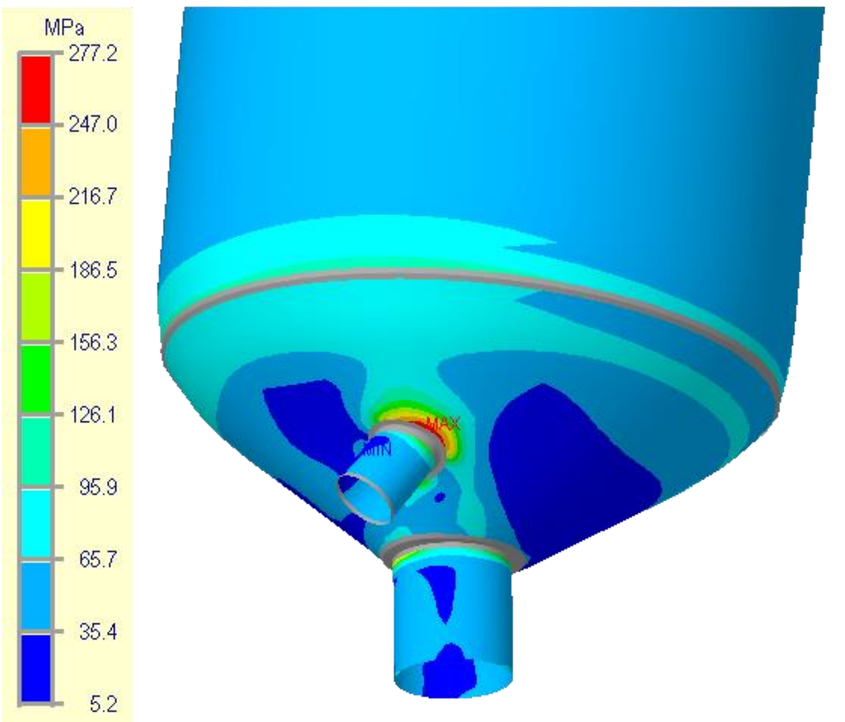
Conical reducer with two nozzles.

Membrane , membrane + bending stresses (inside, outside)

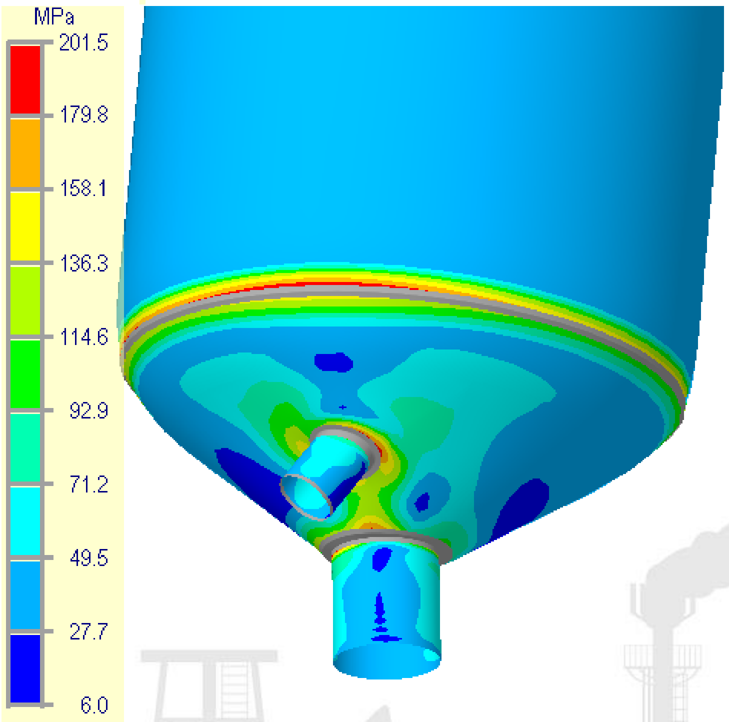
Equivalent membrane stresses from combined action of forces and pressure



