Implementation of Genetic Algorithm on The Design of a Transonic Wing by Using Parallel Processing

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Abstract

In the study presented, dynamic mesh method applications on Heuristic Algorithms are investigated in the design of wing geometry. Under the constant lift value, the drag of the wing is reduced to make L/D ratio to be a value maximum. For the realization of this maximum value, the dynamic mesh technique is implemented on a real coded Genetic Algorithm to demonstrate gain in computational time as well as in higher performance for optimized parameters. The software developed, which handles the multi optimization of engineering problems, is based on parallel processing. The problem tackled here is inherently complex frequently found in engineering applications. Particularly in the aerospace and automotive industries, parallel computing allows to handle more complex problems by utilizing powerful new generation of parallel computers. The flow field solved in this problem is essentially three-dimensional which requires more computational time. However by applying parallel processing in solution part of the problem, it is possible to reduce the computational time up to seven times. MPI library is used for communication of data over different CPUs on a distributed environment.

Keywords: Heuristic Algorithms, Dynamic Mesh, Optimization, Grid Modification, Finite Volume, Parallel Computation

I. INRODUCTION

In the most general sense, optimization is the process of achieving the best outcome of a given operation while satisfying a set of given constraints. The cost (or objective) function is the term applied to this outcome that needs to be improved (or optimized) [1]

Evolutionary algorithms, Genetic Algorithms (GAs), for example, have been enjoying increasing popularity in the field of numerical optimization in recent years. GAs are search algorithms based on the mechanics of natural selection and natural genetics. It has been applied on different problems. [2-3-4-5]

In this work, the airfoil section optimization of Onera m6 wing has been studied. While doing this, the lift force has been held fixed and the drag force was tried to be minimized. In order to model deformation in the geometry of the body mass-spring-damper (MSD) model is used.

The MSD model, which we apply in this study, is the simplest computationally, but does not allow accurate modeling of material properties, which are not needed for the general shape optimization.

II. DYNAMIC MESH TECHNIQUES IN HEURISTIC ALGORITHMS:

In the field of aerodynamics, the inviscid type of modeling [6], the dynamic mesh technique has been applied to unsteady Euler airfoil solutions [7] and unsteady Euler algorithm for complex aircraft aerodynamic analysis [8] by John T. Batina.

By using the dynamic mesh technique, the original mesh can be modified to fit the change in angle of attack or for instance the change in the shape of an aircraft fuselage.

Therefore, in this study, dynamic mesh method is implemented on a real coded genetic algorithm to demonstrate gain in computational time as well as in higher performance for optimized parameters, as indicated in our previous studies. [9,10]

III. STRUCTURE OF THE PARALLEL PROGRAMMING

In serial calculation flow solutions take approximately 95% of the total time. By making this portion of the calculation parallel, the total calculation time can be reduced up to 7 times. The parallel version of the code is such that processor zero inputs the data initially and produces different airfoils and grids around them. It then outputs these data into different files while other processors go to the next step and wait for zeroth processor. Once they all reach to the same point, each processors reads in airfoil and grid data and starts solving the flow field around them. Zeroth processor combines all these solutions and applies genetic algorithms on them. After the best selection of the population, all processors start over to find the flow solution on the new airfoils. Any communication or syncranization between the processors are done using the MPI library which has parallel functions or subroutines. [11] The code is run on a SUN parallel computer having 24GB ram and 32 CPUs.

