# IOSO NM Optimization Software

IOSO is a universal technology and software that can be applied to the whole variety of Industrial and Engineering tasks in different fields.

Successful applications in modern Industry are the only proof of any technology's usefulness and efficiency.

## Aerospace Application

www.iosotech.com

# Multi-objective 3D Fan Optimization

**IOSO software was used by the joint team of engineers of SATURN Russia and Snecma France in designing a new Engine for the SUKHOY SUPERJET Aircraft.**

**In particular, IOSO was applied to ensure the maximum efficiency of the Engine Fan and minimum stresses in its blades, by finding optimal geometry of the fan blade.**

**The goal: to reduce the blade stresses by varying the geometry of the blade while efficiency of the fan should not worsen**

- Stress application is **FEA 3D Commercial Code,** CFD application is **CFD 3D Commercial Code**
- Geometry of the blade is described by 7 - 30 design variables
- There are 5 criteria to minimize: maximum stresses in the blade and displacements of blades under flow pressure (Multi-objective Optimization with 5 objectives)
- Nonlinear constraints: some constructional parameters of the blade and aerodynamic characteristics of the fan

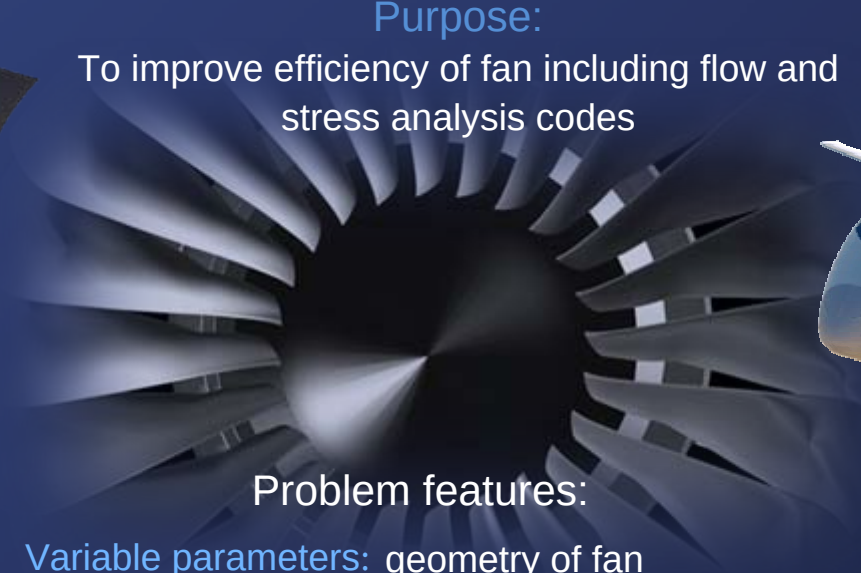
Slide 3 shows parameters of the task as a whole

**Results:** by comparison with the starting position, different stress criteria during the optimization were minimized within the bounds of 9 to 56 percents, in particular the maximum blade stress was reduced by 18 percents. (slide 5).

Publications:

1. Kuzmenko M.L., Egorov I.N., Shmotin Yu. N. “Increasing of Fan Efficiency basing on Optimization Technology”, 17th International Symposium on Airbreathing Engines – ISABE 2005, Munich, Gemany, September 4-9, 2005.
2. Kuzmenko M.L., Egorov I.N., Shmotin Yu. N. “Axial Fan Optimization Using 3D Codes”, Conference ASME Turbo Expo 2005, Reno, Nevada, USA, June 6-9, 2005.

# Multi-objective 3D Fan Optimization



## Purpose:

To improve efficiency of fan including flow and stress analysis codes


## Problem features:

Variable parameters: geometry of fan

( 3D, total 7 design variables)

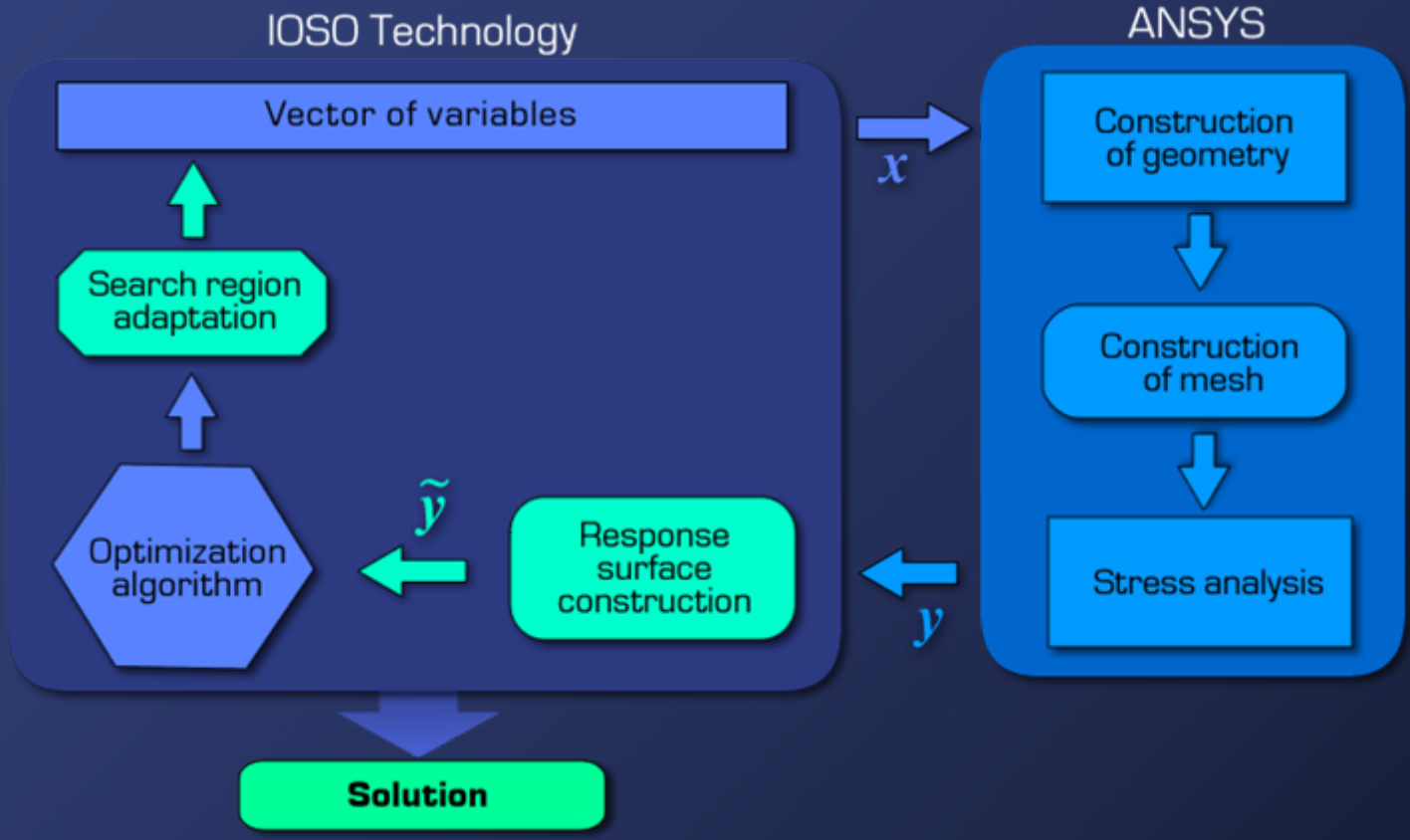
Objectives: efficiency and stress criteria

