



Peter the Great Saint-Petersburg Polytechnic University

Department of «COMPRESSOR VACUUM
AND REFRIGERATION ENGINEERING »

Compressors design experience of the department
«COMPRESSOR VACUUM
AND REFRIGERATION ENGINEERING»

Head of department
Kozhukhov Yuri



Department of
«Compressor vacuum and refrigeration
engineering»

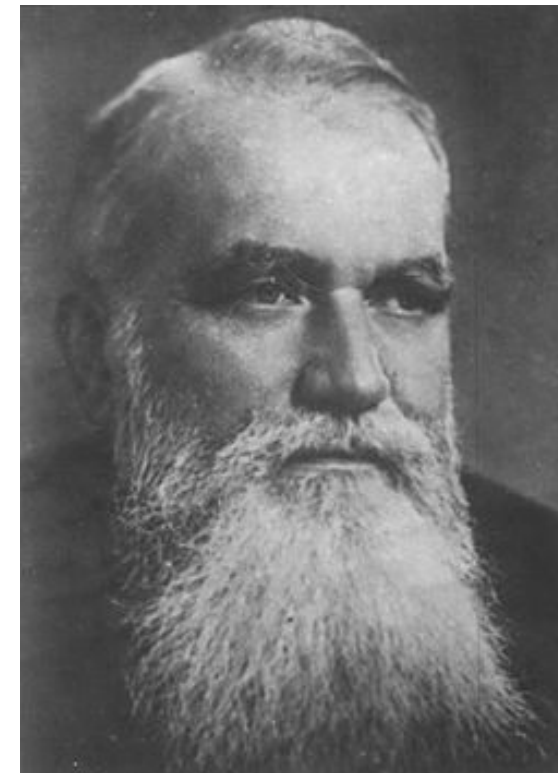
(founded: 21th August 1930)

Strakhovich Konstantin Ivanovich

was the founder and the first head of
department

(1904, Saint-Petersburg — 1968, Leningrad) — expert in the field of thermodynamics, compressor design, hydrodynamics and ballistics. He also was the professor at some another universities in Leningrad.

He worked for the Rybinsk plant at the time of the Great Patriotic War.





1. Main academic programs (full-time and distance education):

«Power Engineering»,

«Technological machines and equipment»

2. PhD and Doctoral studies by scientific major 05.04.06 «Vacuum compressor engineering and pneumatics»

3. Scientific and research laboratory of the department:

Laboratory of «Computer simulation modeling and strength calculations»

4. Students design engineering center «Compressor».

Supervisor – A.M. Danilishin.

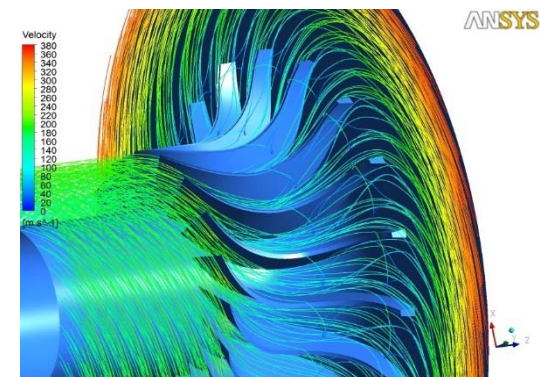
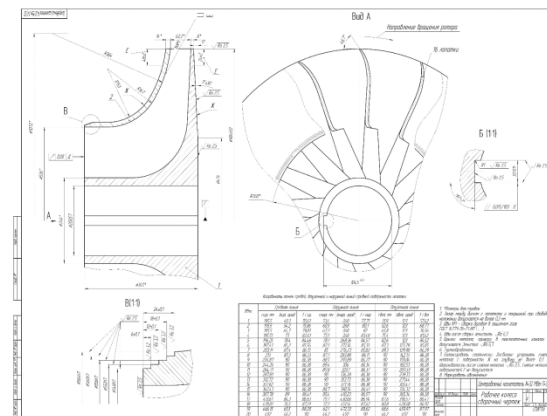




DIRECTIONS OF THE RESEARCH&DEVELOPMENT WORK

Compressors design
of different types

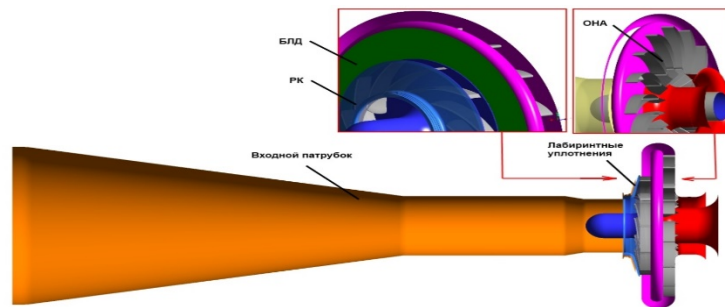
Engineering
computer simulation



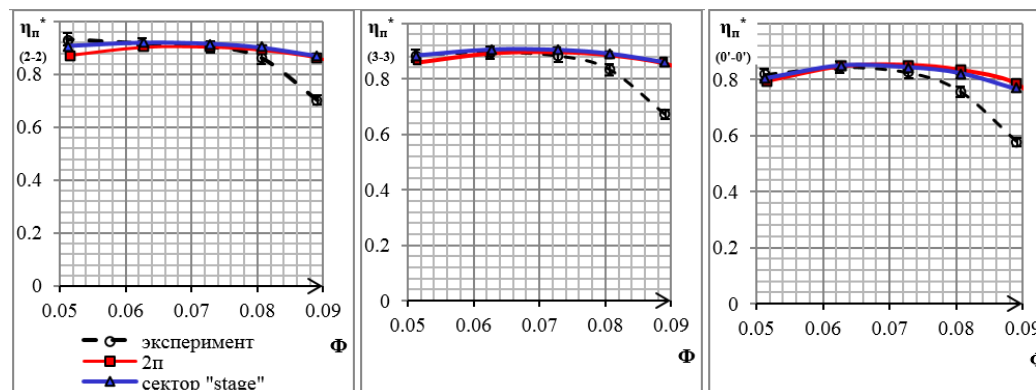
Serious experimentation facility and CFD-modeling results verification

There are 7 test rigs with about 3,5 MW total capacity, including the closed circuit test rig for presser up to 100 atm.

Throughout its long history the department has saved up a great experimentation results facility of real-life experiments (more than 500 experiments)



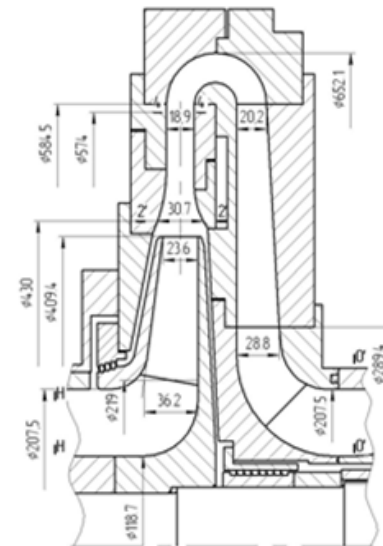
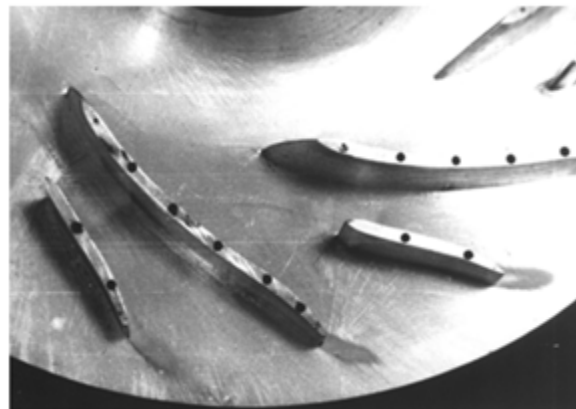
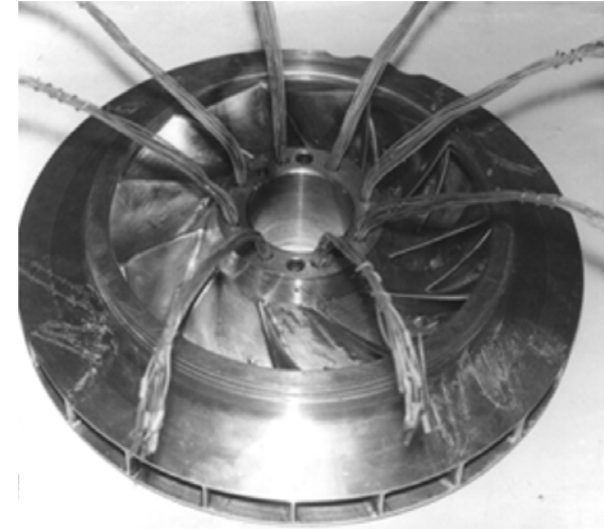
Extensive work on turbocompressors CFD calculations validation and verification with the results of real experiments is constantly conducted



