Amirkabir University of Technology
(Tehran Polytechnic)
Vol. 47, No. 1, Summer 2015, pp. 5- 7

Amirkabir Journal of Science & Research (Mechanical Engineering)
(AJSR - ME)

Introduction of an improved Harmony Search Optimization Algorithm for investigating of Airfoil Parameterization Methods and Aerodynamics optimization

F. Jalili[1*] , M. Malek-jafarian[2], A. Safavinejad[3]

1- MSc Student, Department of Mechanical Engineering, University of Birjand, Birjand,Iran
2- Assistant Professor, Department of Mechanical Engineering, University of Birjand, Birjand,Iran
3- Assistant Professor, Department of Mechanical Engineering, University of Birjand, Birjand,Iran

(Received 12 December, 2011, Accepted 10 March, 2015)

ABSTRACT

Utilizing an airfoil Parameterization method is one of the essential requirements for airfoils optimization. The selection of this method plays an important role, as using an unsuitable method yields the weak results. In addition, it will impose delay on convergence of the solution. Hence, in this work, an improved Harmony Search meta-heuristic optimization algorithm has been developed for investigating three common airfoil parameterization methods (Bezier curves, Parces method and 4-digit-NACA formula) using an inverse optimization design and a non-aerodynamics objective function. The obtained results show that the Bezier curves and Parces method are more efficient than 4-digit-NACA formula. Finally, because of having few control parameters, the Parces method has been used along with an improved Harmony Search algorithm for the shape optimization of an airfoil under a viscose and turbulent flow, with the objective of maximizing lift to drag ratio. To do this, 2-dimentional compressible Navier-Stokes equations with Spalart-Allmaras turbulent method have been solved around the airfoil. The results reveal that the improved optimization algorithm is highly capable of evaluating the airfoil parameterization methods and aerodynamics optimization.

KEYWORDS

Aerodynamics Optimization, Evaluation of Airfoil Shape Parameterization Methods, Improved Harmony Search Meta-Heuristic Optimization Algorithm, Lift to Drag ratio, Navier-Stokes Equations.

* Corresponding Author, Email: f.jalili65@gmail.com

1- INTRODUCTION

The recent progress with the development of increasingly powerful computational fluid dynamics and computational techniques leads to considerable research on the optimum shape of airfoils (using different optimization methods and techniques describing different geometry). In this context , we can address the optimization of airfoils with the aim of maximizing the lift of an airfoil, minimizing the drag, maximum lift to drag ratio, flow separation control, control of transition to turbulent and etc. [3-1].

Harmony Search Algorithm, a non-gradient algorithm, is initially introduced by the Geem et al. [4]. Following the introduction of this algorithm, it has been employed mainly for the optimization of shell and tube exchangers using sensitivity analysis, economic optimization of a composite floor system and optimization of a fin geometry with convection and radiation heat transfer [5-7].

In the present work, a revision is used on the harmony search optimization algorithm which ultimately enhances the performance of the model. A comparison is made between the original algorithm and the modified algorithm (by applying it on various test functions). Additionally, the defined algorithm is employed as a comprehensive study to examine the ability of the conventional methods which describes the geometry of the airfoil (Bezier curves, Parces method and 4-digit-NACA formula). Next, the modified scheme along with the selected methods described above are utilized to inverse optimization technique. Finally, the direct optimization of the airfoil geometry is obtained with the aim of maximum amount of lift to drag ratio (for the first time in aerodynamics).

The results indicated that the use of a non-aerodynamic cost function in a reverse design is a very useful tool for the evaluation of the geometry of the studied airfoil. Therefore, this method can also be used to evaluate the other methods of describing the airfoil. The modified harmony search algorithm provides a powerful tool for inverse and direct optimization, with aerodynamic and non-aerodynamic cost functions.

2- METHODOLOGY

Bezier curves are one of the methods which introduce airfoil. In this method, a set of control points (Bezier points) are considered. Then, Bezier curve equation (a function of Bernstein Polynomials), that consists of the above points, will be introduced to produce the airfoil geometry. In the Parces method, airfoil is created by the 11 control parameters and the method will be able to control the geometry. In the 4-digit-NACA formula, airfoil geometry is generated and controlled with only 3 parameters and a polynomial of the order of 4.

The algorithm used in the present work is the harmony search (HS) optimization algorithm. Each solution is called a harmony in the HS algorithm and presented by an n-dimensional vector. First, an initial population is randomly generated and stored in the algorithm memory. Then, a new solution vector is provided randomly, based on the rule of memory consideration, a pitch adjustment and a random selection. Finally, the generated solution vector is compared with the worst answer existing in the Harmony Memory (HM). The best obtained answer is then replaced with the worst answer vector and the HM will update in this way. This process continues until the establishing a stop condition. According to the above mentioned, the HS algorithm has three main stages, which comprise initialization, improvement of a new harmony and updating of memory. In order to increase the efficiency of the harmony search algorithm, an amendment has been made.

To optimize the geometry of the airfoil, the flow is considered turbulent at transonic speeds. Therefore the flow equations are time-dependent compressible Navier-Stokes equations with Spalart-Allmaras turbulence model [8]. To numerically solve the governing equations, a numerical code is used. Discretization of the equations have been implemented using the finite volume method (central difference scheme), in this work. Explicit time integration has been made based on 4 stages of Runge-Kutta time stepping scheme. Scalar artificial dissipation scheme has been employed in the written code, to eliminate oscillations in the vicinity of shock waves. Due to the steady state flow field considered in this study, convergence acceleration techniques such as local time stepping and implicit residual averaging are used in the solution.

