FIDESYS
strength analysis system

Skolkovo

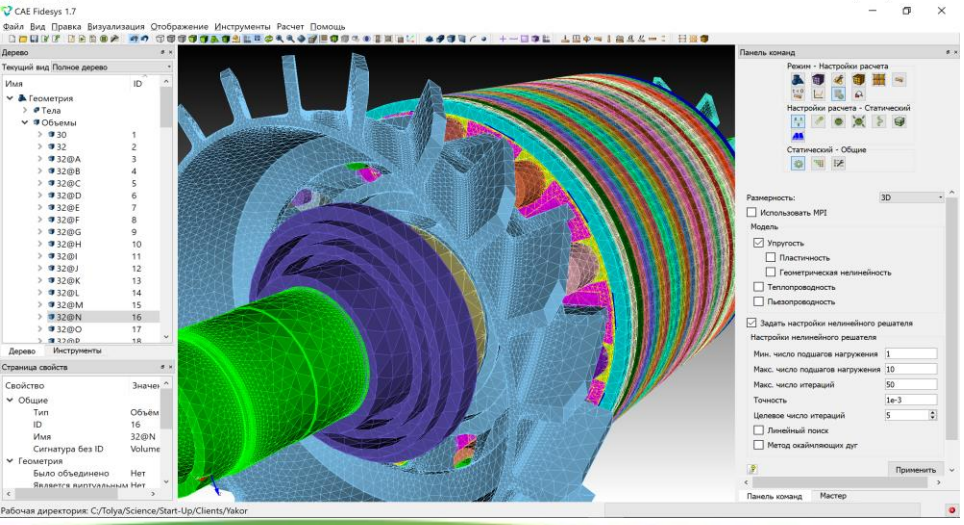
Fidesys

Desktop and cloud engineering analysis

CAE - digital prototyping & testing

Classical testing model

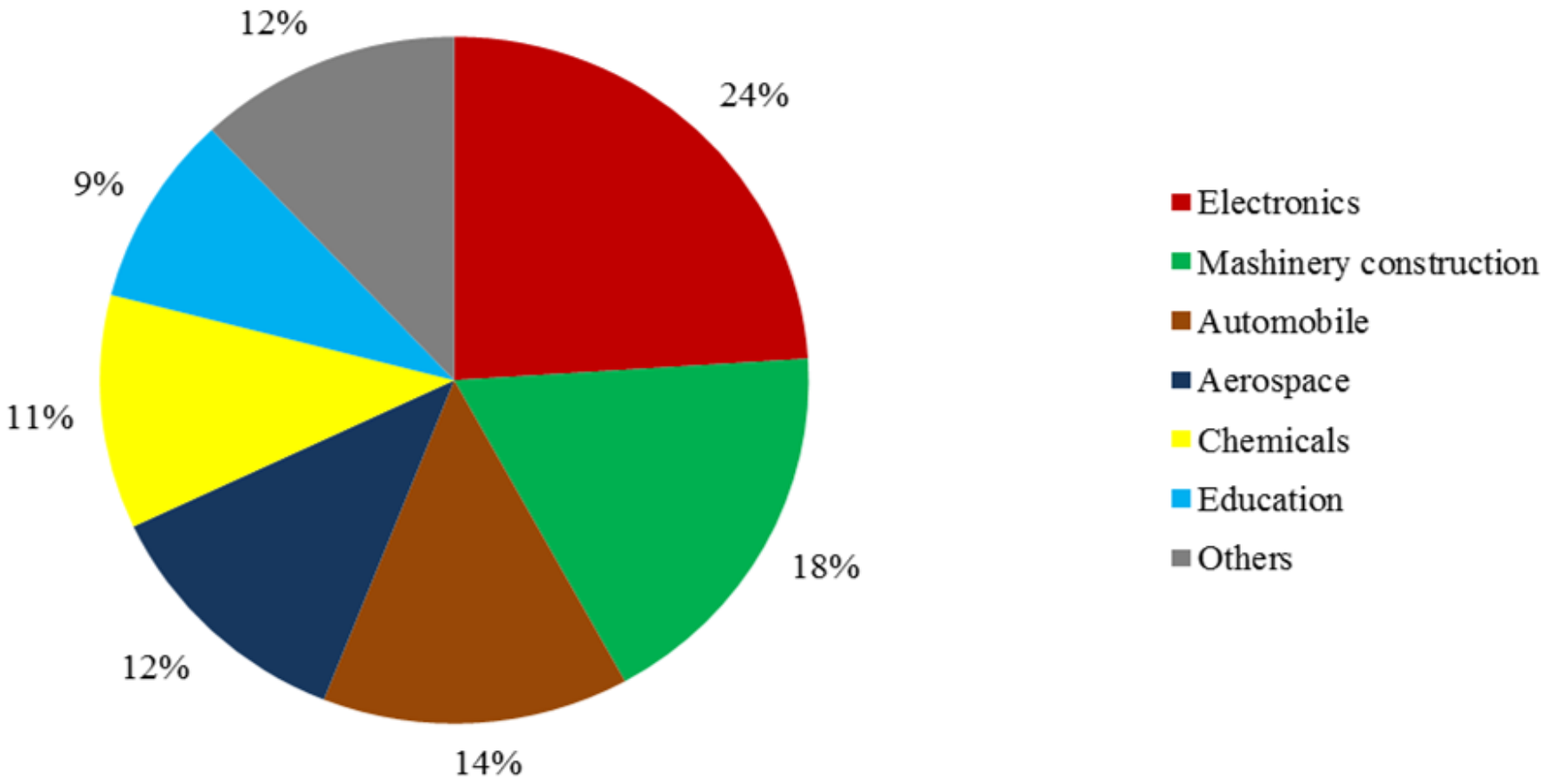
New digital model



- CAE (computer-aided engineering) is a software that enables the shift from expensive classical testing models (crash-tests, experiments in the lab, field tests) to a digital environment simulation. Virtual twin of the physical world
- First of all the product is designed as a 3D model. Afterwards one can apply different loads, pressures, compressions or any other physical processes in the software that affect the quality of the product (for example strength) in the real world
- The ability to carry out millions of tests in the virtual framework with a different set of input parameters instead of limited amount and diversity in the classical testing model
- **As an example physical testing costs at least five to six times the cost of product development resources on vehicle projects. The only way to meaningfully reduce the cost of physical testing is with simulation**

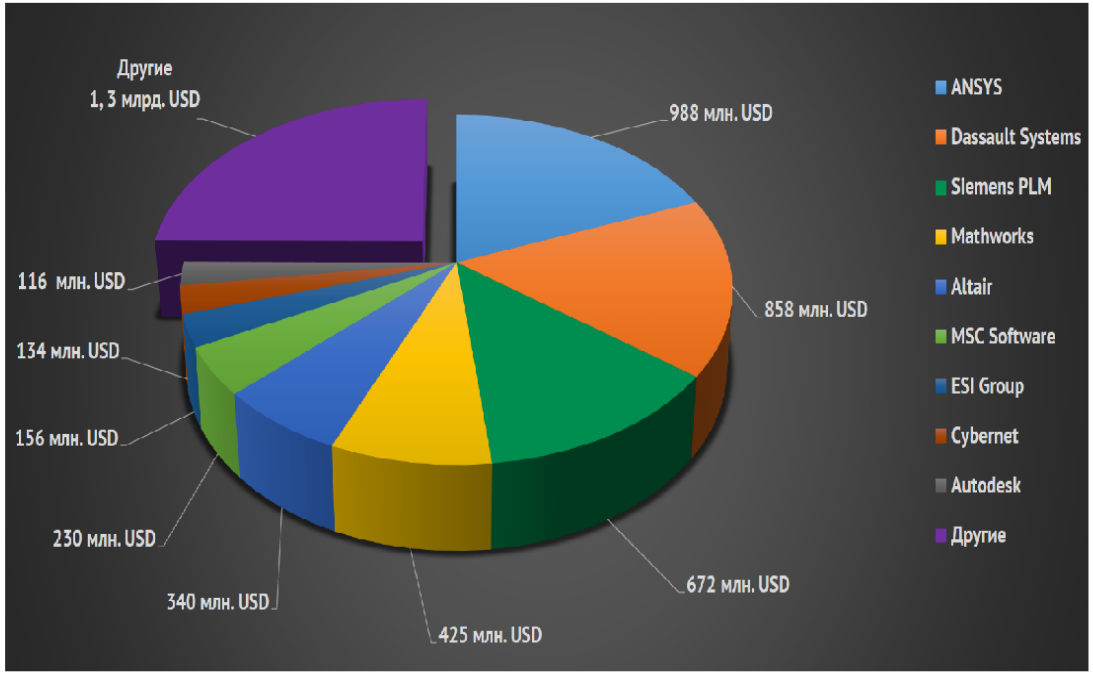
WHO ARE THE CUSTOMERS?

Traditional users (like Automotive) and "newer sectors" (like Mining, Oil&Gas) provide for CAE systems CAGR more than 15% annual



CAE market overview

- The growth of world CAE market from 2.2 bill. USD to 5.3 bill. USD (+146%) during the last 10 years
- Share of EU market (1.85 bill. USD) estimated at 35% of the world CAE market
- New trend in applying simulation technologies in design process. Possible example – topology optimization
- New trend in the industrial internet (IoT). The concept of digital twin, that leads to product lifecycle simulation using sensors
- **According to the latest research top 15 CAE companies have consolidated 78% of world market. The remaining 1. 14 bill. USD opens an opportunity for emergence of new players**



About Fidesys

Fidesys LLC is an engineering software company with offices in Moscow, Russia and NJ, USA, founded in 2009 as a research group of **Lomonosov Moscow State University.**
Fidesys LLC develops the next-gen universal software for high-end structural analysis (CAE, computer-aided engineering) using a new generation of numerical methods.

CAE Fidesys is already used in mechanical engineering, mining, oil and gas industries.

The company is a resident of the **Skolkovo Innovation Center** and a member of **NAFEMS**, the International Association for the Engineering Modelling, Analysis and Simulation Community.

CAE Fidesys is verified according to the NAFEMS standards.

Our Team

- **25 programmers–mathematicians** (postgraduates, PhDs and masters from the top Russian universities*)
- **11 consulting professors**, working in the **Russian Academy of Sciences**, **Columbia University**, **University of New Hampshire** and **Iowa State University**
- Management, sales and marketing specialists with extensive experience in various technical fields and international background

Board of directors incl. top-managers of IT industry (former VPs of PTC CIS, Autodesk CIS)

Key expertise: precise math modeling for structural analysis and related engineering fields

*incl. Lomonosov Moscow State University, Bauman Moscow State Technical University, Moscow Institute of Physics and Technology, and other leading regional universities

CAE Fidesys functionality

CAE Fidesys Standard

- Linear problems of elasticity
- Plane stress and plane strains problems
- 3D static and dynamic (transient) analysis
- Modal and buckling analysis
- Beam/Shell/Solid elements and their combinations

CAE Fidesys Professional

- Accurate estimation of the nonlinear effects: physical, geometrical and contact nonlinearities
- Strength analysis for elastoplastic materials: Mises, Drucker-Prager
- Bonded/sliding/friction contacts
- Hyperelastic materials (Murnaghan, Mooney-Rivlin)
- Thermal conductivity and thermoelastic problems

✓ Fidesys HPC

- Parallelization of major stages of computational process
- Speed-up calculations by up to 30 times
- OpenMP technology: parallelization on all computational cores of a workstation
- MPI technology: parallelization on several workstations inside a network or on nodes of a supercomputer

✓ Fidesys Dynamics

- Application of spectral element method for linear and nonlinear problems
- Non-stationary problems
- Full waveform modeling
- Seismic modeling
- Non-destructive control modeling

✓ Fidesys Composite

- Analysis of composites' effective properties
- Construction of the realistic composite's microstructure
- Strength analysis of tools and parts made of composite materials (including porous, fiber-laminated and woven composites)
- Estimation of effective properties of a monolayer
- Rubber-cord materials modelling

Major clients

GAZPROM NEFT

ارامكو السعودية
Saudi Aramco

ArcelorMittal

LOMONOSOV MOSCOW STATE UNIVERSITY
MSU

RUSNANO
Russian Corporation of Nanotechnologies

Skoltech
Skolkovo Institute of Science and Technology

ROSATOM

NORNICKEL

CIAM

urbanmining co

IOWA STATE UNIVERSITY

NATIONAL RESEARCH NUCLEAR UNIVERSITY
NRNU MEPhI
MEPhI

United Instrument Manufacturing Corporation
Rostec

SAINT-PETERSBURG MINING UNIVERSITY
The First Higher Technical University in Russia

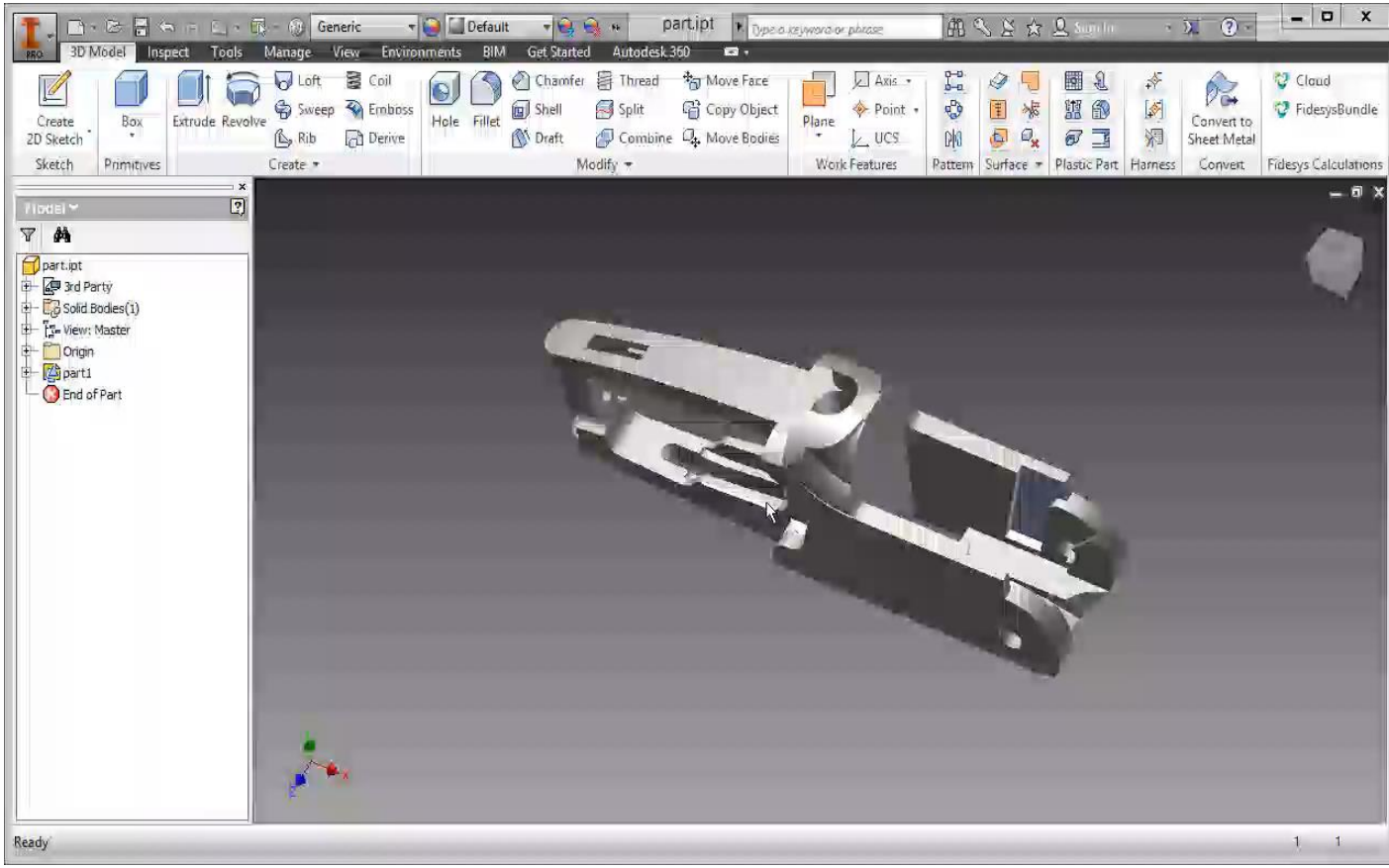
CROCUS NANO ELECTRONICS

MISIS
National University of Science and Technology

Integration with Autodesk Inventor

AUTODESK. Authorized Developer

- One-button export of CAD model from Autodesk Inventor into CAE Fidesys;
- No need to re-build FEA model if the CAD-model parameters were changed in Inventor;
- Export to Sim4Design for analysis in the cloud

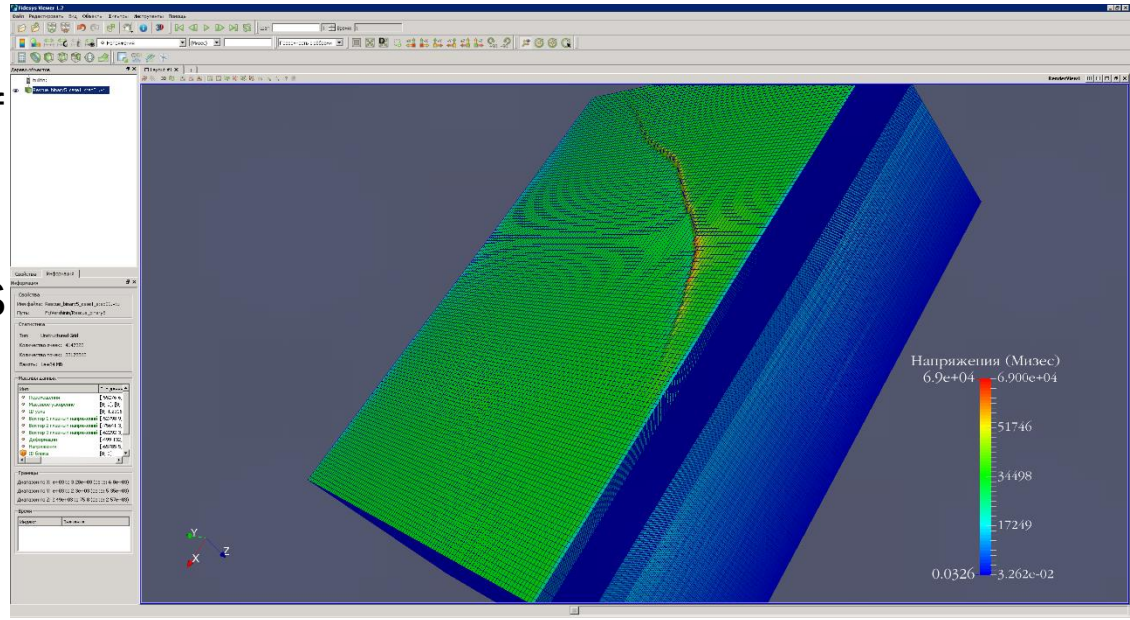


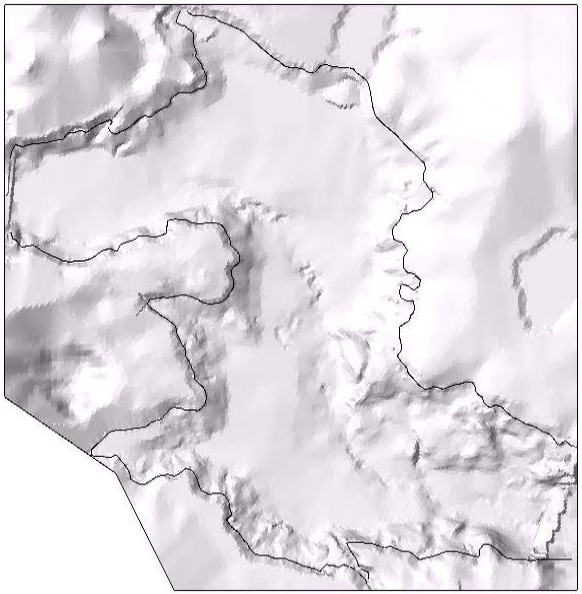
Integration with Roxar

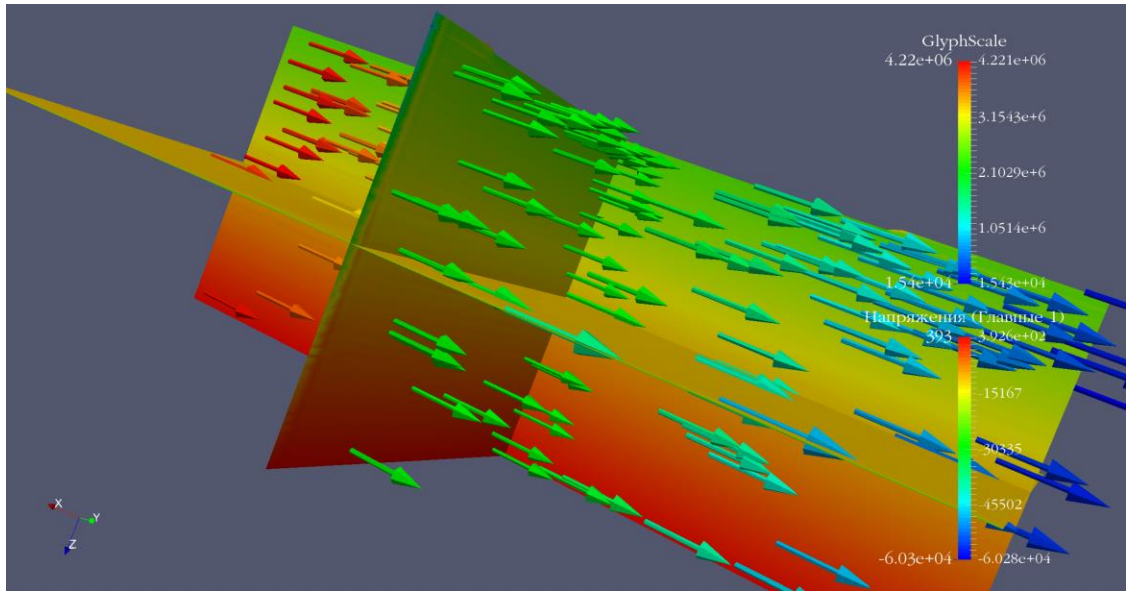
roxar
EMERSON GROUP COMPANY

RMS

- Full 3D geomechanical analysis of the imported model;
- Direct automatic transfer of the geological model from Roxar RMS into CAE Fidesys;
- Predictive modeling for optimization and virtual prototyping.







Compatibility and support

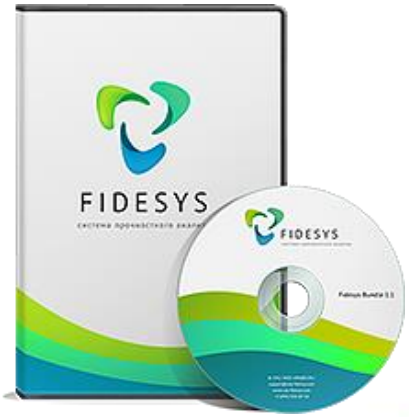
- Support for the most CAD/CAE formats

- Support of general data types
  - ACIS
  - IGES
  - STEP
  - AVS
  - Genesis/Exodus
  - Facets
  - STL
  - Ideas
  - Cubit

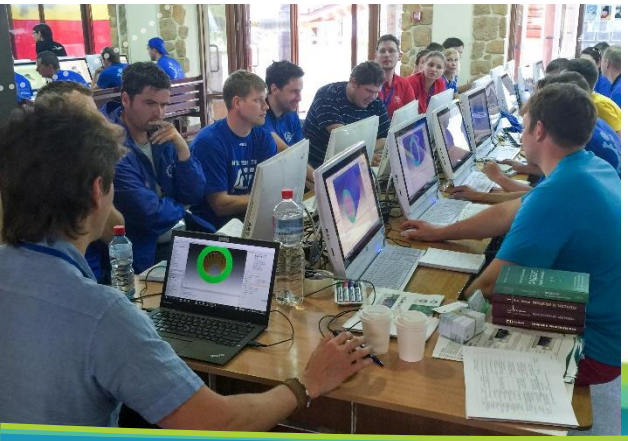
Custom software development

- On the basis of CAE Fidesys's software modules, a custom corporate or industry-specific software is developed (e.g. Fidesys Geomechanics for **NTC Gazpromneft**).
- The customized package will be more functional and easy-to-use than the general purpose CAE. It is focused on specific problems of the client.
- Development cycle of a custom software takes about 6-18 months depending on the customer's specifications with the involvement of leading industry consultants.
- Ability to attract experts from leading Russian universities and Institutes of Academy of Sciences
- As a result, the customer obtains a dedicated corporate product.
- **The package can be used as a simulation software which is capable for fine tuning and extensively applied during R&D stage.**

Russian Academy of Sciences



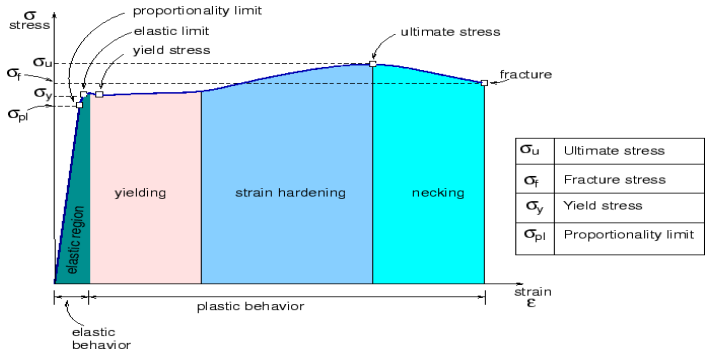
Engineering consulting&training



Simulation Designed for Design

Why aren't more companies using Simulation as an integral part of Design?