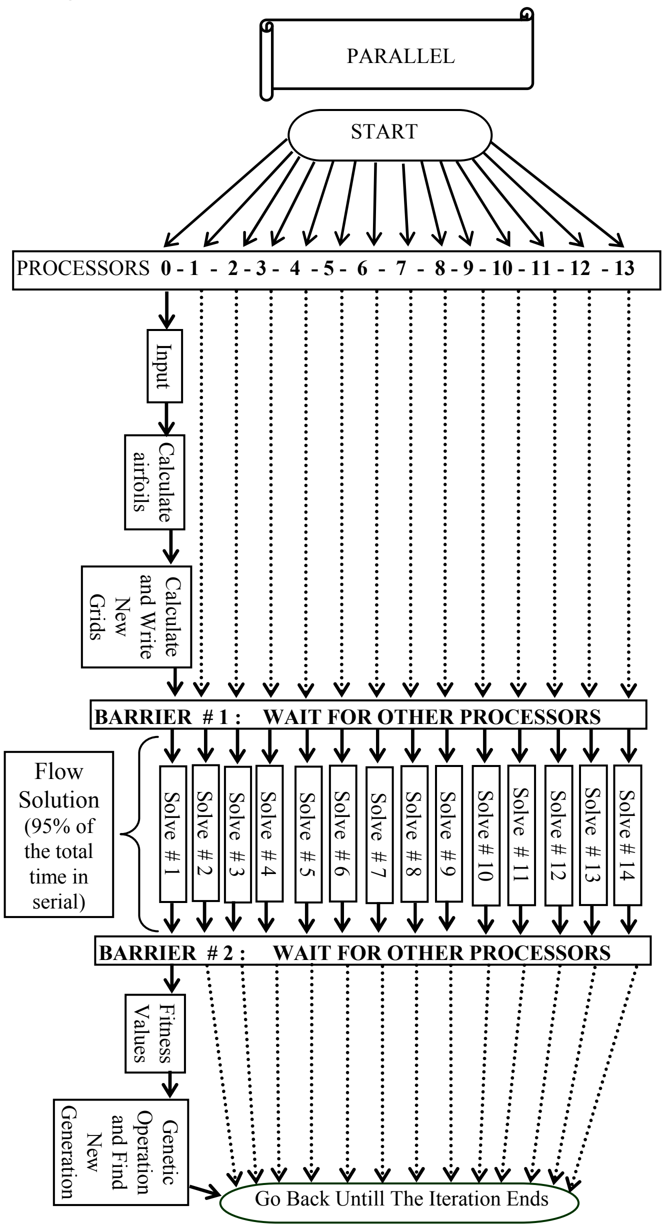

Figure 1: Main Structure of the Parallel Processing

IV. OPTIMIZATION RESULTS :

A. Progress in Generations:

In the optimization process, there are 14 members in each generation. These are 14 Onera m6 wing planforms that have different wing sections. All of them are solved by ACER3D [12-13] and their lift and drag forces are calculated. [14]

By using these forces, fitness values are calculated for each member. The fitness function is taken as:

$$f(i) = C_D + a(C_L - C_{Ld})^2 \quad (1)$$

$$\text{Fitness Value} = 1/f(i) \quad (2)$$

C_D : Drag coefficient calculated

C_L : Lift coefficient calculated

C_{Ld} : Design lift coefficient

a : Constant parameter to define the weight of the lift coefficient

The average fitness value for each generation and the maximum fitness value (i.e. the best member found in that generation) are shown in Figure 2.

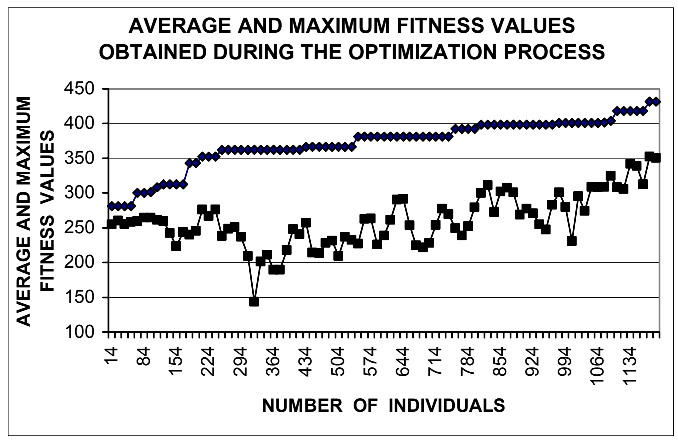

Figure 2: Change in the average fitness and the development of the maximum fitness value

The best member is kept in each generation and taken to the next generation. So the best member found in each generation cannot be worse than the best member of the previous generation.

In the following stages, the wing sections are reproduced according to their fitness ratios based on the genetic processes (crossover, mutation etc.). The wing sections found in 100th generation is shown in Figure 2.