3- SIMULATION RESULTS

Figure (1) shows the direct aerodynamic optimization results of airfoil geometry which achieves the maximum lift to drag ratio (in terms of initial and optimum geometries). The Parces method has been used for the description of airfoil geometry. The Flow conditions are considered to be: viscous, turbulent and transonic flow with $Re_\infty = 6.5 \times 10^6$, $M_\infty = 0.734$ and angle of attack 2.79°.

Wall pressure coefficients distribution of the initial and optimized geometries is shown in Figure (2). As can be observed, the presence of relatively strong shock wave is evident around the initial airfoil (NACA0012) . While the shock wave strength is reduced and is diffused along with the optimal airfoil. In this optimization, the lift coefficient has been increased from 0.4316 to 0.517 and the drag coefficient decreased from 0.01868 to 0.01104. The results depict a relative increase of 19.79 percent of the lift coefficient and relative reduction of 69.13 percent in the drag coefficient. The cost function is the lift to drag ratio and its value has been increased from 27.95 to 46.82. Thus, the lift to drag ratio has an increment of 67.51 percent, meanwhile , the lift has been increased and drag decreased. Both of these phenomena are of interest to the designers of the airfoils.

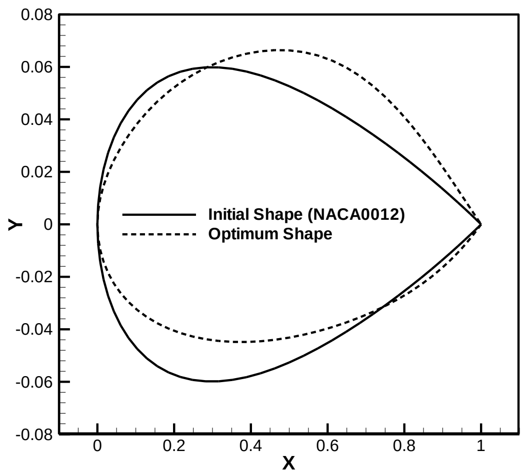

Figure 1: Initial and optimized airfoils geometry (direct optimization) to achieve maximum lift to drag ratio, under condition of α=2.79°, M_∞=0.734, Re_∞=6.5×10^6

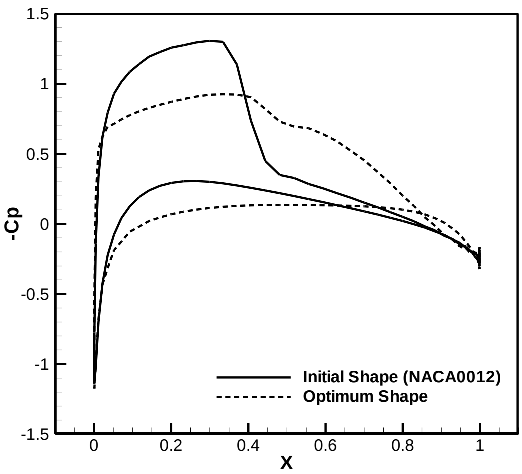

Figure 2: Initial and optimized airfoilsurface pressure coefficients distribution (direct optimization) to achieve maximum lift to drag ratio, under condition of α=2.79°, M_∞=0.734, Re_∞=6.5×10^6

4- CONCLUSION

The results of this study are summarized as follows:

A. Because of the number of less control parameters, the Parces method was introduced as the better method among the methods (Bezier and 4-digit-NACA formula) which describe the airfoil.

B. In the cases where flexibility is more important, using the Bezier curves (with more control parameters) will provide better results. Although it leads to a delay in the convergence rate.

C. The strength of shock waves is substantially reduced at the optimized airfoil and the shock waves location moves towards the end of the airfoil.

D. The modified harmony search algorithm provides a powerful tool for inverse and direct optimization, with aerodynamic and non-aerodynamic cost functions.

5- MAIN REFRENCES

[1] Giannakoglou K.C., “Design of optimal aerodynamic shapes using stochastic optimization methods and computational intelligence”, Progress in Aerospace Sciences, vol. 38, pp. 43– 76, 2002.

[2] Shahrokhi A. and Jahangirian A., “Airfoil shape parameterization for optimum Navier–Stokes design with genetic algorithm”, Aerospace Science and Technology, vol. 11, pp. 443– 450, 2007.

[3] de’ Michieli Vitturi M. and Beux F., “A discrete gradient-based approach for aerodynamic shape optimization in turbulent viscous flow”, Finite Elements in Analysis and Design, vol. 43, pp. 68– 80, 2006.

[4] Geem Z.W., Kim J.H. and Loganathan G.V., “A New Heuristic Optimization Algorithm: Harmony Search, Simulation”, 2001.

[5] Fesanghary M., Damangir E. and Soleimani I., “Design optimization of shell and tube heat exchangers using global sensitivity analysis and harmony search algorithm”, Applied Thermal Engineering, Volume 29, Issues 5– 6, April, pp. 1026- 1031, 2009.

[6] Kaveh A., Shakouri A. and Mahmud Abadi, “Cost optimization of a composite floor system using an improved harmony search algorithm”, Journal of Constructional Steel Research, Volume 66, Issue 5, May, pp. 664- 669, 2010.

[7] Jalili F., Azizi H. and Safavinejad A., “Fin Geometry Optimization with Convection and Radiation Heat Transfer Using Harmony Search Algorithm”, 19th Annual Conference on Mechanical Engineering, Birjand, Iran ISME2011

[8] Spalart, P.R. and Allmaras, S.R., “A One-Equation Turbulence Model for Aerodynamic Flows,” La Recherche Aerospatiale, No. 1, pp. 5- 21, 1994.

[9] Jameson A., “the Present Status, Challenges, and Future Developments in Computational Fluid Dynamics,” Twelfth Australasian Fluid Mechanics Conference, The University of Sydney, Australia, pp. 423- 459, 1995.