- Simulation is often considered too much to be used for influencing design decision
  - Too difficult - Too complex - Too much expertise required - Too expensive - Too compute intensive
- Just too much?



Simulation Designed for Design is now available!

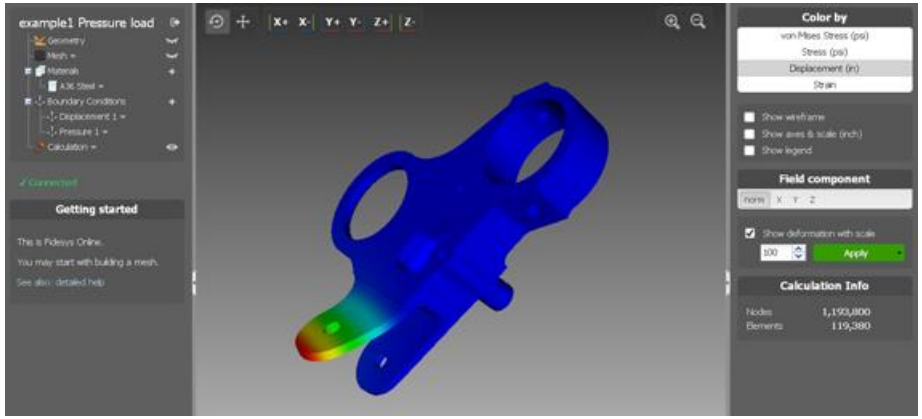
- Simulation is no longer too much

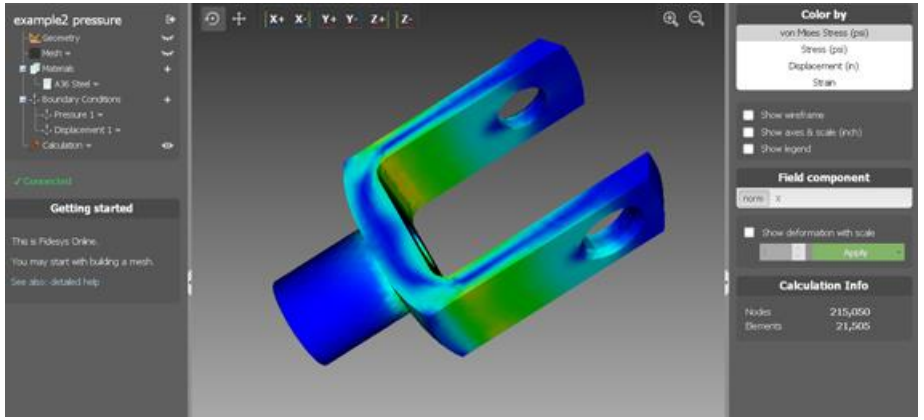
SaaS solution - Sim4Design

SimForDesign targets the users of Computer-aided Design software (CAD), who are now able to make their design process more effective by employing structural analysis early on and often in the design stages.

These users are currently cut off from CAE software because of its complexity (special education/training is required) and high cost (approx. $40k per one seat per year).

We have managed to transform SimForDesign into an easy-to-use, affordable, approachable service, effectively solving these problems.

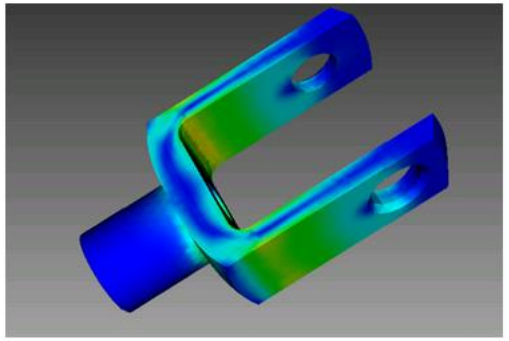


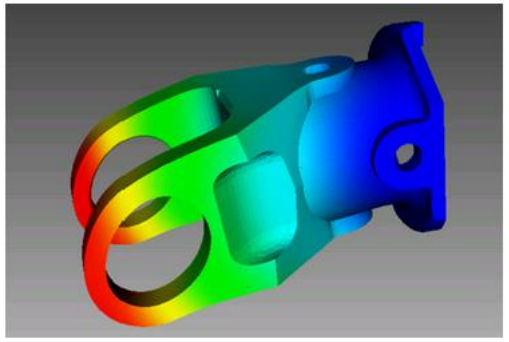


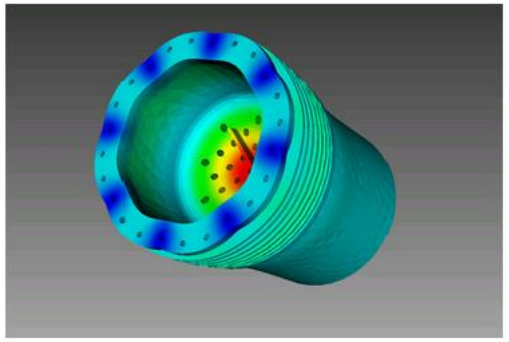
In February,2019 Sim4Design graduated 500 Startups accelerator.

Main features

- SimForDesign – simplified engineering analysis for smarter design decisions
- No need to be an expert in CAE-systems usage
- Evaluation of structural performance of design alternatives quickly
- Better understanding of design changes
- All simulations are run in the cloud – only web browser and internet connection are needed
- End users pay only for computing hours – much lower prices compared to desktop solutions
- Multi-user simultaneous work on the problem







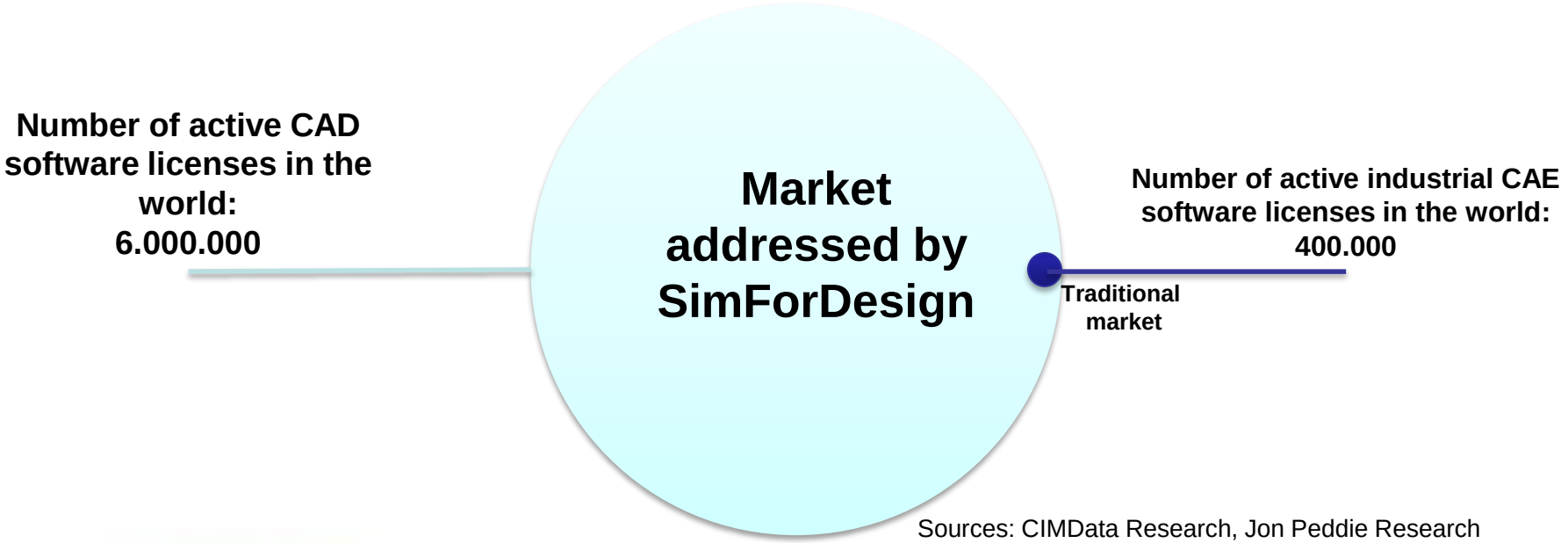
"I am pleasantly surprised to see an innovative approach to reducing the expertise required for CAE as part of the design process … Sim4Design.com focuses on leveraging commercial grade meshing and solver technology in an attempt to improve the design process. Providing a streamlined method to enable better design decisions may open the door for significantly broader use of CAE. Oh yeah... it's in the cloud."

Joe Walsh, CEO of intrinSIM

Market

As far as we consider designers as our main target audience, SimForDesign is not supposed to replace traditional CAE systemes. The service is aimed at helping designers – the users of CAD systems.

That makes the market of CAD users our market as well.



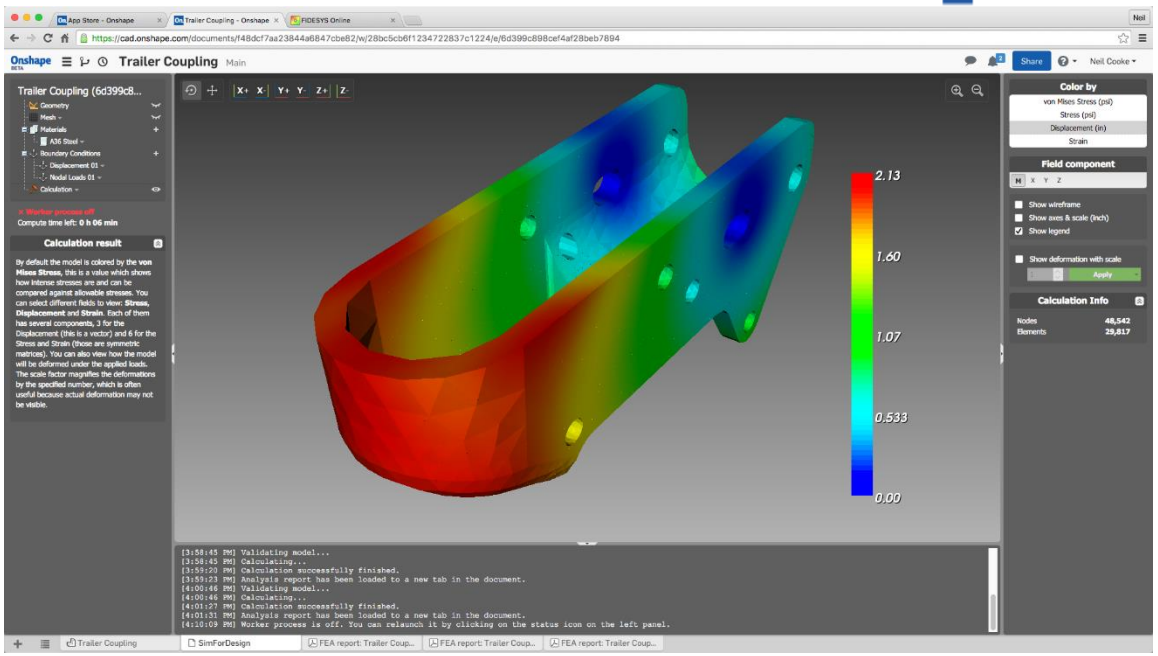
Sources: CIMData Research, Jon Peddie Research

SimForDesign at Onshape

SimForDesign is the first simulation service fully integrated with cloud-based CAD service called Onshape

Taking into consideration that Onshape is the only cloud-based CAD system and that SimForDesign is considered by Onshape as the example of full integration with their system see high number of leads coming from OnShape.

Onshape has as far as 150.000 users at least half of which are interested in CAE services integrated in their workflow. As far as Onshape has now a huge budget for marketing activities we think their users amount will grow exponentially in the next few years.



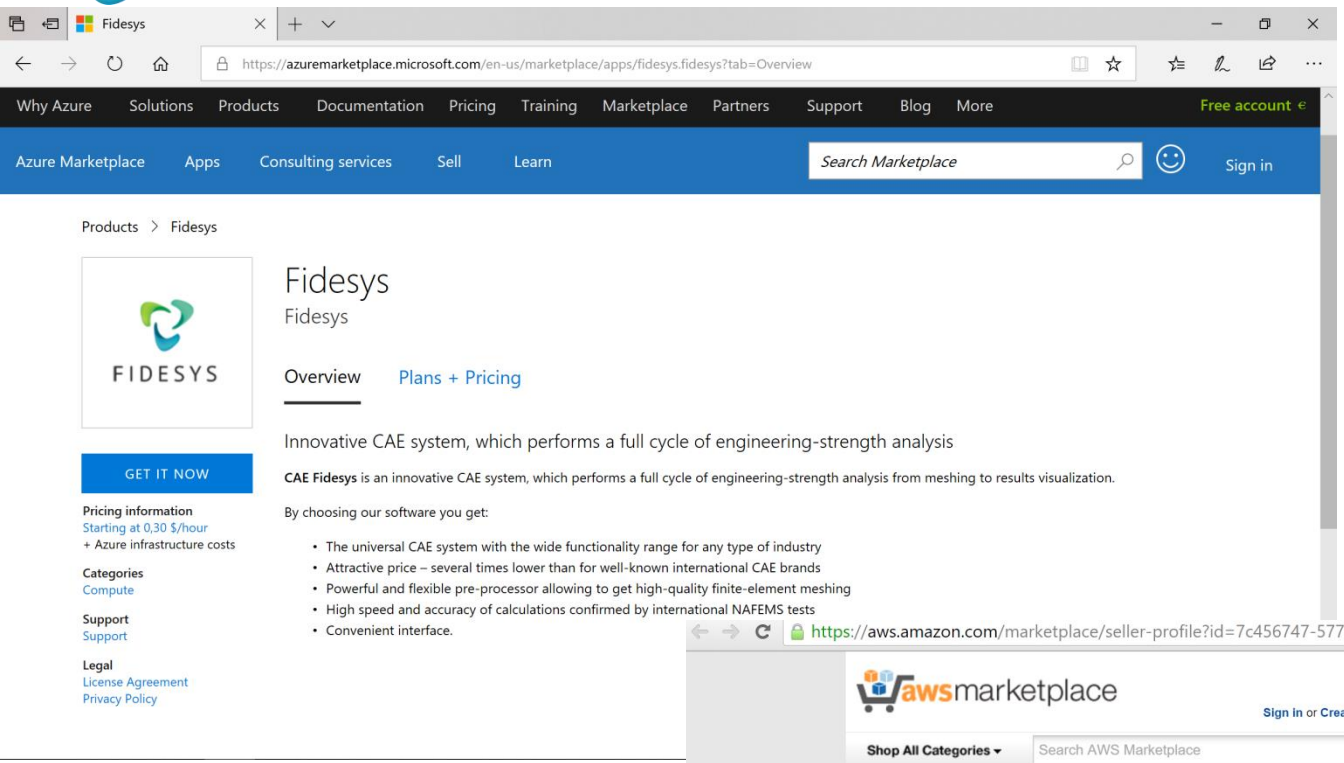
"I am excited to see the success of the international expansion of FIDESYS. … FIDESYS has been among the first to bring technology that had previously only been available as an expensive installed product to the new platform of cloud computing"

Michael Payne, Cofounder of PTC, Solidworks, Fidesys Advisory Board

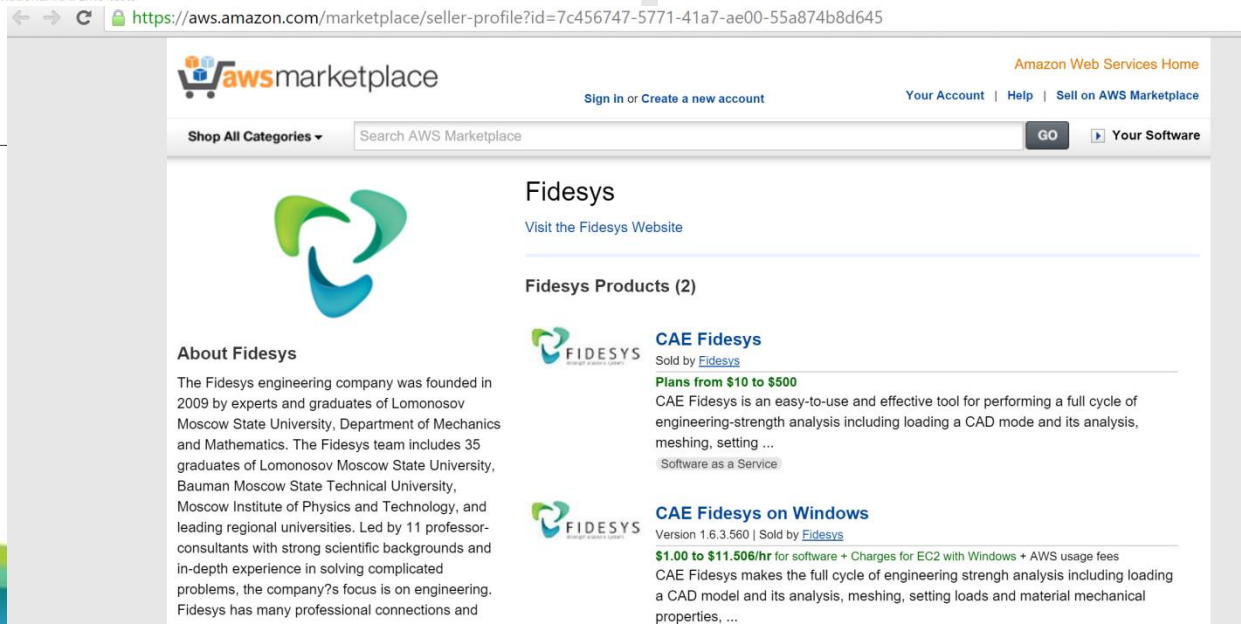
Corporate CAE-platform

- Private cloud solution for the client's internal usage
- Available from any device connected to internal Ethernet/VPN
- Cost reduction: cost of ownership, support, security

Fidesys in Azure/Amazon marketplaces



Preprocessing, simulation, analysis, rendering etc. are done in the cloud. 24/7 access in the browser.



Pay-as-you go and subscription based licensing models flexible for different problem sizes.

Advantages of CAE Fidesys

- High speed and accuracy of calculations
- Flexible & adaptive to the geometry mesh generator
- Wide range of supported formats for the input 3D model
- Cross-platform (OS Windows, Linux)
- Low system requirements
- Cloud version - Fidesys online (SaaS)

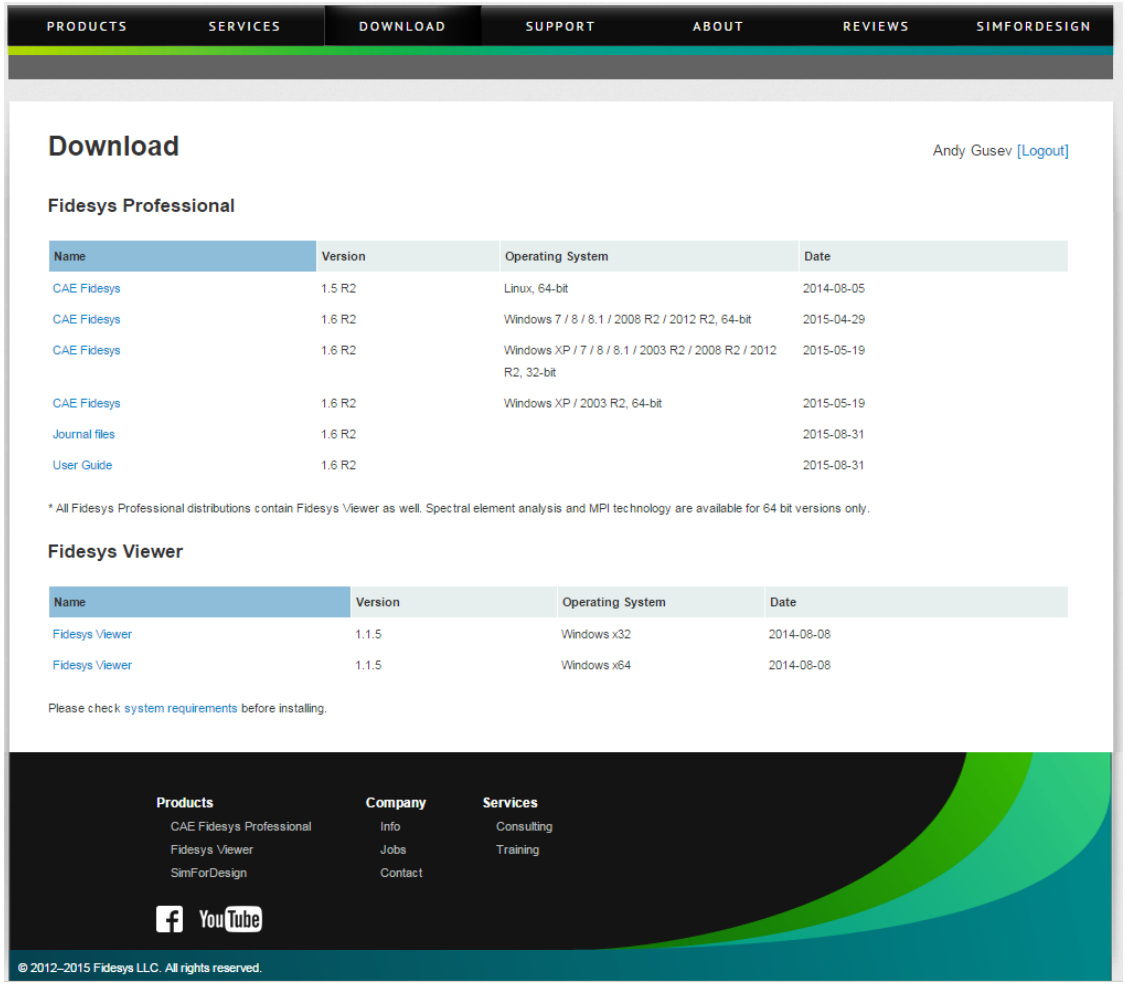
*"The CAE Fidesys is a full function CAE with a **unique feature of spectral element modeling** (SEM), offering highly accurate results and more robust functionality to all Autodesk customers in the industry who rely on Autodesk Inventor for their design projects. I personally visited Fidesys LLC office in Science park of Lomonosov Moscow State University and was impressed by the team of researchers (**10 of them hold doctorates in their fields**) and developers who create this innovative solution sometimes even **out-of-working hours**".*

- Jim Quanci**, senior director of the **Autodesk Developer Network

CAE Fidesys trial version

http://www.cae-fidesys.com/

- 30 days
- Fully functional
- Step by step examples (+scripts)
- Test report
- Windows/Linux 32/64



Thank you!
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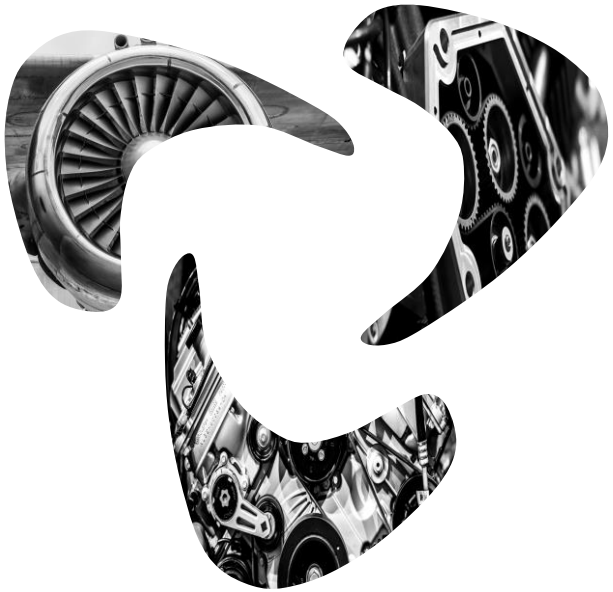
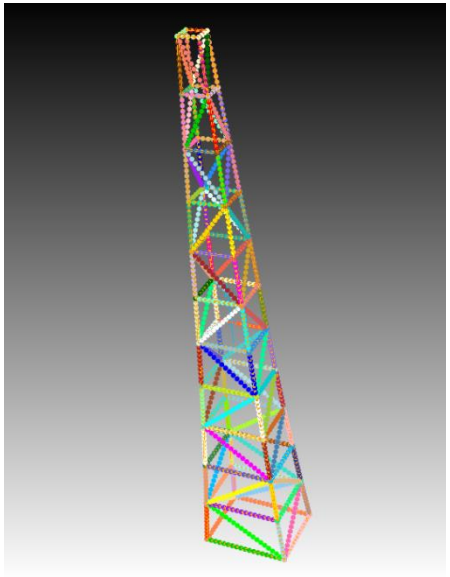
youtube.com/user/Fidesys