Department's modularized stages

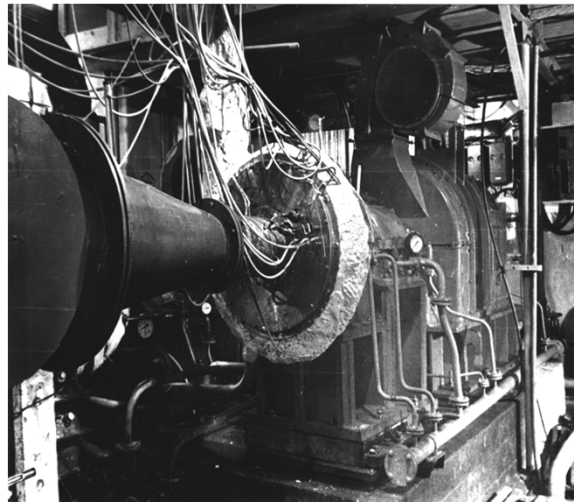
A huge database has been created during the long-term designing and experimental work:

- More than 300 real-life experiments of centrifugal compressors stages;
- More than 150 experiments of compressors flow passage parts;
- More than 50 real-life research results of unsteady processes in centrifugal compressors.

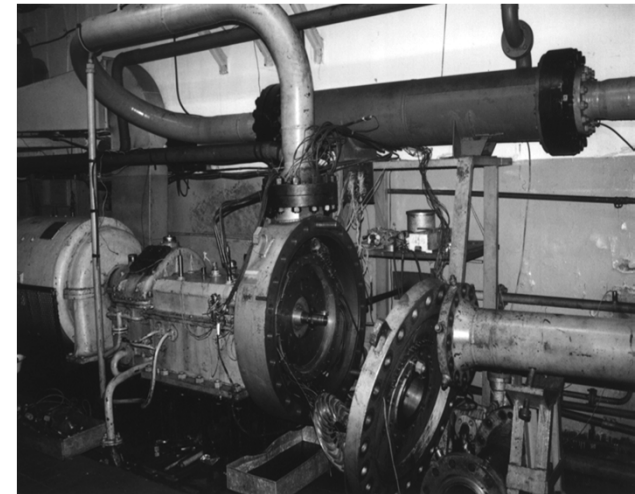


Department's test rigs

In order to develop the theory and design problems solution it is necessary to carry out experimental researches of compressors models at the specific test rigs.



**Test rig for centrifugal compressors models test run
(capacity up to 800 kW,
variable number of revolutions 18000 rpm)**



**Test rig for centrifugal compressors models with
pressure up to 100 atm**





COMPRESSORS DESIGN AND COMPUTER SIMULATION

CENTRIFUGAL COMPRESSORS

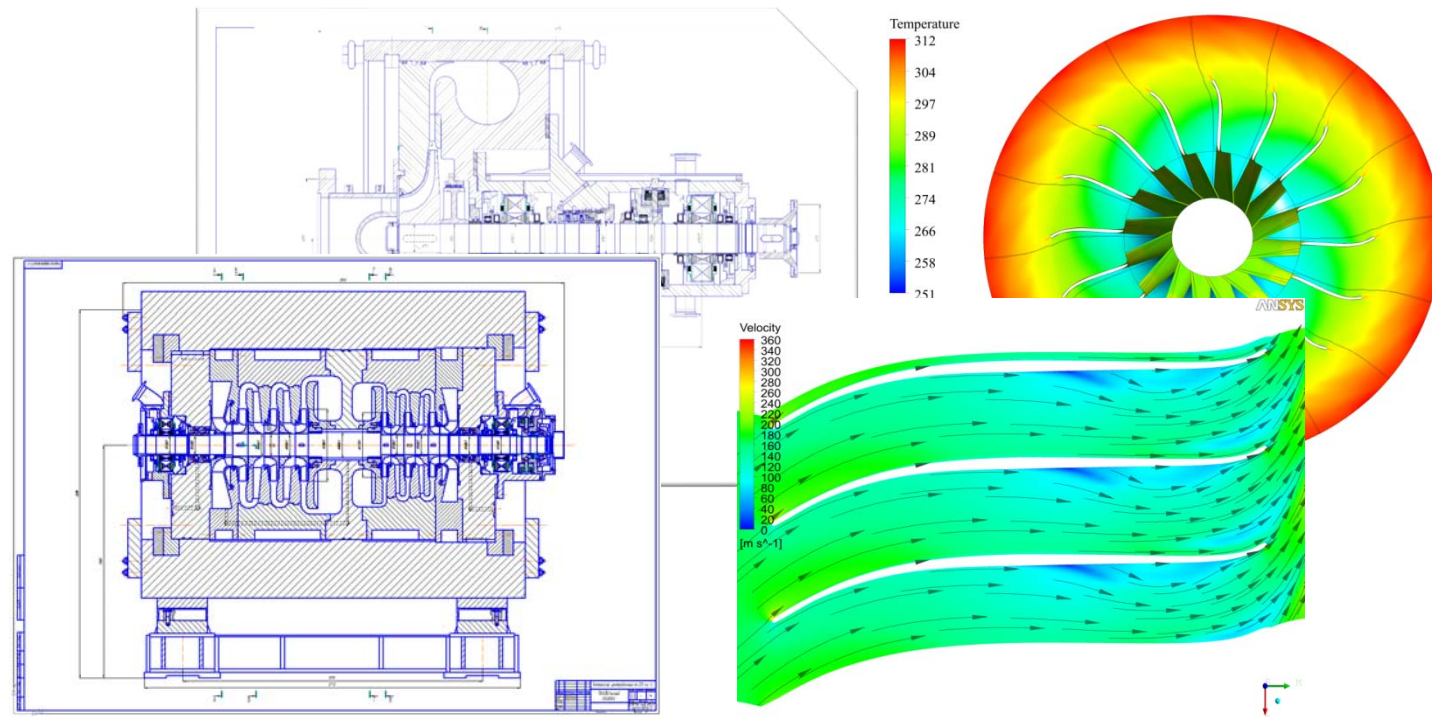
The department has its own gasdynamic flow passage design methods of centrifugal compressors, including its own design methods of high efficiency axial-radial impellers.



