RESEARCH ARTICLE OPEN ACCESS

Application Of Optimisation Techniques In Aviation Industries

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ABSTRACT
In the modern aircraft many components were produced because of the effort of engineering fraternity, most of the components were designed in a manner that they are subjected to various types of loads and stresses. In their life span members need to carry more amount of load but with a shorter thickness, designing them will induce curiosity among the engineers. There are many tools which are used practically for the design purpose and one such tool is optimization techniques. Design of engineering components is a costly process in which a small reduction in size wills ultimate lead to huge saving, many researchers and engineers focus on this area of called as optimization. To support optimization process many techniques were evolved in the recent decades some of them proved to be highly successful in optimizing and also widely used by many industries. Aviation industry one of the core engineering industry carries importance in designing and many design procedures were evolved in designing aircraft components which are not only costly to produce but also need utmost care in designing. Optimization plays a key role in design process let it be designing of a wing or landing gears, fuselage or rudders reducing the size for the load applied proves to be the only viable option for cost reduction. In this work an attempt is made to optimize the thickness of wing of an aircraft using Size-topology optimization technique.
Keywords: Optimisation, Size-topolody optimisation, crossover, Genetic algorithm, particle swarm optimization.

I. Introduction

Aircraft designers have always tried to make their newest design the “best ever”, and have eagerly used the latest tools at their disposal to determine the combination of design features and characteristics that will produce that “best.” The Wright Brothers performed parametric wind tunnel trade studies of wing aspect ratio and camber, and part of their eventual success was due to this early form of optimization1. Subsequent generations of aircraft designers have learned how to make “carpet plots” for two-variable optimizations, and have laboriously extended that to a dozen or so variables by repetition and cross-plot. When electronic computers became available, aircraft designers gladly accepted their help in the repetitive calculations required for aircraft design optimization (see Ashley2 for a definitive survey of aerospace optimization as of the late 1970’s).Today improved techniques for the optimization of complicated engineering problems are emerging from universities and research laboratories. Aircraft design is a long and costly endeavor and traditional aircraft conceptual design establishes basic aircraft geometry and engine thrust requirements by considering basic performance constraints such as field length, speed, and altitude. Detailed assessment of more complex and realistic mission profiles that comply with air traffic and airworthiness requirements occurs after the aircraft layout has been established. This can lead to sub-optimal designs and costly revisions. Ultimately, an aircraft must be built, tested, and flown to have any assurance of design certifiability. However, considering airworthiness constraints as early as possible in the design process promises to reduce the likelihood of costly design revisions beyond the conceptual level. Additionally, growing concern regarding the environmental footprint of air travel is leading to new regulations that target aircraft noise and pollutant emissions as well as contrail formation .This research aims to introduce airworthiness constraints to a general MDO framework for aircraft conceptual design that has the flexibility to quickly accommodate new and changing environmental regulations and predict the impact these have on aircraft conceptual design [4].

Stringent weight target plays a major role in the civil aircraft design which results in additional payload and better performance. This can be effectively achieved with the help of advanced computer aided optimization techniques viz., topology, size and shape optimization. There are many research works conducted related to the optmisation of structural weight using size-topology technique and some of the components which are commonly designed are Stub-Wing Spar, Nose Landing Gear Bracket and Wing Attachment Bulkhead of a Typical Light Transport Aircraft using Altair OptiStruct. By using these techniques, it is found that a weight reduction of 15% to 30% has been achieved. This methodology can be adapted to various Aircraft Structural components in achieving optimized design.[4]

II. Optimization Techniques

Optimization is a mathematical discipline that concerns the finding of minima and maxima of functions, subject to so-called constraints. Optimization originated in the 1940s, when George

Dantzig used mathematical techniques for generating "programs" (training timetables and schedules) for military application. Since then, his "linear programming" techniques and their descendents were applied to a wide variety of problems, from the scheduling of production facilities, to yield management in airlines. Today, optimization comprises a wide variety of techniques from Operations Research, artificial intelligence and computer science, and is used to improve business processes in practically all industries.

