Electrozavodskaia St., 20,
Moscow, 107023, Russia
Phone/fax +7 (495) 788-1060
www.iosotech.com

Optimization of Turbine Disk aimed to Mass and Stress Reduction

INTRODUCTION

Modern computer technologies now allow us to conduct rather complex mathematical calculations in a relatively short period of time. Thus, it has become possible to employ optimization methods in the design of various parts of aircraft engines, even when calculations require large computational resources (structural, thermal, and gasdynamics calculations).

The designer may have to vary more than a hundred design variables and constraints during the optimization process. Therefore the procedure of preparing the initial data for optimization may take a long time. That is why we developed the optimization software system for designing turbomachines and their parts. This software system includes the IOSO optimization procedure and modules of automatic data preparation and handling. The data is represented in the format that is convenient and understandable for a designer.

This prospect presents the results of optimizing a real-life turbine disk. The optimization goals were to improve the disk stress characteristics and to reduce the mass of the disk.

This work is aimed to demonstrate the possibilities of IOSO optimization technique when used in combination with well-known commercial software application for the design of modern real-life objects.

OPTIMIZATION SOFTWARE FEATURES

The IOSO NM package is designed to solve complex problems of single- and multi-objective constrained and unconstrained optimization with various classes of objective function: smooth, non-differentiable, stochastic, with multiple optima, with the portions of the design space where objective function and constraints can not be evaluated at all, with the objective function and constraints dependent on mixed variables, etc. The optimization procedure is based on the response surface methodology, when response surfaces are constructed for objective functions and constraints and then optimized at each iteration in a current search region. The objective function and constraints are then evaluated at the optimal point using the mathematical model of the system under consideration. Algorithms of IOSO NM have good invariant features, high level of stability of calculation while optimization of complex objects; they also ensure search for extreme with presence of incompatibility areas. These features of the algorithms make it possible to expand substantially the classes of problems being successfully solved, facilitating the use of this software for complex real-life problems.

IOSO NM software works with executable modules or CAE applications representing the mathematical models. This facilitates significantly the customizing of the interaction between the user's model and the optimization procedure since IOSO NM does not require specific programming language to write the analysis code. Data exchange is provided by means of input/output text files, making it easy to integrate the analysis codes into IOSO NM package.

IOSO NM software has user friendly GUI and is simple to use. The software provides all necessary information to the user interactively. The parameters of IOSO optimization routine are either pre-programmed or adaptively changing during the search for extreme without the user's intervention. Most of the algorithm's tunings are being carried out internally, that is, they are "hidden" from the user. Hence, user is not required to have any knowledge of nonlinear programming or optimization procedures. The only important thing for the user is to understand the physics of the problem and to have a mathematical model of the investigated system. Creating an interface between IOSO and a mathematical model typically takes several minutes.

We have fulfilled numerical experiments to estimate the developed optimization method effectiveness. The testing consisted in solving a series of optimization problems, where various test functions were considered as the goal functions.

On smooth objective functions IOSO algorithm works not worse than gradient methods. However, for complex (and more probable to be faced in practice) object functions, having incompatibility areas, discontinuities, multiple extremes and noise, IOSO efficiency is being decreased insignificantly, while gradient methods are inapplicable for such task solutions and genetic algorithms require much more calculation time.

DISK OPTIMIZATION

Object under study

We chose the real-life turbine disk (Fig. 1) to investigate the possible ways of improving the modern disk characteristics and properties.

Fig 1 Real-life turbine disk geometry

STRUCTURAL TASK STATEMENT

As the structural analysis tool the well-known commercial software package ANSYS is used. Geometry parameterization and mesh generation are fully performed with ANSYS.

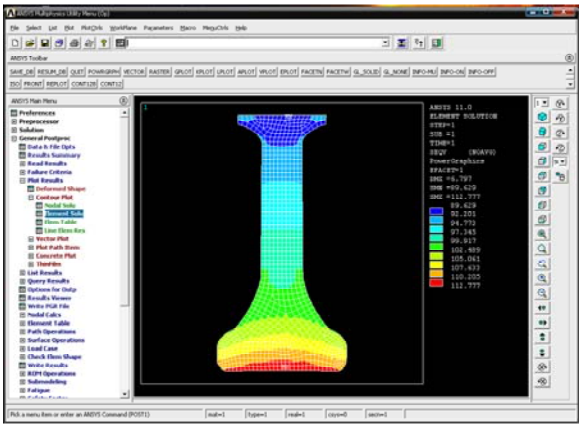

Fig 2 ANSYS Disk Model

OPTIMIZATION TASK STATEMENT

As the optimization variables geometrical parameters of the turbine disk are used.

As the objectives minimization of stresses and minimization of mass are used. From this point of view, this task represents a **multi-objective optimization problem**.

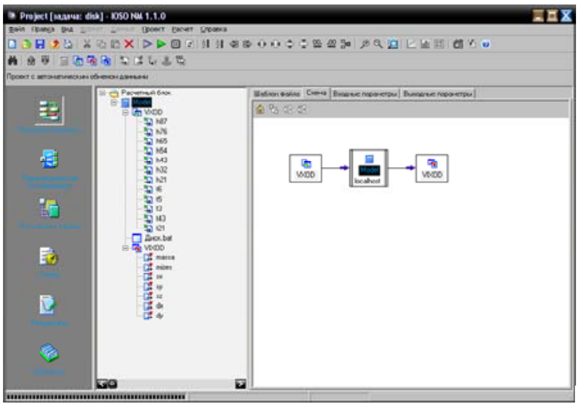

Fig 3 IOSO NM optimization project settings

Main Results

As a result, mass reduction up to 4.5% was achieved. It is considered as a very essential one taking into account that we operate in high-end technical field and optimize real-life objects.

Fig 4 and 5 show stress characteristics and properties of initial and optimized disks.

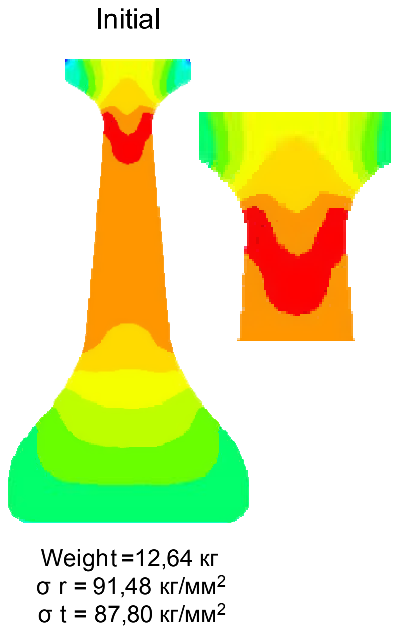

Fig 4 Initial prototype

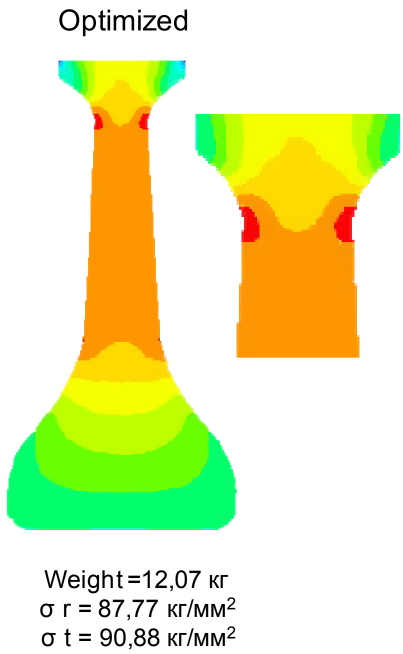

Fig 5 Optimized geometry