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DESIGN, DEVELOPMENT & ANALYSIS OF AIRCRAFT DROOP NOSE RIBS BY USING OPTIMIZATION TECHNIQUE

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ABSTRACT

This master thesis work presents the development of a parameterized automated generic model for the structural design of an aircraft wing. Furthermore, in order to perform finite element analysis on the aircraft wing geometry, the process of finite element mesh generation is automated. The generic model that is developed in this regard is able to automate the process of creation and modification of the aircraft wing geometry based on a series of parameters which define the geometrical characteristics of wing panels, wing spars and wing ribs. Two different approaches are used for the creation of the generic model of an aircraft wing which are “Knowledge Pattern” and “Power Copy with Visual Basic Scripting” using the CATIA V5 Software. A performance comparison of the generic wing model based on these two approaches is also performed. In the early stages of the aircraft design process, an estimate of the structural characteristic of the aircraft wing is desirable for which a surface structural analysis (using 2D mesh elements) is more suitable. In this regard, the process of finite element mesh generation for the generic wing model is automated. Furthermore, the finite element mesh is updated based on any changes in geometry and the shape of the wing panels, wing spars or wing ribs, and ensure that all the mesh elements are always properly connected at the nodes. The automated FE mesh generated can be used for performing the structural analysis on an aircraft wing. Topology optimization has for a considerable time been applied successfully in the automotive industry, but still has not become a mainstream technology for the design of aircraft components.. Also, aircraft components are often stability designs and the compliance based topology optimization method still lacks the ability to deal with any buckling criteria. The present paper considers the use of the compliance formulated topology optimization method and detailed sizing/shape optimization methods to the design of aircraft components but also discusses the difficulties in obtaining correct loading and boundary conditions for finite element based analysis/optimization of components that are integral parts of a larger structure.

KEYWORDS: Aircraft, Power Copy, 2D Mesh Elements.

1. INTRODUCTION

Aircraft design is a complex and multi-disciplinary process that involves a large number of disciplines and expertise in aerodynamics, structures, propulsion, flight controls and systems amongst others. During the initial conceptual phase of an aircraft design process, a large number of alternative aircraft configurations are studied and analyzed. Feasibility studies for different concepts and designs are carried out and the goal is to come up with a design concept that is able to best achieve the design objectives. One of the crucial studies in any aircraft design process is the conceptual design study of an aircraft wing. The aircraft wing is one of the most critical components of an aircraft not only from an aerodynamics point of view but also from a structural point of view. The aircraft wing is designed in such a way that it is able to provide the requisite lift while minimizing the drag. Drag is critical from the aerodynamics point of view because it directly affects the performance of the aircraft like fuel efficiency and range. Not only does the wing provide the necessary lift during flight, the aircraft wing is designed structurally to carry the entire weight of the aircraft. Also, in modern commercial aircrafts and fighter airplanes, the aircraft wing has more than one role. It not only carries the fuel required for the flight but is also used to provide storage bays where, the aircraft landing gears can be mounted and stowed during takeoff (which are normally placed inside the wing root of an aircraft). Furthermore, modern commercial airplanes have padded engines which are placed below the wing.\

This means that the aircraft wing has to be sufficiently strong from the structural perspective to carry the weight of these engines, fuel inside the wing box and internal components. A variety of components are also placed inside the aircraft wing which includes electro- mechanical actuators, fuel lines, and hydraulic, pneumatic and electrical systems amongst others. All of these components are to be compactly placed inside the wing, thus, the aircraft wing has to perform structurally and aerodynamically well to deliver the desired performance. Weight is one of the fundamental critical factors in any aircraft design process and aircraft designers are always on the lookout for ways to minimize the weight of the aircraft. This means that a light weight aircraft should have a light weight wing as shown in Fig.1. A light weight aircraft is thus beneficial for increasing the design performance. In the conceptual phase of an aircraft design process, different design studies are carried out for different components of the aircraft. One of the major portions of these studies is dedicated towards the design of the aircraft wing both from a structural and aerodynamics point of view. However, in this stage High-end CAD software"s are not employed as they are thought to be too complex or demanding to be used during this stage. Therefore, the promising design configurations have to be remodelled again later in the detail design process which increases cost and the time to production. It can be very beneficial from a design perspective, if these CAD software"s are employed from the start of the aircraft design process. This would enable less remodelling of the design in the detail design process and would also enable increased capability to do modelling and simulation during the conceptual phase. A generic model is thus required in this regard that would speed up the design process of analyzing different aircraft win configurations.