Discrete optimization problems arise, when the variables occurring in the optimization function can take only a finite number of discrete values. For example, the staff scheduler of a hospital unit has a finite set of staff members available, and thus staff scheduling consists of taking discrete decisions, one for each slot of the resulting schedule. Discrete optimization aims at taking these decisions such that a given function is maximized (for example revenue) or minimized (for example cost), subject to constraints, which express regulations or rules, such as required numbers of rest days for the staff in a schedule. [3]
Normative economic decision analysis involves determining the action that best achieves a desired goal or objective. This means finding the action that optimizes (that is, maximizes or minimizes) the value of an objective function. For example, in a price-output decision-making problem, we may be interested in determining the output level that maximizes profits. In a production problem, the goal may be to find the combination of inputs (resources) that minimizes the cost of producing a desired level of output. In a capital budgeting problem, the objective may be to select those projects that maximize the net present value of the investments chosen. There are many techniques for solving optimization problems such as GA, ANN, NN, Size-topology optimization etc.

Genetic algorithms (GA) have been popular in design optimization, operations research, and for general combinatorial search problems[1]. A key operator is the encoding step that results in a binary, real, or hexadecimal chromosome. The length of the chromosome, i.e. the number of alleles, in the genotype space is a surrogate for the amount of information describing an artifact in the phenotype space.. Traditionally, in design optimization, the chromosome length is fixed a priori, and it cannot change with the evolution of subsequent generations. Evolution in this sense is only understood as the process of approaching an optimal instantiation of alleles given a constant phenotype-genotype mapping and a fixed chromosome length.

2.1 Topology optimization?

The Topology Optimization method solves the basic engineering problem of distributing a limited amount of material in a design space, resulting in the optimal shape of a mechanical structure. The structural shape is generated within a pre-defined design space. In addition, the user provides structural support and loads. Without any further decisions and guidance from the user, the method will form the structural shape thus providing a first idea of an efficient geometry [7].

Topology optimization optimal material distribution within the structure. Topology optimization is used to find preliminary structural configuration that meets pre defined criteria. This type of optimization sometimes gives design that can be completely new and innovative. The design domain comprised of large number of candidate elements, and topology optimization process selectively removes the unnecessary elements from the domain. It can be characterized into two general approaches. The first approach, the assumed micro structure, tries to find micro structure parameters (ex: size and orientation of a hole) second approach deals with physical properties of a material. [1]

2.2 Size optimization

Size or parameter optimization typically uses the element cross sectional properties as design variable. These include parameters such as plate thickness, area and moment of inertia of a beam cross section. Size optimization involves the modification of cross section or thickness of finite elements. The optimization is carried out by mathematical programming techniques [2].

III. Aircraft Design Optimization – Purpose and Importance

During the development of a new aircraft concept, the optimization of the design to provide the desired capabilities at a minimum cost is of paramount importance. Aircraft are incredibly expensive compared to almost any other single man-made item. Thus designing them is a key factor which need to be addressed with utmost care. Identification of the best balance must be done in the context of the aircraft's roles and Missions, and has the potential for a substantial overall cost savings. Specific aircraft optimization methods are discussed below, and span a spectrum from simple one-variable parametric trades or even closed-form solutions, to highly sophisticated, mathematically based multivariable/multidisciplinary optimization 9methods. Properly applied, aircraft design optimization offers reduced cost in all phases of design. It is the specific intention of this research to improve the aircraft. (Daniel P. Raymer, 2002).

3.1 Importance in Aviation industry

Optimization provides an elegant blend of theory and applications. The theory uses elements beginning with elementary calculus and basic linear algebra and continues with functional and convex analysis. Applications of optimization involve science, engineering, economics, and industry. The wide and growing use of optimization make it essential for students and practitioners in every branch of science and technology. (Source: Study of University of

Waterloo, 2010). Air transport is still one of the continuously growing industry sectors worldwide. Like all industrial sectors there is the constant request to reduce cost, improve quality and enhance security and safety. The aircraft as the central mean for transportation is under similar threats. But if we want to improve the aircraft further we have to understand the air transport system itself, identify the different actors and their role, identify each partners strengths and weaknesses and then identify the areas where further aircraft improvements will bring best value to the system. The presentation will start to quickly describe the air transport system with its main elements and partners. ACARE, the European consortium for air transport, has developed their Vision 2020 and defined two strategic research agendas to achieve the defined goals that can be used as a good basis for the next challenges. The aircraft design process can be described in four different levels. The first level is the air transport system which defines the environment and constraints in which the aircraft can be operated. In this first level, the market requirements for the aircraft have to be derived. Once the market requirements are identified, then the industrial process starts:

- Which aircraft in terms of size and range would best fit?
- What is the competitive situation?
- What type of aircraft, a derivative or a new design?
- What level of technology and risks should be taken?
- What propulsion system and how to secure exclusivity?
- Who and how many risk sharing partners/subcontractors?