Constraints: Parameters of flow and Stress

Analysis codes: 3D FEA Commercial Code

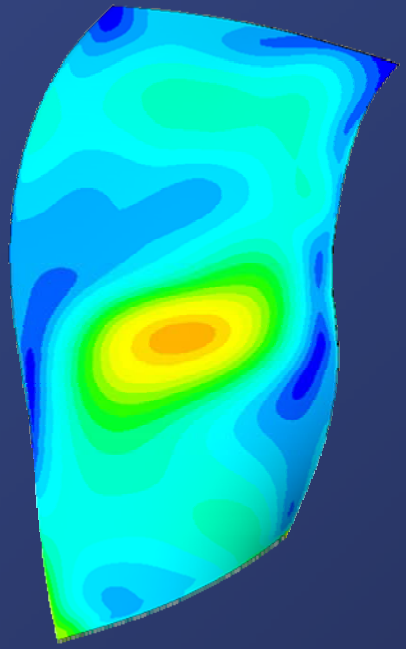
# Optimization of 3 Stage axial fan

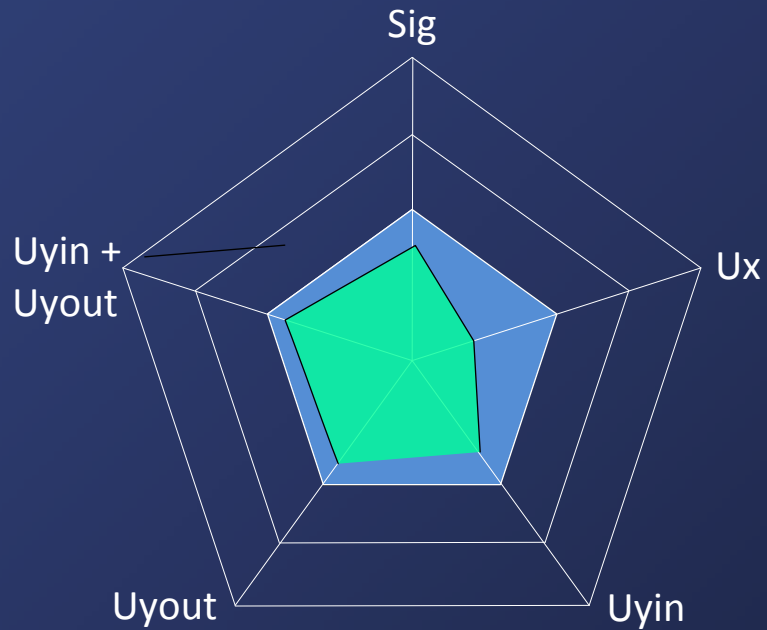
IOSO Software is easily integrated with different CAE software and makes it possible to find optimal solutions of problems through automatic optimization cycle.



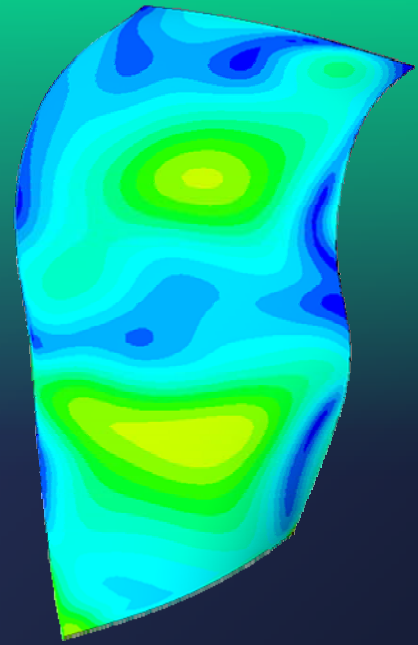
# Multi-objective 3D Fan Optimization

INITIAL STATE






OPTIMIZED



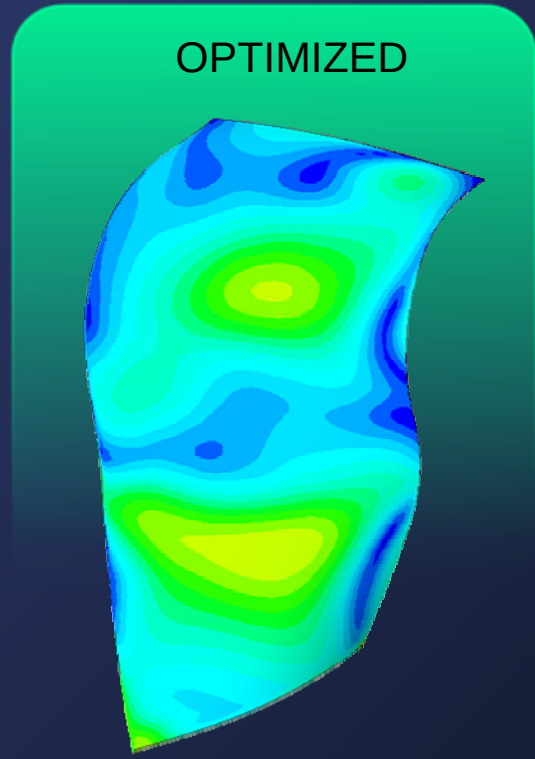
## Main results

The solution, that shows the improvements of initial object
(only 22 calls of analysis codes )

Improvements of individual objectives are from **9**% till **56**%.

# Multi-objective 3D Fan Optimization

Here is the 3D geometry of the Fan.



# Multi-objective 3D Fan Optimization

**The goal: to improve the aerodynamic efficiency of the fan by varying the geometry of the fan blade**

- CFD application is **3D CFD Commercial Code**
- The geometry of the blade was described by 36 design variables
- Single criterion Optimization task
- Nonlinear constraints: some constructional parameters of the blade and aerodynamic characteristics of the fan (absolute total pressure ratio and flow rate should not change – slide 9)

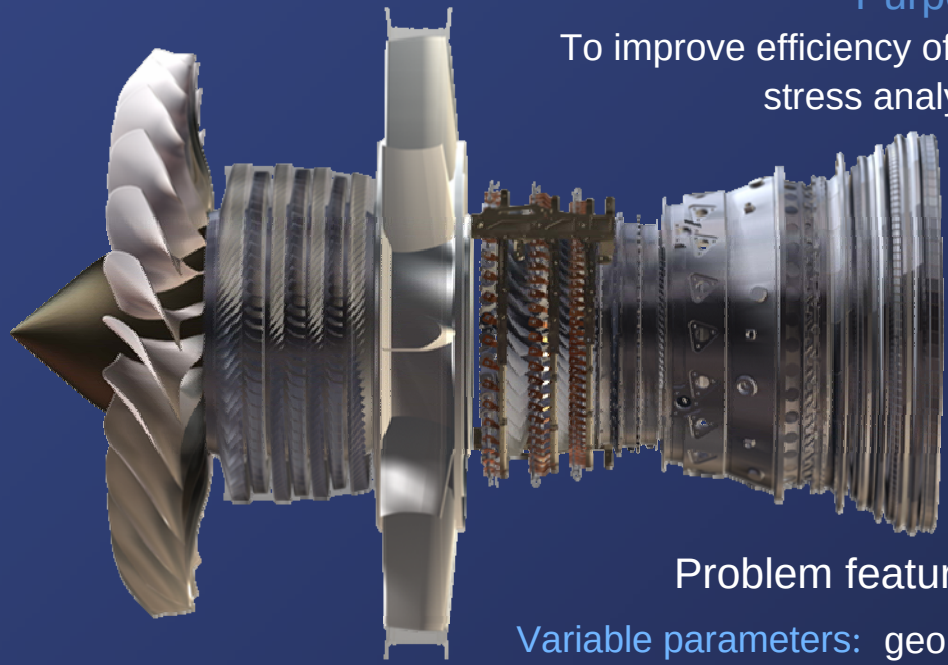
Slide 8 shows parameters of the task as a whole

**Results:** by comparison with the starting position, the efficiency was improved by **1.5%** - slide 12

Publications:

1. Kuzmenko M.L., Egorov I.N., Shmotin Yu. N. “Increasing of Fan Efficiency basing on Optimization Technology”, 17th International Symposium on Airbreathing Engines – ISABE 2005, Munich, Gemany, September 4-9, 2005.
2. Kuzmenko M.L., Egorov I.N., Shmotin Yu. N. “Axial Fan Optimization Using 3D Codes”, Conference ASME Turbo Expo 2005, Reno, Nevada, USA, June 6-9, 2005.