2. OBJECTIVE AND CHALLENGE OF DROOP NOSE RIB

To the aerospace industry, the overall weight of an aircraft is a critical design requirement due to the impact just a few kilograms can have on fuel efficiency and co2 emissions. Heavier aircraft use more fuel during flight which leads to increased running costs for the airline carriers. When designing the world"s largest passenger aircraft, the airbus wanted to ensure the design was as lightweight as possible while maintaining all performance standards. To achieve objective and challenge we are using this thesis work presents the development of the generic parameterized aircraft wing model by using CATIA V5 CAD software which provides tools and features for automated geometry generation and modification. In using this CAD software, A structural mesh generation of the generic aircraft wing model is also created. It is ensured that the mesh elements are properly connected at the nodes and the mesh elements are of good quality. Altair Hypermesh for pre-processing, Solver is Altair Radioss, for post processing Altair Hyper view and for achieving new design and less weight using Altair Optistruct.

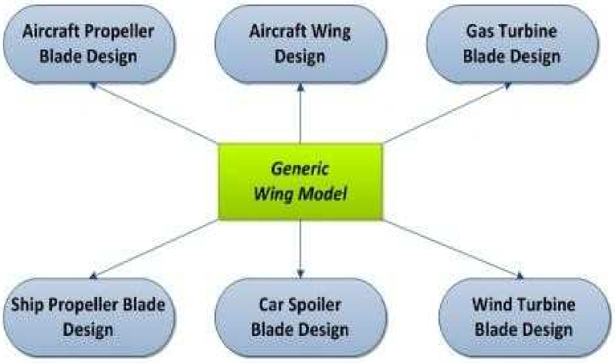

Fig.1. Application of general wing model

2.1 Applications

The generic wing model that is developed in this thesis work can not only be used for designing of the aircraft wing which is its primary application, but, also can be used for designing other types of wing shapes used in other applications. The structure of the model is made as general and generic as possible for enabling its use in different applications. For example, the generic wing model can be used for designing aircraft propeller blades, gas turbine blades, wind turbine blades, car spoilers and ship propeller blade etc.

2.2 Positioning and Shape Of Wing

When the positioning of the wing on the fuselage and the shape of the wing is changed, different types of wing configurations can be achieved, some of which are shown in the fig.2 below,