The axial-radial impeller by the project of «RK-6»,
 $\Pi=1,74$, polytropic efficiency by total parameters at the design mode: $\eta_{p\ st}^*=0,915$

COMPRESSORS DESIGN AND COMPUTER SIMULATION

CENTRIFUGAL COMPRESSORS

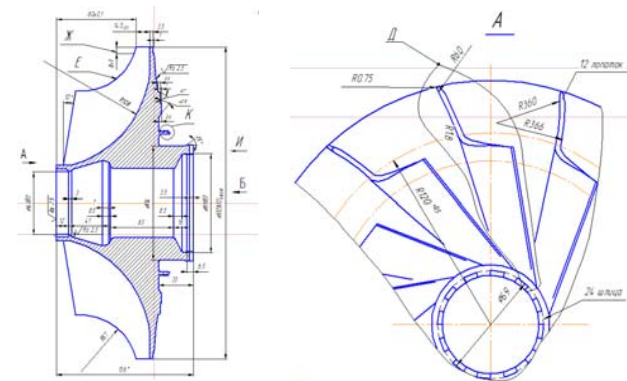
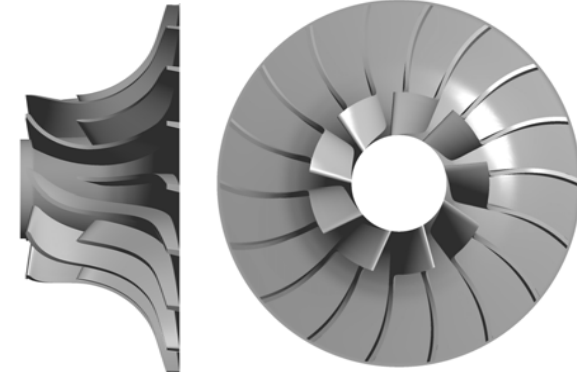
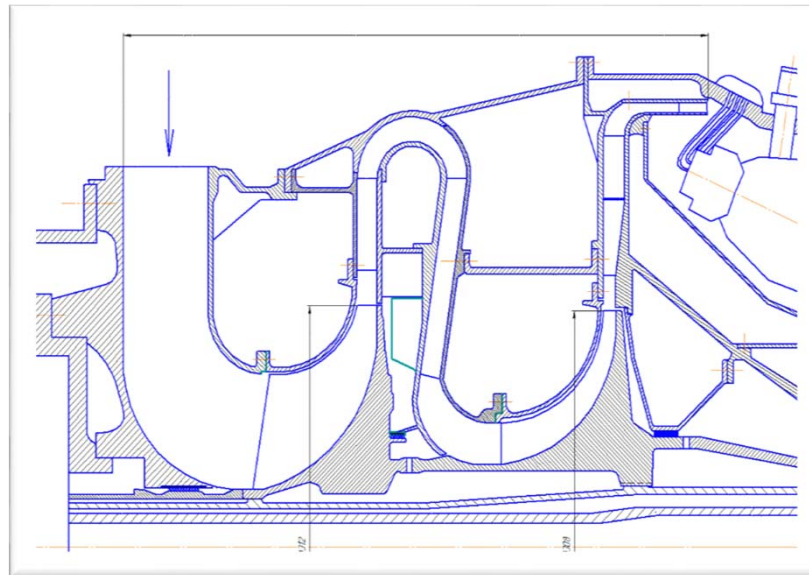


Modern and prospective natural gas centrifugal compressors
(chargers)



COMPRESSORS DESIGN AND COMPUTER SIMULATION

CENTRIFUGAL COMPRESSORS



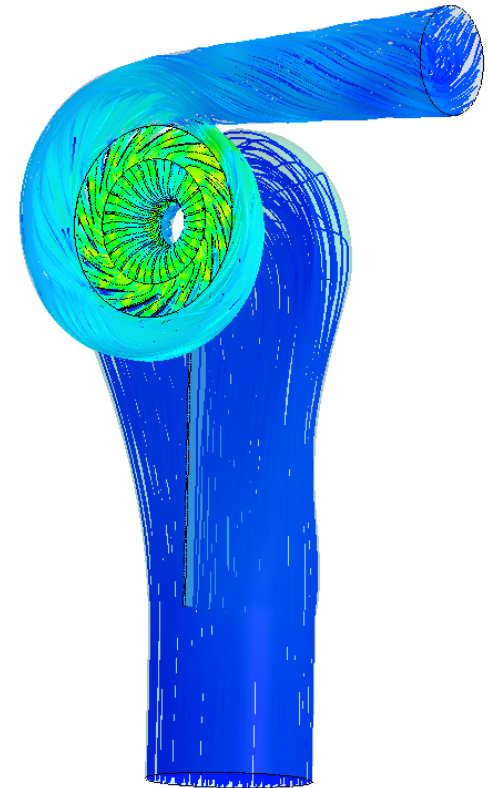
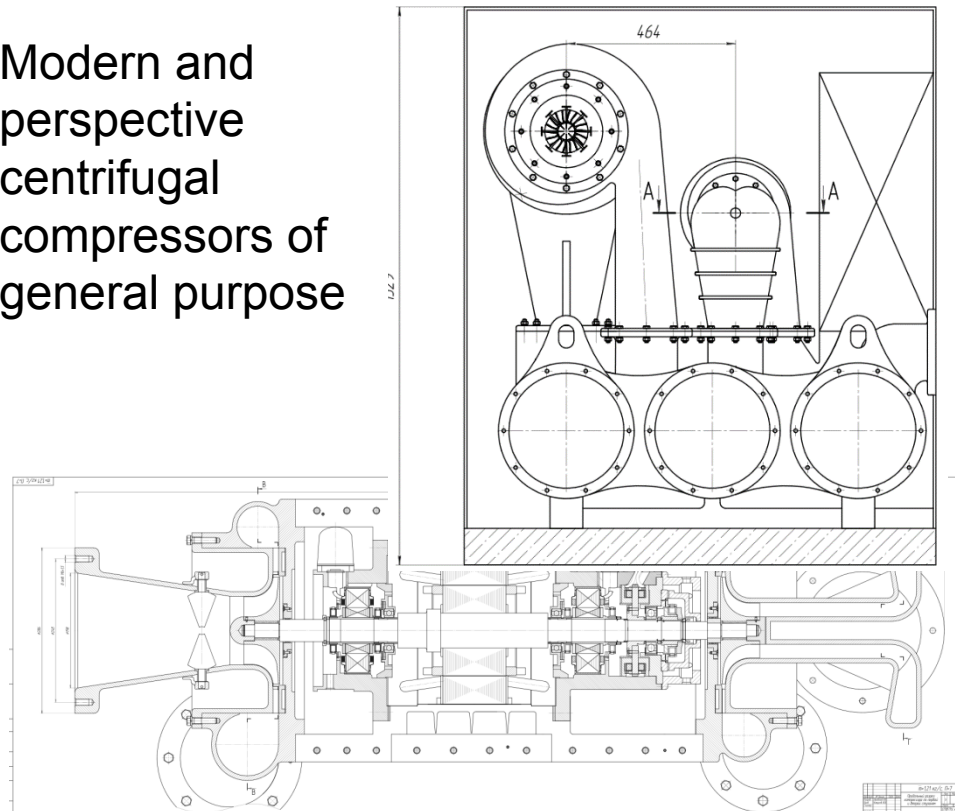
Modern and perspective centrifugal
compressors for aviation