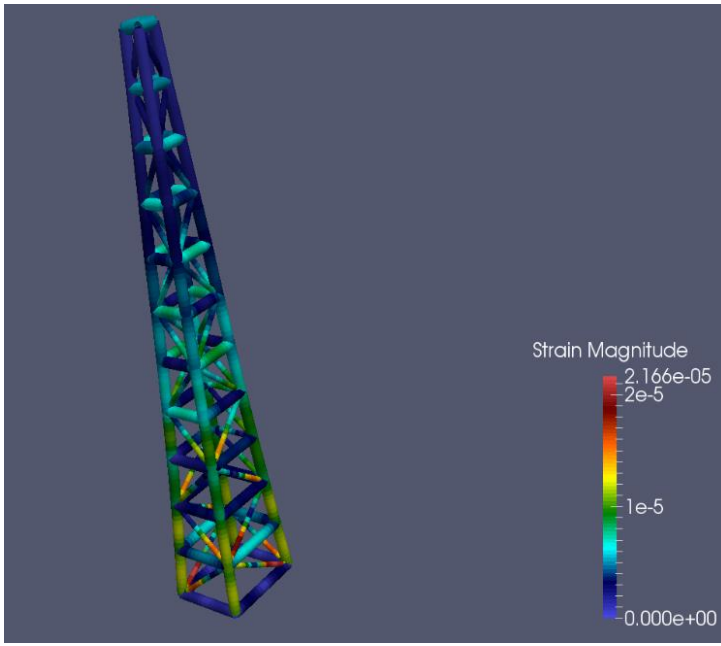
FIDESYS

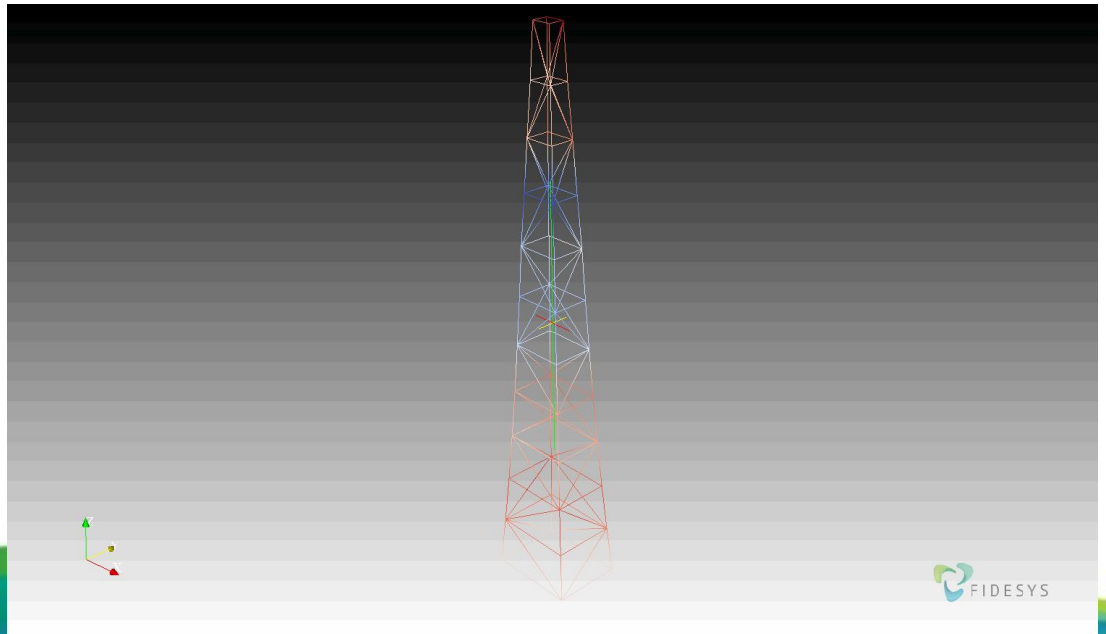
Industrial Applications

Truss structure analysis

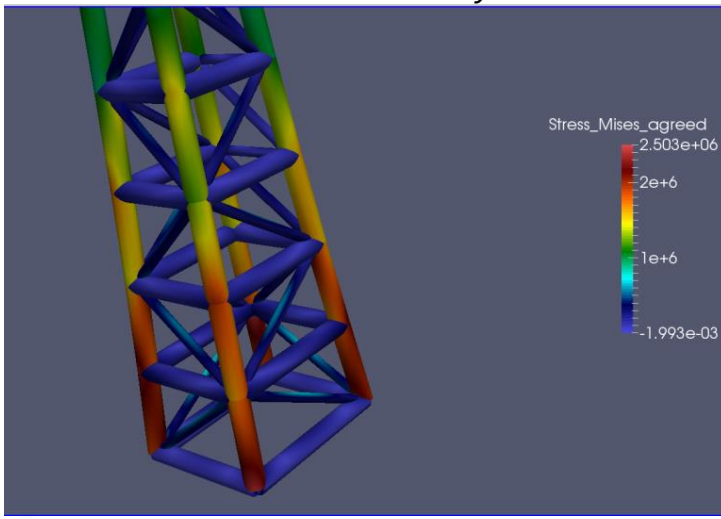


Strain distribution

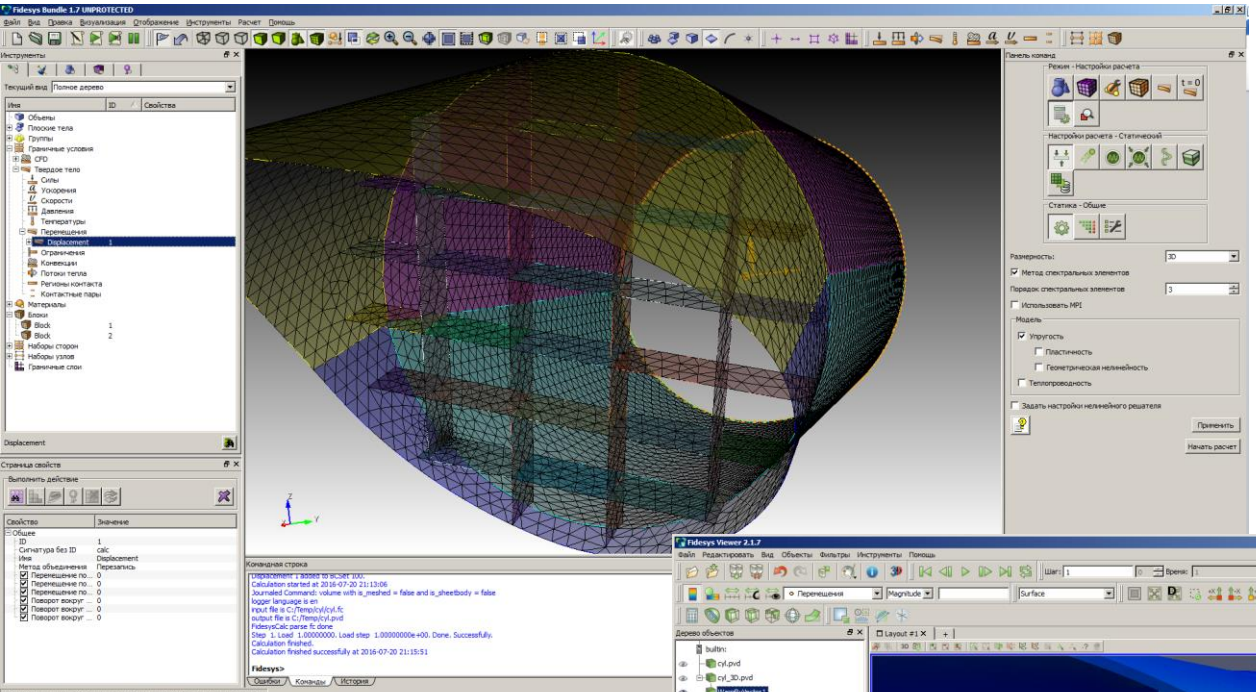


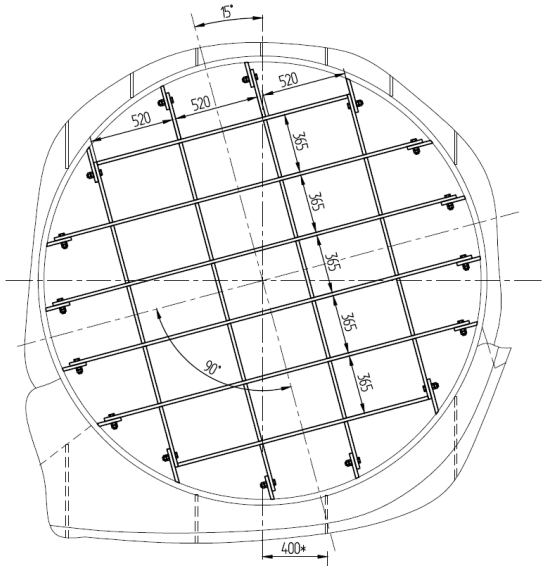


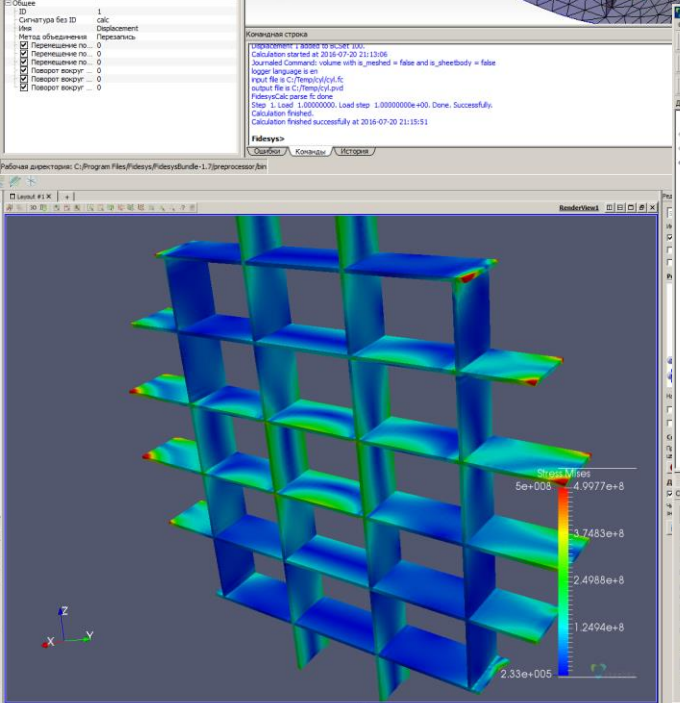
Stress intensity

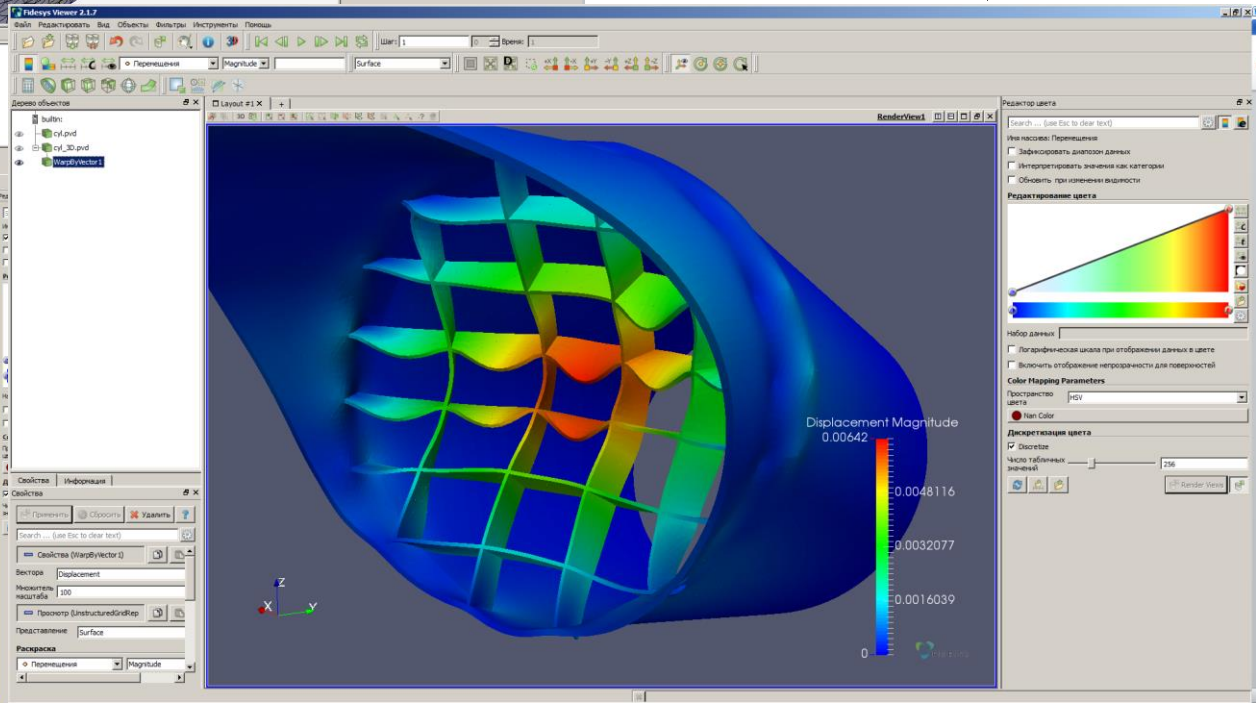


Analysis of the ice load on the thruster

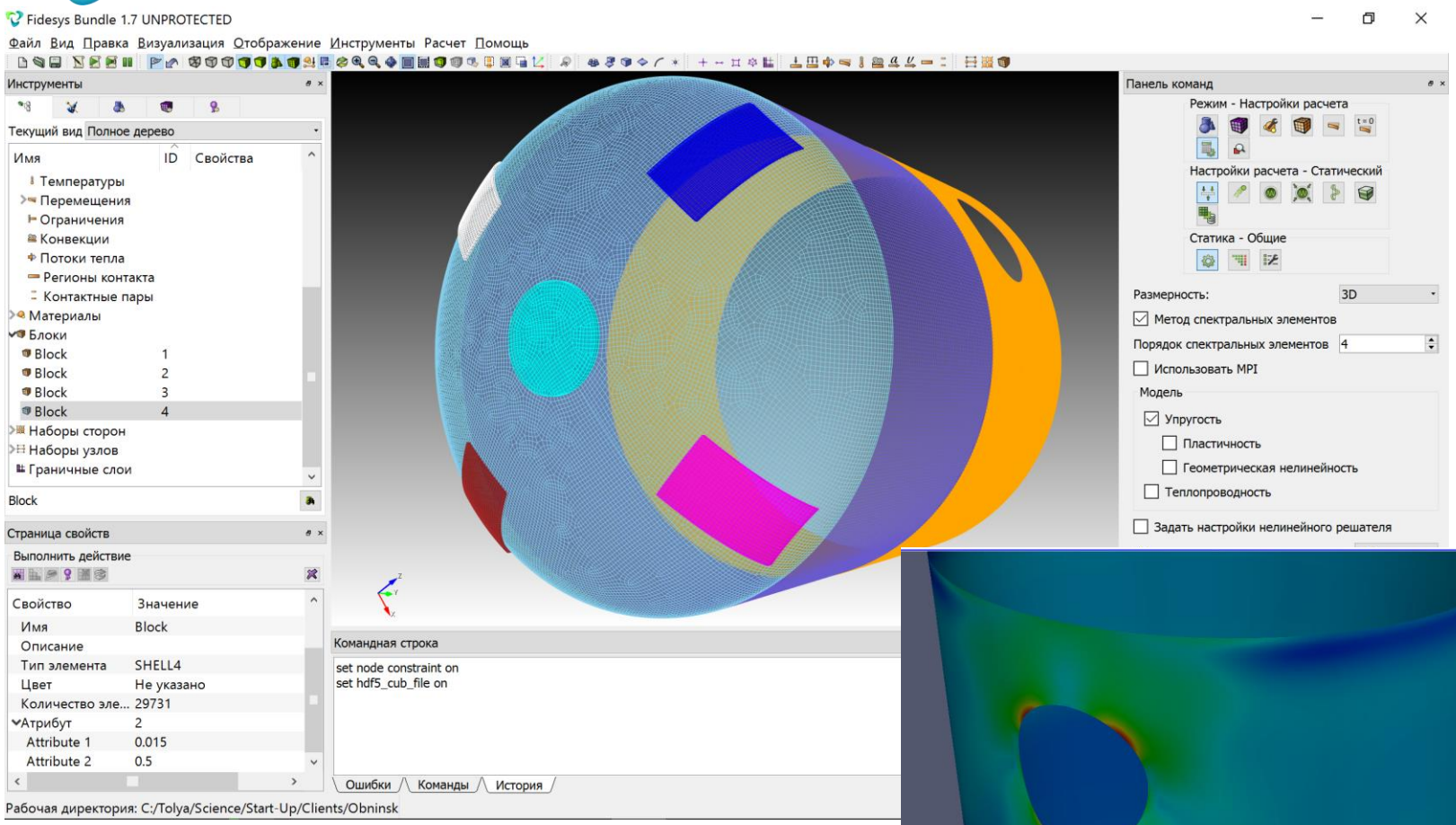


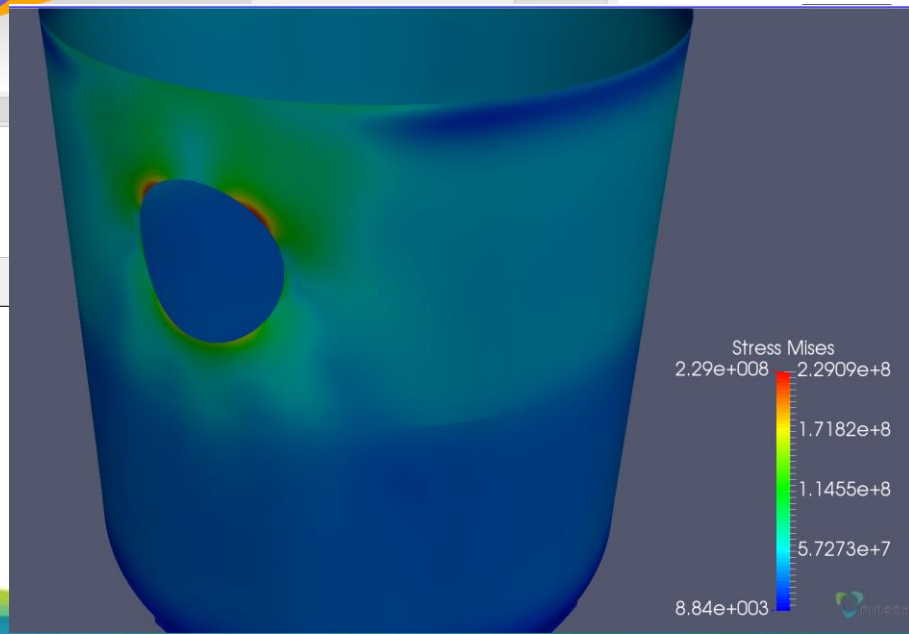




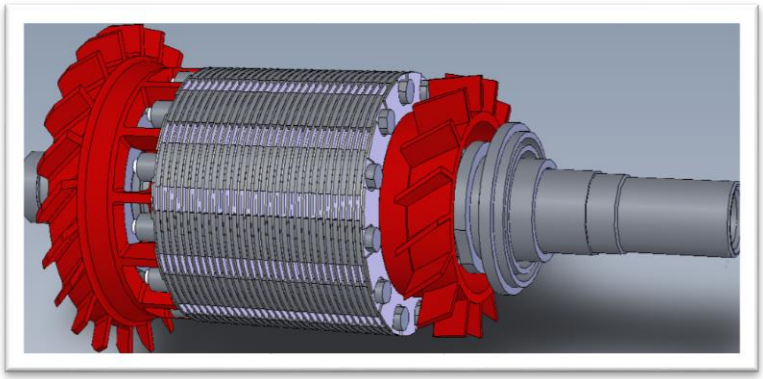


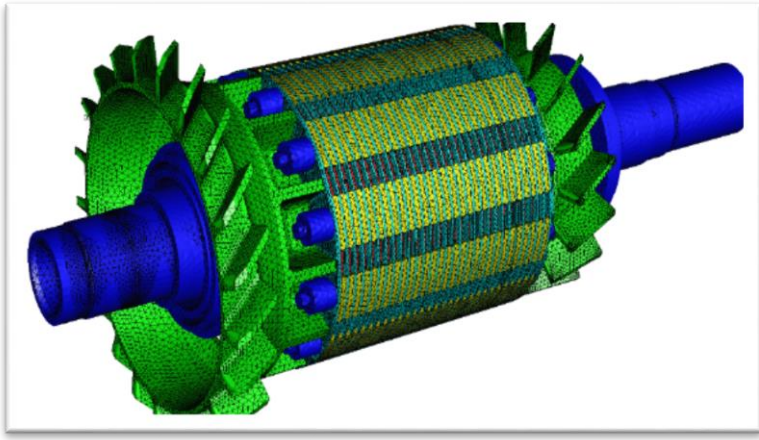
Analysis of the pressure tank

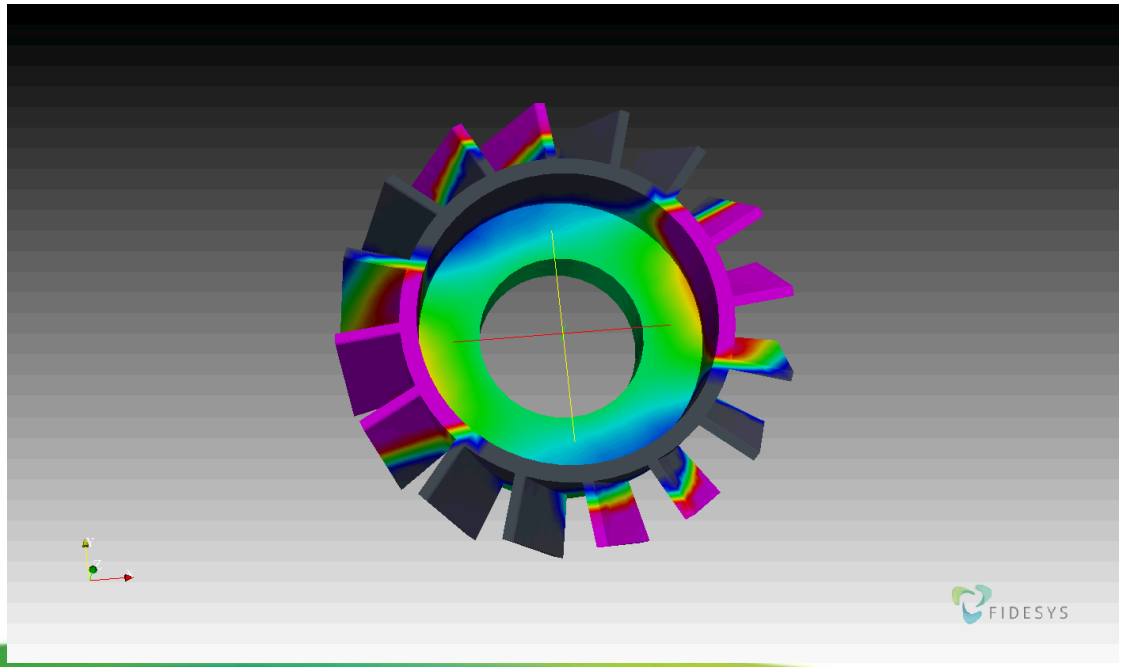


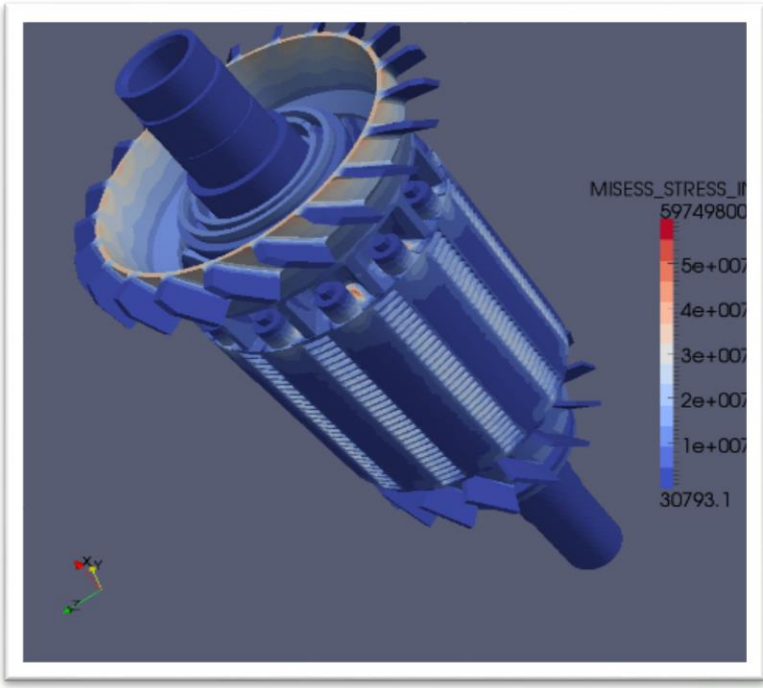


Analysis of the of the electrical rotor

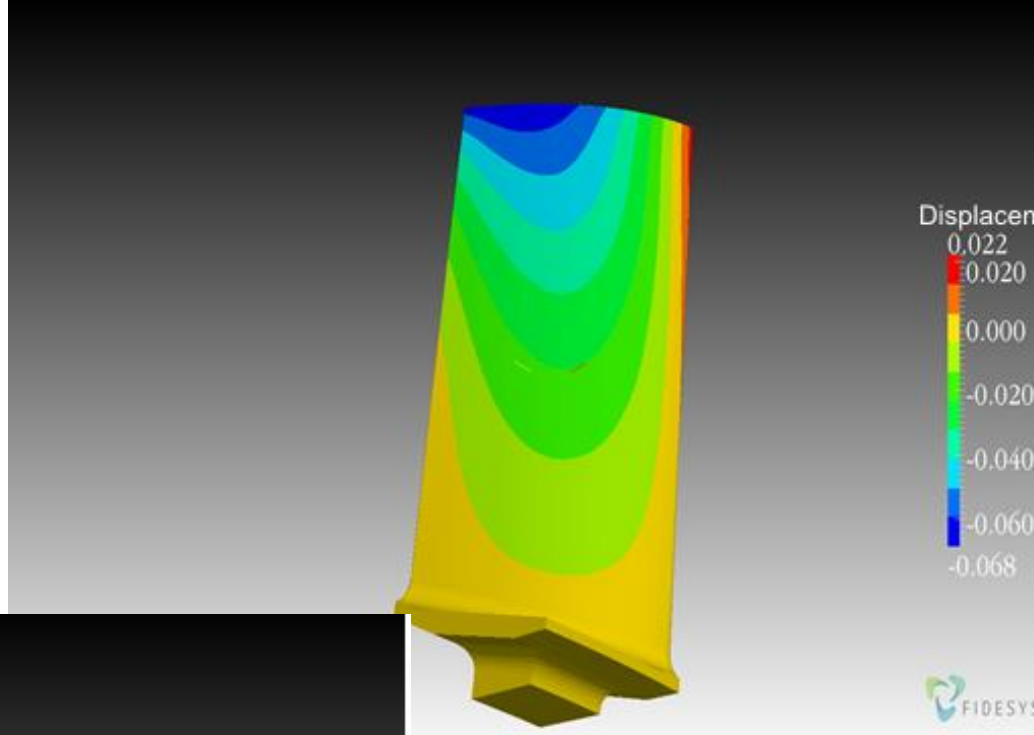


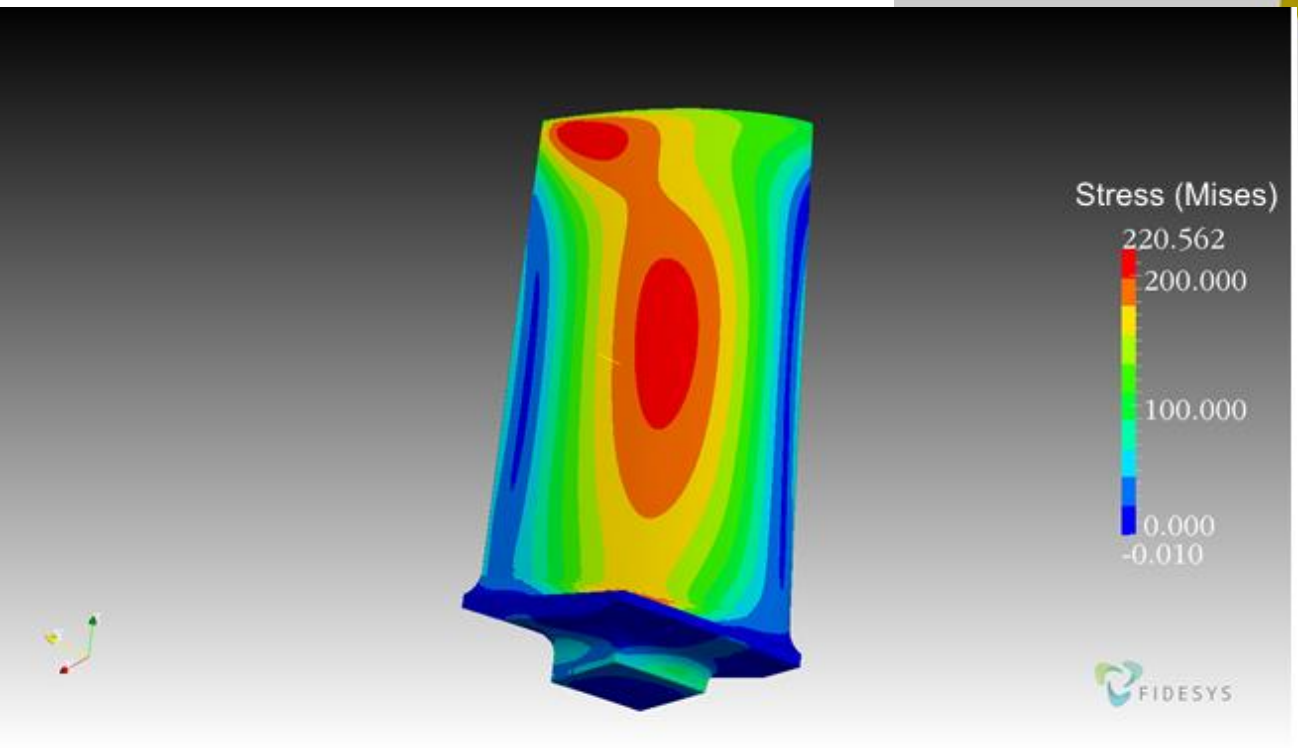




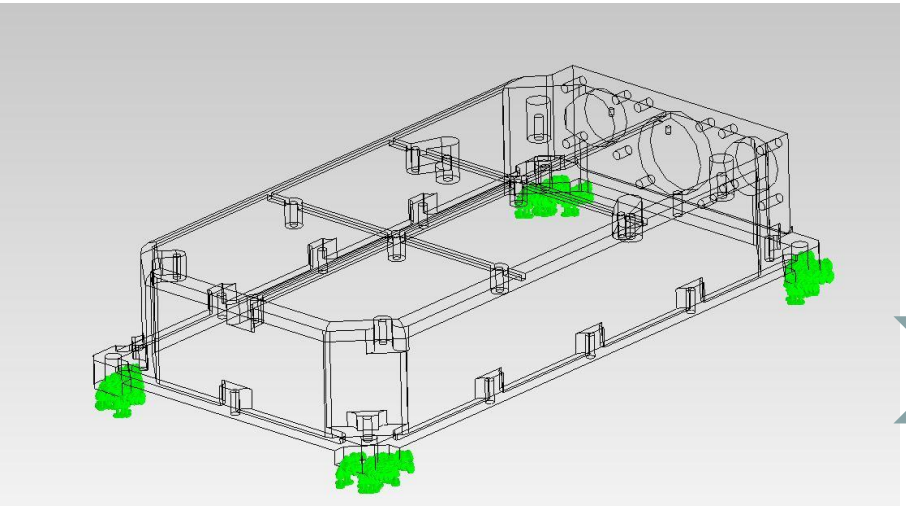


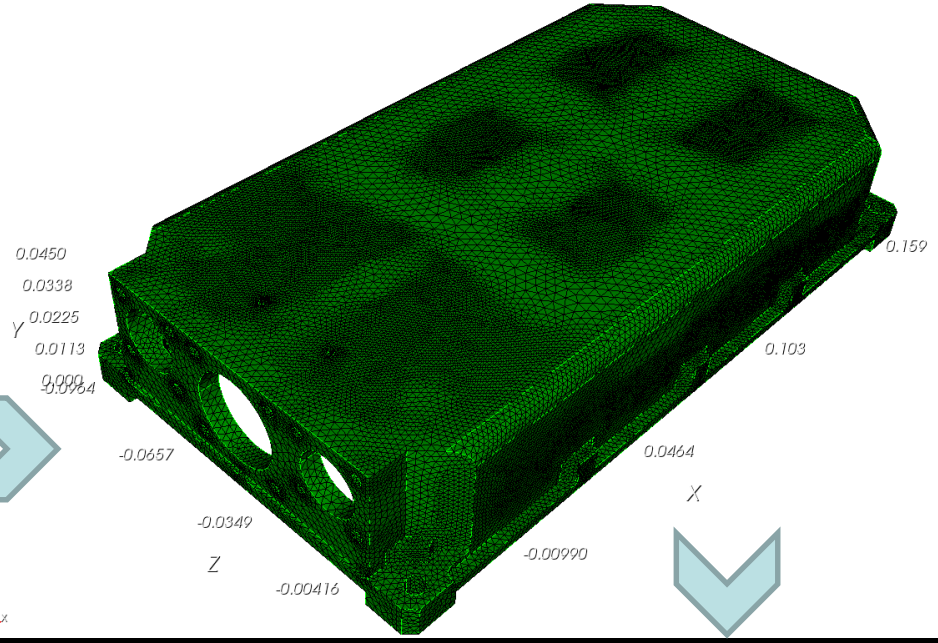
Structural & Performance Analysis
Engine Blades