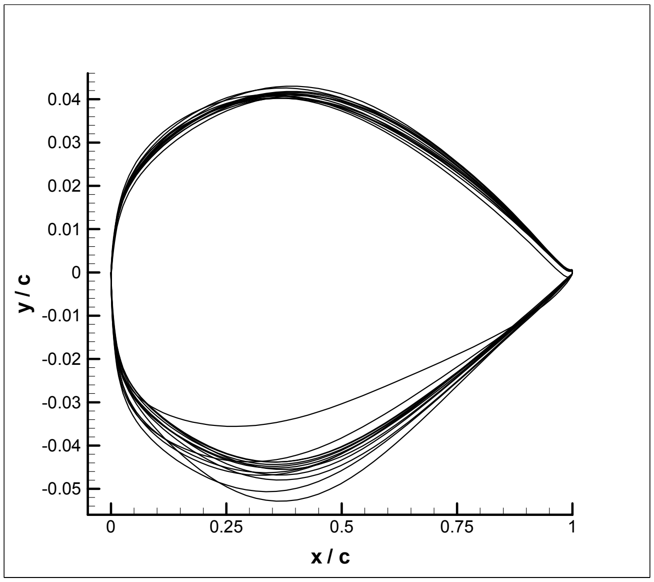

Figure 3: Wing sections of the 100th population (14 members)

B. Change in Mesh Structures:

The unstructured tetrahedral mesh is modified according to the change in wing section by using dynamic mesh technique and for all members of a generation; new mesh structures have been calculated. For instance, the meshes calculated for two different wing sections are shown in Figures 4.

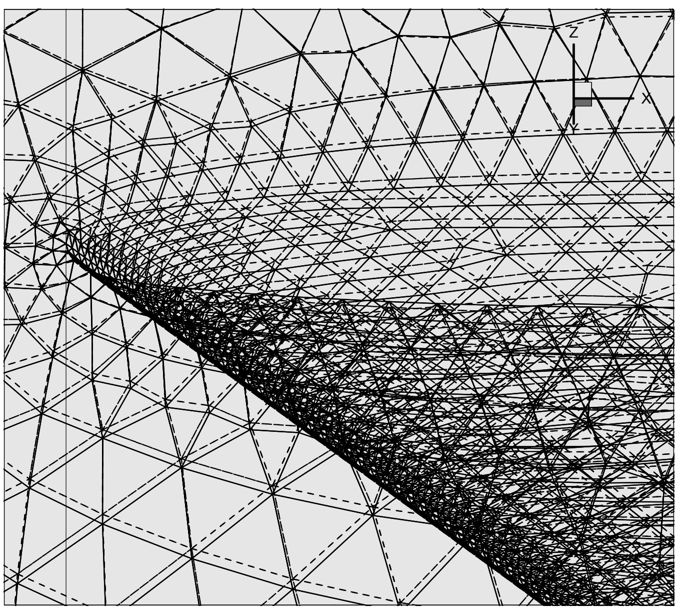

Figure 4 : The mesh structures of the first and the best wing found at the 100th population (initial: dashed line, 100^{th} : solid line)

C. Change in Pressure Coefficients:

In Figure 5, the differences between pressure coefficient distributions of the initial wing and the best member produced in the 100^{th} generation can be seen.

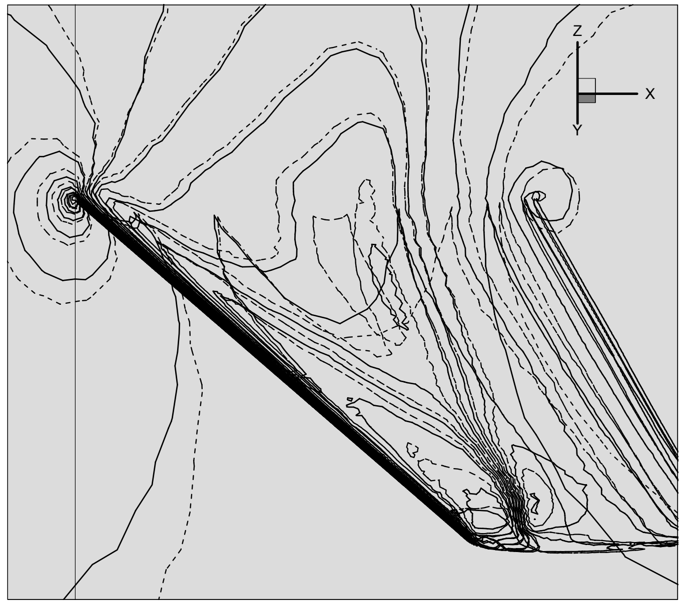

Figure 5 : The Cp distributions of the first and the best wing found at the 100^{th} population (initial: dashed line, 100^{th} : solid line)