COMPRESSORS DESIGN AND COMPUTER SIMULATION

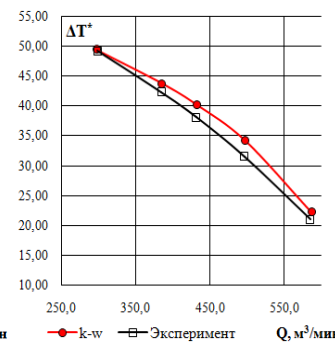
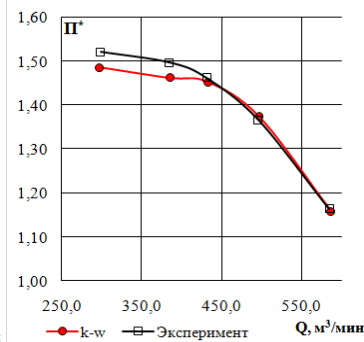
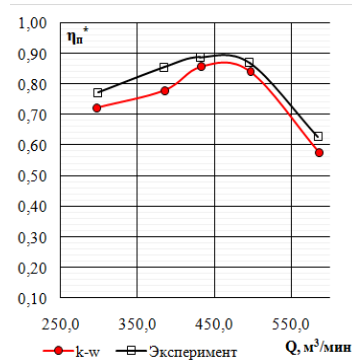
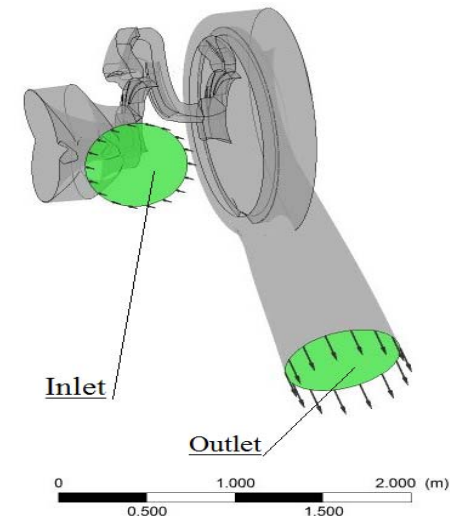
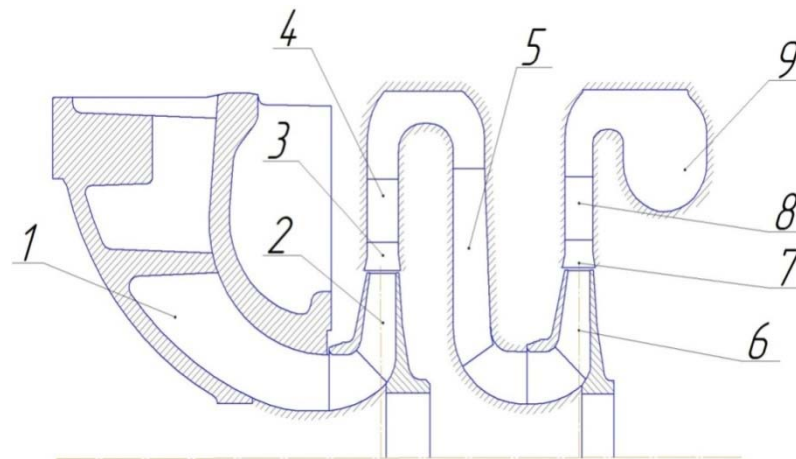
CENTRIFUGAL COMPRESSORS

Modern and
perspective
centrifugal
compressors of
general purpose



COMPRESSORS DESIGN AND COMPUTER SIMULATION

CENTRIFUGAL COMPRESSORS

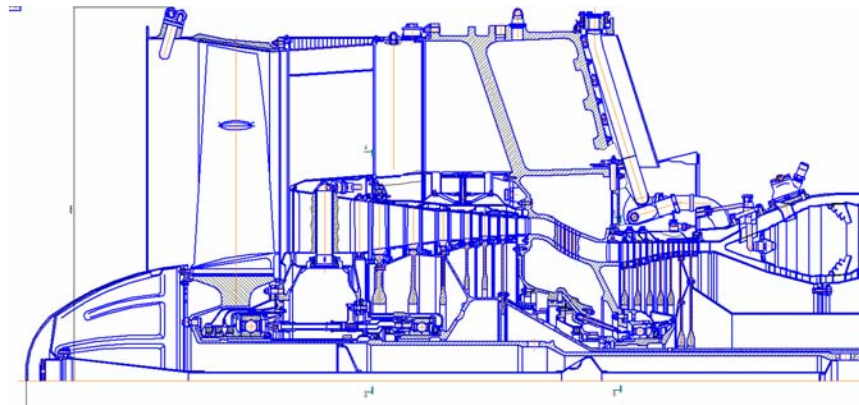


Verification results of CFD-simulation with the real-life experimental data for multi-stage centrifugal compressor of ZAO NZL (ZAO REPX)



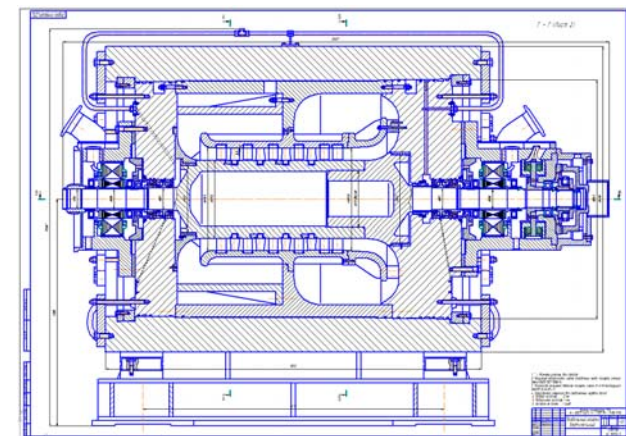
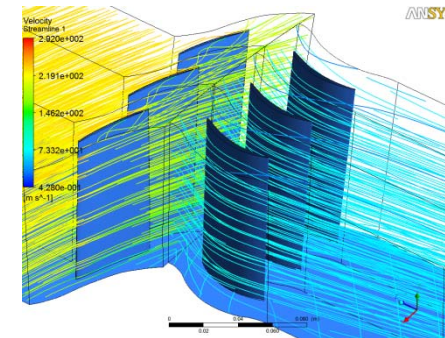
COMPRESSORS DESIGN AND COMPUTER SIMULATION

AXIAL COMPRESSORS



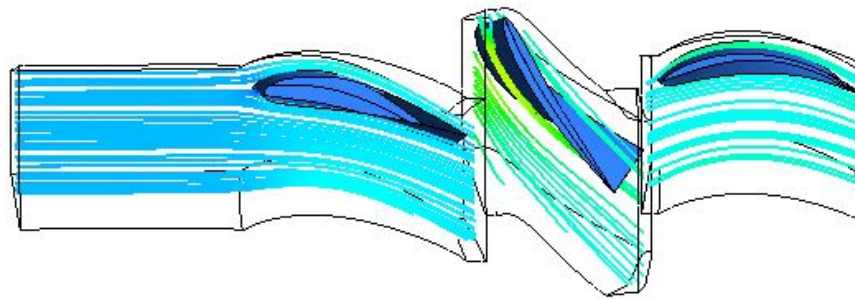
Modernization project in order to efficiency increase and mass-dimensional parameters decrease of the aviation engine GTE D-36.

Axial compressor project of natural gas for long distance pipeline

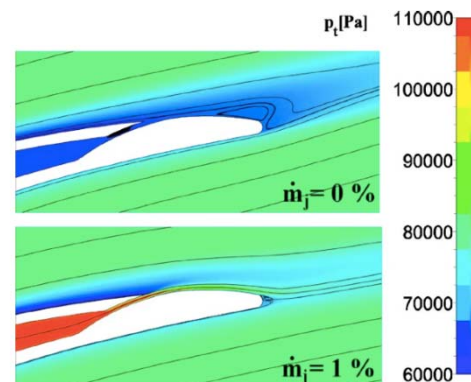
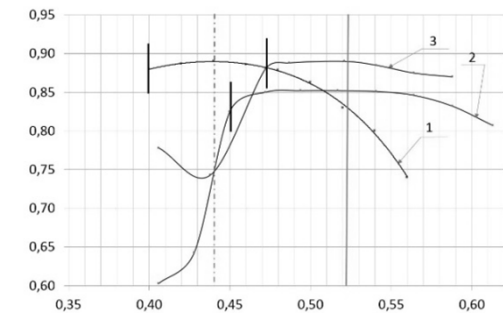


COMPRESSORS DESIGN AND COMPUTER SIMULATION

AXIAL COMPRESSORS



Three dimensional viscous flow research
of the K-100-2Л stage.