# Multi-objective 3D Fan Optimization



## Purpose:

To improve efficiency of fan including flow and stress analysis codes


## Problem features:

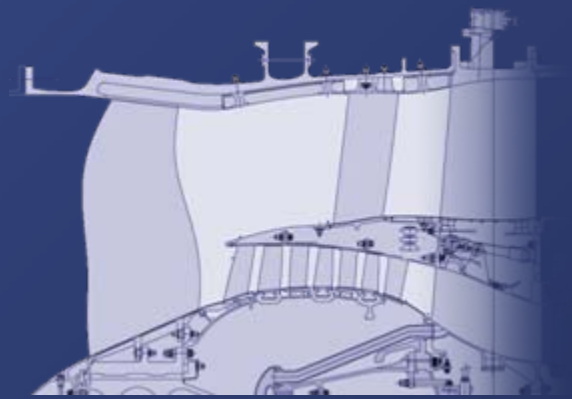
**Variable parameters:** geometry of fan
( 3D, total 36 design variables)

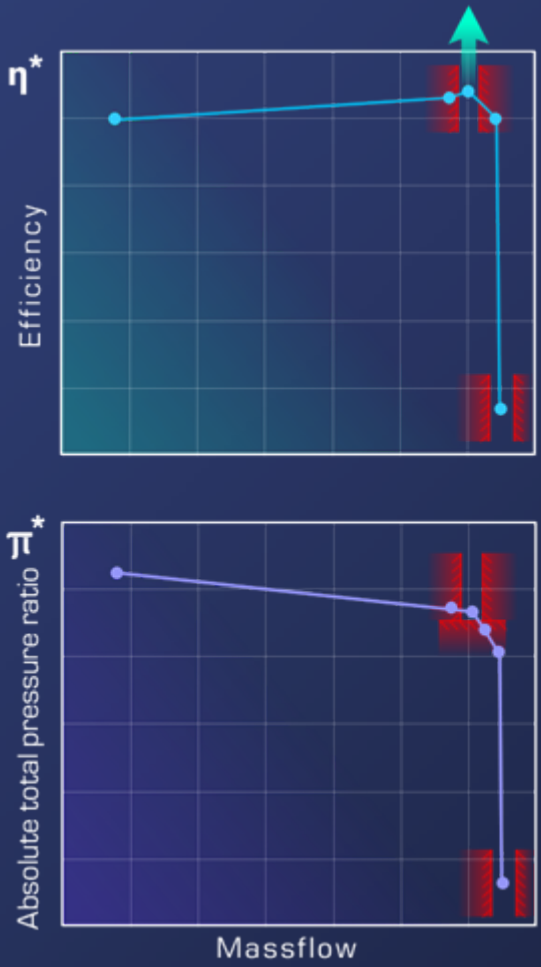
**Objectives:** efficiency

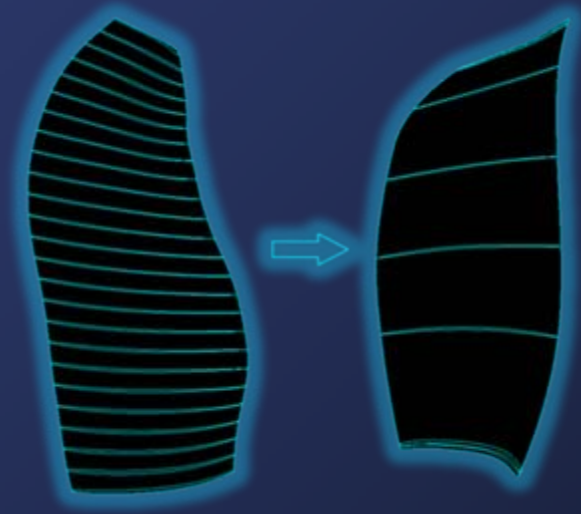
**Constraints:** parameters of flow

**Analysis codes:** 3D CFD Commercial code

# 3D CFD Code & IOSO Technology





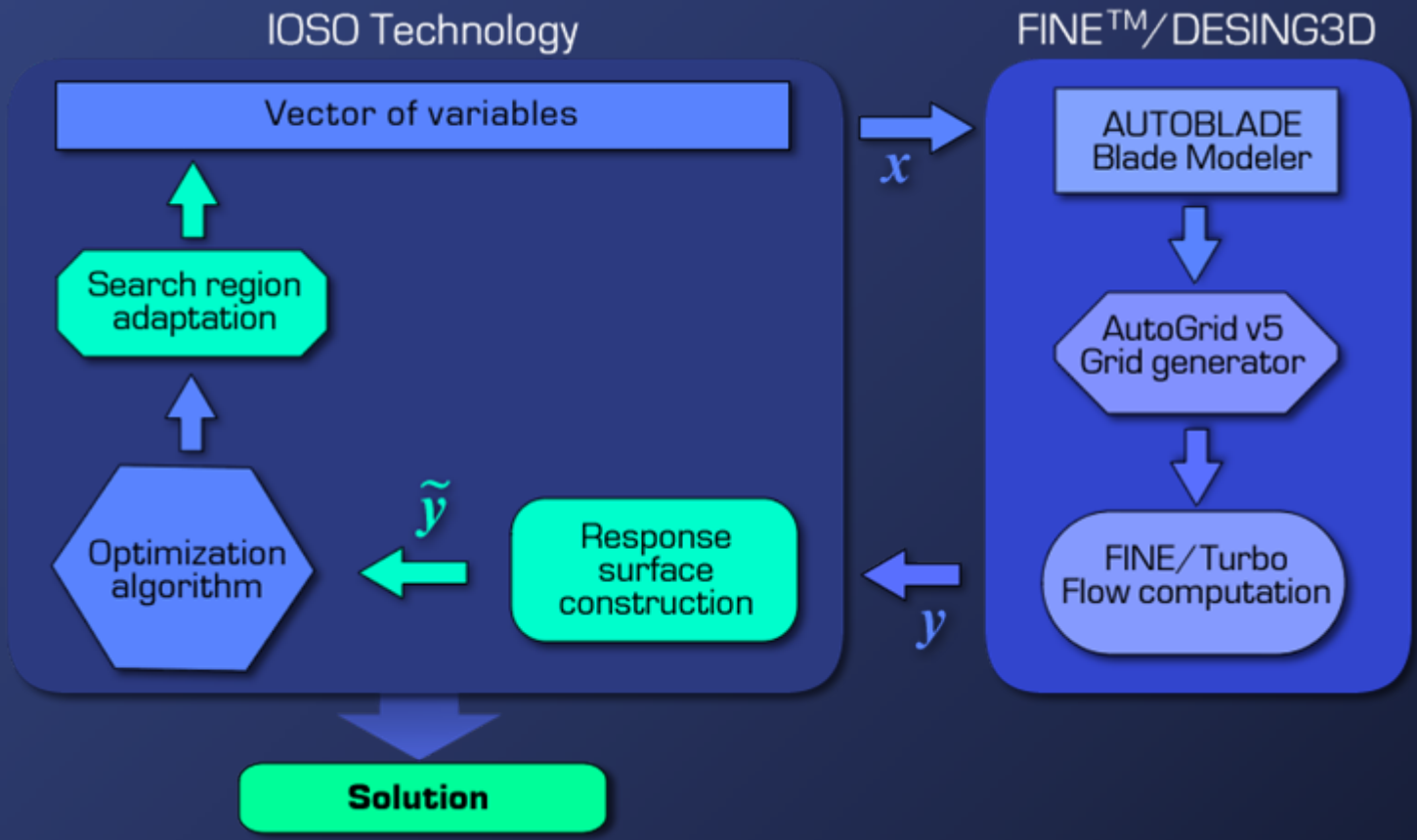
## The features

This way of blade geometry parameterization leads to:

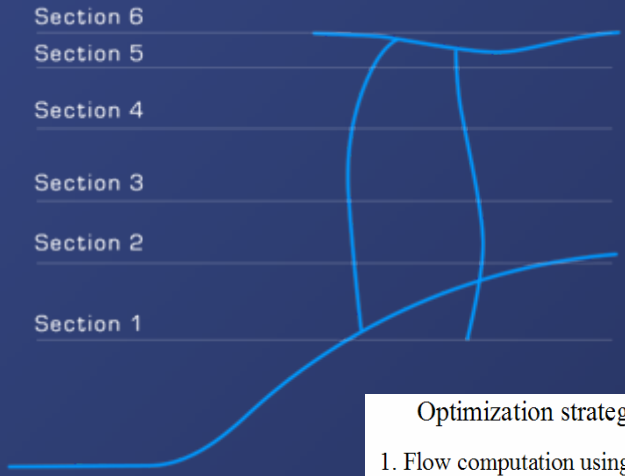
*+ low number of variables, symmetric profile, easier blade manufacturing*

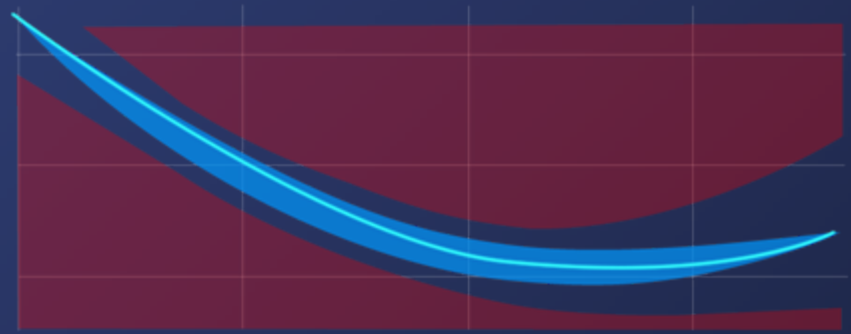
*- the initial shape of the fan blade can not be parameterized (efficiency and pressure ratio are reduced by 1,5-3% )*

# Optimization of 3 Stage axial fan



# 3D CFD Code & IOSO Technology



Optimization strategy using 3D-CFD

1. Flow computation using bad grid with subsequent verification of the solution using fine grid of 3D-CFD

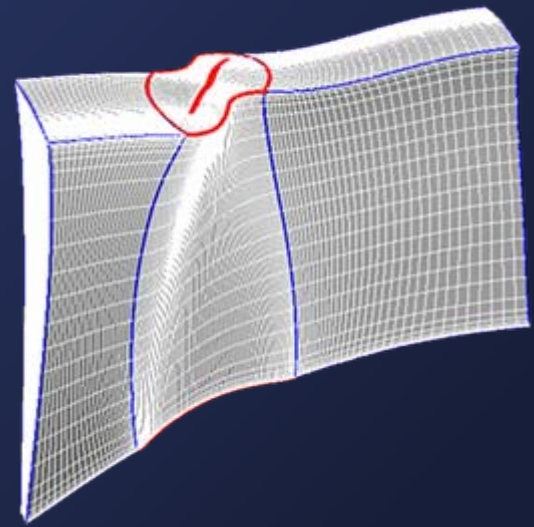
*+ relatively low time expenditures (3hours.- P IV 3.0 GHz), minimum CPU resources, fast result obtaining*

*- pre-defined constraints can be violated, final solution must be verified using fine grid.*

2. Usage of fine grid only for 3D-CFD

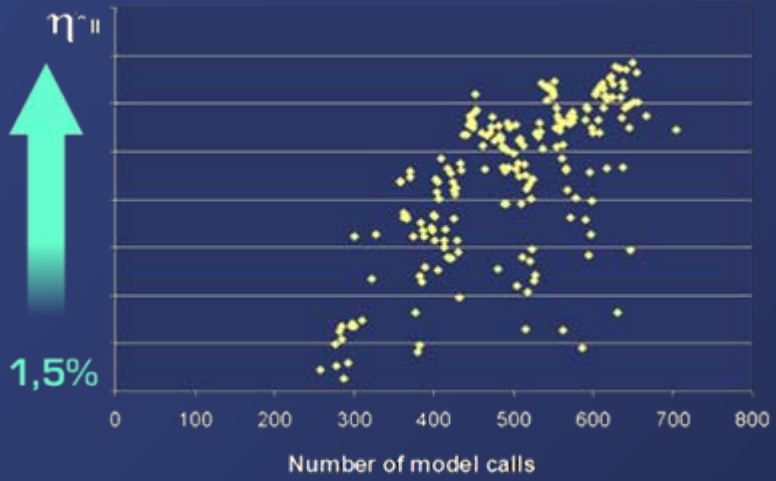
*+ constraints are reliably satisfied, the obtained result is considered as final one*

*- large computation time (9hours. - P IV 3.0 GHz), enormous CPU resources*

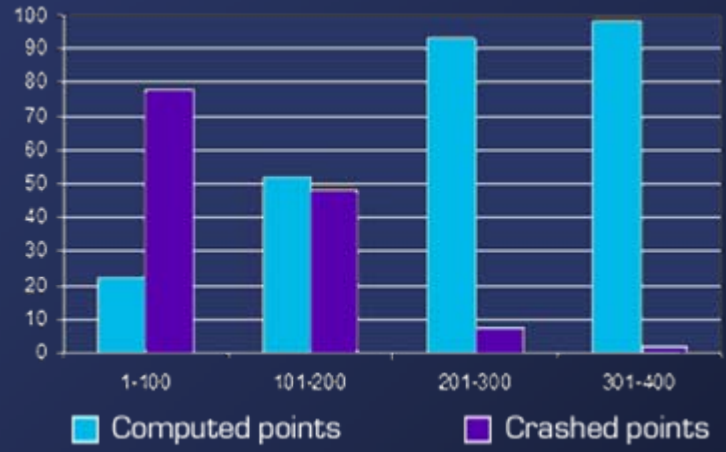


# Optimization of 3 Stage axial fan

Solving the task using bad grid for 3D/CFD




Dynamics of 3D/CFD
module stability while solving



# Optimization of 3 Stage axial fan

This is a task of the multiobjective fan optimization. The objectives were to identify the geometry of the blade of the fan so as to enable maximum aerodynamic efficiency in cruise mode and in design mode simultaneously.

