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UTILITY OF STOCHASTIC METHODS IN SOLUTION OF PROBLEMS OF AERODYNAMIC OPTIMIZATION OF GAS-TURBINE ENGINE COMPRESSOR CASCADE SHAPE

The paper presents the response surfaces of the basic aerodynamic characteristics of compressor cascades (the turning flow angle and the total pressure loss coefficient) under selected flow conditions. The parametric description of the cascade profile shape is implemented using the original method based on Bezier curves and smooth convex Hicks-Henne functions. The calculation of the objective function is performed by simulating the flow on the basis of the numerical integration of the averaged Navier – Stokes equations closed by the one-parameter Spalart – Allmaras turbulence model. The complexity of the response surfaces of the basic compressor cascades aerodynamic characteristics is demonstrated resulting in difficult searching their extremes using deterministic methods of nonlinear programming. The aerodynamic optimization of compressor cascades is carried out using a deterministic approach, namely, the adjoint gradient method and a stochastic approach, namely, the genetic algorithm. It is shown that the gradient method under different initial conditions converges to the different objective function extremes resulting in an essential decrease in the advantages of its application to the solution of aerodynamic optimization problems. The effectiveness of the genetic algorithm in the sense of the number of the objective function calculations is higher than that of the gradient method with a multi-start option. Thus, the utility of stochastic methods to the solution of problems of aerodynamic optimization of compressor cascades is illustrated by a specific example.

Keywords: *compressor cascade, optimization of shape, aerodynamic characteristics, geometrical parameters of cascade, response surface, genetic algorithm.*

1. *Aulchenko S. M.* Optimization of profile cascades using variation and gradient method (in Russian) / *S. M. Aulchenko* // Teplofizika i Aeromekhanika. – 2005. – Vol. 12, No 3. – P. 357 – 363.
2. *Gallimore S. J.* Axial flow compressor design / *S. J. Gallimore* // Journal of Mechanical Engineering Science. – 1999. – Vol. 213, Issue 5. – P. 437 – 449.
3. *Calvert W. J.* Transonic Fan and Compressor Design / *W. J. Calvert, R. B. Ginder* // Journal of Mechanical Engineering Science. – 1999. – Vol. 213, Issue 5. – P. 419 – 436.
4. Design of industrial axial compressor blade sections for optimal range and performance / *F. Sieverding, M. Meyer, B. Ribi, M. Casey* // Journal of Turbomachinery. – 2004. – Vol. 126, N 2. – P. 323 – 331.
5. *Dickens T.* The design of highly loaded axial compressors / *T. Dickens, I. Day* // ASME Journal of Turbomachinery. – 2011. – Vol. 133, Issue 3. – P. 57 – 67.
6. *Massardo A.* Axial flow compressor design optimization Part I: Pitch line analysis and multi-variable objective function influence / *A. Massardo, A. Satta* // ASME Journal of Turbomachinery. – 1990. – Vol. 112. – P. 399 – 404.
7. *Sang-Yun Lee* Design optimization of axial flow compressor blades with three dimensional Navier-Stokes solver / *Sang-Yun Lee, Kwang-Yong Kim* // Journal of mechanical science and technology. – 2000. – Vol. 14, N 9. – P. 1005 – 1012.
8. *Farshi B.* Preliminary design optimization of axial compressors / *B. Farshi, R. Taghavi-Zenouz, S. Mirshamsi* // Iranian journal of Mechanical Engineering. – 2004. – Vol. 5, N 1. – P. 5 – 14.
9. *Lingen Chen* Optimum design of a subsonic axial flow compressor stage / *Lingen Chen, Fengrui Sun, Chih Wu* // Journal of Applied Energy. – 2005. – Vol. 80, Issue 2. – P. 187 – 195.
10. *Hoda Maleki* Design Optimization of Axial Flow Compressor Stage / *Hoda Maleki* // Atlas conference: Mathematical Problems in Engineering and Aerospace. – Italy, June, 2008. – 3 p.
11. *Lampart P.* 3D Shape Optimisation of Turbomachinery Blading / *P. Lampart, S. Yershov* // Task Quarterly. – 2002. – Vol. 6, N 1. – P. 113 – 125.
12. *Bamberger K.* Optimization of Axial Fans With Highly Swept Blades With Respect To Losses And Noise Reduction / *Konrad Bamberger, Thomas Carolus* // FAN 2012. – Senlis (France), 18 – 20 April, 2012. – 12 p.
13. *Bunimovich A. I.* Aerodynamic Characteristics of Flat Compressor Cascades at High Subsonic Speed (in Russian) / *A. I. Bunimovich, A. A. Svyatogorov* // Bladed Engines and Jet Devices. – Moscow : Mashinostroyenie, 1967. – Issue 2. – 97 p.
14. *Melashich S. V.* Technique for parametric describing profiles of compressor cascades (in Russian) / *S. V. Melashich* // Tekhnicheskaya Mekhanika. – 2012. – No 2. – P. 77 – 82.
15. *Himmelblau D.* Applied Nonlinear Programming (in Russian) / *D. Himmelblau.* – Moscow : Mir, 1975. – 536 p.
16. *Poli R.* A Field Guide to Genetic Programming / *R. Poli, W. B. Langdon, N. F. McPhee.* – Published via http://lulu.com, 2008. – 250 p. –http://www.lulu.com/items/volume_63/2167000/2167025/2/print/book.pdf
17. *Hicks R.* Wing Design by Numerical Optimization / *R. Hicks, P. Henne* // Journal of Aircraft. – 1978. – Vol. 15, N. 7. – P. 407 – 413.
18. *Spalart P. R.* A one-equation turbulence model for aerodynamic flow / *P. R. Spalart, S. R. Allmaras* // AIAA Paper. – 1992. – Vol. 12, No 1. – P. 439 – 478.