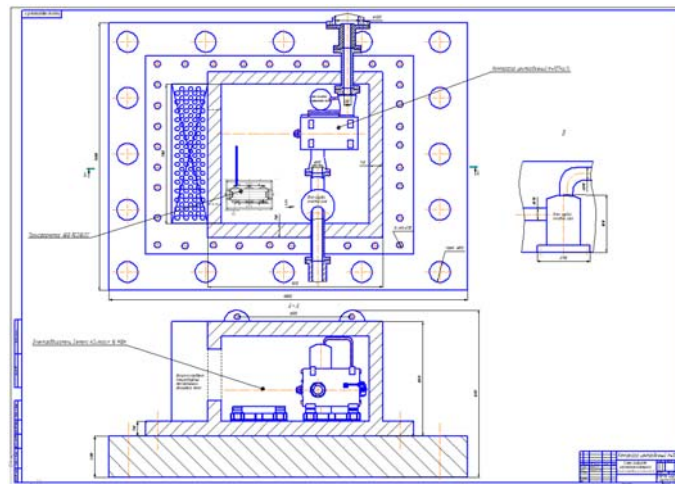
Example of numerical
investigation of active flow
control at the high-speed
four-stage aviation axial
compressor



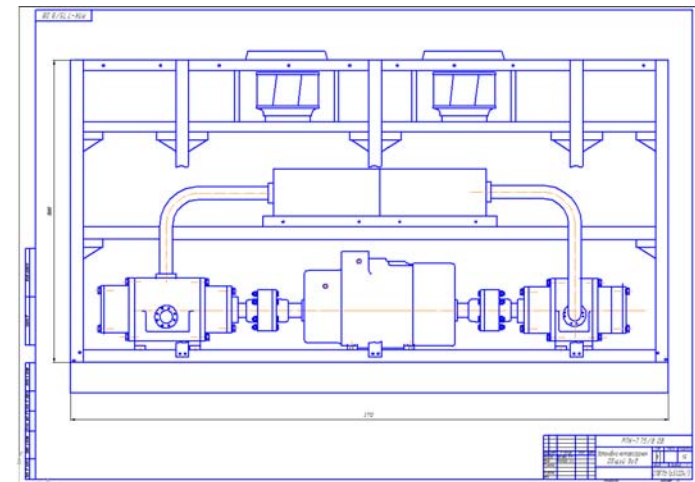
COMPRESSORS DESIGN AND COMPUTER SIMULATION

COMPRESSOR UNITS AND INSTALLATIONS

Compressor installation for
associated petroleum gas utilization
with rotary plated compressor



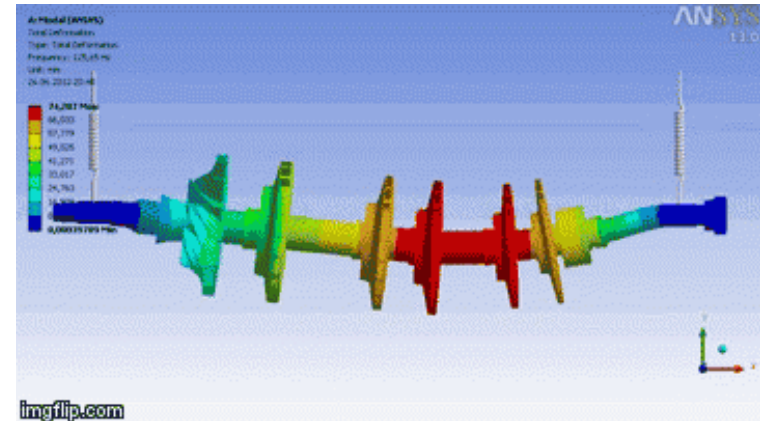
Leak proof part of gas-compressor
unit with capacity of $N=16$ MW. This
is an underwater compressor,
situated at the hole top of
Shtokmanovskoe mine.



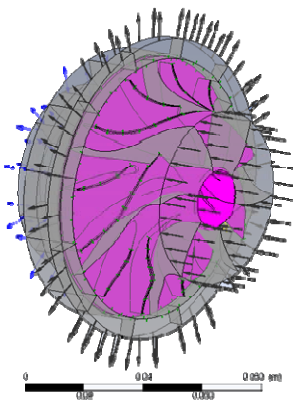
VIRTUAL PROTOTYPING

Dynamics and strength

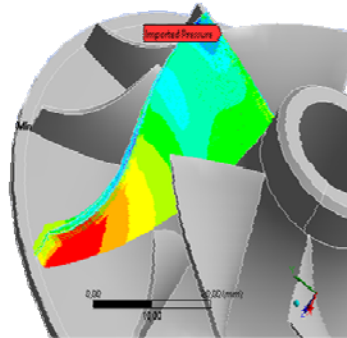
Interdisciplinary approach



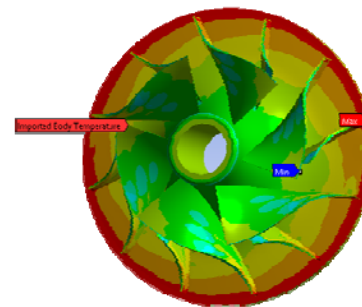
Conjugate CFD and FEA



Pressure force
distribution



The distribution of
fields of temperature



Strength calculation

SOFTWARE PACKAGES USED

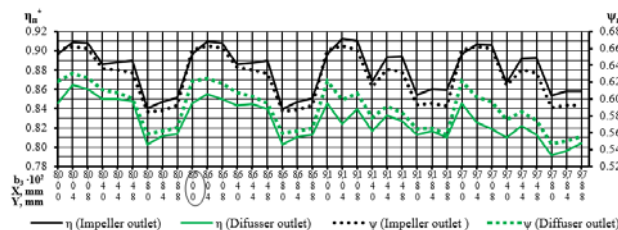
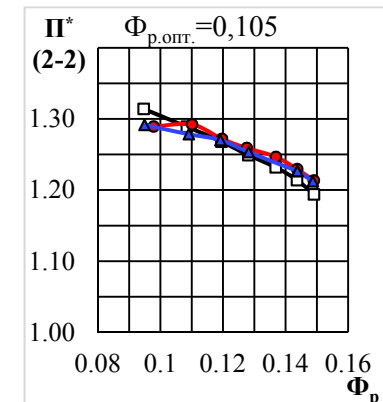
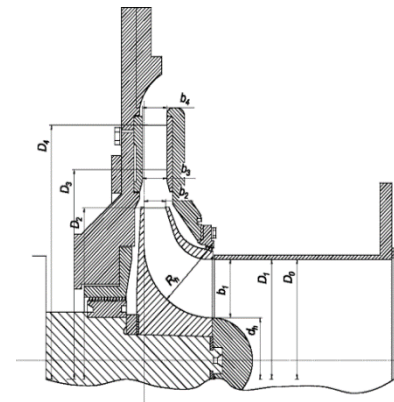
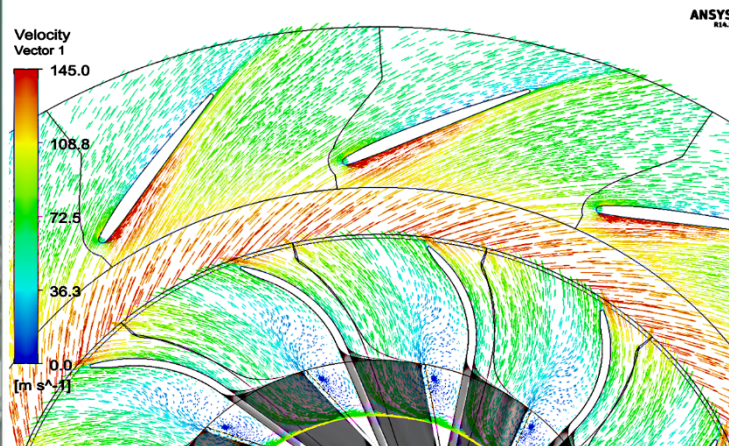
There are 15
programs, which
are made by the
department staff