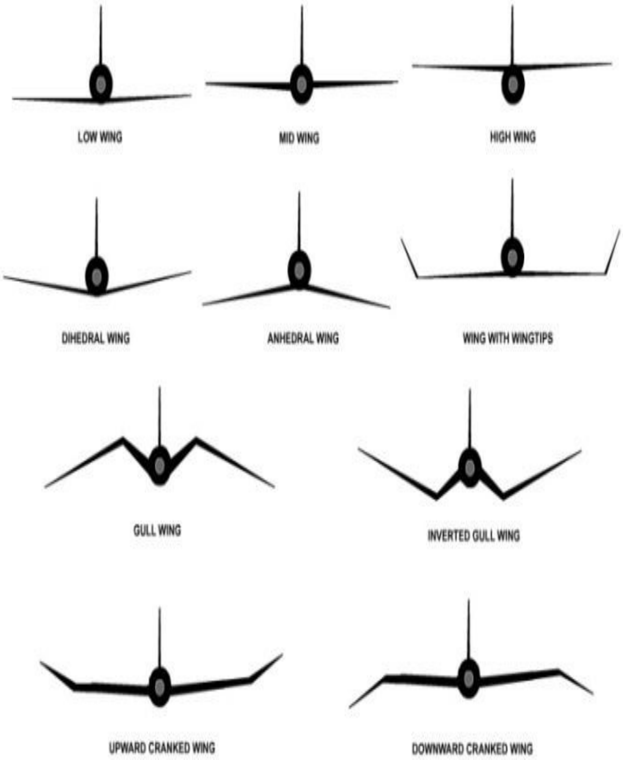

Fig.2. Positioning and Shape of the Wing

3. GENERIC AIRCRAFT STRUCTURAL WING DESIGN CONCEPT

3.1 Aircraft Design Process

Aircraft design process is a complex undertaking, however, the design process can generally be divided into three phases which are outlined in the fig.3 below. There is a certain amount of overlapping between these three phases and the number of people, resources and cost associated with the design gradually increases between these phases. The different stages of the aircraft design process are,

- Conceptual Design
- Preliminary Design
- Detail Design

Fig.3. General Overview of Aircraft Design Process.

3.2 Tools And Methods

A breakdown of the tools and methods used in this thesis work is given in the fig.4

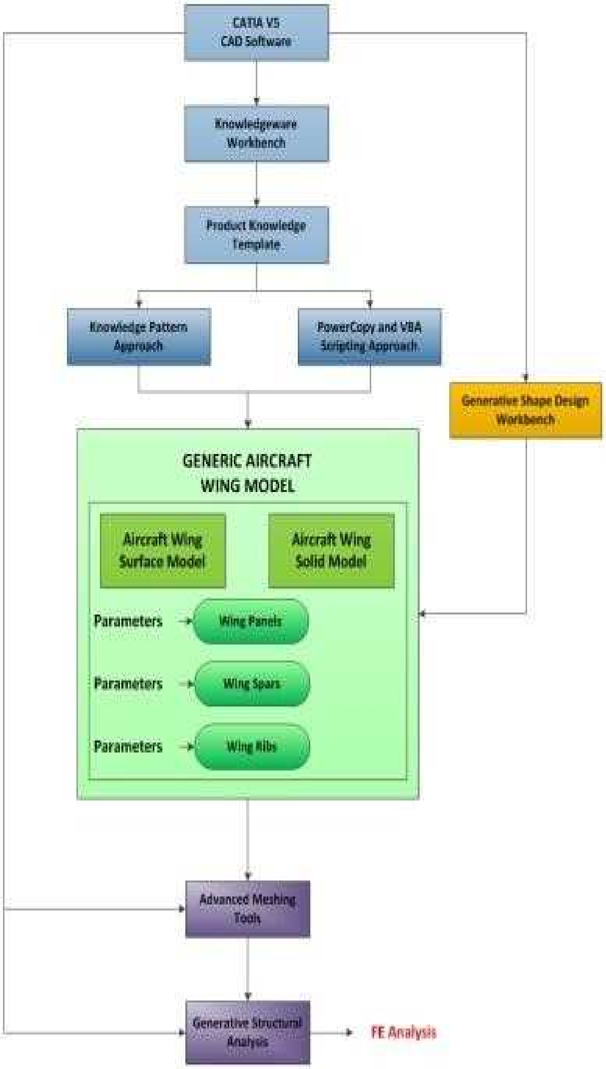

Fig.4. Tools and Methods used for creation of generic aircraft wing model

A. Modelling Of Wing RIB

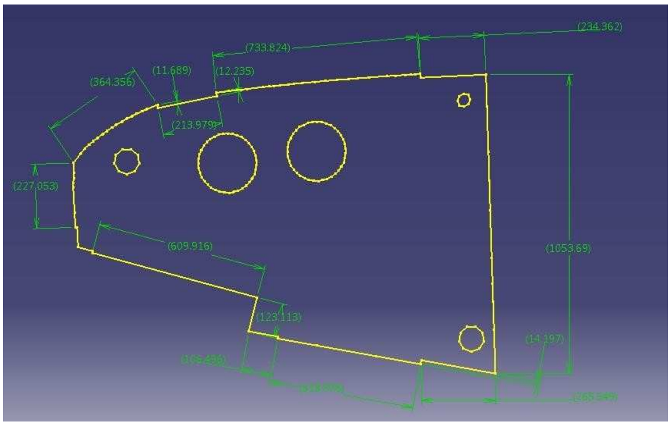

Fig.5. 2D drawing Using CATIA V5R19 Software.