Here a compromise between the different aspects of marketing, engineering, finance and production has to be developed. At the third level then is the purely engineering task, handled by the chief engineer. He has to define together with his engineering teams from aerodynamics, structures, aeroelasticity, propulsion, cabin, etc., the suitable aircraft configuration which fulfils all these requirements as a compromise between the different disciplines. At this level, the aircraft performance or the DOC (direct operating cost) can be the yardstick to measure and identify the improvements compared to previous and competitors design. Today there is even a fourth level of aircraft optimisation. This is at the level of aircraft subsystems design, where another optimisation of functionalities is needed.

- What is the best way to control the aircraft?
- What is the future architecture to ensure communication within the aircraft (cable, wireless, mixed), between aircraft and ground and also for entertainment with all the new features like onboard TV, video on demand, use of mobile phones, etc.
- What is the optimum way of onboard power generation, distribution and economic consumption?

IV. Optimization Problem Definition

In a design optimization problem, the objective is to find the values of a set of n given design variables X € R^n which minimize or maximize a function f(x), denoted “objective-function”, while satisfying a set of equality (hk (x) =0) as well as inequality (gr(x)£ 0) constraints which define the viable region of the solution space. The constraints xlj £ xj £ xuj are called side constraints. Â is the set of the real numbers.

Design variables: x, y

Criterion Function: Area = A = x y

Constraint: 2 x + y = 1.94 ft
or y = 24 - 2 x

4.1 Choice of the Wing Design Variables

The allowable shapes are defined using shape basis vectors. The engineer uses these to describe how the structure is allowed to change. The optimizer determines how much the structure can change by modifying the design variables [5]. It is used the Direct Input Shape method to describe these shape basis vectors. With this method, externally generated vectors are used to define shape basic vectors and an auxiliary model analysis provides these externally generated vectors. A total of 43 design variables, including sizing and shape, are defined for the wing model [6]. The figures shows the internal structure of a UAV wing & the figure 18,19,20,21 shows the analysis result of the same wing wing structure. In our work we made an attempt to optimize the wings of an aircraft with the following parameters

Initial weight of wing	**= 395 kgs**
Length	**= 20 ft**
Breadth	**= 3.5 ft**

To reduce the iteration process and to speed up the design we had used the following software’s in our work