MULTIVARIABLE OPTIMIZATION

using the department's and university's supercomputers

It is a powerful tool to increase flow passage operation efficiency



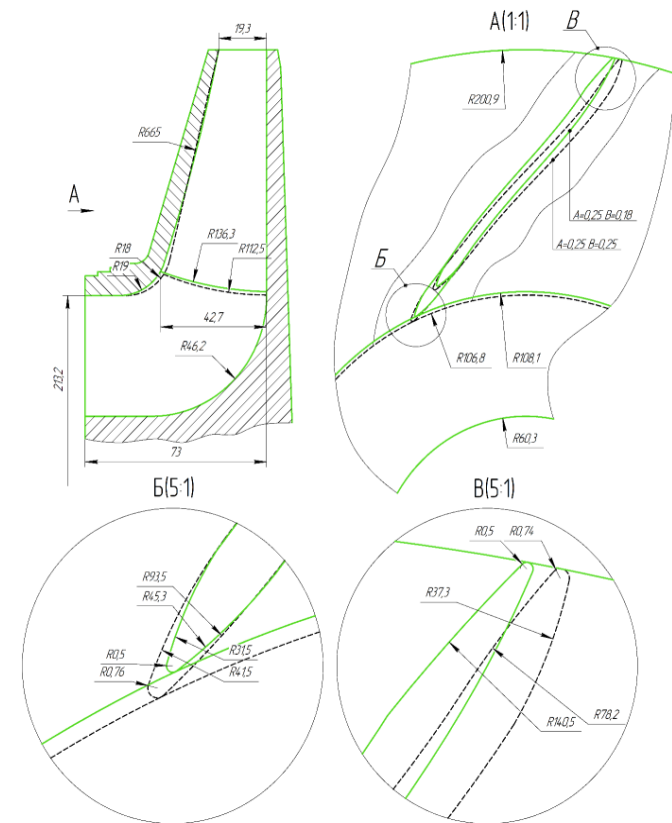
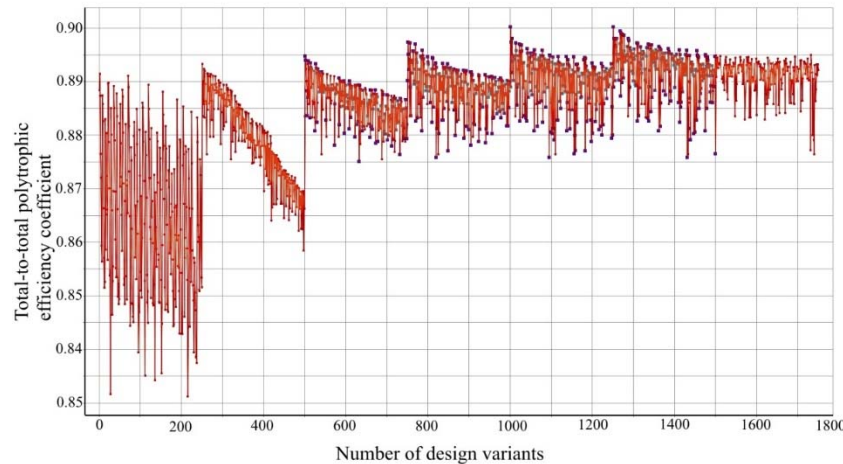
As a result of made multistage optimization it was managed to increase the design efficiency of the NZL model stage by 1,58%



MULTIVARIABLE OPTIMIZATION

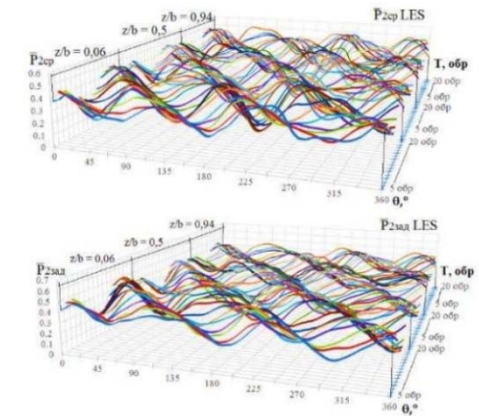
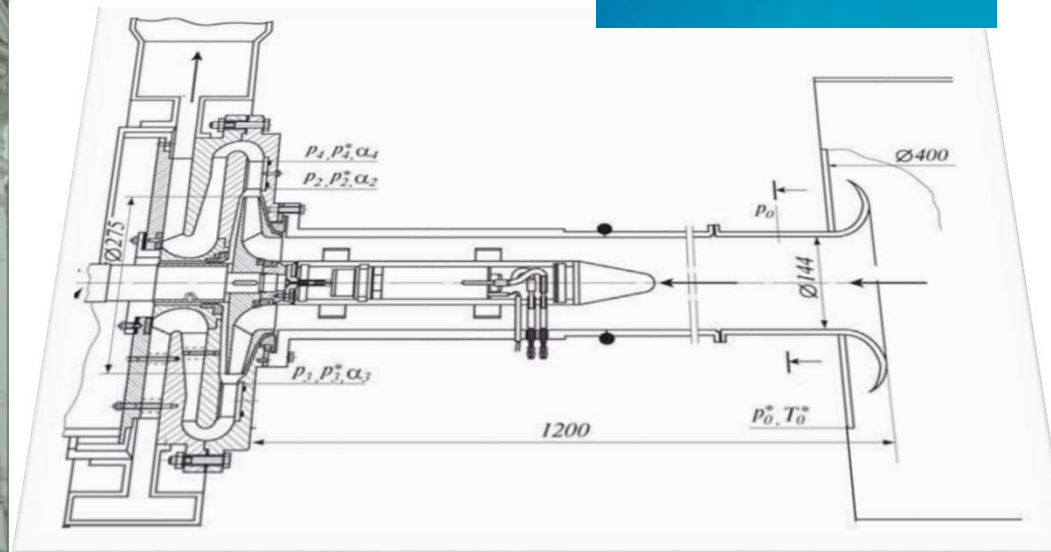
Statement of the problem
multiobjective and multivariable
optimization

1. Increased efficiency
2. Eliminating gas-dynamic characteristics
3. The calculation of the compensation of the axial forces



UNSTEADY FLOW PROCESSES INVESTIGATION IN CENTRIFUGAL COMPRESSORS

Development of the turbocompressor surge protection system



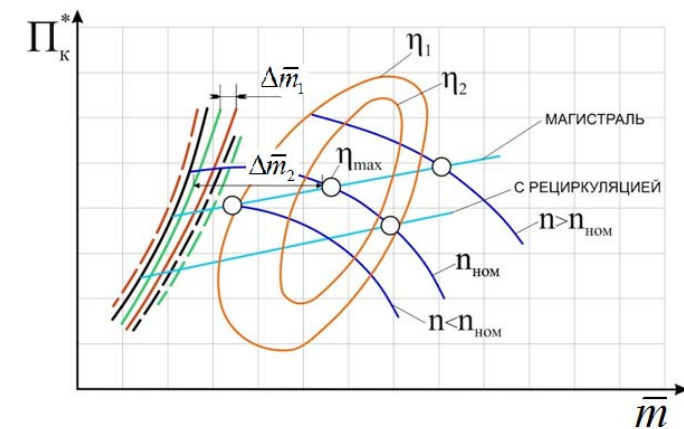
Department's test rig for investigation of unsteady flow phenomenon in the flow passage including pre-stall, flow separation and surge



UNSTEADY FLOW PROCESSES INVESTIGATION IN CENTRIFUGAL COMPRESSORS

The turbocompressor surge protection system benefits

1. Determination of **authentic** board of surge beginning according to **current** exploitation conditions.
2. **Expanding** of stable operation region not less than **5%** to the surge side.
3. **Real time** monitoring of gasdynamic stable operation parameters.



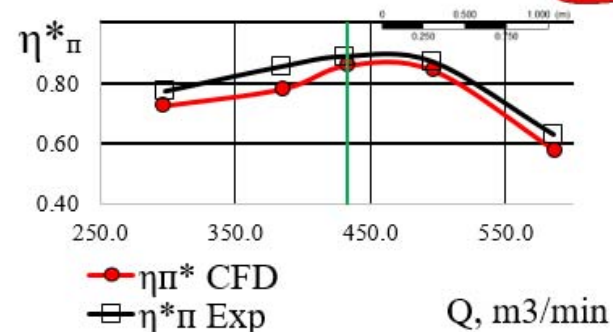
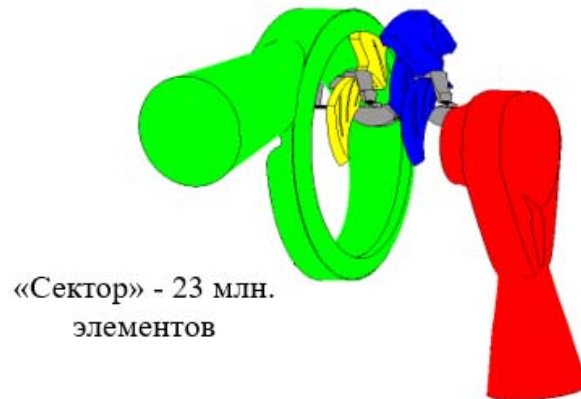
Parameter: centrifugal compressor characteristic for natural gas with the surge region indication.