**The goal: to improve the aerodynamic efficiency of the stage at speeds 100% and 80% simultaneously by varying the geometry of the fan blade**

- CFD application is **3D CFD Commercial Code**
- The geometry of the blade is described by 36 design variables
- Multi-Objective Optimization task
- Nonlinear constraints: some constructional parameters of the blade and aerodynamic characteristics of the fan (absolute total pressure ratio and flow rate should not change – slide 14)

Slide 14 shows parameters of the task as a whole

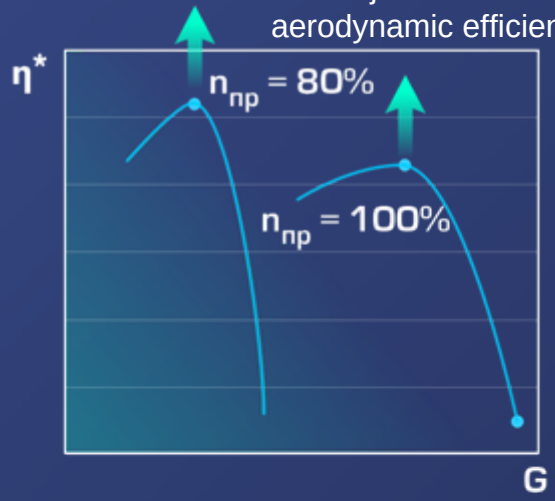
**Results:** slides 16 – 18; Maximum efficiency improvement at 100% speed regime – 5.4%, at 80% - 4.5%; at two regimes simultaneously – 3.2% and 4.3%

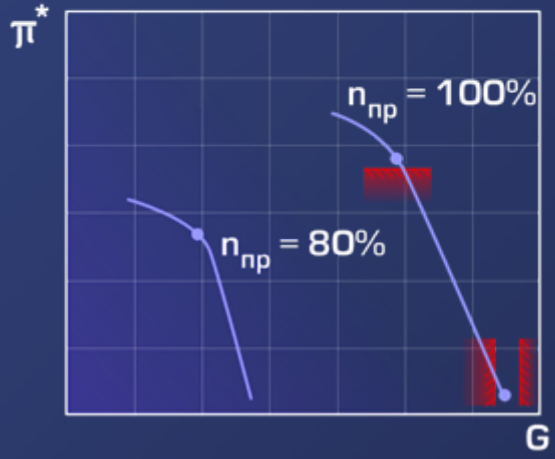
Publications:

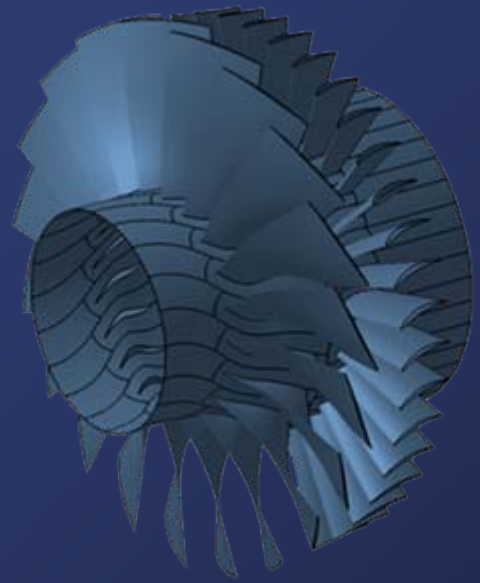
1. Kuzmenko M.L., Egorov I.N., Shmotin Yu. N., Chupin P.V., Fedechkin K.S. “Multistage axial flow compressor optimization using 3D CFD code”, 6th ASMO UK/ISSMO conference on Engineering Design Optimization, Oxford, UK, 3-4 July, 2006.

# Optimization of 3 Stage axial fan

The objectives were to identify the geometry of the blade of the fan so as to enable maximum aerodynamic efficiency in cruise mode (80%) and in design (100%) mode simultaneously.



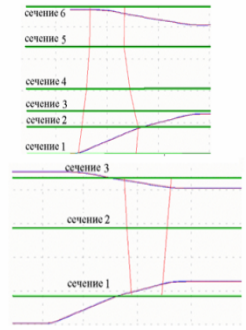
## Problem features

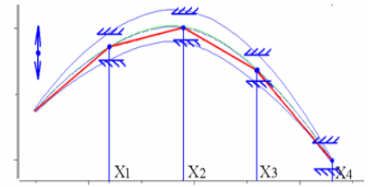
***Problem features:***

**Objective:** improving Efficiency at speed 100% and 80% in the point of max Efficiency

**Constraints :** total pressure, mass flow, outlet angles

**Model:** Fine/Design3D, calculation of 3 point for each speed of performance map




**36 design variables**

# Optimization of 3 Stage axial fan

As a result, efficiencies were increased by 3.2% and 4.3% simultaneously.

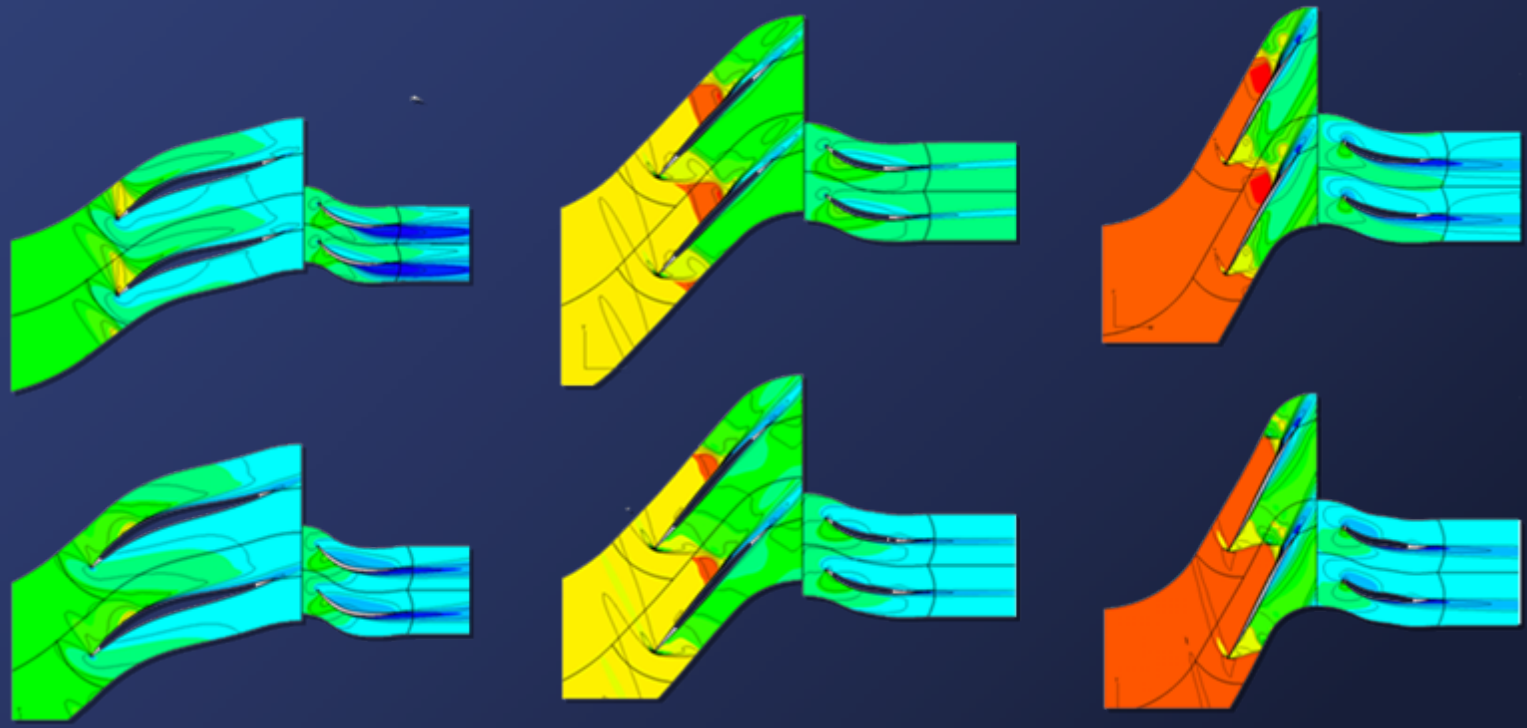
# Optimization of 3 Stage axial fan

Here are several pictures of the results.