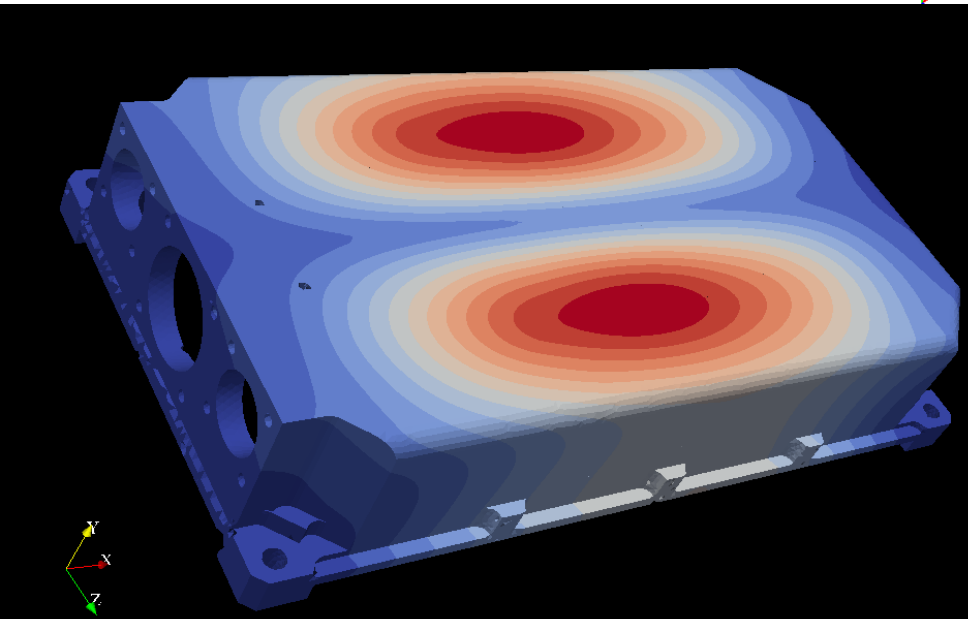


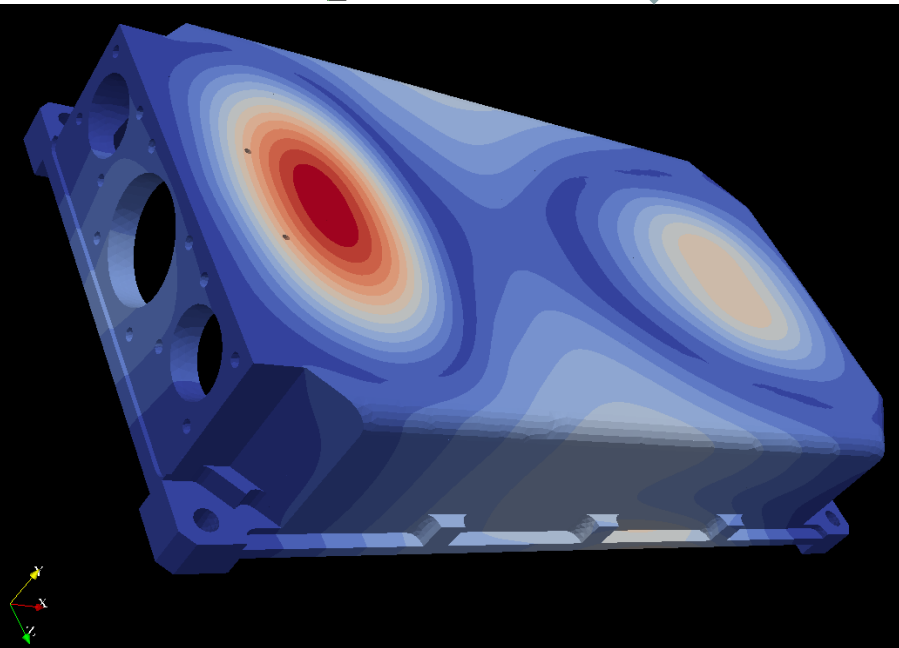


Modal analysis of the cover

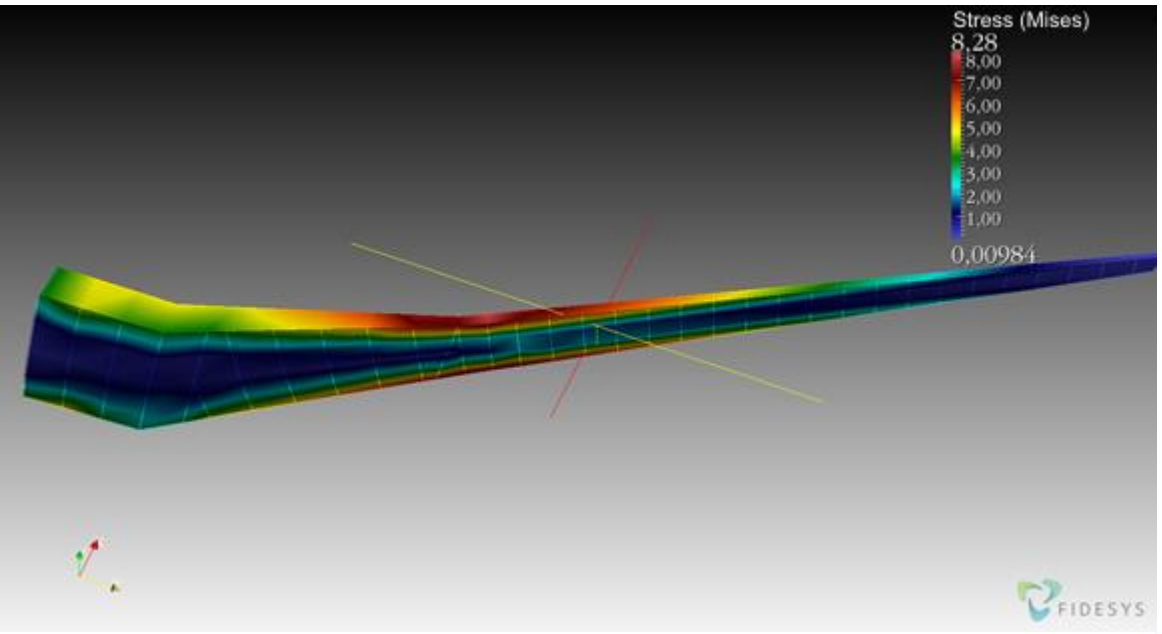


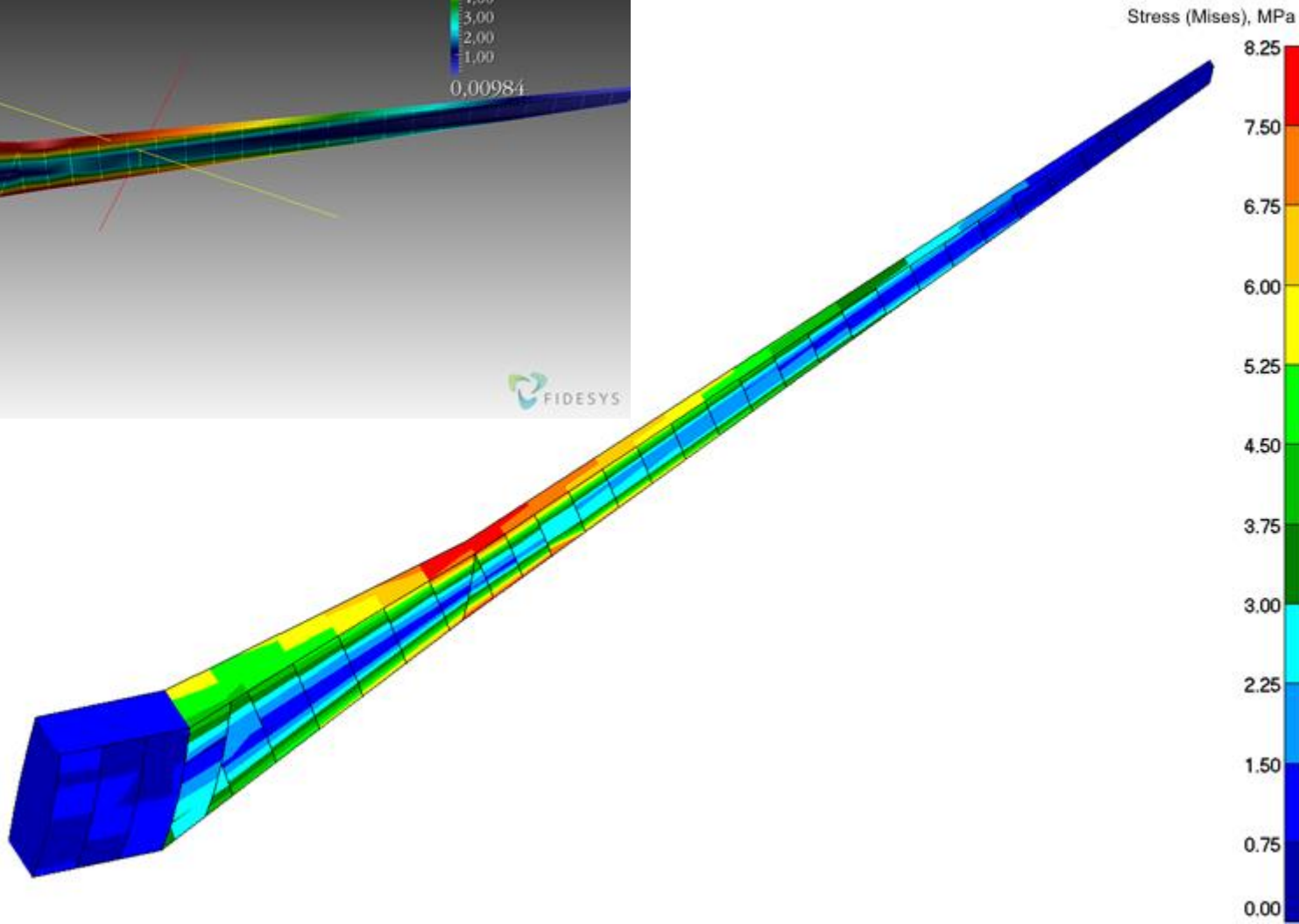




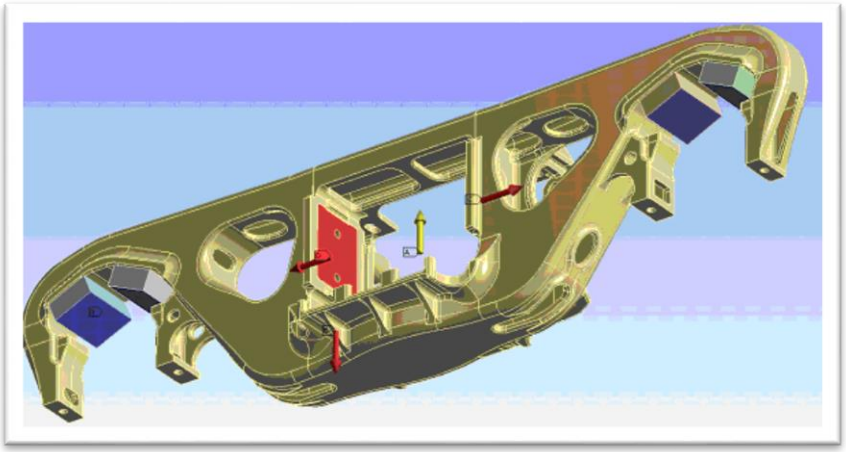


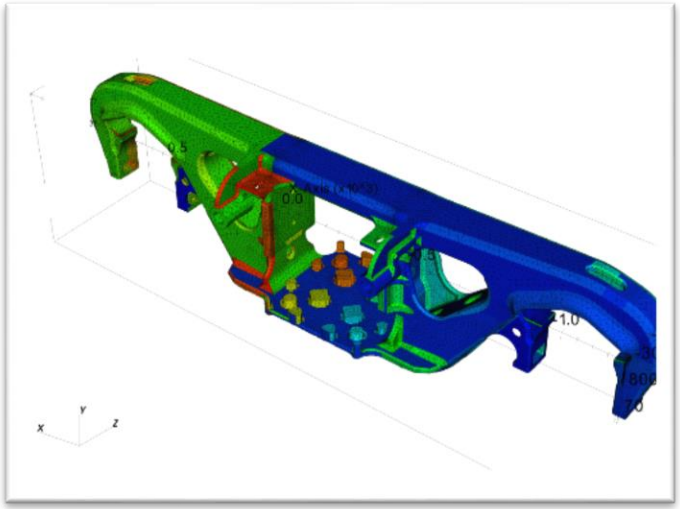
Analysis of the wing box

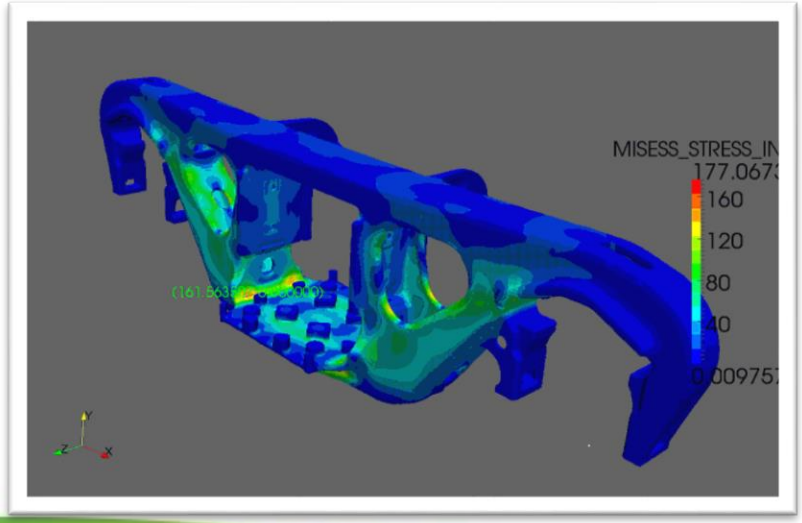




Railway wheel side analysis



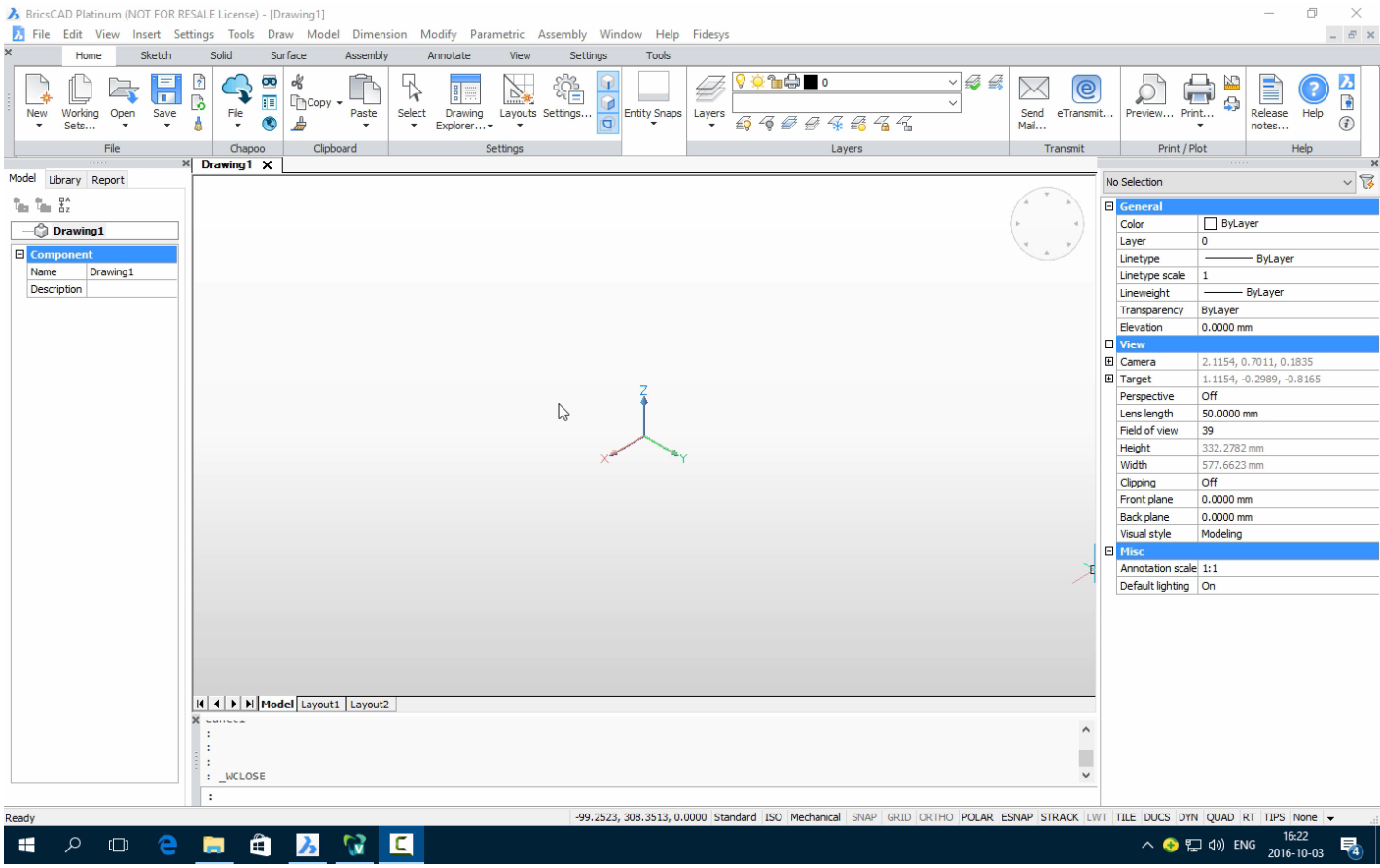




CAE Fidesys features

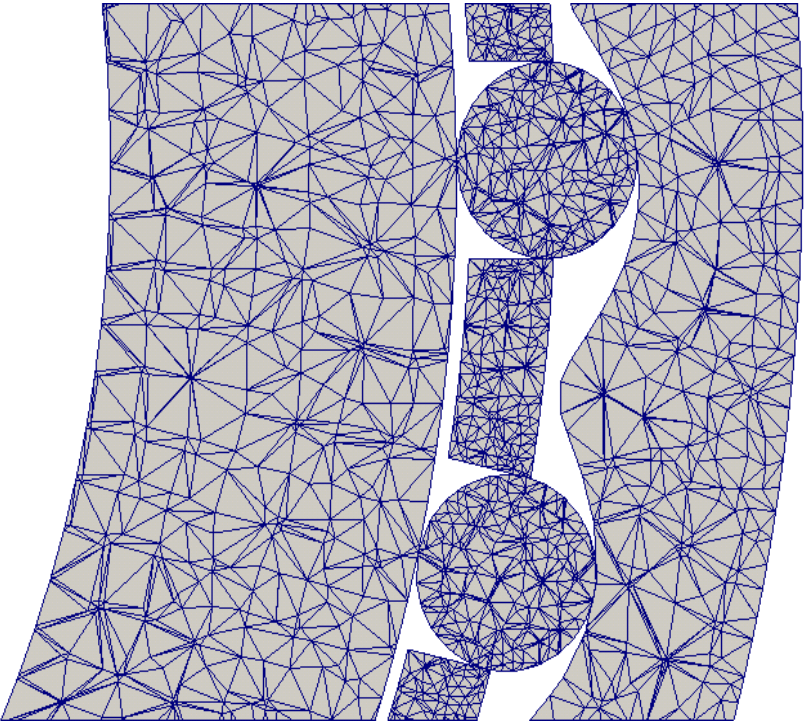
Integration with BricsCAD

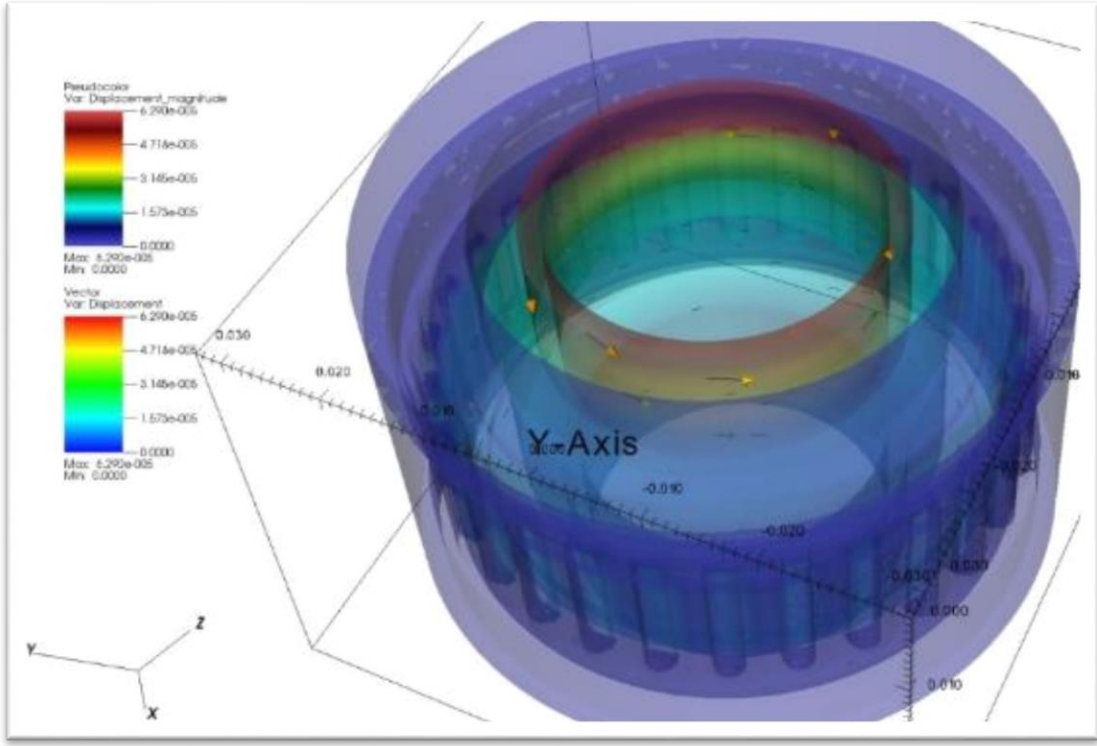
- One-button export of CAD model from BricsCAD into CAE Fidesys;
- Automatization of engineering analysis of the model in BricsCAD;
- A possibility to perform model optimization and tuning



Contact mechanics of elastic bodies

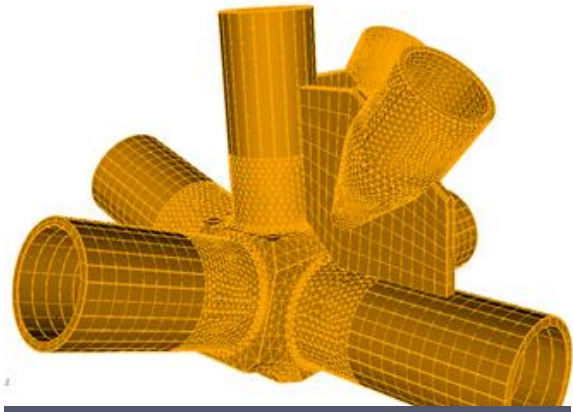
- Non-linear contact interactions between solids
- Static or dynamic (with/without friction) contact problems
- Bonded contact
- Internal penalty method, Lagrange multipliers method



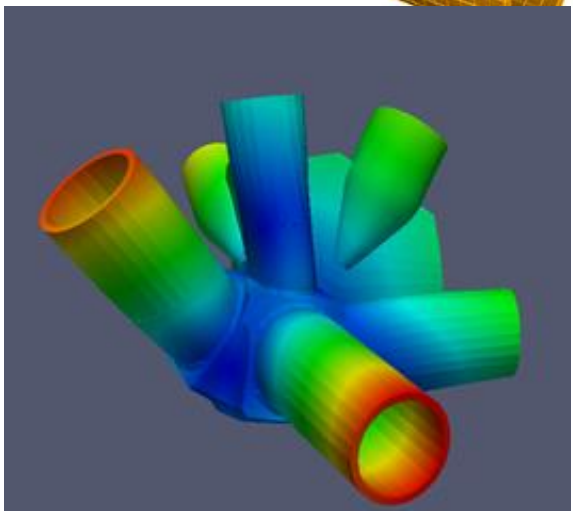


Contact interactions between rollers in the mechanical reductor

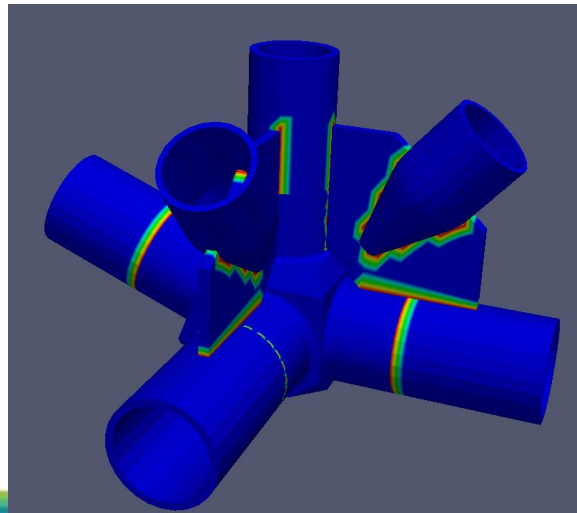
Bonded contact



- Support for nonconformal meshes with gaps/overlaps between contacting bodies => no need for simplification/healing of an input CAD assembly

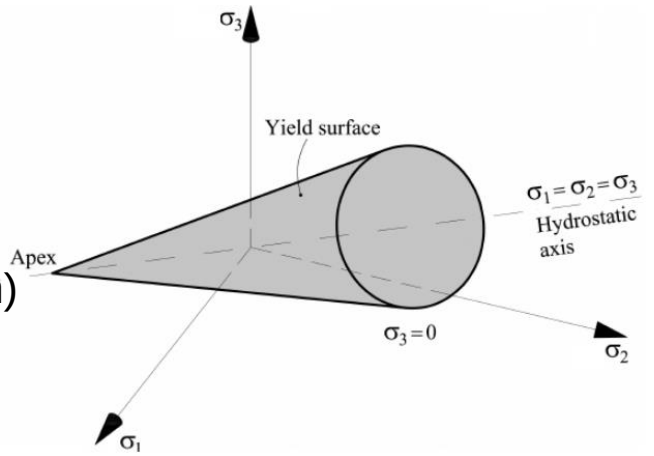


- Continuous displacements and stresses even in case of gaps/overlaps!



- Automatic contact zones detection based on a specified geometrical parameter

Physical nonlinearity

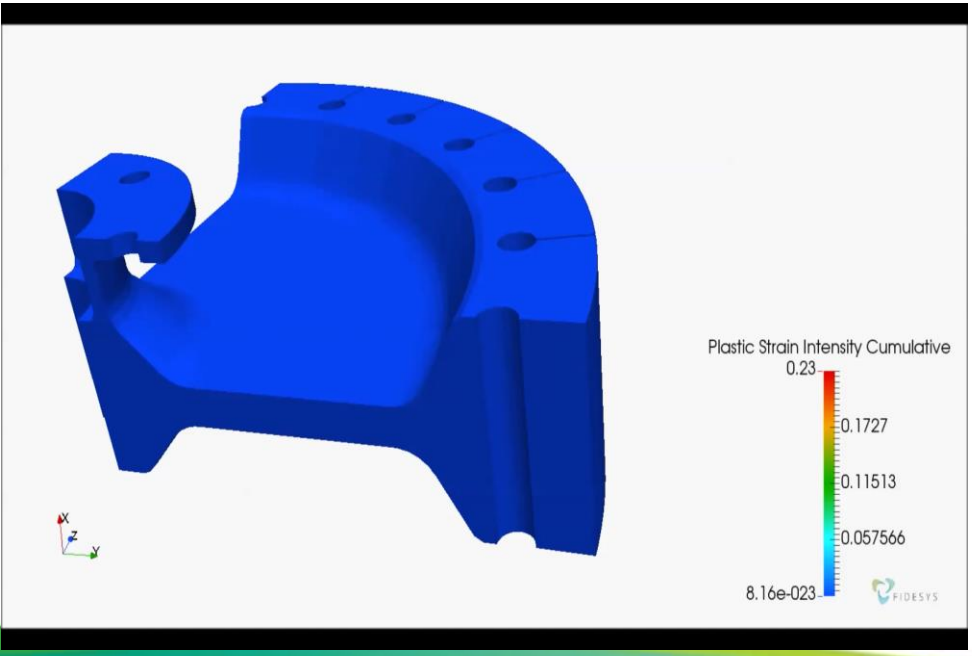