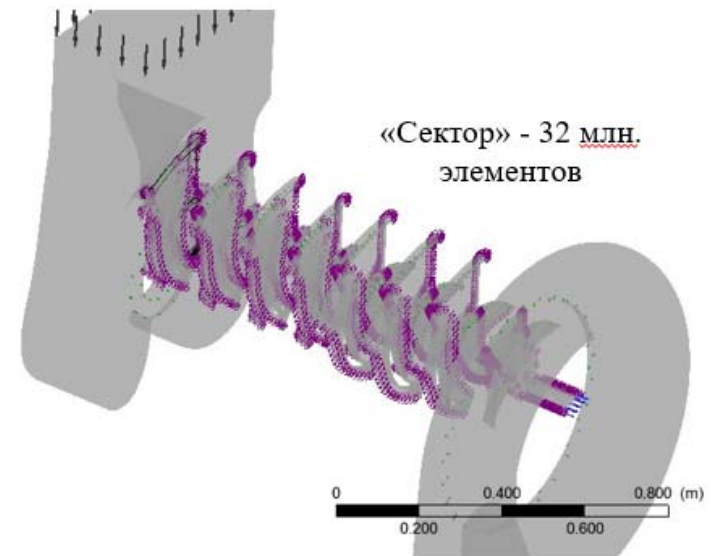
WORK EXAMPLES:

The CVRE department actively uses modern software packages like: Ansys, Ansys VISTA CCD (centrifugal compressor design), AFD (axial compressor design), NUMECA, COMSOL, NREC, IOSO, and also its own software packages which are designed at the department.

Multistage centrifugal compressor

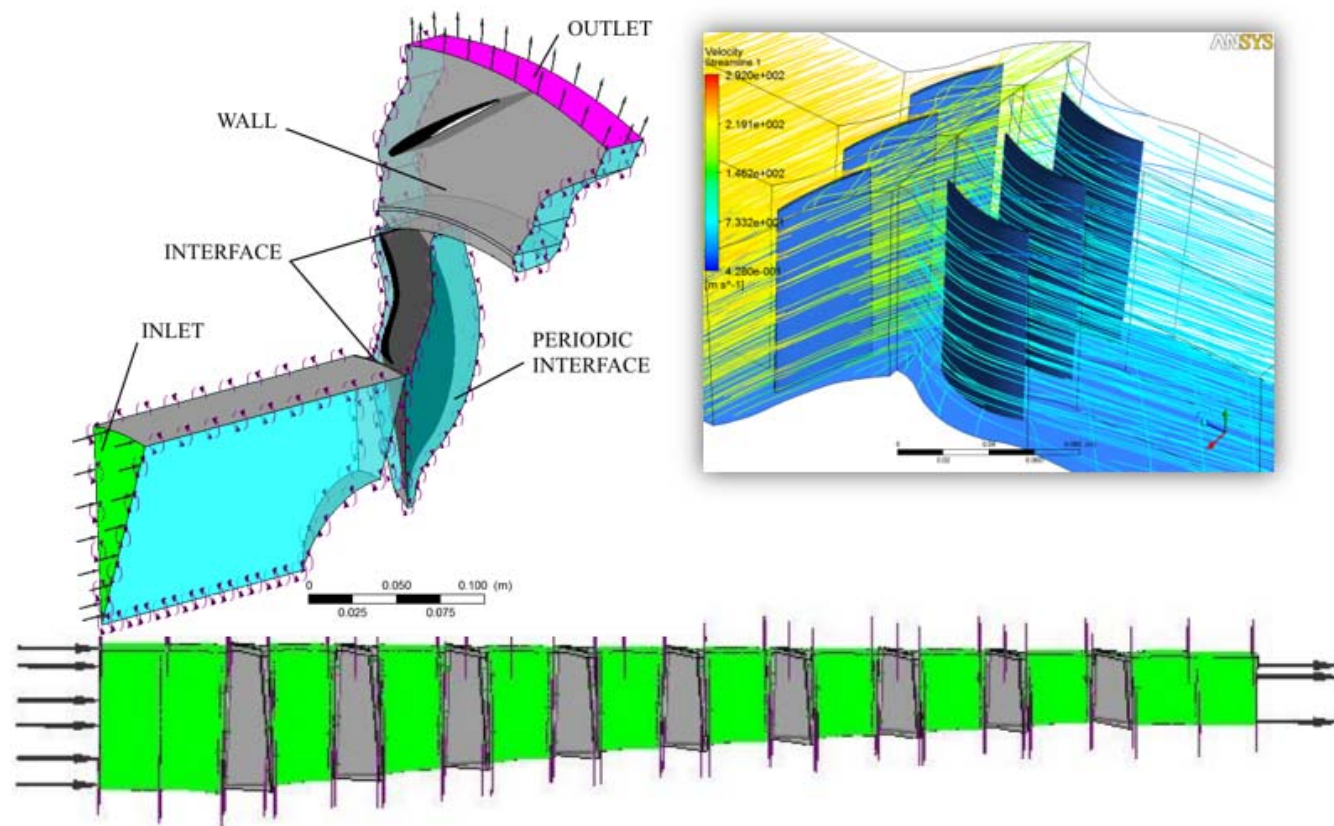


8-staged centrifugal compressor

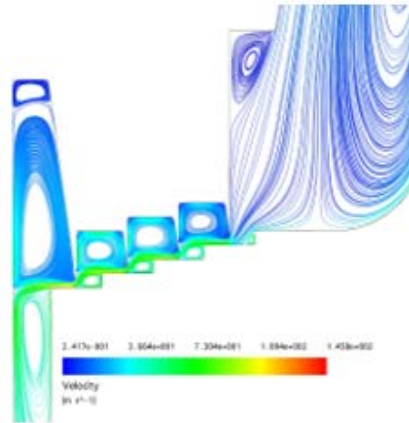


WORK EXAMPLES:

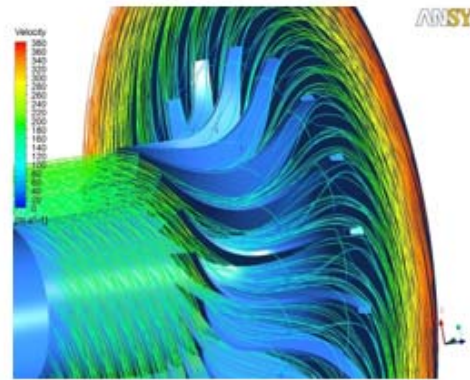
All numerical works which are made at the department CVRE are based on our own model experiments (more than 350). Calculation in software packages are being made with achieved results validation.



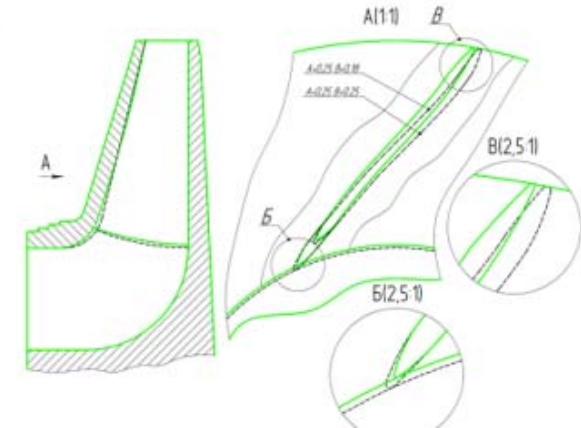
WORK EXAMPLES:



Gas movement at the gap between the top disk of the impeller and the stator and also at the lab seal.



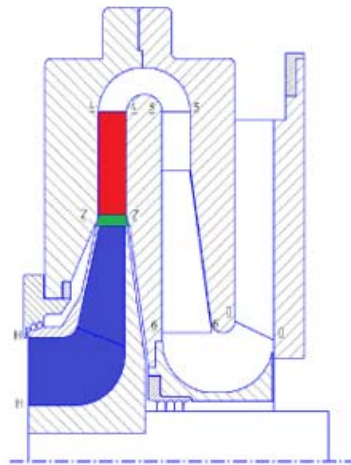
Flow structure at the axial-radial impeller: streamlines and speed values at relative motion.