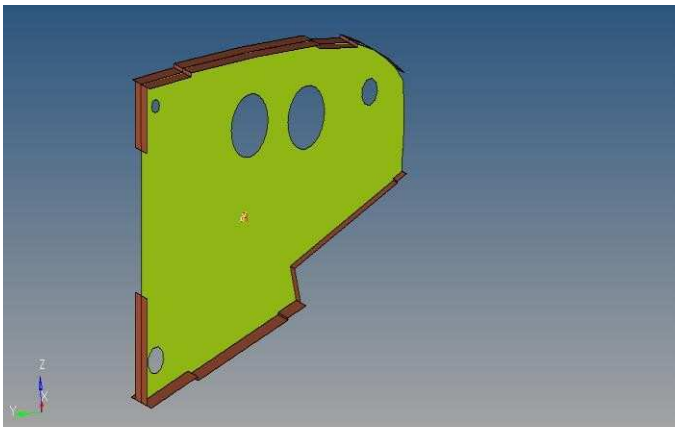

Fig.6. 3d model is developed in catia v5r19 software model.

3.2 Solid Meshing

Using solid geometry, HyperMesh can utilize both standard and advanced procedures to connect, separate or split solid models for tetra-meshing or hexa-meshing. Partitioning these models is fast and easy when combined with Hypermesh powerful visualization features for solids. This allows users to spend less time preparing geometries for solid meshing. The solid-meshing module allows users to quickly generate high quality meshes for multiple volumes as shown in Fig.7.

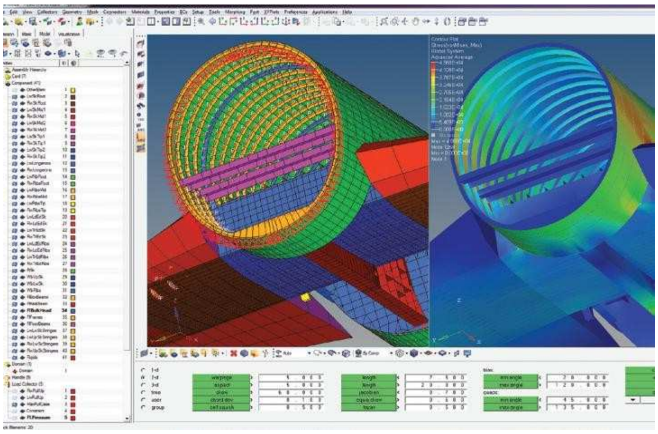

Fig7.Modern and Efficient CAE Modeling Environments

4. PREPROCESSING AND SOLVER

4.1 Preprocessing

Altair® HyperMesh® is a high-performance finite- element pre-processor that provides a highly interactive and visual environment to analyze product design performance. With the broadest set of direct interfaces to commercial CAD and CAE systems and a rich suite of easy-to-use tools to build and edit CAE models, HyperMesh provides a proven, consistent analysis platform for the entire enterprise.

4.2 Best In Class Meshing

HyperMesh presents users with an advanced suite of easy-to-use tools to build and edit CAE models. For 2D and 3D model creation, users have access to a variety of mesh generation capabilities, as well as Hypermesh"s powerful automeshing module.

4.3 High Fidelity Meshing

- Surface Meshing
- Solid map Hexa Mesh
- Tetra Meshing
- CFD Meshing
- SPH Meshing

Surface Meshing: The surface meshing module in HyperMesh contains a robust engine for mesh generation that provides users with unparalleled flexibility and functionality. This includes the ability to interactively adjust a variety of mesh parameters, optimize a mesh based on a set of user- defined quality criteria, and create a mesh using a wide range of advanced techniques.

