Topology Optimisation of Wing Mounting Bracket Under Static Loading Conditions

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Abstract- *It is very important to reduce the development times from the initial concept development stage to the mass production stage in engineering. Much trial and error occurs from the initial design to mass production to verify the performance and durability and other design criteria. Computational simulations for reducing such trials and errors are generally utilized and have proven to be useful tools in many areas. The ability of using CAD/CAE has become one of the core technologies nowadays because of shortened development periods. The wing mounting bracket was studied in this paper. Because of heavy vibrating load conditions and the need for reducing weight to improve the fuel efficiency, the wing bracket is one of the most important parts that requires optimum structural design. The reliability of structural analysis results should be proved first of all for the optimum design iteration. Material properties, modelling methodologies and boundary conditions should be checked for structural analysis reliability and these efforts for the optimum design can give great effects at the concept or initial Design stage of parts.*

I. INTRODUCTION

Structural optimisation is concerned with maximizing the utility of a fixed quantity of resources to fulfill a given objective. Three categories of structural optimisation exist; shape, size and topology. Structural topology optimisation is the most general of the three categories yielding information on the number, location, size and shape of openings within a continuum. The first solutions to a topology optimisation problem (fig.1) were presented by Michell . Modern topology optimisation techniques can be applied to generalised problems through the use of the Finite Element (FE) method, as a relatively recent innovation. Aerospace, automotive and mechanical engineers have successfully utilised topology optimisation in order to achieve weight savings in structures. Enthusiasm for topology optimisation in the field of civil/structural engineering, where weight savings are seen as less critical due to the one off nature of building structures, is generally accepted as being more muted . However, in the era of sustainable and resilient infrastructures, where the concept of redundancy plays a significant role, we should reconsider optimising every single structure to the best of its efficiency. Indeed the one off nature of every civil-structural engineering project necessitates the use of rigorous optimisation techniques to drive efficiencies on the increasingly complex projects of today.

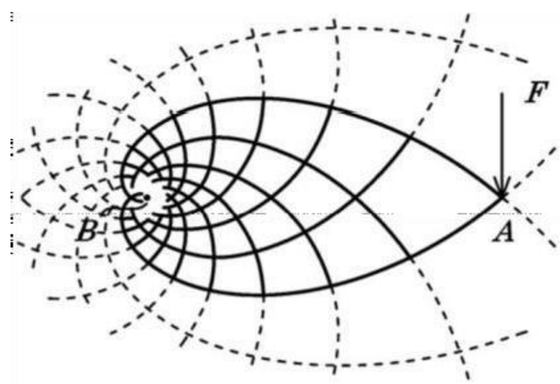


Figure 1 - One of the first proposed solutions to a structural topology optimisation problem

Topology optimisation has found several novel applications in the field of civil engineering, most notably; a novel technique for geotechnical analysis and reinforcement layout optimisation in concrete structures . The main focus of this review study is applications of topology optimisation to the design of large scale structures and structural engineering components.

2.1 GENERAL PERSPECTIVE

This second chapter deals with the literature review on Shape and Topology optimization performed separately and also on integrated Thickness/Shape and topology optimization. Today, optimization is one of the most discussed topics of engineering. Structural designing methods usually depend on the formulae and result in a feasible design may not be necessarily an optimum one. This leads to choose an optimal layout of a certain structure or a structural component from the available domain of solutions which represent a physical model of the actual problem. Therefore optimized designs produce highly efficient and reliable results. Thickness/Shape and topology optimization are the major objectives of structural optimization. The significant progress in these fields is a parallel progress in the fields of structural analysis, mathematical programming, geometric modelling and computer hardware. Specialized structural optimization software also emerged subsequently, utilizing more advanced approximation technology for enhancing overall efficiency. Optimization theory focuses on the quantitative study of optima and methods for finding them.

Real world problems are very complex and Classical methods of optimization are not sufficient to solve them. The solution method developed in the past cannot tackle the complex problems in various fields of Engineering and science. Various review papers,

Technical papers, Master's/Ph.D. thesis and text books published in this area reflect the increasing interest in this field of structural optimization.

