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Sam146 Fan Stress Characteristics Optimization by IOSO

ABSTRACT

Modern computer technologies allow conducting 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).

In this prospect we present a real-life problem. It is dealing with the search for the optimum geometry of the modern fan rotor. The goal of the research was to ensure the highest strength indices of the rotor. To accomplish this task we used the multi-objective approach (5 objectives). ANSYS software was used for structural analysis, while the search for the optimum solutions was carried out using the IOSO NM algorithm designed for parallel multi-objective optimization within the framework of IOSO Technology. **As a result, the improvement from 9% to 56% was obtained in all the strength indices compared to the prototype.**

INTRODUCTION

The design of modern compressors is a very complex task, since it takes into account a large number of efficiency parameters and constraints evaluated in various disciplines. An extensive use of modern numerical design methods combined with highly efficient optimization techniques, can substantially reduce the time and cost of the design.

In spite of the similarity to solving the problems of nonlinear programming, the optimization of compressors and its elements has its own specific features. First, due to contradictory requirements for the compressor, it is of practical interest to search for the extreme and compromise values of a set of efficiency factors: air flow, engine pressure ratio, gas-dynamic stability margin in different operation modes, various strength characteristics. From this point of view, optimization represents a **multi-objective problem**. When solving real-life tasks, designers usually pick up one or several of the most important efficiency characteristics. The solution is searched in a limited area defined by various gas-dynamic, kinematical, design, technological, etc. parameters. **This results in a single- or multi-criteria constrained optimization problem.**

Second, the optimization criteria and constraints in a particular problem are defined by the mathematical modeling of the compressor operation. In order for the results to have practical importance, the model has to describe processes with a required extent of adequacy and reliability. These days a number of various fidelity models are used: from simplified ones to those based on numerical calculation of Navier-Stokes three-dimensional equations (CFD codes) for flow analysis and finite-element codes for structural analysis.

Third, the geometry of modern compressors is usually developed in special CAD software and involves a large number of parameters. To perform an optimization process, the compressor geometry should be described by a minimal set of parameters (vectors of variables). It is necessary for the special procedures of compressor parameterization to be developed. The problem of optimizing compressor and its elements may have a large number of variables (since the researchers seek to achieve a maximum possible effect). **Today, for a multi-stage axial compressor the typical number of variables may be tens or even hundreds. The larger the number of variables in the optimization process, the more efficiency gain can be achieved.**

Fourth, problems of the compressors optimization may belong to several classes of problem (with smooth, non-differentiable, stochastic, etc. objective functions), when the topology of the objective function and constraints being unknown at the stage of the problem formulation. The best way of solving optimization tasks of various classes is nonlinear programming methods. **The problem of choosing an optimization technique is a difficult one.**

Fifth, obtaining an optimal solution may take a considerable amount of computational time (as much as several months). The time is directly linked with the level of the compressor simulation, with the number of variables in the optimization task, with the topology of the objective function, etc.

The purpose of this work is to demonstrate the capabilities of IOSO optimization technique when used in combination with well-known commercial software applications for the design of modern compressors. The distinctive feature of this task is presence of multiple –objective criteria.

OPTIMIZATION OF FAN STRENGTH CHARACTERISTICS

Problem statement

In this work an optimization of the static strength characteristics of a fan impeller was performed by offsetting the centers of gravity of the plane sections.

The task was to reduce the maximum values of the stresses and deformations in the fan blade when it is transferred to the "hot state". The values of the offsets of the main points of plane sections in 7 sections along the fan blade were selected as variables. The following optimization criteria were used (Figure 1):

- maximum stress value in the blade of the impeller (*Sig*);
- deformation in the radial direction (*Ux*);
- deformation in the tangential directions along the front and back edges (*Uyin, Uyout*);
- The extent of the "symmetry" of deformations along the front and back edges ($|Uyin + Uyout|$).

Thus, for the problem considered, there are 7 independent variables and 5 optimization criteria. In addition, 5 criterion constraints representing "non deterioration" of the criteria from the initial project are introduced.

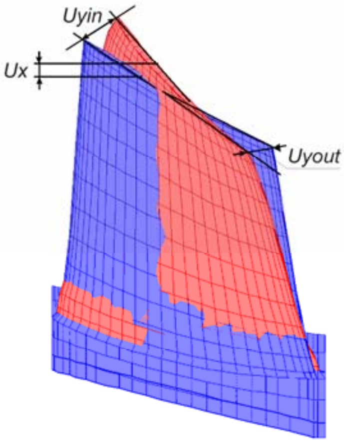

Fig. 1: Possible deformations in the radial and tangential directions

Main results

During optimization a total of three iterations of the parallel optimization algorithm of the IOSO technology were performed (6 calculations at the first iteration, and 8 calculations at the second and third iterations each).

It is important, from a mathematical point of view, for the solution of the multi-objective problem to be a set of Pareto-optimal projects, from which the designer can choose some compromise option. However, to obtain such a set a large number of calculations should be performed. When solving practical tasks the designers can interrupt the process of optimization if a desired compromise has been reached. In this case the project (Fig 2) met all desired requirements and was accepted to be optimal.

Thus, in the described case the solutions were obtained in as few as three iterations of the optimization process, with the total number of structural ANSYS code calculations being 22. This is an indication of the high efficiency of the IOSO optimization technique.

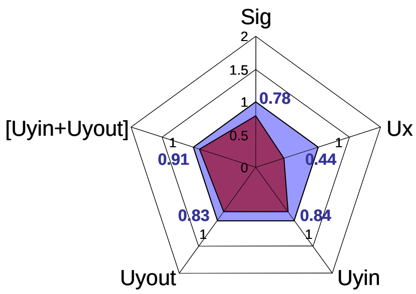

Fig. 2:

Optimal design criteria

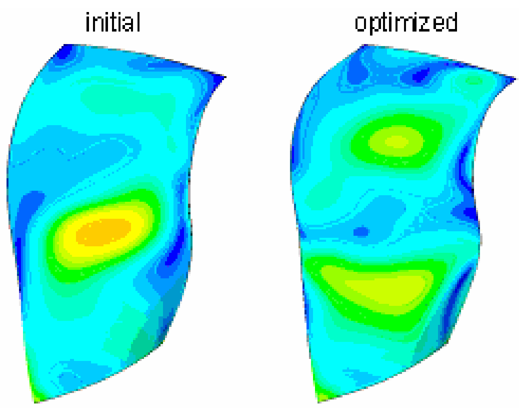

Fig. 3: Stress distribution in blades of the fan under optimization