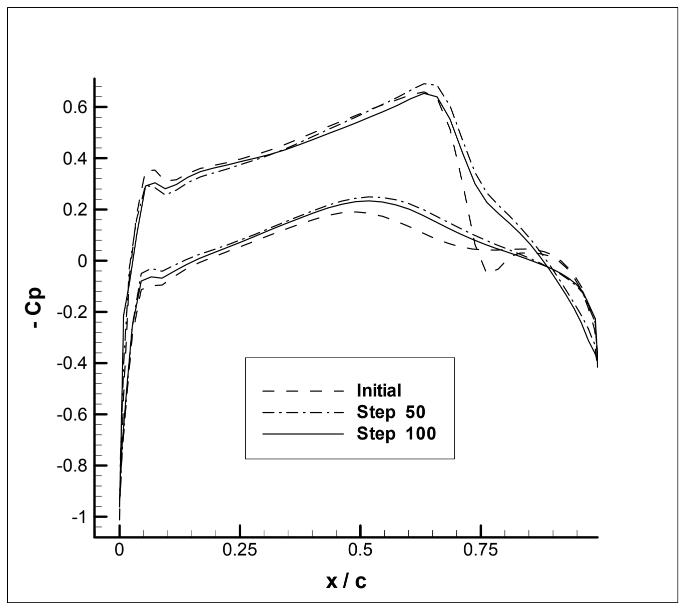

Figure 6: The Cp distributions of the root sections at different stages

D. The Best Wing Sections Found by Genetic Processes:

In Figure 7, the best members obtained in different stages are shown. If the wing section found at 100^{th} generation (shown as solid line) and the initial wing section (i.e. Onera m6 – shown as dashed line) are compared, it can be seen that the wing section has become thinner. During this process the lift coefficient has been tried to be held fixed, while the drag coefficient has been reduced 30 percent.

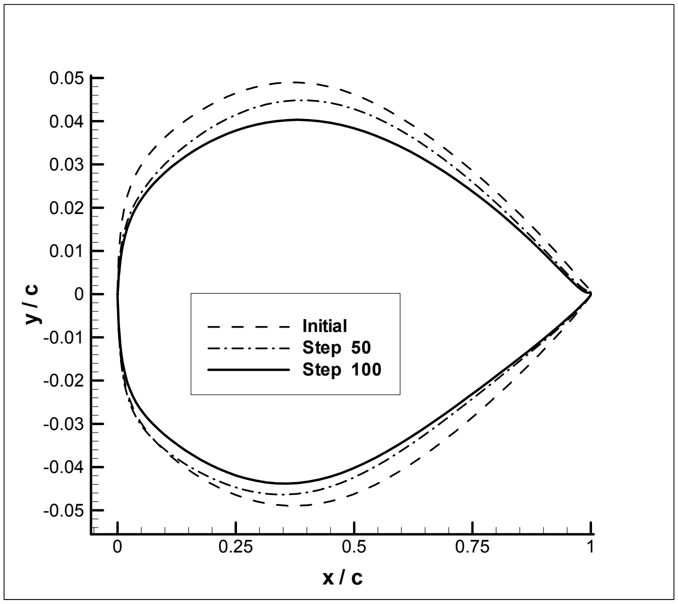

Figure 7: Wing sections of the first and the best members found at the steps 50 and 100

IV. CONCLUSION:

To get satisfactorily accurate results number of the short runs required are changing between 700 – 3000 for the considered geometry. Restarting the flow solver from previous solution and using the dynamic mesh technique for re-meshing the new population members can reduce the computing time up to 3 times. In our recent studies, we turn our solver into parallel working form, which reduces this computing time up to 7 times.

It is observed that the optimization process is working as expected. The wing section has become thinner while its drag coefficient was lessened. Simultaneously, its lift coefficient is tried to be close to the design value determined at the beginning. This is done by arranging the fitness function. At the 100th generation the difference between the lift coefficient of the best member and the design lift coefficient value is about 2 percent.

However when the more constraints are added, in case the initial wing section be already optimized, it will be difficult to find better ones and it also takes more computational time.

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