STUDY ON OPTIMIZATION OF AIR FOIL USING DIFFERENT CFD APPROACHES

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ABSTRACT:

Optimization techniques are commonly used as fluid flow control in air foil equipment's in many engineering applications. Thus it's more and more essential to know the flow characteristic inside the air foil. Due to the fast progress of the flow simulation and numerical technique, it becomes possible to observe the flows inside aair foil and to estimate the performance of aair foil. This review presents the modeling and simulation of the flow components. The flow system with globe air foils is complex structure and has non-linear characteristics, because the construction and the hydraulic phenomena are associated of globe air foils. In this paper, three-dimensional CFD simulations were conducted to observe the flow patterns and to measure air foil optimization when flow component air foil with different flow rate and constant pressure drop across the air foil were used in aair foil system. Furthermore, the results of the three-dimensional analysis can be used in the design of low noise and high efficiency air foil for industry.

Keywords: *CFD, Air foil optimization*

1.0 Introduction:

The aircraft design process applied in industry is a complex endeavour that involves concurrent engineering of the many systems that comprise a fully functional aircraft. In addition to the aerodynamic performance of an aircraft, equal consideration must be given to the disciplines tasked with specifying appropriate structures, controls, materials, and propulsion systems necessary to satisfy a truly comprehensive set of design requirements. In this day and age where greenhouse gas emissions associated with commercial aviation are of public concern with regard to climate change, and rising jet fuel prices are negatively impacting profits of commercial carriers, the design objective of improving aircraft fuel efficiency has become increasingly important. If it can be shown that a novel aerodynamic shape will provide the greatest improvement in aircraft fuel efficiency, then this shape should drive the design process such that the above mentioned disciplines strive to adapt their systems in order to minimize divergence from this optimal shape. The coupling of computational fluid dynamics with numerical optimization techniques has resulted in aerodynamic shape optimization algorithms that are efficient at producing aircraft shape configurations with improved performance characteristics at a given aircraft operating condition. While significant progress in the field of aerodynamic shape optimization has been made over the past 20 years, further advancement is still required to make numerical optimization techniques useful to solve practical aerodynamic design problems. Practical aerodynamic design problems are characterized by design requirements that must be satisfied over a broad range of aircraft operating conditions. For aerodynamic shape optimization to be considered a viable alternative to the traditional cut-and-try approach to aerodynamic design, it must be capable of producing an optimal design that satisfies the design requirements over this broad range ofoperating conditions

AIRFOIL PARAMETERIZATION:

The airfoil profile is regenerated through altering the value of the control points during the optimal design of 2-D airfoil, while parametric description tends to be more advantageous. The is paper uses the linear superposition method of analytic function to fi t the airfoil profile, which is defined from the baseline one, type function and corresponding coefficients, as:

$$\bar{y}(\bar{x}) = \bar{y}_b(\bar{x}) + \sum_{k=1}^{n} a_k f_k(\bar{x})$$

Where: – yb (– x) represents the baseline airfoil profile; n and ak are the number of control points and the coefficients, respectively; f k (– x) denotes the type function; ak f k (– x) is the perturbation of the baseline airfoil. In this paper, NACA 0012 is chosen as the baseline airfoil, which is similar to the airfoil for Space Shuttle Orbiter Columbia NACA 0012-64 These airfoils have the same leading-edge radius, and the only difference is the location of the maximum thickness.

2.0 Objectives:

- To study Aero dynamic Optimization and Control Theory
- Solving the Formulation of the Design Problem as a Control Problem
- To review the Design Optimization Procedure
- To present the Airfoil Design for Potential Flow using Conformal Mapping
- To present Wing Design using the Euler Equations

3.0 Literature review:

[1] Howard P. Buckley,(2009),aerodynamic design problems must balance the goal of performance optimization over a range of on-design operating conditions with the need to meet design constraints at various off-design operating conditions. Such design problems can be cast as multipoint optimization problems where the on-design and off-design operating conditions are represented as design points with corresponding objective/constraint functions.To address the competing design objectives between on-design and off-design operating conditions, an automated procedure is used to efficiently weight the off-design objective functions so as to limit their influence on the overall optimization while satisfying the design constraints.**[2] Chen Zhou1, Zhijin Wang(2017)**the aerothermodynamic optimization of aerospace plane airfoil leading edge is conducted. Lift-todrag ratio at landing condition is taken as a constraint to ensure the landing aerodynamic performance. First, airfoil profile is parametrically described to be more advantageous during the optimization process, and the Hicks-Henne type function is improved considering its application on the airfoil leading edge.[3]