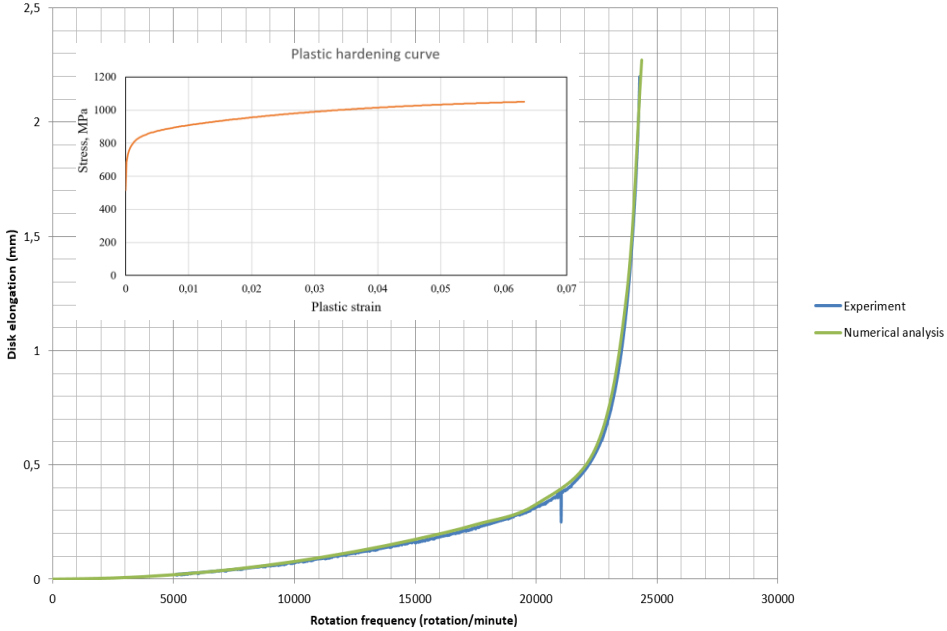
- Nonlinear elastic material models (Murnaghan, Mooney–Rivlin)
- Elastoplastic models (Mises, Drucker-Prager)
- Non-associated plastic flow rule
- Linear/Polylinear/Power hardening

$$f(\sigma_{ij}, \varepsilon_{ij}^{p}) = 0, \quad f(\sigma,\tau) = \tau - \alpha\sigma - Y$$

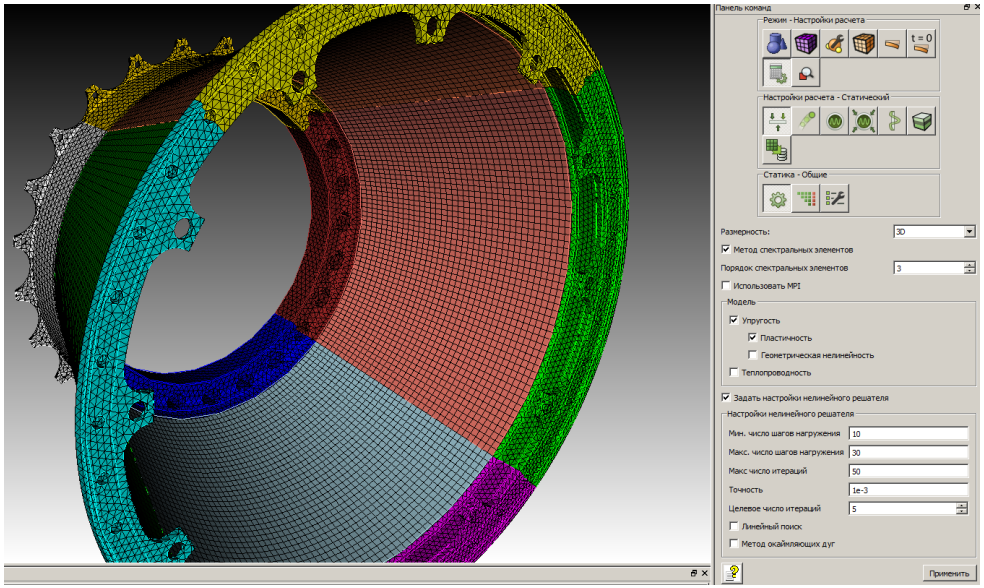
$$g(\sigma_{ij}, \varepsilon_{ij}^{p}) = 0, \quad g(\sigma,\tau) = \tau - \Lambda\sigma$$

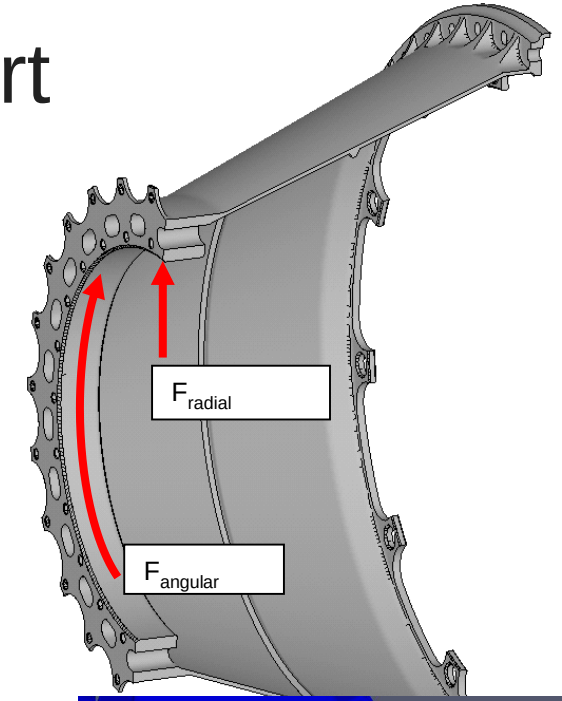
$$\mathrm{d}\varepsilon_{ij}^{p} = \mathrm{d}\lambda \frac{\partial g}{\partial \sigma_{ij}},$$

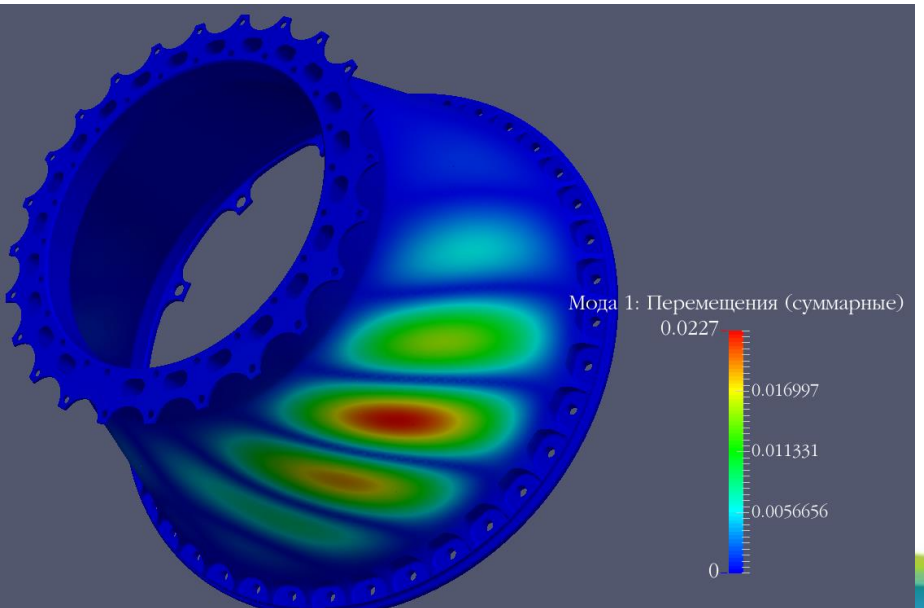


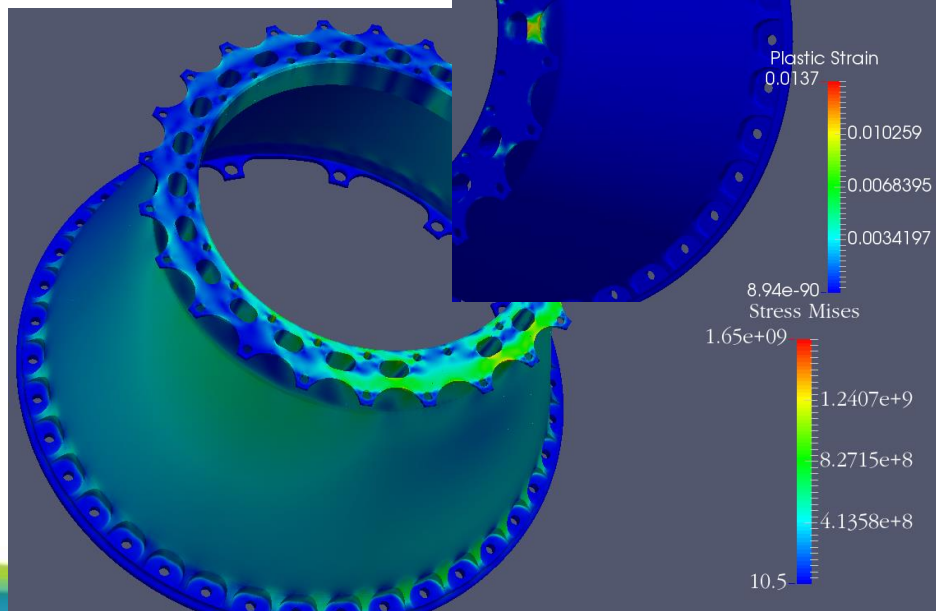


Stresses in the bearing support due to the fan blade breakage

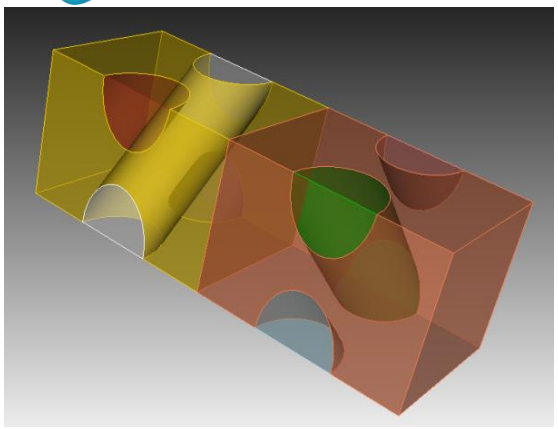


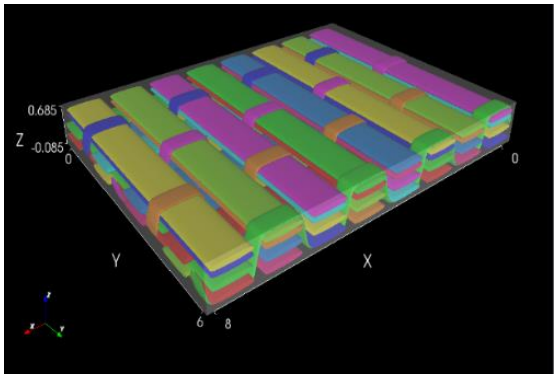


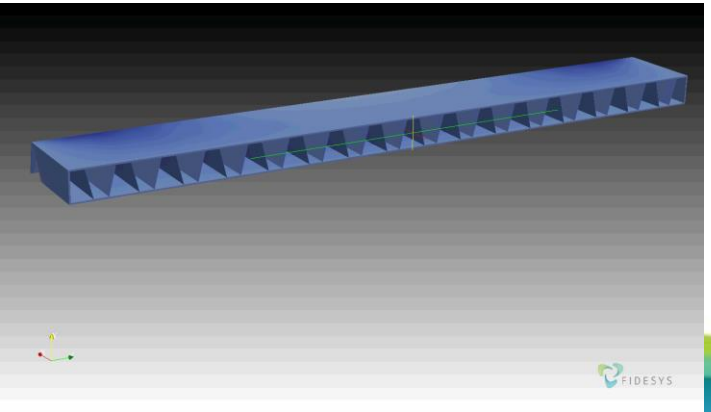




CAE Fidesys structure







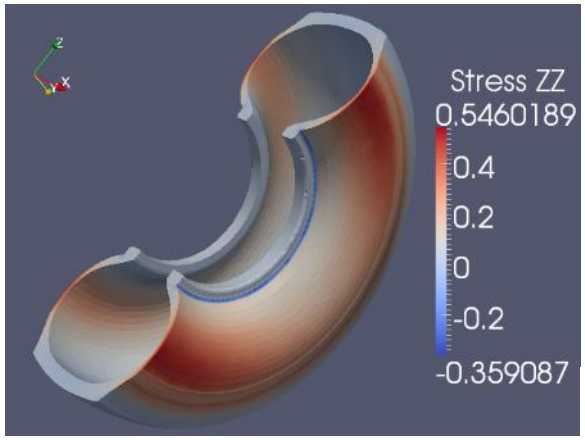
Fidesys Composite
Multiscale simulation

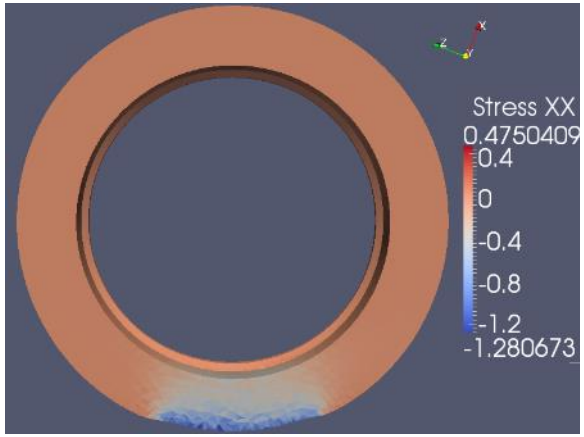
Estimation of the composite effective properties

- Engineering analysis of composites and structural elements made of them
- Multiscale simulations
  - Properties of reinforcing fibers
  - Composite matrix modeling
  - Effective properties of the composite are estimated based on the representative volumetric element (RVE) analysis
- Progressive fracture growth in the composite
  - Determination of the critical stress value of the structure
  - Simulation of a composite behavior after fracture initiation
- Nonlinear effective properties, prestressed materials

