World Academy of Science, Engineering and Technology
International Journal of Aerospace and Mechanical Engineering
Vol:10, No:12, 2016

A Study on Computational Fluid Dynamics (CFD)-Based Design Optimization Techniques Using Multi-Objective Evolutionary Algorithms (MOEA)

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Abstract : In engineering applications, a design has to be as fully perfect as possible in some defined case. The designer has to overcome many challenges in order to reach the optimal solution to a specific problem. This process is called optimization. Generally, there is always a function called “objective function” that is required to be maximized or minimized by choosing input parameters called “degrees of freedom” within an allowed domain called “search space” and computing the values of the objective function for these input values. It becomes more complex when we have more than one objective for our design. As an example for Multi-Objective Optimization Problem (MOP): A structural design that aims to minimize weight and maximize strength. In such case, the Pareto Optimal Frontier (POF) is used, which is a curve plotting two objective functions for the best cases. At this point, a designer should make a decision to choose the point on the curve. Engineers use algorithms or iterative methods for optimization. In this paper, we will discuss the Evolutionary Algorithms (EA) which are widely used with Multi-objective Optimization Problems due to their robustness, simplicity, suitability to be coupled and to be parallelized. Evolutionary algorithms are developed to guarantee the convergence to an optimal solution. An EA uses mechanisms inspired by Darwinian evolution principles. Technically, they belong to the family of trial and error problem solvers and can be considered global optimization methods with a stochastic optimization character. The optimization is initialized by picking random solutions from the search space and then the solution progresses towards the optimal point by using operators such as Selection, Combination, Cross-over and/or Mutation. These operators are applied to the old solutions “parents” so that new sets of design variables called “children” appear. The process is repeated until the optimal solution to the problem is reached. Reliable and robust computational fluid dynamics solvers are nowadays commonly utilized in the design and analyses of various engineering systems, such as aircraft, turbo-machinery, and auto-motives. Coupling of Computational Fluid Dynamics “CFD” and Multi-Objective Evolutionary Algorithms “MOEA” has become substantial in aerospace engineering applications, such as in aerodynamic shape optimization and advanced turbo-machinery design.

Keywords : mathematical optimization, multi-objective evolutionary algorithms "MOEA", computational fluid dynamics "CFD", aerodynamic shape optimization
Conference Title : ICAAAAR 2016 : International Conference on Applied Aerodynamics, Aerostructures and Aerospace Robotics
Conference Location : Miami, United States
Conference Dates : December 05-06, 2016