2.2 REVIEW OF LITERATURE

2.2.1 Thickness/Shape Optimization

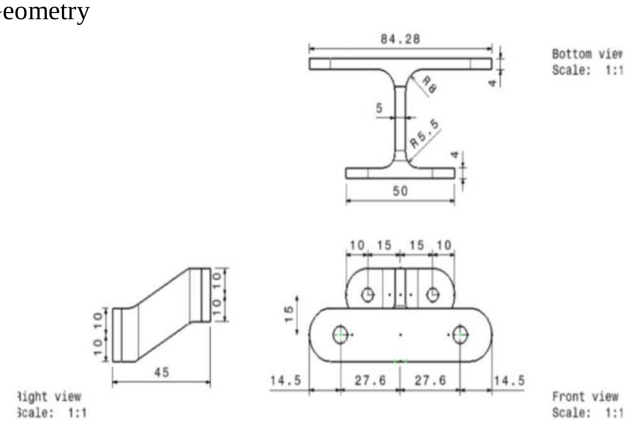
Structural shape optimization combines mathematics and mechanics with engineering and has become a multidisciplinary field. It has wide applications in almost all the fields of engineering and science. In this form of optimization the topology of structure is known before but there can be some part and/or detail of the structure which can produce problems. Therefore the objective is usually to find the best shape that will result in the best solution. Parameters of shapes are dimensions of the optimized parts or a set of variables describing the shape such as coefficients of spline functions. In order to establish the functional requirements of structural shape optimization scheme it is desirable to examine the objectives

• To achieve a safe design which simultaneously satisfies constructional/manufacturing and functional requirements, and
• To reduce the cost of the construction/manufacture and maintenance of a structure or structural component.

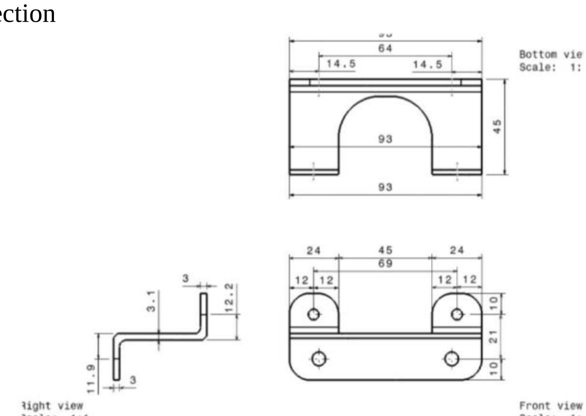
Shape optimization is a mathematically inverse problem. Extensive literature survey on structural thickness/shape optimization can be found in the review papers by Barnes, Berke and others, Byug man quak, Jaroslav Mackerle6, Pathak, Haftka and Grandhi, Ding and in books by many authors such as Allaire, Gajewski and Zyczkowski, Rao,S.S, Zienkiewicz and Campbel. Various researches have proposed different methods for shape optimization. Bletzinger proposed inverse technique for form finding of shell structures. Authors such as Bennet and Botkin, Rasmussen99, Kimmich and Ramm68, Braibant and Fleury developed computer aided optimum design tools for plane stress/strain problems. A good introduction into shape optimization problems can be found in Gotsis, Botkin, Zolesio, Ramm, Bletzinger and Kimmich. From the mathematical point of view, two representations of variables - continuous and discrete ones can be found within the shape optimization area. The first contributions to the analysis and theory of shape optimization of continuum structures was by Zienkiewicz and Campbell and the overview can be found in the works of Liang and Vanderplaat and the research on structural optimization of discrete structure is comprehensively summarized by Gutkowskia and Bauer.

Authors such as Hinton and N.V.R.Rao, Hartman and Neumann studied the structural design and optimization of folded plates and prismatic shells using finite strip method with different objectives such as strain energy minimization, maximizing the fundamental frequency etc. M.Ozacka and Tyasi conducted study on box-girder section straight and curved in plan for free vibrations. Olhoff investigated optimization of circular plates for free vibrations for maximizing the fundamental frequency for a specific value of material volume. Shape optimization of structures for free vibrations was investigated by Bratus ,Mota