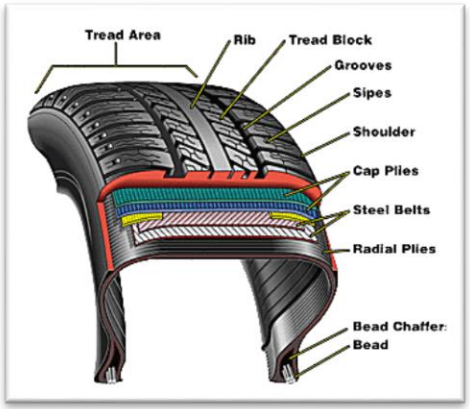
Effective properties of composite materials

Fidesys Composite
Multiscale simulation

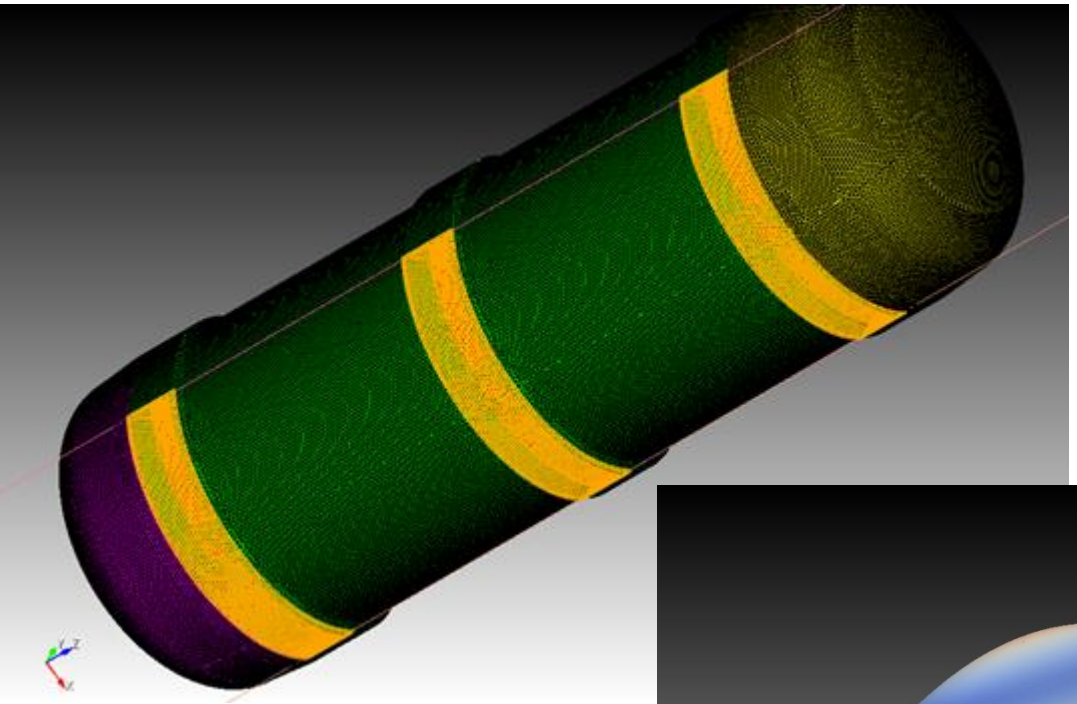


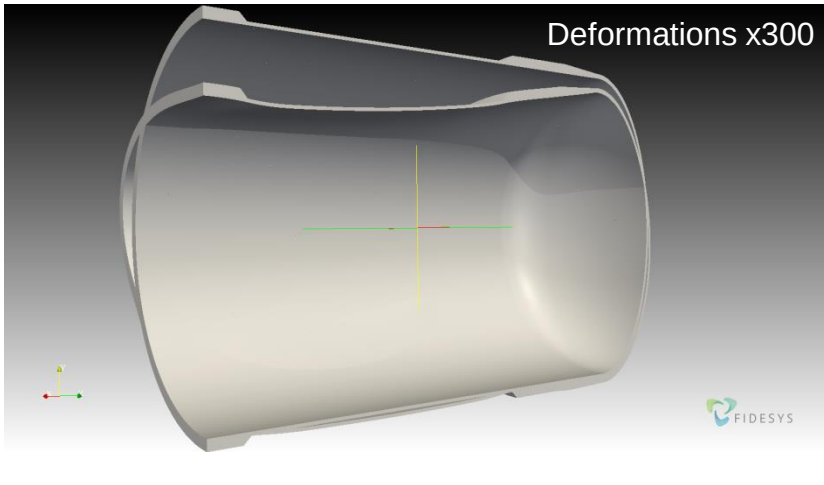


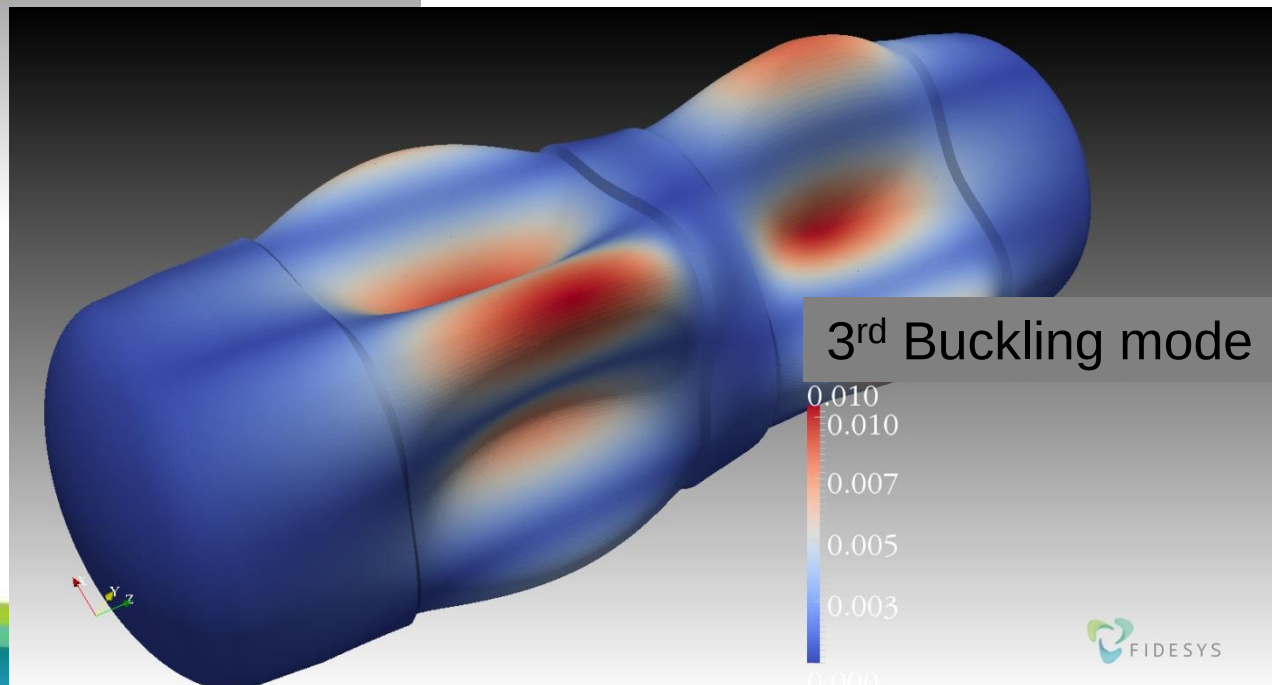
- Modeling a realistic composite microstructure
- Simulation of products made of a rubber cord



Analysis of the composite tank under internal hydrostatic pressure





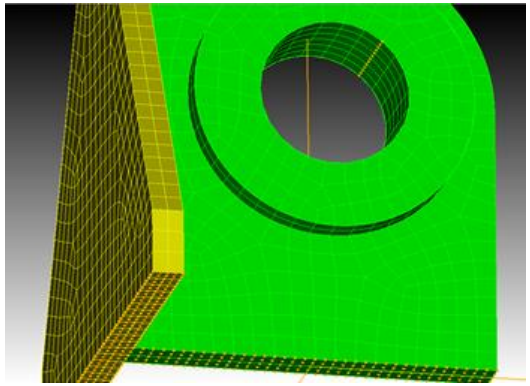


CAE Fidesys structure

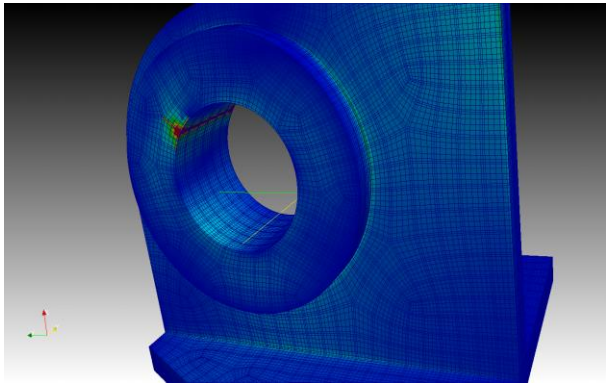
Fidesys Dynamics
Spectral element method.

High order space discretization (SEM)

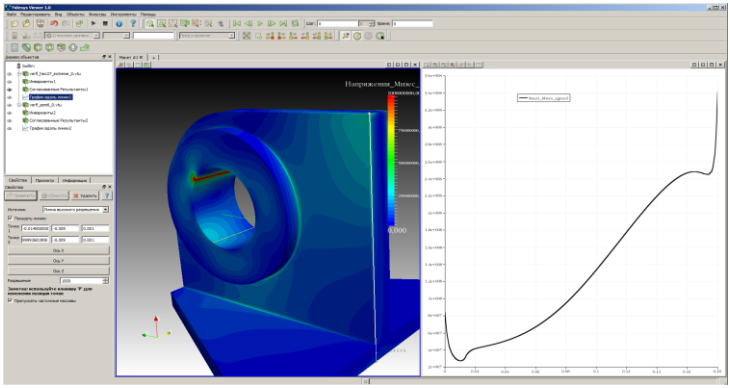
- High accuracy and stability of the numerical algorithm
- Automatization of grid convergence analysis
- Lack of locking issues for high orders of the numerical scheme



A 3D discrete model of the deck eye

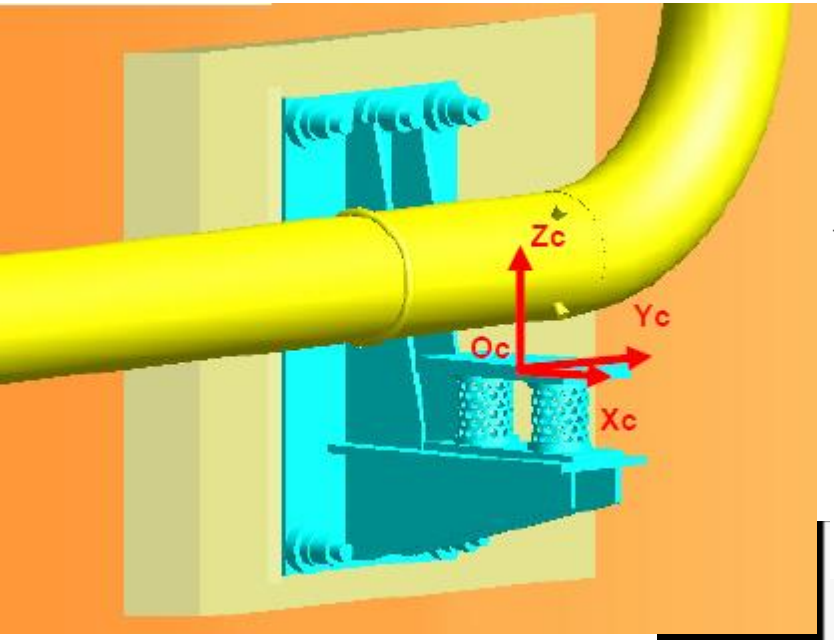


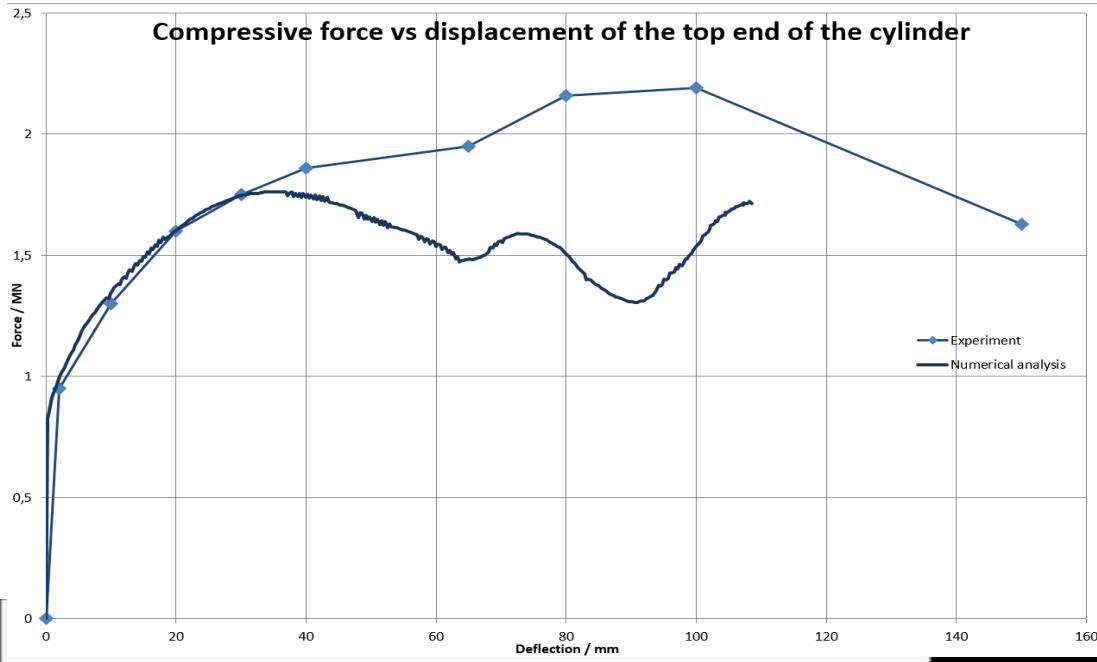
Spectral element mesh of the model



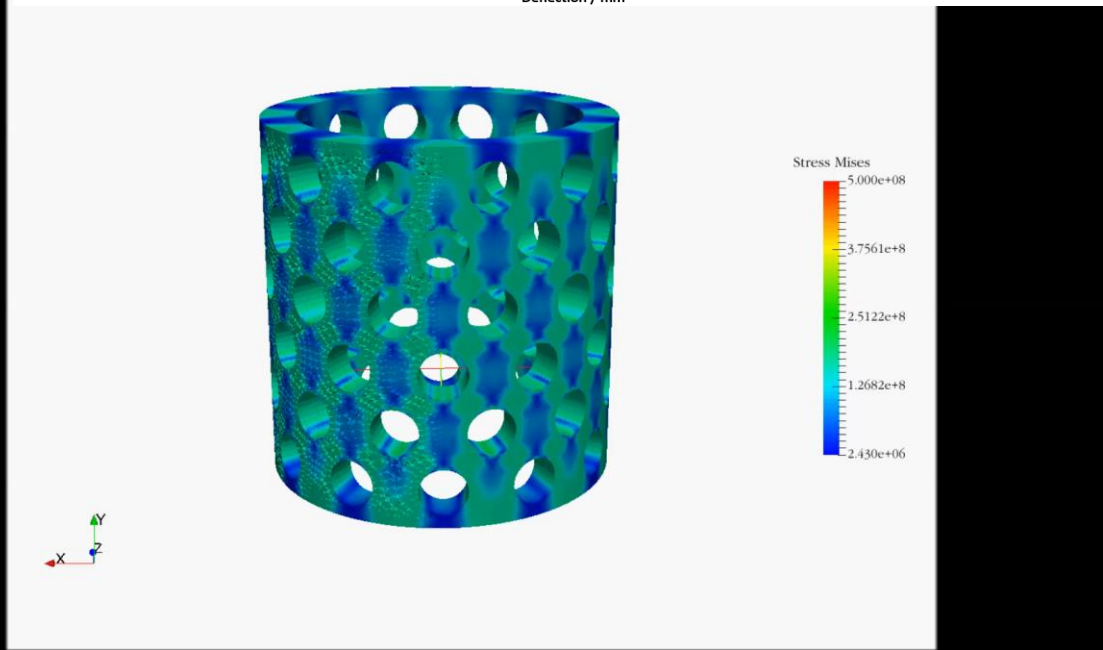
Analysis of stress concentrations

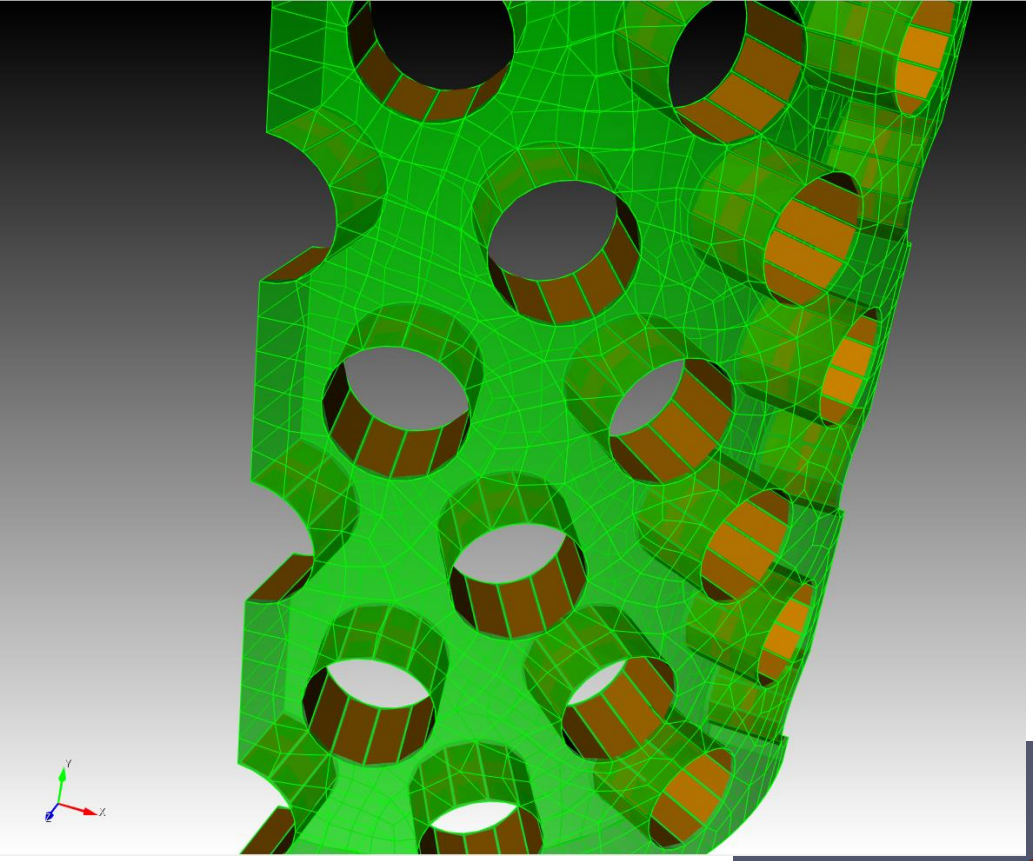
Mathematical modeling of whiplash limiters for pipeline ruptures



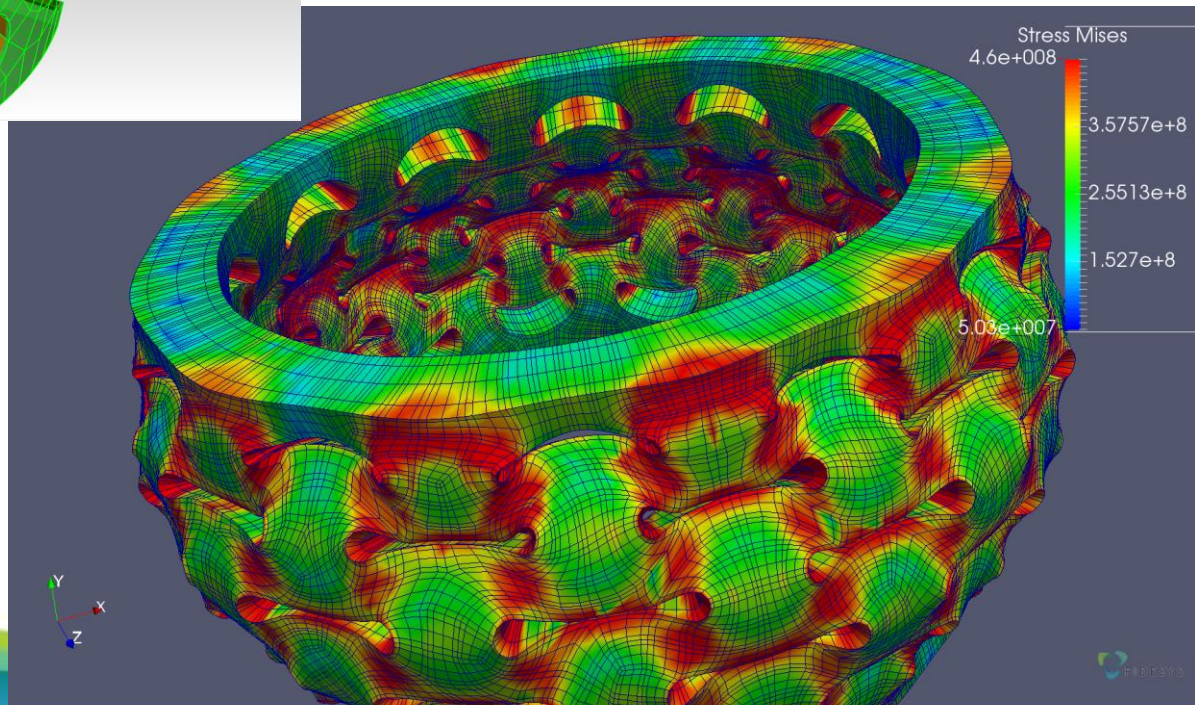


Elastoplastic nonlinear hardening under finite strains and multiple self contacts





Curvilinear coarse mesh used for simulation

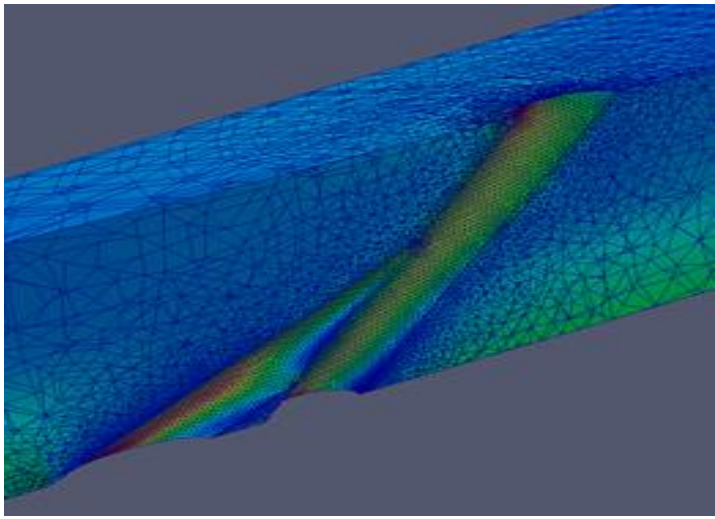


Numerical results at high order spectral element mesh

Geophysical and geomechanical applications

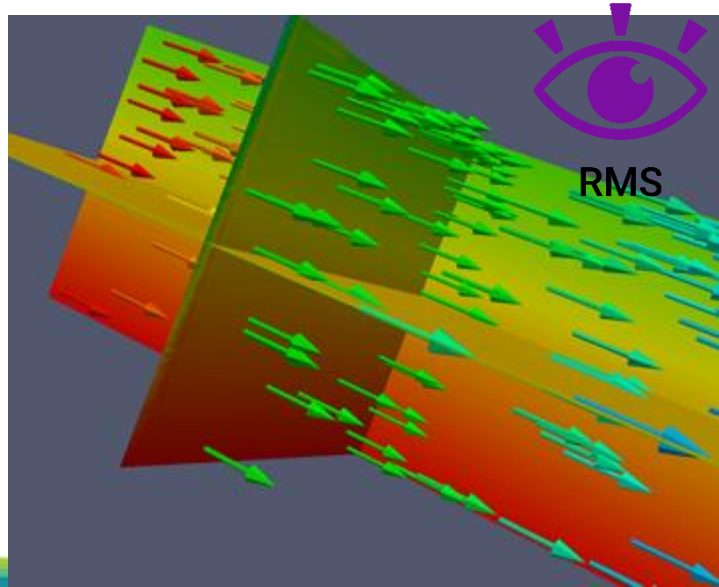
1. Drilling operations.

Wellbore stability analysis using nonlinear (physically and geometrically) **thermo-poro-elasto-plastic geomechanical model** both for (quasi)stationary and dynamic problems.