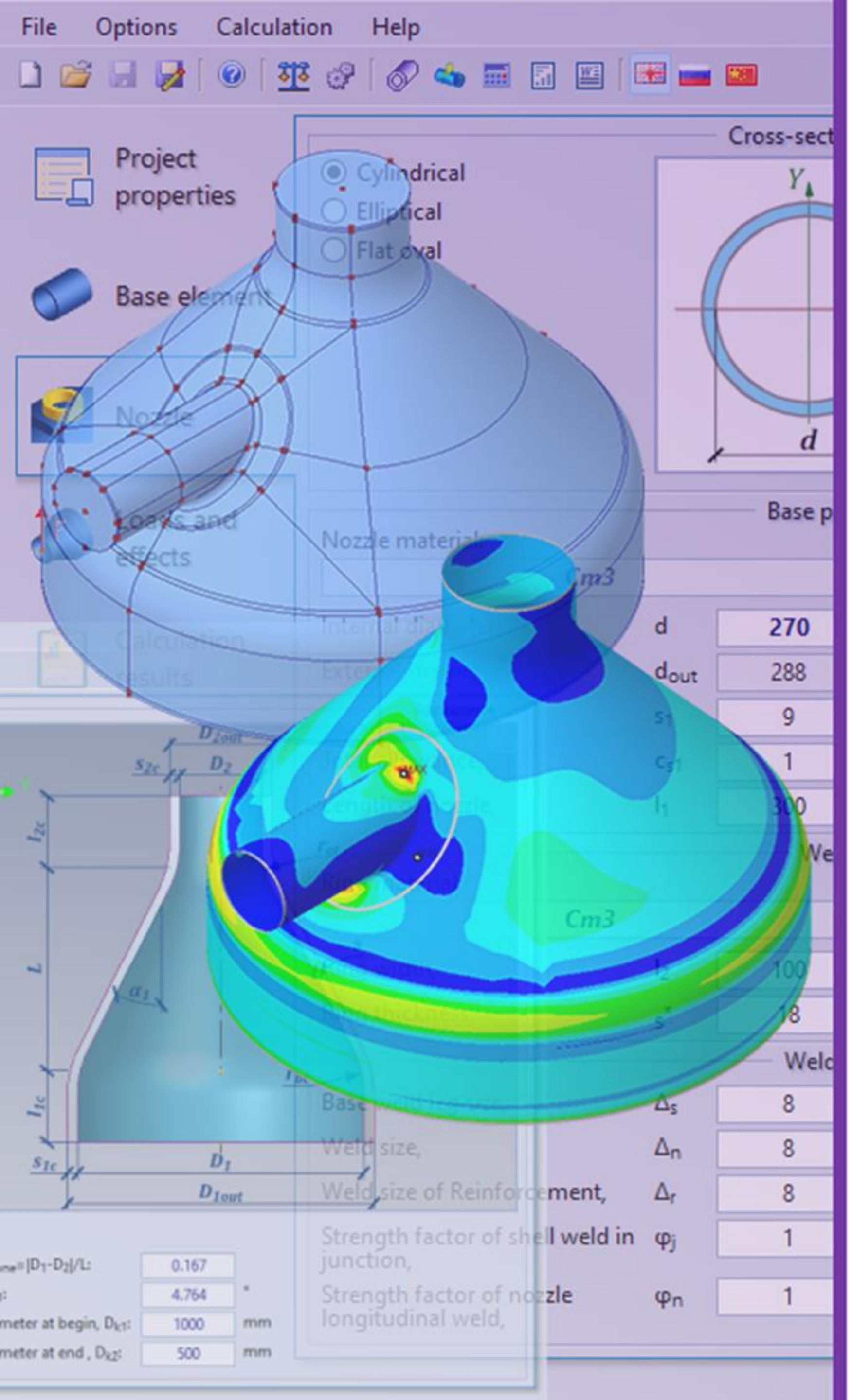
Total (membrane and bending) stresses on the outside surface from combined action of force



Total (membrane and bending) stresses on the inside surface



PASS
PIPING AND EQUIPMENT
ANALYSIS & SIZING SUITE



Q&A

PASS

PIPING AND EQUIPMENT
ANALYSIS & SIZING SUITE

PASS

PIPING AND EQUIPMENT ANALYSIS & SIZING SUITE

P: +7 495 225 94 32

F: +7 495 368 50 65

E: sales@passuite.com

W: www.passuite.com

THANK YOU!