Tian-tianzhang, weihuang (2015)airfoil with a high lift-to-drag ratio may decrease oil consumption and enhance the voyage.. The computational fluid dynamics method is applied to obtain numerically the aerodynamic parameters of the parameterized airfoil, and the result is proved credible by comparison with available experimental data in the open literatureparameterization methods of airfoil have been compared and a numerical method has been utilized to optimize the airfoil with better aerodynamic performance based on the response surface model.[4] **Alfredo Arias-Monta Carlos A.(2013)**optimization approach to optimize airfoil aerodynamic designs. Our approach makes use of multiple surrogate models which operate in parallel with the aim of combining their features when solving a costly multi-objective optimization problem. The proposed approach is used to solve five multiobjective airfoil aerodynamic optimization problems. We compare the performance of a multi-objective evolutionary algorithm with surrogates with respect to the same approach without using surrogates. As part of our future work, we plan to add more combinations of surrogate models to the ones adopted here. It would also be interesting to couple our surrogate-based approach to other MOEAs and, more interestingly, to combinations of them. [5] **Haipeng Li, Jason Stewart(2006)**Two-dimensional airfoil and various threedimensional wing planforms to investigate the impact of energy on aerodynamic designs. Our intent here is to report our efforts to couple a numerical code with an energy analysis, a shape shifting algorithm and an optimization code to achieve desired airfoil and wing shapes. Energy-based optimization is performed to minimize entropy generated on simple airfoilsthe semi-empirical value for each wing. The results from the energy-based method were in much better agreement with the semi-empirical value than the surface integration method of obtaining drag values.[6] **Alfredo Arias-Monta Carlos A. (2013)**we present a surrogate-based multi-objective evolutionary optimization approach to optimize airfoil aerodynamic designs. Our approach makes use of multiple surrogate models which operate in parallel with the aim of combining their features when solving a costly multi-objective optimization problem. The proposed approach is used to solve five multiobjective airfoil aerodynamic optimization problems. We compare the performance of a multi-objective evolutionary algorithm with surrogates with respect to the same approach without using surrogates.[7] **H. Djojodihardjo, M. F. Abdul Hamid (2013)**various methods of flow control for enhanced aerodynamic performance have been developed and applied to enhance and control the behavior of aerodynamic components. with a view on its incorporation in the wind turbine. CFD numerical experiments have been carried out to elaborate work reported earlier with the objective to verify the favorable effects of airfoil for enhanced aerodynamic performance and obtain some guidelines for the critical features of configured airfoil. Care has been exercised in the choice of turbulence model and other relevant parameters commensurate with the grid fineness desired, in particular since the number of grid utilized is relatively small in view of the desktop computer utilized capabilities.[8] **F. Duchaine T. Morel(2016)**Current state-of-the-art in

Computational Fluid Dynamics (CFD) provides reasonable reacting flow predictions and is already used in industry to evaluate new concepts of gas turbine engines. In parallel, optimization techniques have reached maturity and several industrial activities benefit from enhanced search algorithms. However, coupling a physical model with an optimization algorithm to yield a decision making tool, needs to be undertaken with care to take Advantage of the current computing power while satisfying the gas turbine industrial constraints[9] **Zitzler, E., Thiele, L., Laumanns, (2002)** A CFD parametric study has been performed to analyze the flow characteristics of a cavityequipped airfoil with vortex trapping and suction playing. Different values of the suction mass flow rate and of the suction slot locations have been considered. A comparison between the airfoil shape with no cavity + distributed suction and with trapped vortex cavity + suction has been carried out. The trapped vortex cavity resulted to be more effective with respect to the distributed suction either in terms of lift/drag coefficient either in terms of aerodynamics efficiency/required energy for the control.[10] **SlawomirKoziel (2014)**a computationally efficient procedure for multi-objective design optimization of transonic airfoil shapes is presented. The proposed approach utilizes the multi-objective evolutionary algorithm (MOEA) that works with a fast surrogate model of an airfoil under design, obtained with rigging interpolation of low-fidelity CFD airfoil simulations. The initial Pareto front generated by multi-objective optimization of the surrogate using MOEA can be iteratively refined by local enhancements of the surrogate model. The latter are realized with space mapping response correction based on limited number of high-fidelity CFD training points allocated along the initial Pareto front. The proposed method allows us to obtain-at a low computational cost-a set of airfoil geometries representing trade-offs between the lift and drag coefficients. [11] **Slawomir KozielLeifur Leifsson (2016)**Vast majority of practical optimization problems are of multi-objective nature. In many cases, especially if the designer's priorities are known beforehand, the problem can be turned into a single-objective one by selecting the primary goals and handling the remaining objectives through appropriately defined constraints. Also, it is possible to aggregate the objectives into a scalar cost function using a weighted sum approach or penalty functions.