Automatic multivariable optimization of the impeller form

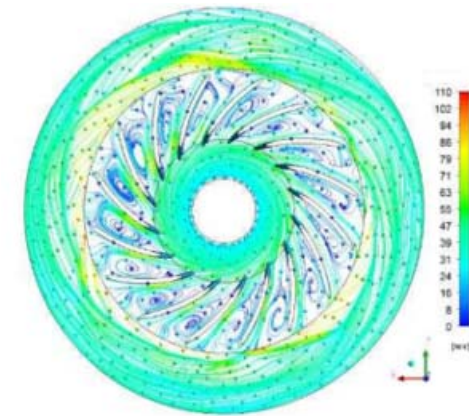
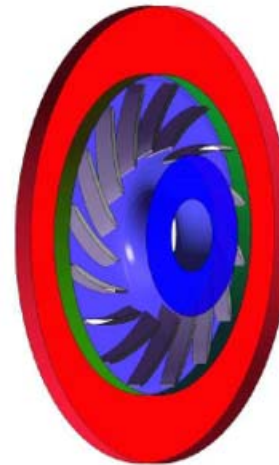
WORK EXAMPLES:

Unsteady tasks solving
URANS SST and LES

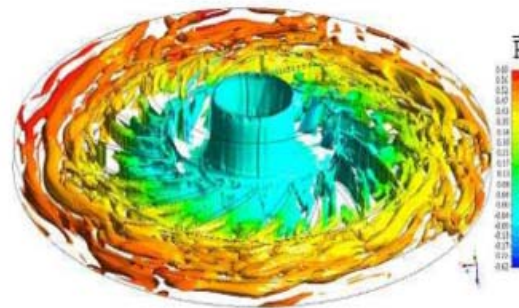


« 2π » simulation

30,2 mln elements for numerical
model of the impeller and the diffuser



Velocity streamlines (MT:LES)



3D static pressure field at the stall
mode (MT:LES)

Stall – calculations duration – LES
and SST – 8-11 days

AMD OPTERON 280
LES, SST: 24 cores; 24 Gb. RAM



FURTHER EDUCATION COURSES WITH THE CERTIFICATE WITHDRAWAL IN THE FIELD OF COMPRESSOR ENGINEERING AND PNEUMOSYSTEMS

Program examples:

- Compressor engineering general and advanced modules;
- Turbocompressors, general and advanced modules;
- Plate-rotational compressors, general and advanced modules
- And others
- 14 designed programmes
- It is possible to make the program according to the customer's specificity.



NEW POWER OF SPbPU

New cluster-based complex “Polytekhnik” started up in 2015,
Top №3 CIS:

1) **Top №3 CIS: Linpack: 658.11 Tflop/s; 19 936 cores.**

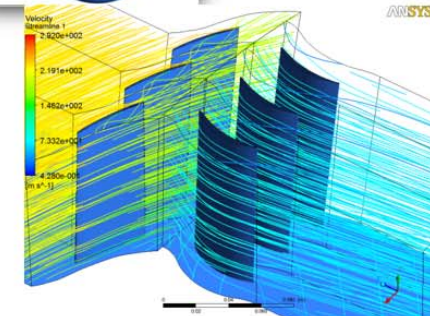
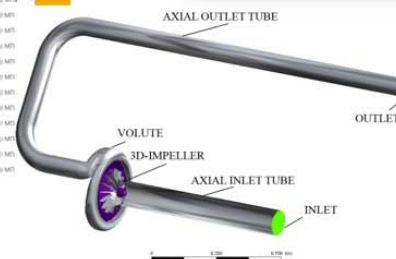
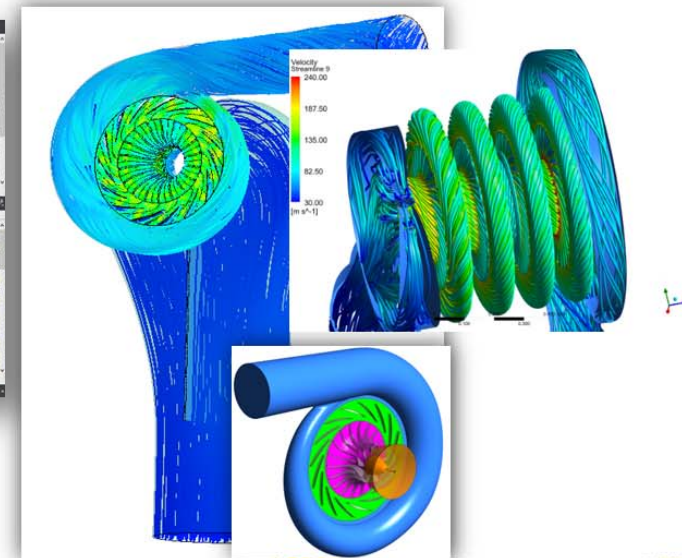
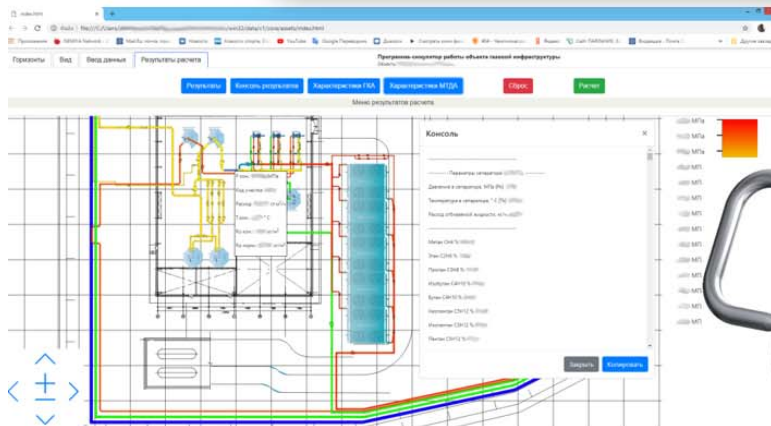
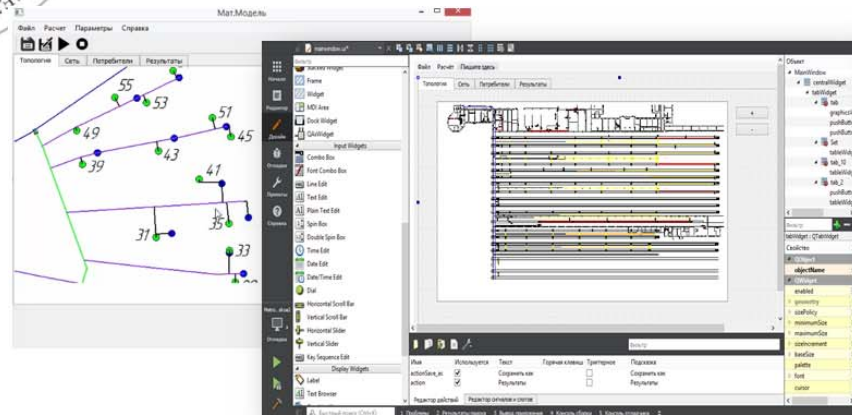
Units: 712 (2 x Xeon E5-2697v3 2.6 GHz 64 MB RAM).

2) **Top №8 CIS: Linpack: 165 Tflop/s; 17 280 cores.**

Units: 288 (Acc: Xeon Phi 5120D 1.053 GHz 8 GB RAM). Started up in 2014.



TWINS FROM INDUSTRIAL NETWORKS TO SPECIFIC UNITS





Thank you for your attention!

Department of “Compressor vacuum and refrigeration engineering”

Kozhukhov Yuriy Vladimirovich, tel. +7 (921) 5678-4-91

Kartashov Sergei Vladimirovich, tel. +7 (950) 005-98-90

WWW.KVIHT.RU