Speed 100%

Initial

Optimized

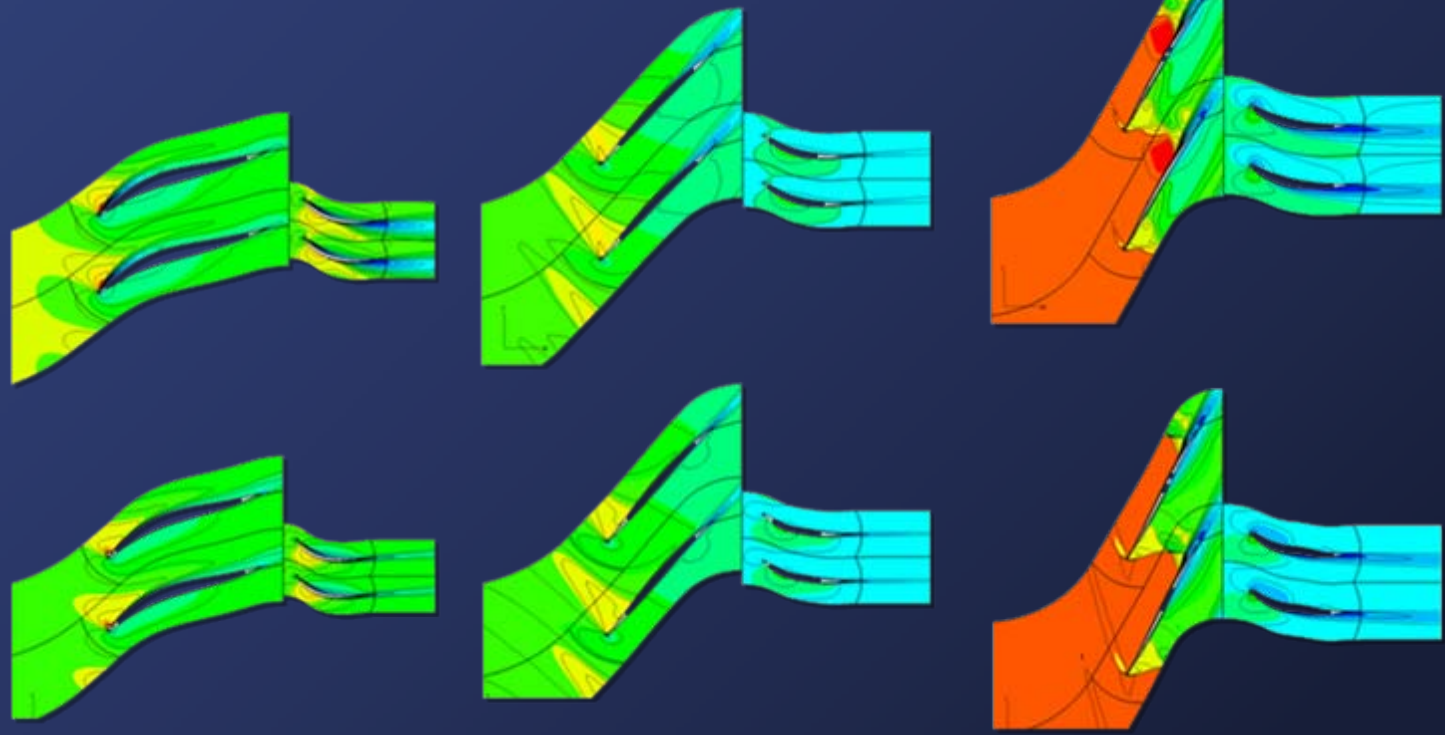


# Optimization of 3 Stage axial fan

Speed 80%

Initial

Optimized



# Multidisciplinary optimization of Fan (3D FEA + 3D CFD) & IOSO Technology

**The goal: to find the optimal geometry of the fan blade ensuring minimum blade stress and maximum fan efficiency**

- Stress application is **FEA 3D Commercial Code**, CFD application is **CFD 3D Commercial Code**
- The geometry of the blade is described by 7 design variables
- There are 2 criteria to optimize: minimization of maximum stress in the blade and maximization of the fan efficiency (multi-objective Optimization with 2 objectives)
- Nonlinear constraints: some constructional parameters of the blade and aerodynamic characteristics of the fan

Slide 20 shows parameters of the task as a whole

**Results:** slide 22 - 23; by comparison with the starting position, the blade stress was decreased by 1.2% and the fan efficiency was increased by 1.5%

Publications:

1.Kuzmenko M.L., Egorov I.N., Shmotin Yu. N., Chupin P.V., Fedechkin K.S. “Multistage axial flow compressor optimization using 3D CFD code”, 6th ASMO UK/ISSMO conference on Engineering Design Optimization, Oxford, UK, 3-4 July, 2006.
2.Kuzmenko M.L., Egorov I.N., Shmotin Yu. N., Chupin P.V., Fedechkin K.S. “Multistage axial flow compressor optimization using 3D CFD code”, 11th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference, Portsmouth, Virginia, USA, 6-8 September, 2006.
3.Kuzmenko M.L., Egorov I.N., Shmotin Yu. N., Fedechkin K.S. “Optimization of the Gas Turbine Engine Parts Using Method of the Numerical Optimization”, Conference ASME Turbo Expo 2007, GT-2007-28205.Barselona,Spain,May,2007.

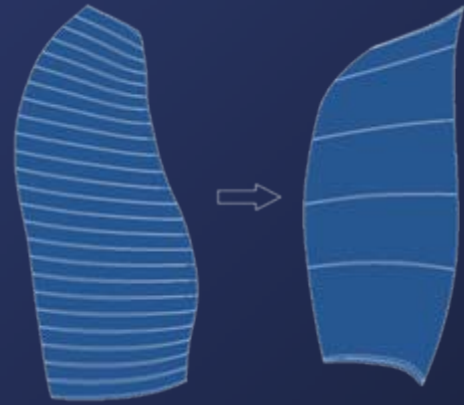
# Multidisciplinary optimization of Fan (3D FEA + 3D CFD) & IOSO Technology

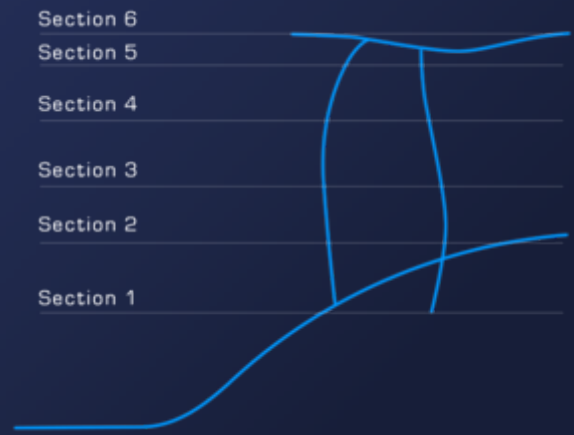
**Problem #1 (Stress-ANSYS)**
Objective : minimization of stress
Design variables : geometry of blade (7 variables)
Constraints: not

**Problem #2 (CFD – 3DFINETM/Design)**
Objective : maximization of efficiency
Design variables : geometry of blade (7 variables)
Constraints: total pressure, mass flow