Geometry



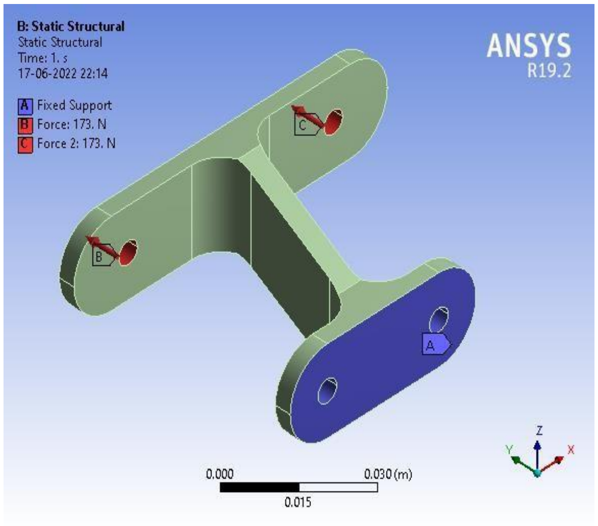
I section



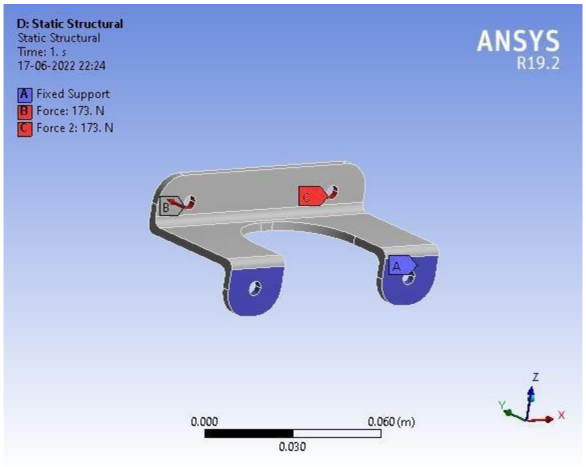
Z section

Boundary conditions

I section



Z section



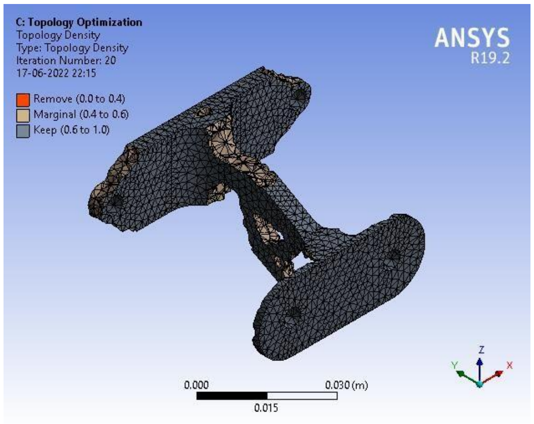
Topology Optimization

Response Constraint Object Name	*Response Constraint*
State	Fully Defined
Scope	
Scoping Method	Optimization Region
Optimization Region Selection	Optimization Region
Definition	
Type	Response Constraint
Response	Mass
Define By	Constant
Percent to Retain	50%
Suppressed	No

Results

Topology Optimization of I section

Topology Density Object Name	*Topology Density*
State	Solved
Scope	
Scoping Method	Optimization Region
Optimization Region	Optimization Region
Definition	
Type	Topology Density
By	Iteration
Iteration	Last
Retained Threshold	0.5
Exclusions Participation	Yes
Calculate Time History	Yes
Suppressed	No
Results	
Minimum	1.00E-03
Maximum	1
Average	0.56521
Original Volume	1.4504e-005 m^3
Final Volume	8.3319e-006 m^3
Percent Volume of Original	57.444
Original Mass	4.0757e-002 kg
Final Mass	2.3413e-002 kg
Percent Mass of Original	57.444
Visibility	
Show Optimized Region	Retained Region
Information	
Iteration Number	20



Topology Optimization of Z section

Topology Density Object Name	*Topology Density*
State	Solved
Scope	
Scoping Method	Optimization Region
Optimization Region	Optimization Region
Definition	
Type	Topology Density
By	Iteration
Iteration	Last
Retained Threshold	0.5
Exclusions Participation	Yes
Calculate Time History	Yes
Suppressed	No
Results	
Minimum	1.00E-03
Maximum	1
Average	0.53327
Original Volume	1.5019e-005 m³
Final Volume	8.3023e-006 m³
Percent Volume of Original	55.278
Original Mass	4.2204e-002 kg
Final Mass	2.3329e-002 kg

II. CONCLUSIONS

This study is mainly concentrated on the optimization of Material of the model aircraft wing mounting bracket, optimization will help in reducing the unwanted material investment, simplifying the design and reduce the production time, in this work 2 components of mounting bracket are optimized , all the observations are discussed below, the optimized models have irregular shapes, and are not ready for manufacturing, these models are to be redesigned excluding the portions that are removed during optimization.

1. As these optimizations are targeted for material optimization the dead mass is optimized.
2. Successive models are to be redesigned excluding the volumes removed during optimization.
3. For I section the mass of the object is optimized to 57% of its original mass. (4.0757e- 002 kg to 2.3413e-002 kg)
4. For Z section the mass of the object is optimized to 55% of its original mass. (4.2204e- 002 kg to 2.3329e-002 kg)
5. By optimizing these models we can reduce the material cost by 44% and additionally material handling cost, machining cost etc. are also reduced significantly

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