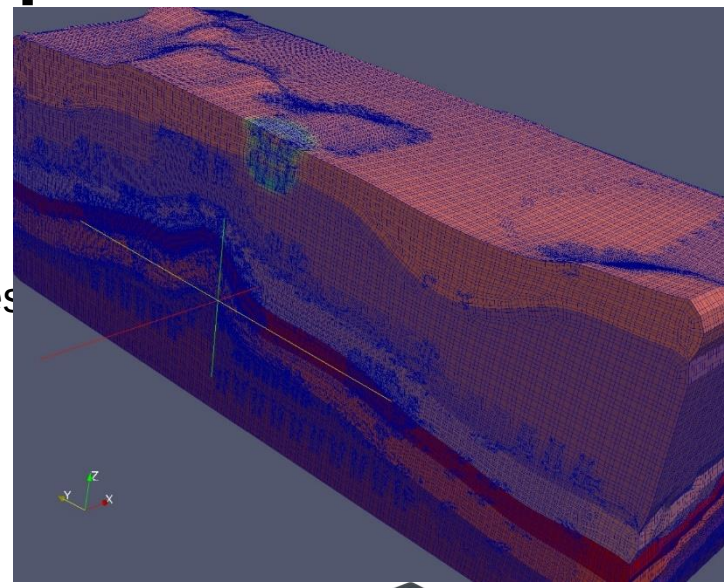


2. Reservoir simulation.

Two way and two scale **hydrogeomechanical coupling** with reservoir simulator in order to take into account dynamic changes of porosity and permeability due to geomechanical strains in porous medium and fractures (double porosity model). Updated permeabilities, porosities and compressibilities of porous fractured rock are computed directly at the microscale using representative volume element (RVE) and upscaled then to macroscale according to effective medium approach. **Direct coupling with Roxar RMS** is implemented – a geological model is automatically transferred and computed in CAE Fidesys at RMS's gridblock mesh.



Geophysical and geomechanical applications



3. Ustructured meshes.

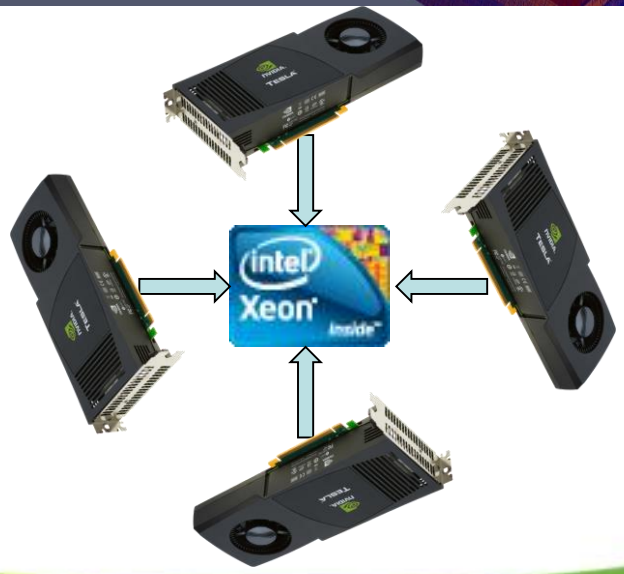
CAE Fidesys preprocessor is based on best-in-class unstructured tetrahedral and hexahedral mesh generators including commercial universal FEA meshers provided by SANDIA (USA) and INRIA (France).

Also CAE Fidesys supports nonconformal unstructured meshes for all types of analysis using special kind of interface mortar elements. For **spectral element method** a user may specify different approximation orders at different subdomains.

4. Efficiency.

CAE Fidesys HPC module parallelizes the whole computational workflow (not only sparse solvers due to Amdahl's law!) at multicore and cluster systems using **OpenMP/MPI technologies**. CUDA parallelization at massively parallel GPUs and manycore systems is implemented for R&D version of the code.

Algorithmically the efficiency is achieved by means of spectral element method (SEM) implemented in CAE Fidesys. The required accuracy is achieved without remeshing and refining of the grid.



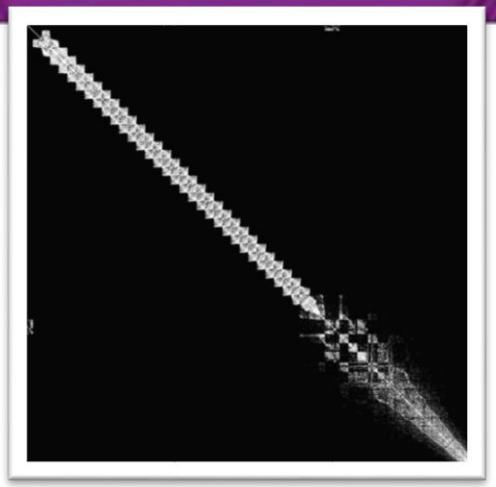
Geophysical and geomechanical applications

5. Seismic modeling.

Curvilinear unstructured SEM meshes of high order are used in CAE Fidesys to deal with complex geometry (layers, inclinations, faults, salt bodies etc.) and complex near-surface topography. Integrated into CAE Fidesys commercial mesh generators produce adaptive to geometry unstructured meshes with local refinements.

6. Solvers.

Both commercial and in-house parallel sparse solvers are used in CAE Fidesys: direct (Cholecky, LU) and iterative (CG, BICGStab, GMRES with preconditioners: ILU0, ILU2, ILUT, algebraic multigrid etc.).



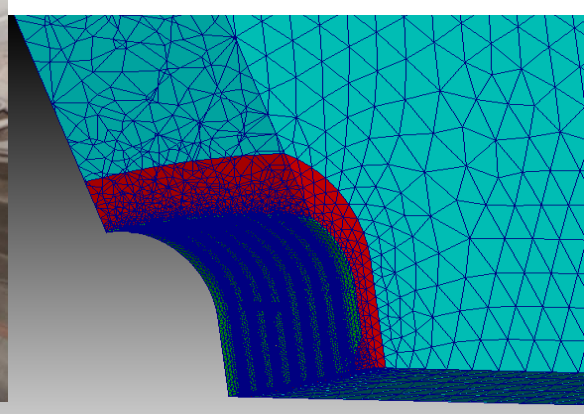
7. Platform.

CAE Fidesys is available both under Windows and Linux desktops as well as in the cloud (both public and corporate with remote GPU access).

https://azuremarketplace.microsoft.com/en-us/marketplace/apps/fidesys.fidesys

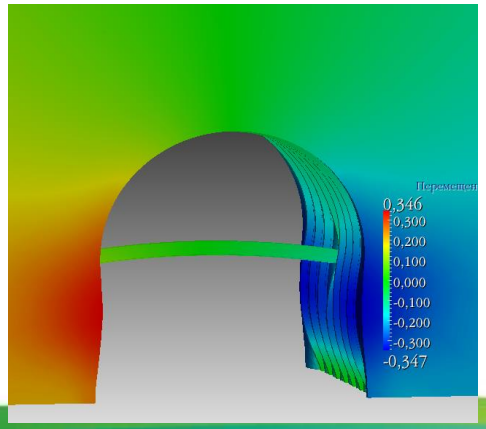
https://aws.amazon.com/marketplace/pp/B01BDRF5O

HPC example: geomechanical analysis of mine workings (> 30 mln. elements)

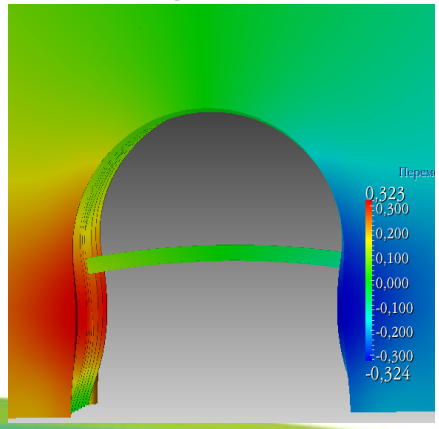


The current geomechanical situation in the mine is reproduced and the result of the possible strengthening of the rock mass after puffing (tamponage) or the replacement of the linings.

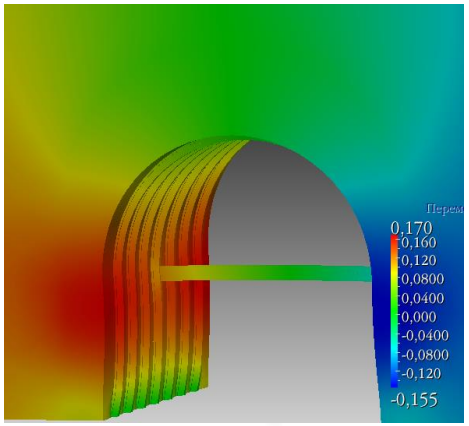
Current situation horizontal convergence 70cm



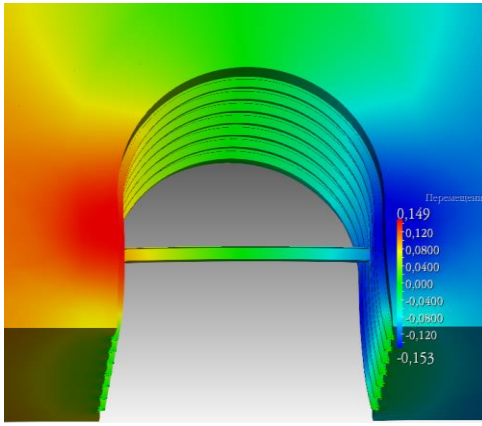
Replacement of SVP 27 for SVP 33 Horizontal convergence 64 cm



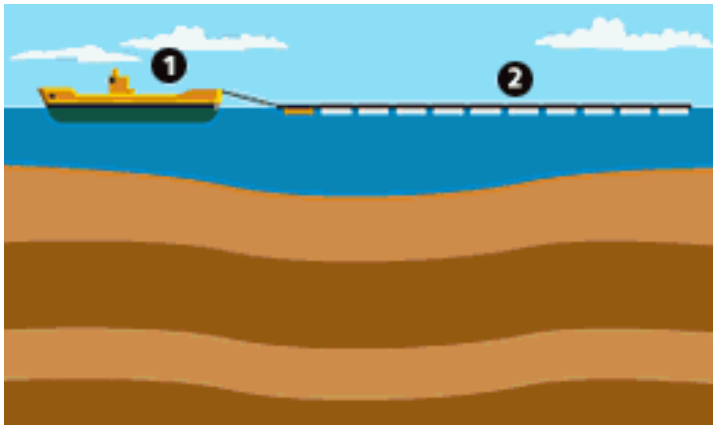
Reinforcement (tamponage) Horizontal convergence 32 cm

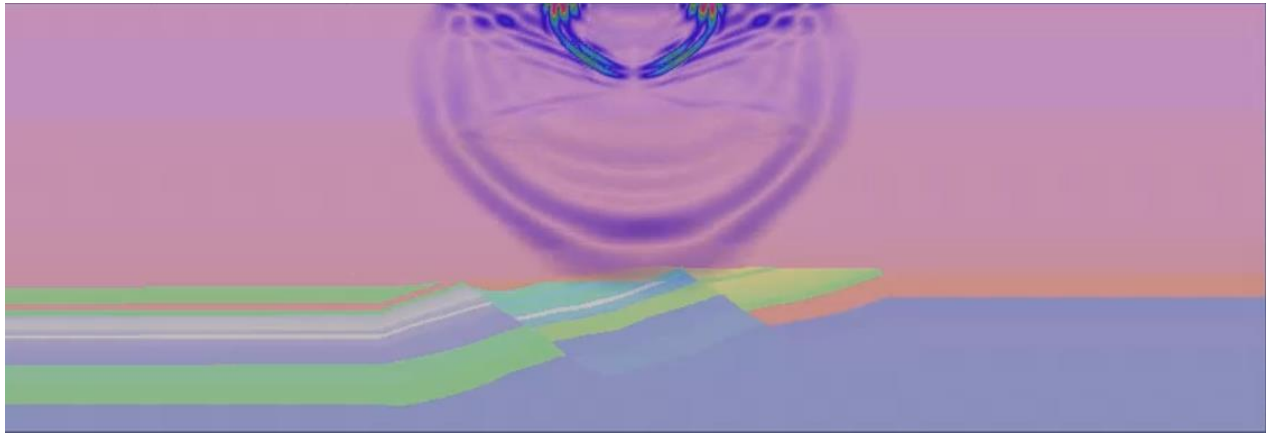


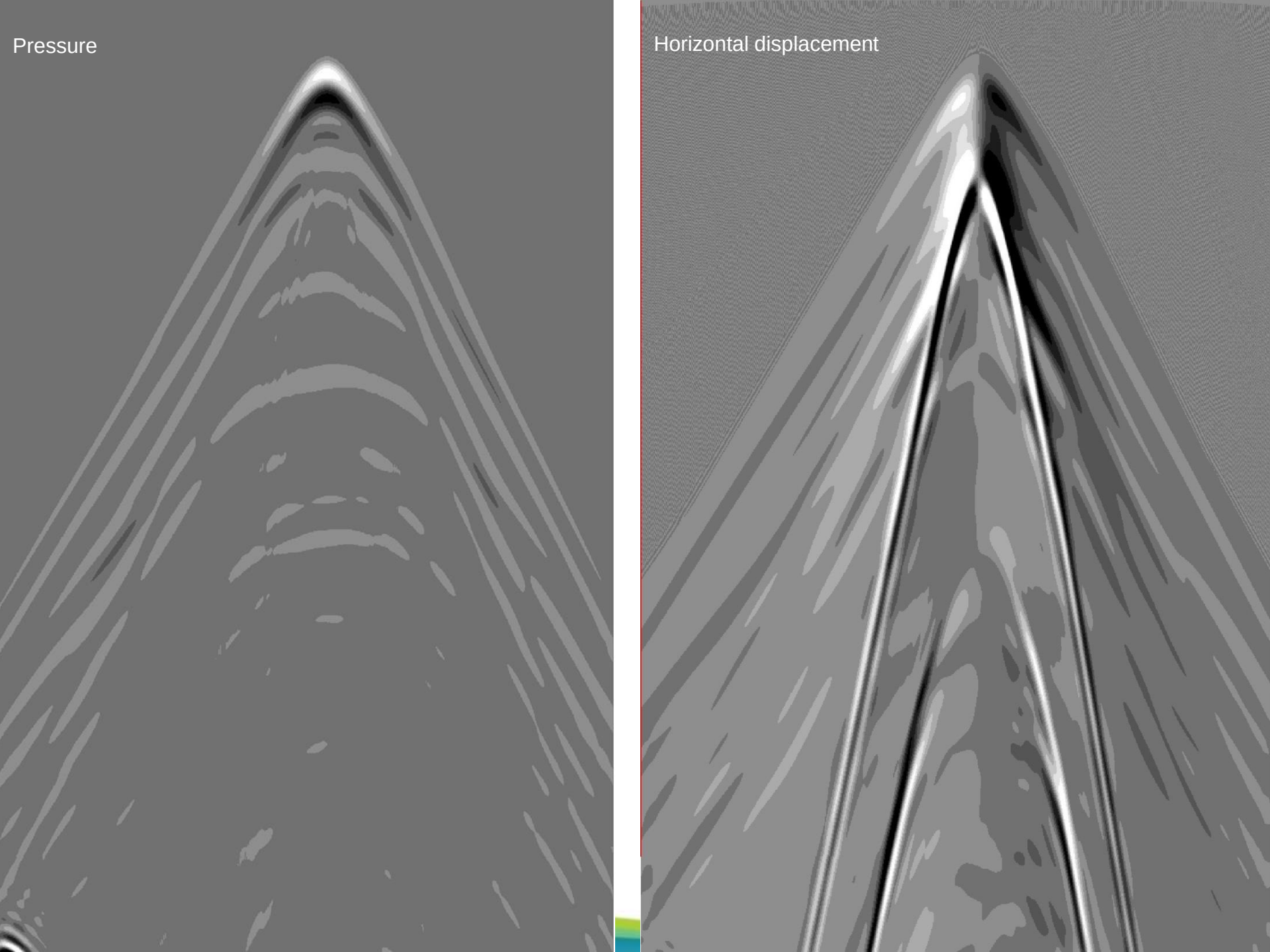
Reinforcement (tamponage) + Replacement of SVP 27 at SVP 33 Horizontal convergence 30 cm



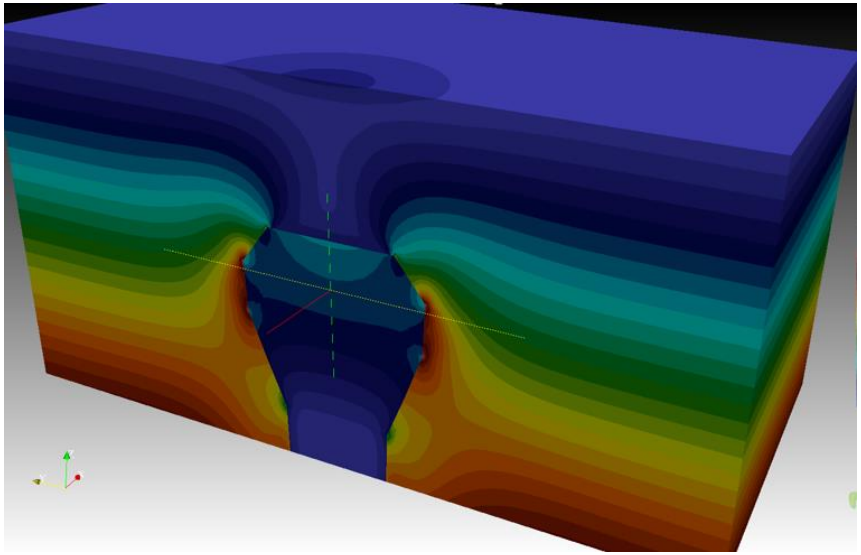
Geophysics studies - layered media
Marine seismic survey

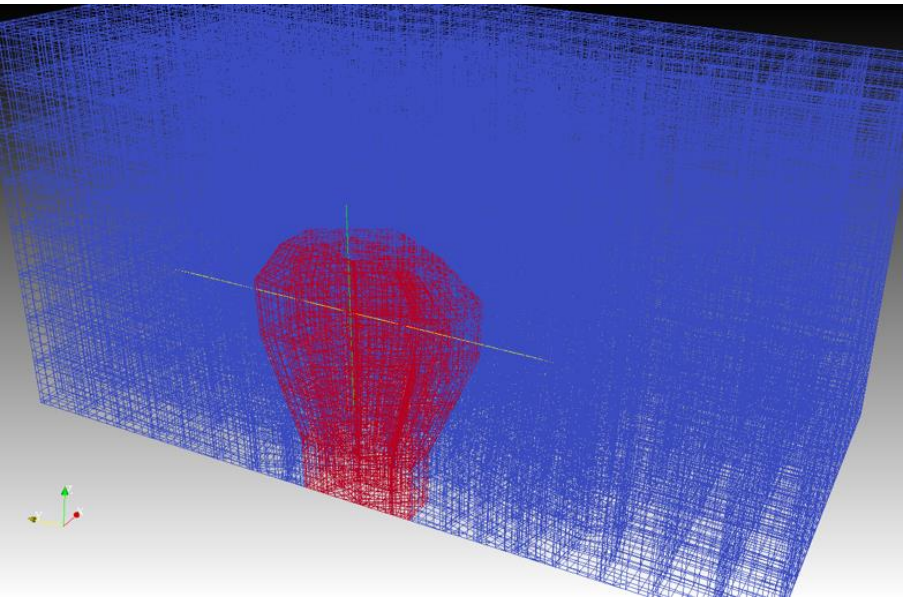


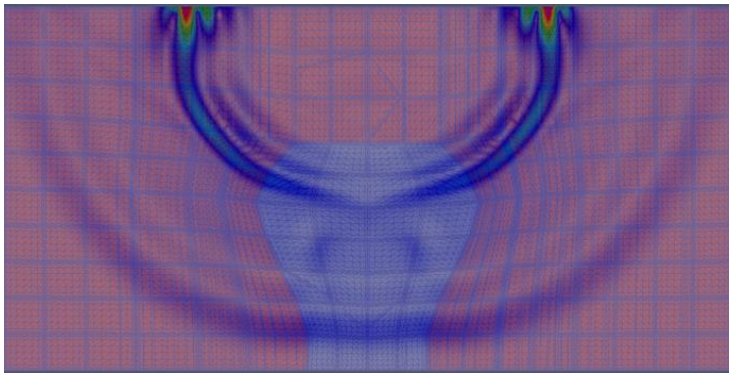



Pressure
Horizontal displacement

Geophysics & Geomechanics challenge cases at salt dome and pre-salt oil bearing layers



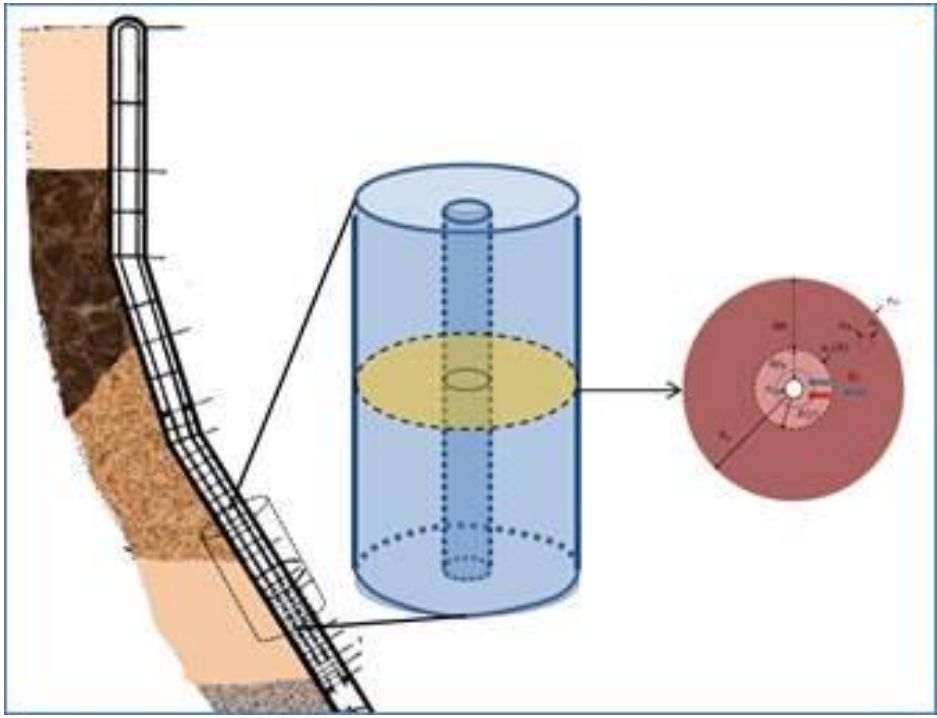




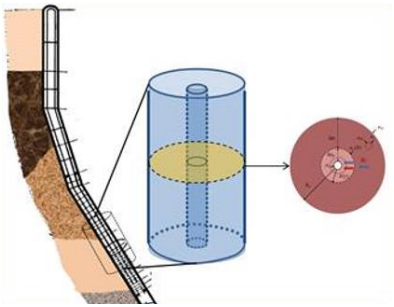
Wellbore stability analysis

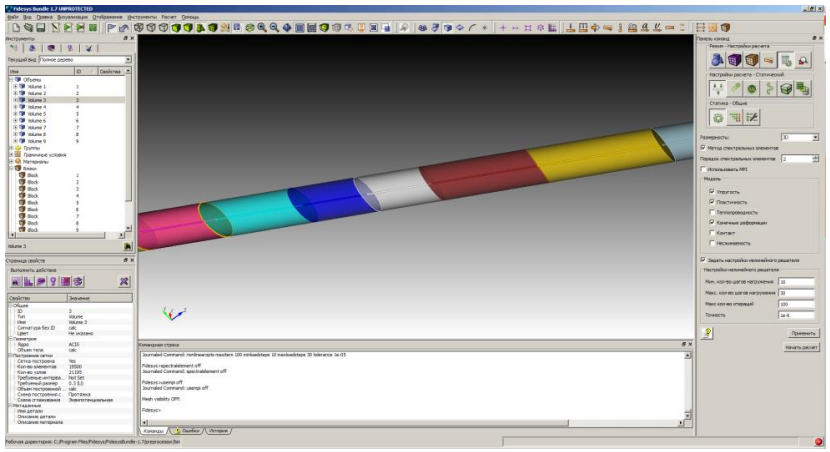
One of the key problems of geomechanics is the determination of technological parameters, for which the wellbore will maintain its stability. The different rock's properties (modulus of elasticity, Poisson's ratio, density, friction and dilatancy angles, strength and yield strengths for tension and compression, adhesion, porosity, permeability, compressibility, etc) should be taken into account. In addition, the rock is prestressed, which is determined by the components of the generally anisotropic nonuniform stress tensor.

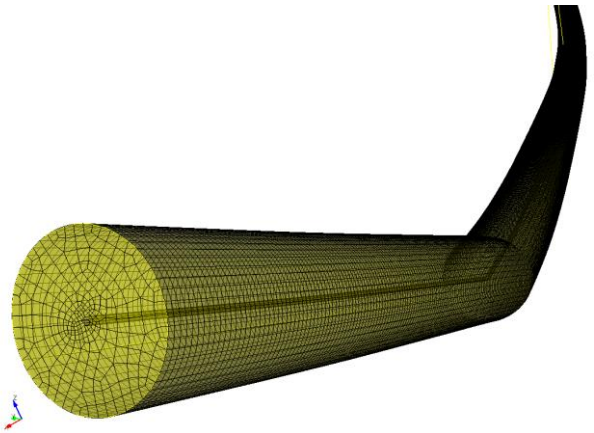
When drilling,in general, a bit and mud generates a pressure on the rock, thereby deforming it and redistributing the stresses (superposition of generally finite deformations), causing the reaction of the rock to the applied impact.