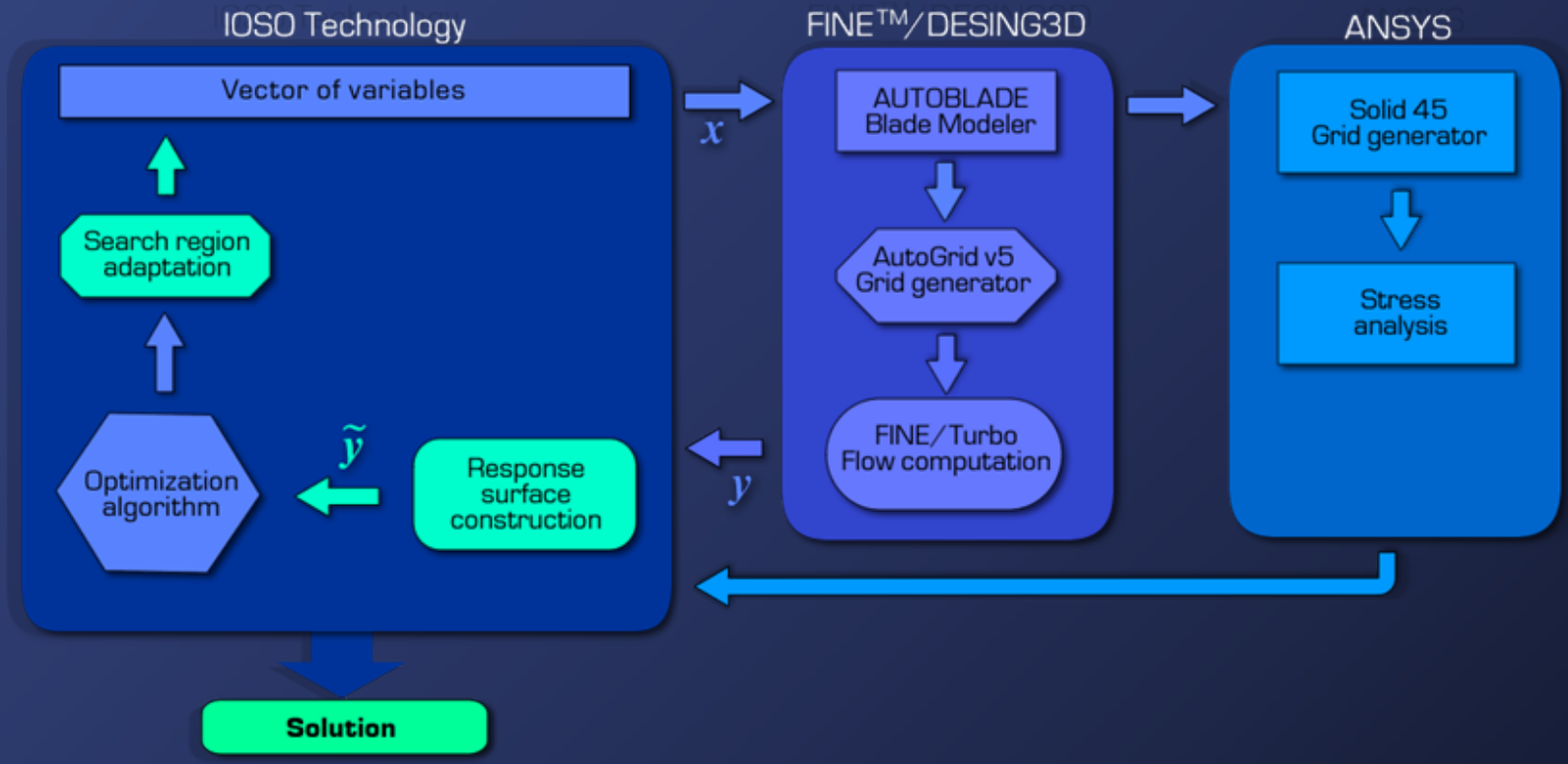
**Problem #3 (CFD+Stress – 3DFINETM/Design+ANSYS)**
Objective : maximization of efficiency and minimization of stress
Design variables : geometry of blade (7 variables)
Constraints: total pressure, mass flow