Modeling	**– Solid works**
Analysis	**- ANSYS**

The output of the work done is given in the following

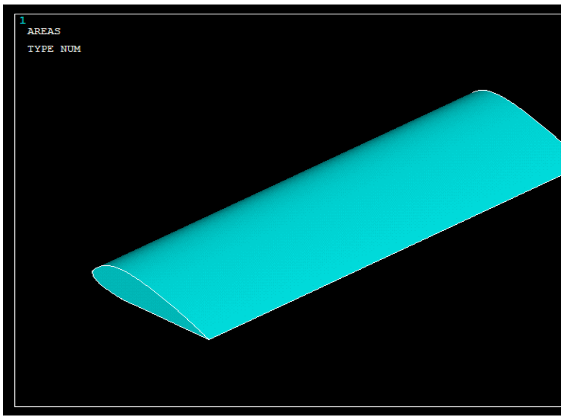

Fig 5: Wing model

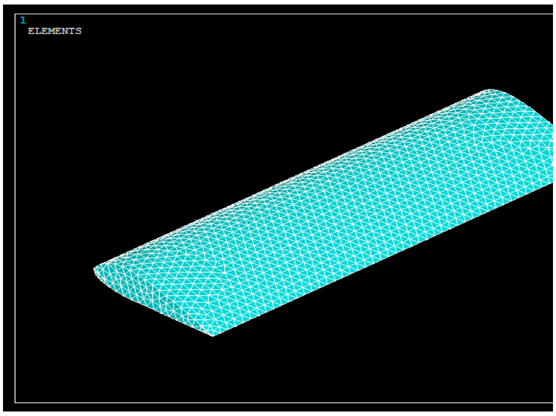

Fig 6: A model of meshed wing

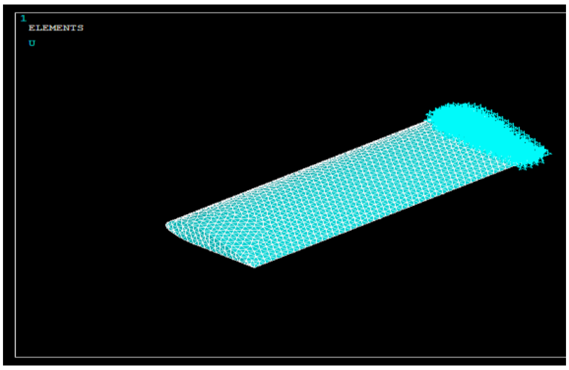

Fig 7: Wing elements

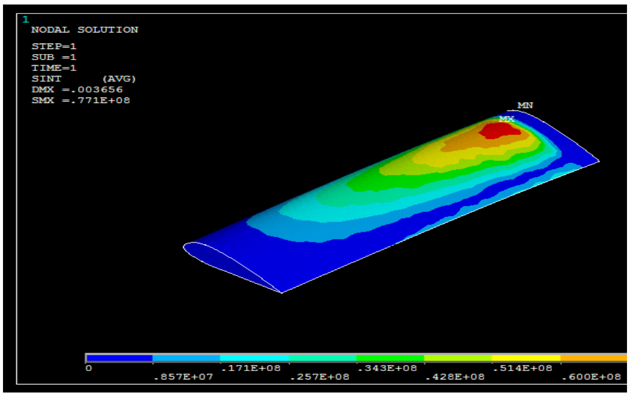

Fig 8: Wing nodal solution

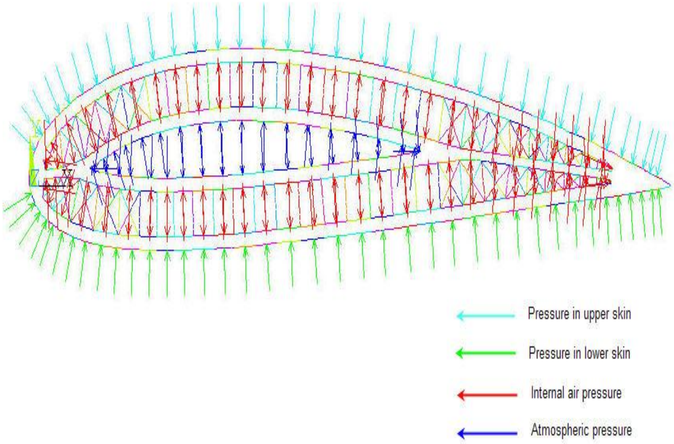

Fig 9: Pressure Contour

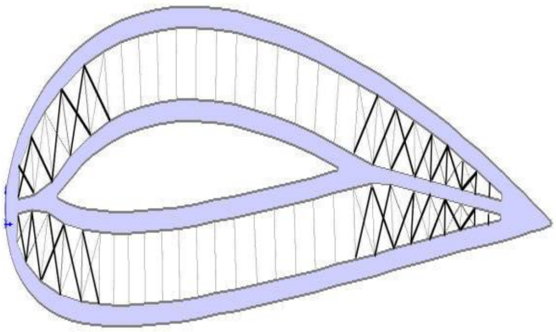

Fig 10: Optimized configuration of UAV wing

The optimization is done by the following 5 cases.

CASE 1: THICKNESS OF SPAR, RIBS, PANELS
CASE 2: MASS
CASE 3: RIBS POSTION
CASE 4: BOTH RIBS & SPAR POSTION
CASE 5: BEAM CROSS SECTIONAL

The reduction of weight obtained in the optimized design is
Case 1: 335.4 kg
Case 2: 349.17 kg
Case 3: 339.47 kg
Case 4: 327.78 kg
Case 5: 319.78 kg

In our work we are able to receive the optimized values which are not only in the side of cost savings but also shown durability and reduction in volume

1. CASE I 15 % reduction in weight
2. CSAE II 11 % reduction in weight
3. CSAE III 13 % reduction in weight
4. CASE IV 17 % reduction in weight
5. CASE V 19 % reduction in weight

We found that by optimizing a saving of nearly 20% in all ways and weight reduction of nearly 11% TO 19 % is obtained which is a considerable amount of material saving compared to the cost of aircraft wing components and thus its proved that size-topology method can be effectively employed for optimizing wing thickness of an aircraft.

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