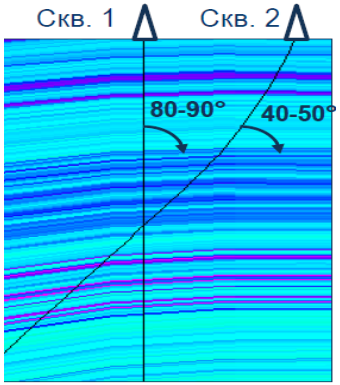


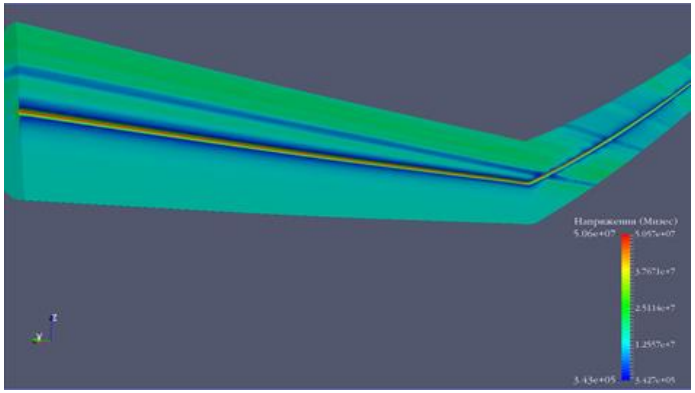
3D stability analysis for wellbore at layered media

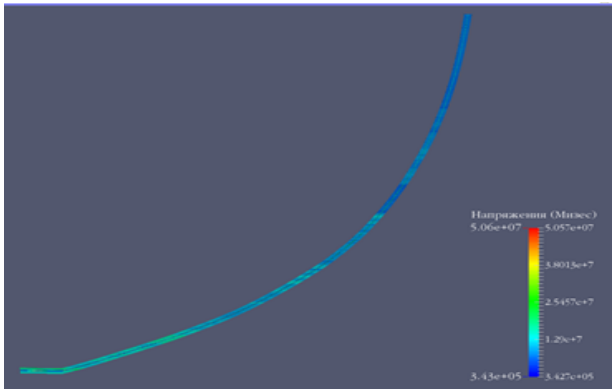




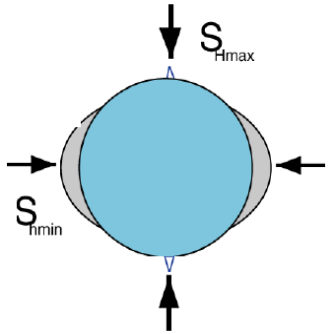


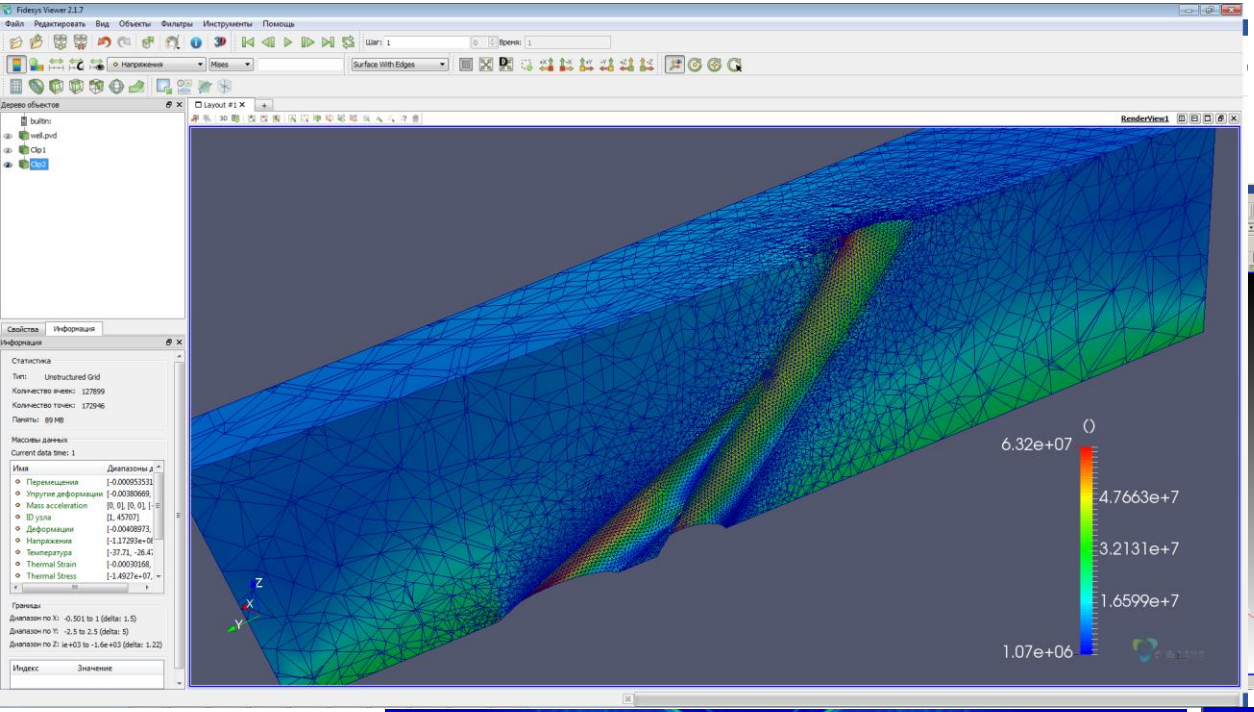


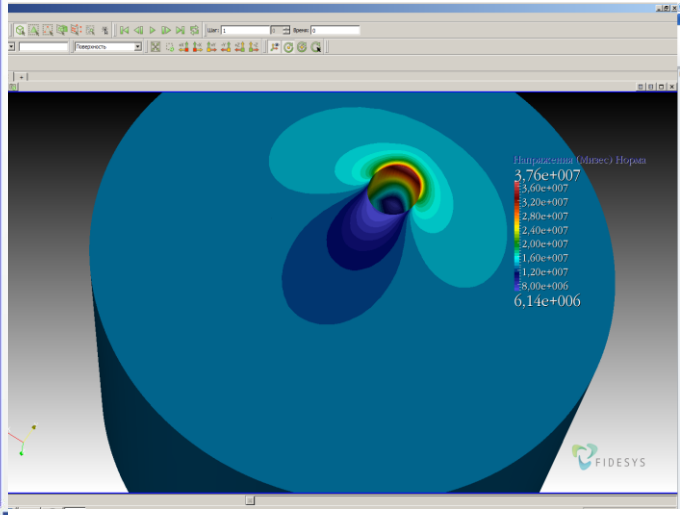




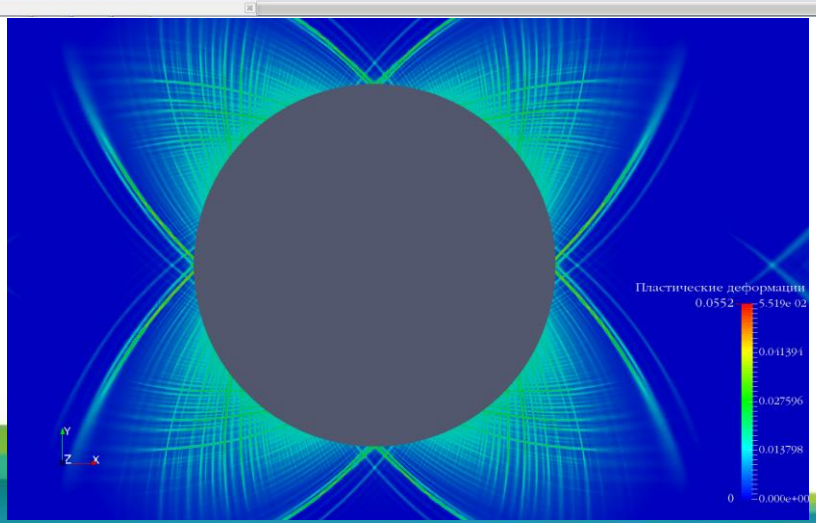
Localization of elastoplastic stresses

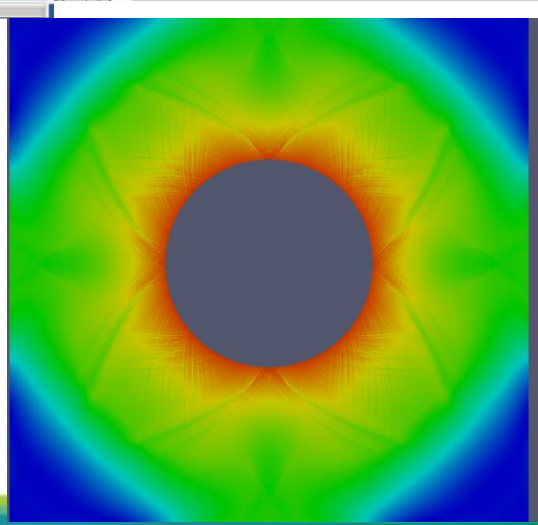




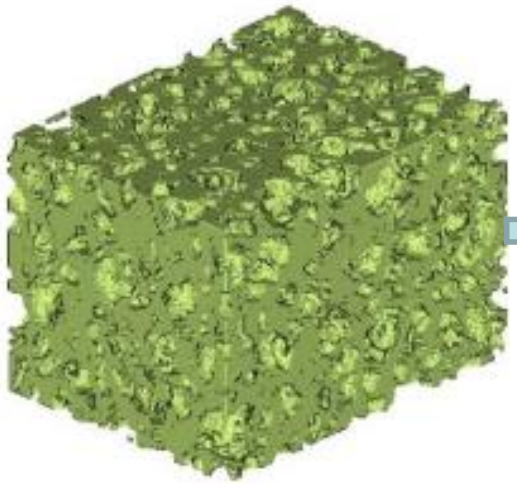


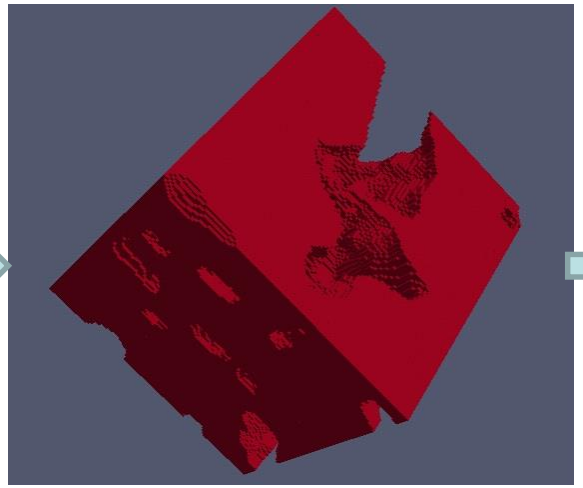
Luders plastic sliding lines nearby the wellbore

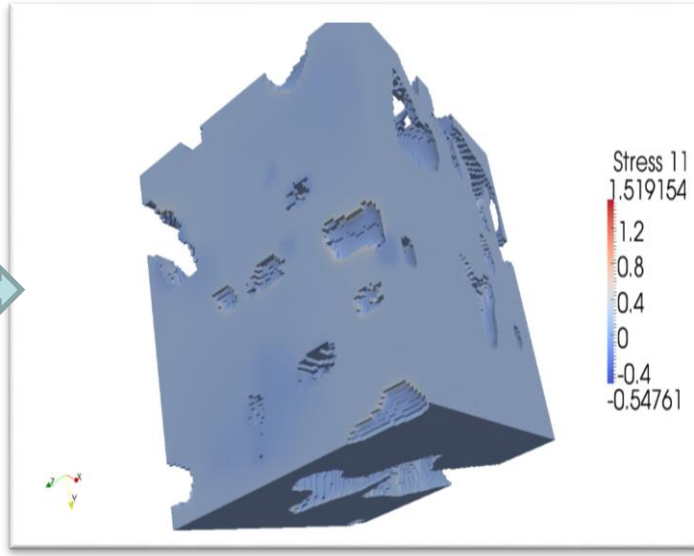




Effective properties estimation of rock samples







We search effective properties in a way of the Hook's law:

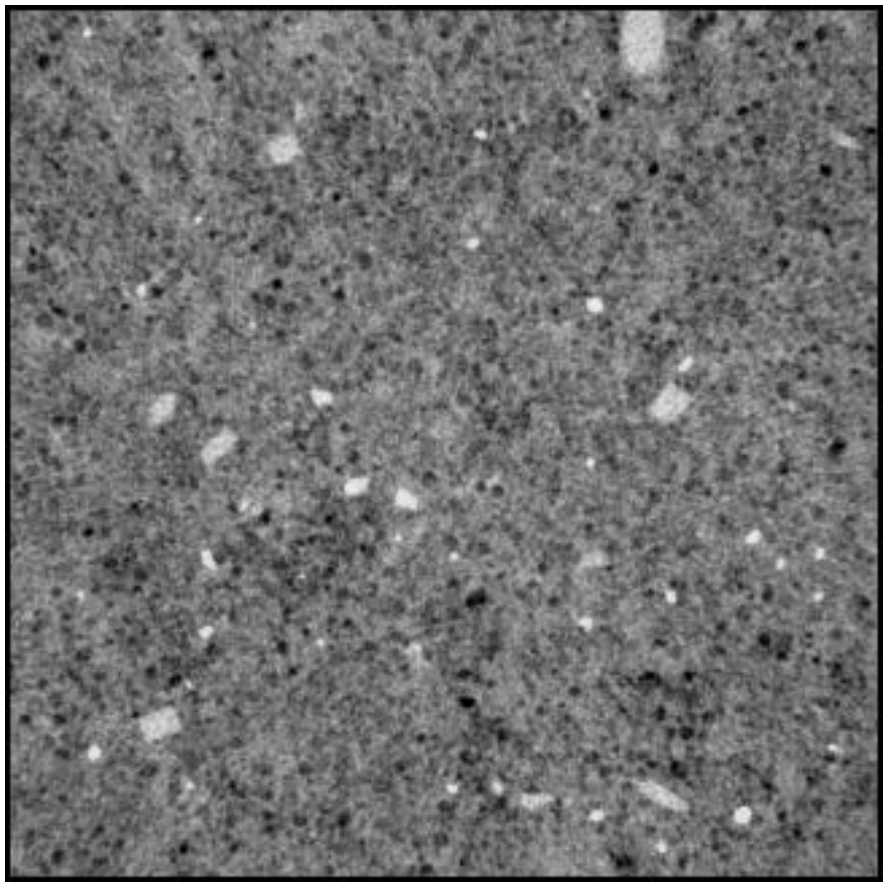
$$\sigma^{e}_{mn} = C_{mnij} E^{e}_{ij}$$

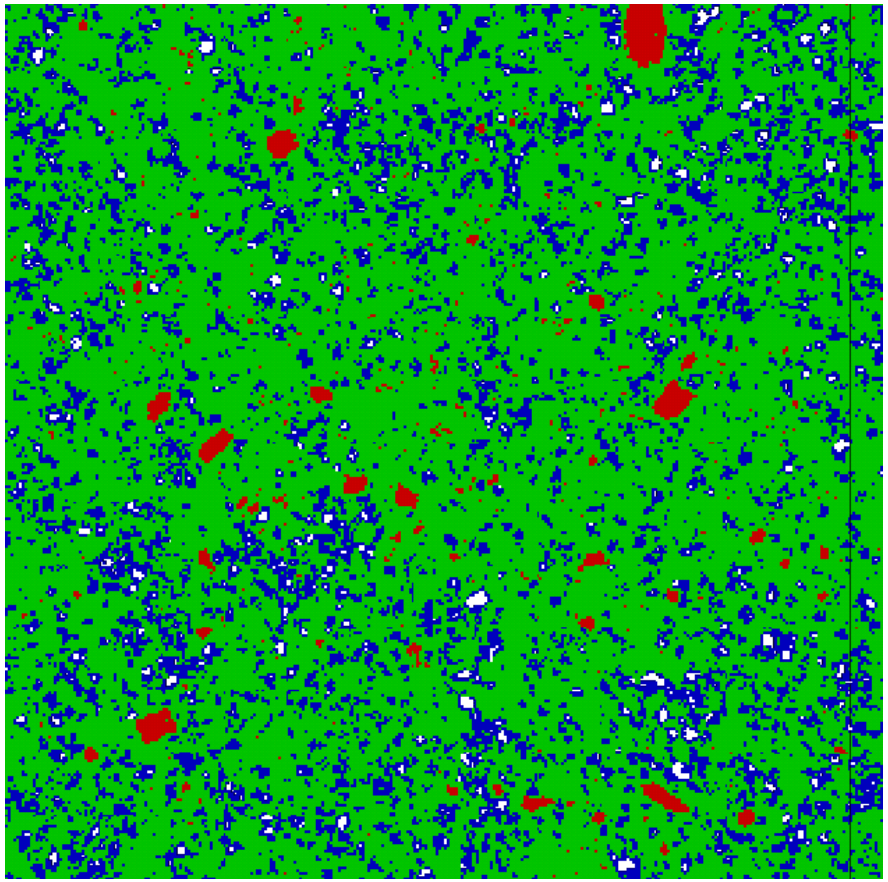
Numerical experiments (as opposed to real ones) allow changing material properties, constitutive relations, pore pressure. We model several types of experiments: 1-, 2-, 3-axial, hydrostatic etc.

Modeling results:

- Anisotropic mechanical properties of core samples;
- Stress and strain fields;
- Dependencies on skeleton properties, porosity, etc.

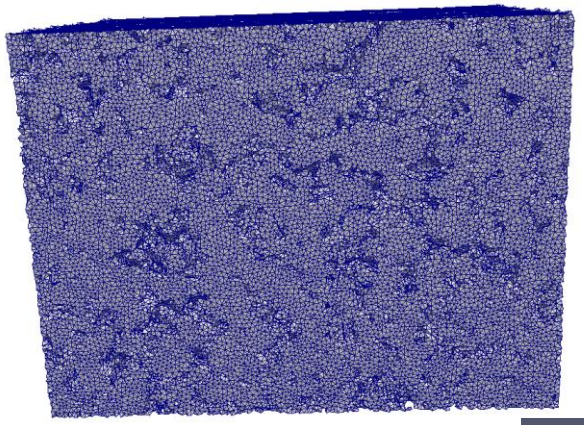
CT-scan data for shales



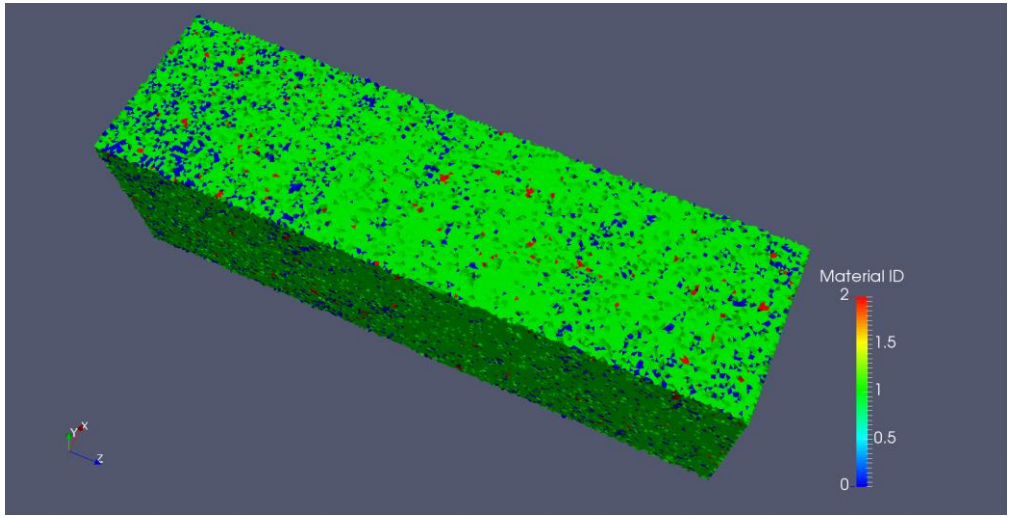


CT-scan images and their interpretation was provided by geological department of Lomonosov Moscow State University

FEA mesh generation

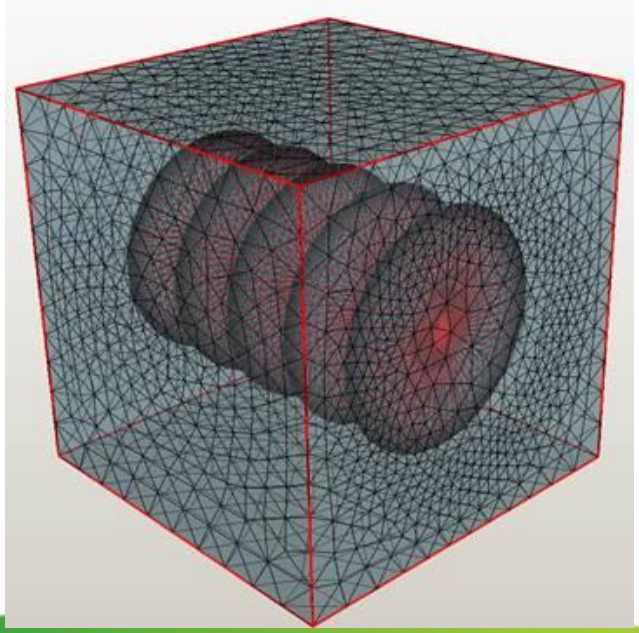


The mesh is generated based on the imaging data for the size of the rock sample fragment of 900x900x1200 voxels. The obtained mesh size is 2 million tetrahedrals.



Effective properties of fractured media
(provided by Lukoil)

- Fractures are modeled as plane ellipsoidal inclusions filled with fluid or gas
- Elastic moduli depends of several fracture parameters:
  - Aspect ratio
  - Number of fractures (~ fracture porosity)
  - Type of media inside fractures (fluid/gas)
- In case of rotational ellipsoids (ellipsoid's axes $r_1 = r_2 >> r_3$) and isotropic matrix the resulted effective fractured media is transversely isotropic

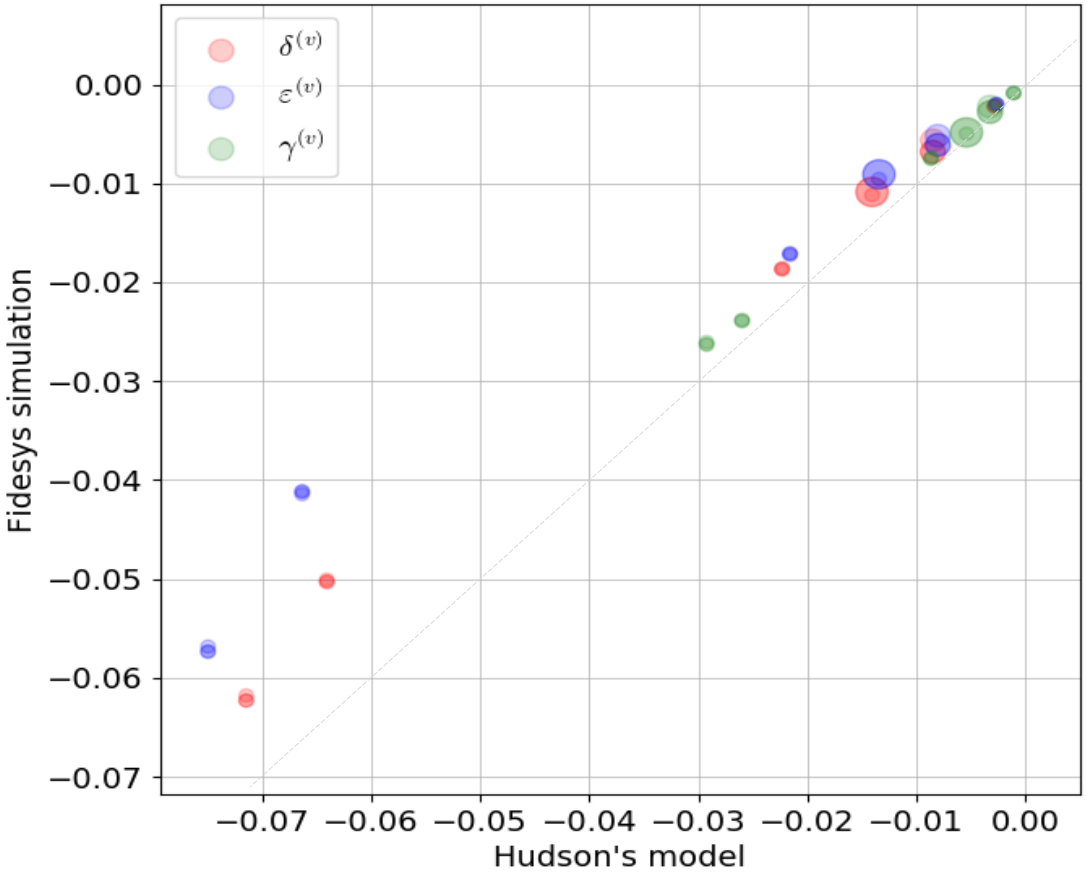


Test model for effective periodicity cell of ellipsoidal fractured media

Numerical results

(provided by Lukoil)

Effective moduli $\mathbf{C}_{ij}$ are used to compute dimensionless anisotropy parameters of Ruger-Tsvankin $\varepsilon^{(v)}$, $\delta^{(v)}$, $\gamma^{(v)}$ which in turn are compared with analytical values predicted by Hudson model (Hudson, 1980)



CAE Fidesys allows one to build periodic cells of arbitrary geometries and relative orientations of fractures and inclusions (Hudson model considers only the case of uniformly distributed fractures of the same shape and size)