**Analysis codes:** Numeca Fine/Turbo, Sress3D.

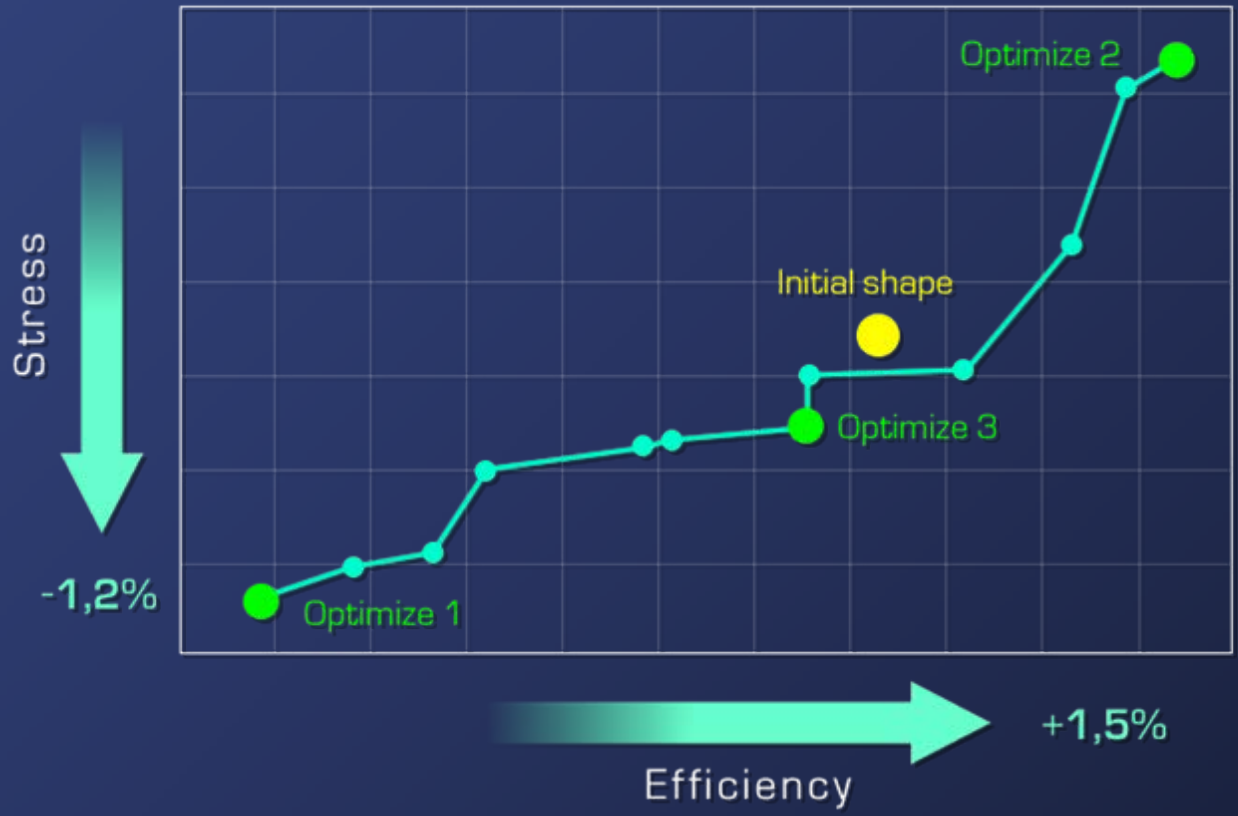




# Multidisciplinary optimization of Fan (3D FEA + 3D CFD) & IOSO Technology

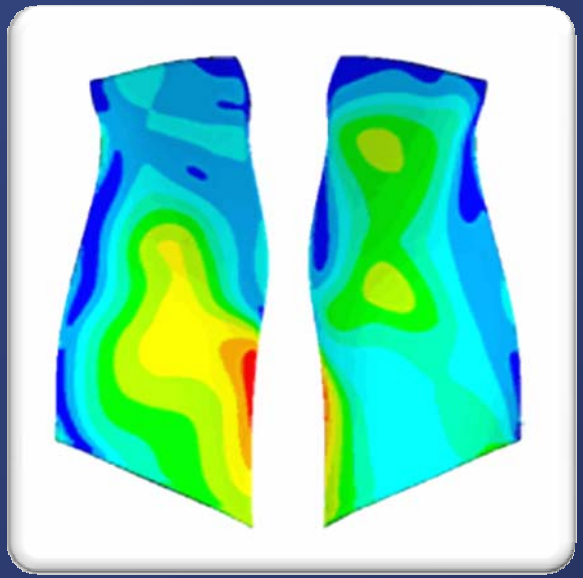


# Multidisciplinary optimization of Fan (3D FEA + 3D CFD) & IOSO Technology

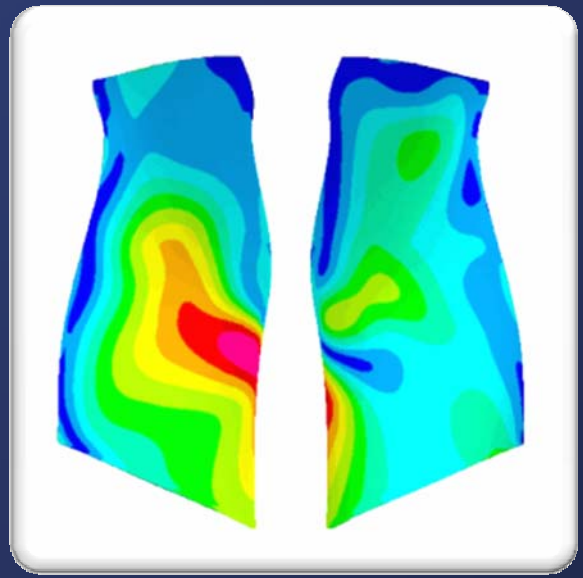


# Multidisciplinary Optimization of Fan

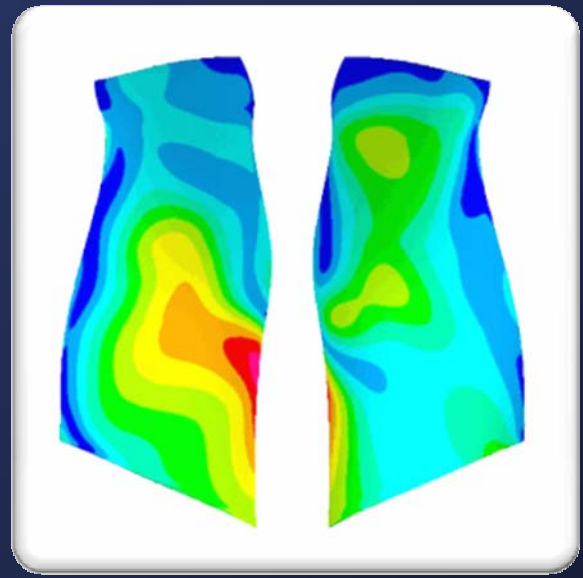
Optimized stress



Optimized efficiency



Optimized efficiency and stress



# Multi-objective 3D Fan Optimization

Here is a ready-to-use Fan after the manufacturing process is finished.

SaM 146 -
Russian-French aircraft engine


Sam 146 fan manufactured

Optimization allows to design and product new generation of SaM – 146 engine Fan with high level of efficiency

# Optimization of multistage axial fan

Improve the aerodynamic characteristics of a three-stage fan in cruise mode
Objective: To identify the geometry of the six blades of the fan so as to enable maximum aerodynamic efficiency in cruise mode, while maintaining the same (or better) efficiency in design mode and the same air consumption and sustainable operation time.

The 3D CFD code was used to identify the aerodynamic characteristics (21 hours are required for one iteration)
The geometry of the blades of the three-stage fan was described with 65 independent variables

Output: Total amount of iterations is 340. The increase in the aerodynamic efficiency of the fan amounted to 1.2%. There were involved 12 calculation nodes for solving the Parallel Optimization Task. Total time consumption was decreased more then 10 times in comparison with traditional approaches in optimization.

**No analogues of solving this problem have been published**

Slide 26 shows parameters of the task as a whole
**Results:** slide 27; by comparison with the starting position, the efficiency at speed 80% was managed to improve by 2.2% while the efficiency at speed 100% did not worsen

Literature:

1. Kuzmenko M.L., Egorov I.N., Shmotin Yu. N., Chupin P.V., Fedechkin K.S. “Multistage axial flow compressor optimization using 3D CFD code”, 6th ASMO UK/ISSMO conference on Engineering Design Optimization, Oxford, UK, 3-4 July, 2006.
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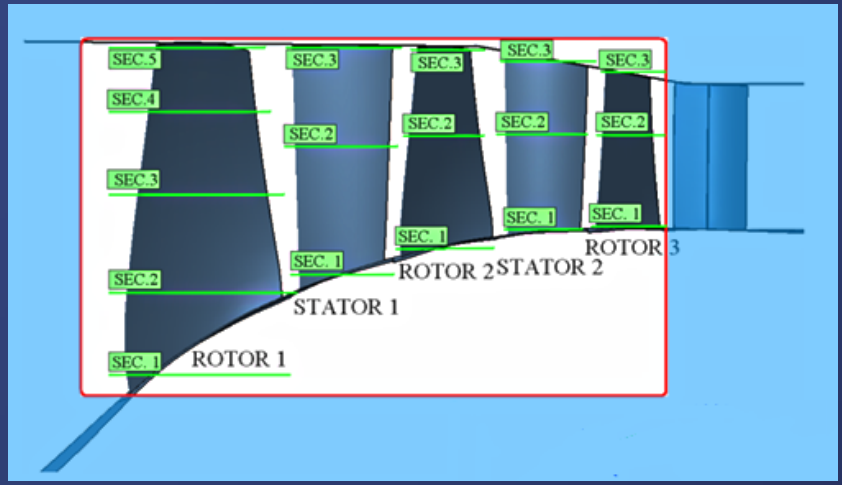
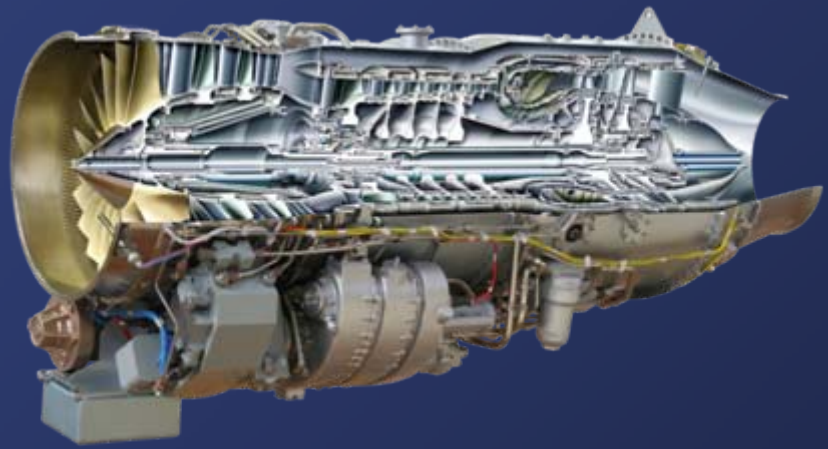
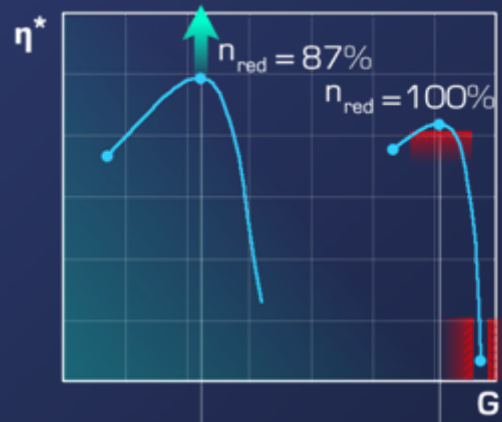
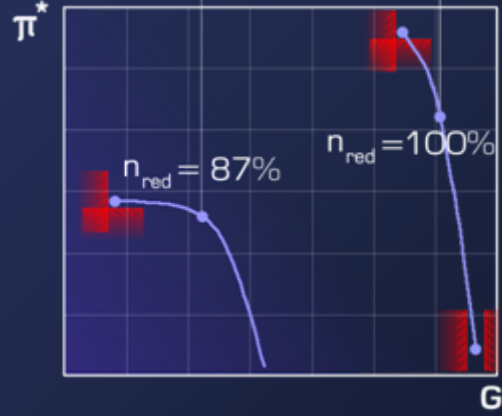
# Optimization of multistage axial fan



## Novel AL-55 engine



# Multidisciplinary Optimization of Fan