4.0 Results and discussions:

Cambered Airfoil Design As mentioned previously, a second objective of this research was to see if Air foil could find an airfoil that outperforms the current state-of-the-art. After Air foil was tuned by the test cases presented in the last section, the performance of Air foil was measured against an optimized cambered airfoil with known design specification. This test is different than the previous section in that the goals of the designer for the benchmark airfoil are known. Thus, the real effectiveness of Air foil could be compared to a current, modern airfoil design technique. the performance of many existing airfoils for different design lift coefficients at a Reynolds number of 300,000. As can be seen in the figure, the SG604x family of airfoils represents a bound on the current state-of-the-art. A goal of this research was to see if Air foil could find airfoils that could extend this bound. The SG6042 was chosen as the benchmark airfoil for this test. The optimization problem formulated as follows: find a 10% thick cambered airfoil with minimum drag at a lift coefficient of 0.92 and a Reynolds number of 300,000. Air FOIL predicts L/D = 104 for the SG6042 section at the specified conditions. The lower surface of the cambered airfoils could be parameterized many ways including the approaches.

Sampling and modeling approach:

An airfoil with better capacity in the lowvelocity condition is required in this study. The curve of NACA 0012 will be applied as the design baseline. the airfoil curves upwards and downwards, and has already illustrated the fitting effect. The lift-to-drag ratio of the airfoil for the low-velocity condition is chosen to be the optimization objective, and it is expected to be as large as possible. Bernstein's coefficient is limited to range in the zone from 70% to 130% of the baseline to prevent tortuosity of the curves, which will influence the quality of the grid. Therefore, the optimization result will be restricted in certain values, and the permission zone of Bernstein's coefficient could be enlarged in future

Discussions:

An optimization method-based procedure for the analysis of airfoil-size devices, in which doubly curved shell elements are used to represent the air foil control the results, which is quite comparable to their molecular modeling counterparts. 2. The use of a continuum-based procedure, such as the one developed in the present work, enables the analysis of airfoil-size devices, for which a purely molecular analysis would be either impractical or impossible

5.0 Conclusions:

An aerothermodynamic optimization procedure considering the landing aerodynamic performance has been developed for airfoil. In the optimization study, a modified Hicks-Henne type function is first adopted to parametrically describe the airfoil leading edge. CFD models are then established and further validated to simulate the hypersonic and landing problem. An optimization approach composed of DOE, RSM and MIGA is used to obtain the optimal airfoil. It is found that the surrogate model results agree well with the CFD ones. The optimal airfoil has a lower peak heat flux at the stagnation point compared with the baseline one.Optimization of flow control-equipped configurations using overset grids is proposed and discussed. The tool was successfully applied to the challenging case of a twodimensional airfoil having a simply hinged flap and equipped with constant blowing actuation, with the aim of maximizing lift in landing conditions. A complete reattachment of the flap flow was achieved, with an almost total recovery of the aerodynamic efficiency when compared to a conventional fully slotted reference geometry

Scope:

The possible application of flow control strategies will be assessed on more realistic three dimensional cases, based on the general results obtained during simpler and cheaper twodimensional parametric surveys, as the one proposed and validated here.

- Improve the modern airplane
- New configuration
- New rules and requirement

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