4.4 Automesh

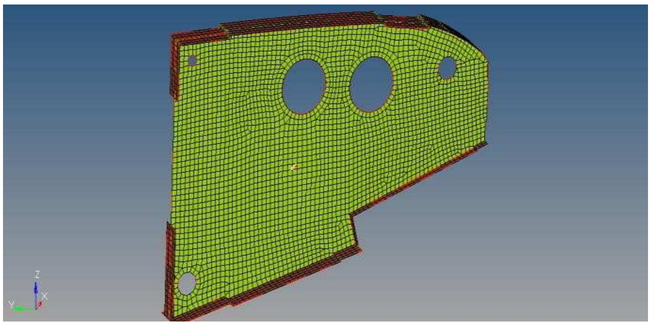

Fig.8.Automesh using 20mm element size. Thickness for Rib component:

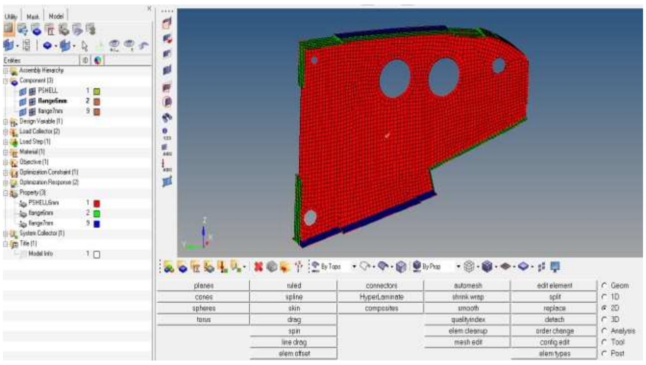

Fig.9. Thickness for Rib component

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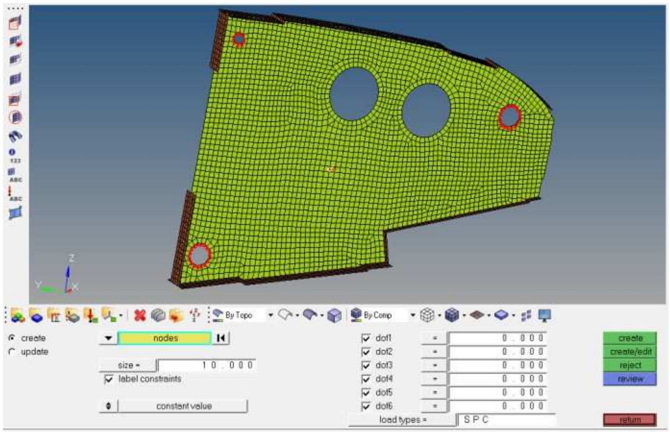
Analysis page- Constraints (FIX) and Pressure applied: Go to analysis page it will shown some tools take constraints option and fill the three circles of smaller diameter select each node in each circle it will highlited as constraints for every circle after that applying pressure in analysis page.



● create
○ update

nodes

size = 10.000

☑ label constraints

constant value

☑ dof1 = 0.000
☑ dof2 = 0.000
☑ dof3 = 0.000
☑ dof4 = 0.000
☑ dof5 = 0.000
☑ dof6 = 0.000

load types = SPC

Fig.10. Analysis page- Constraints (FIX) in all DOF, selected nodes are highlighted.

5. RESULTS AND DISCUSSIONS

Aerodynamic load is applied to wing rib and solved results are shown below Figs.11 & 21.

5.1 Displacement

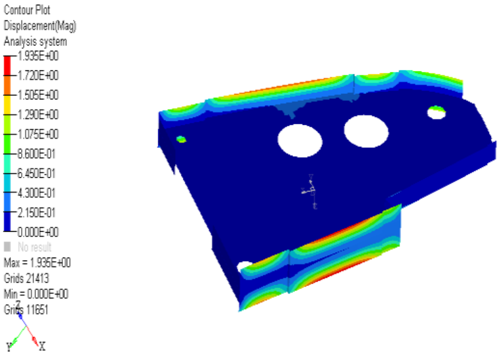


Fig.11. The value of Displacement is 1.935 mm. Stress:

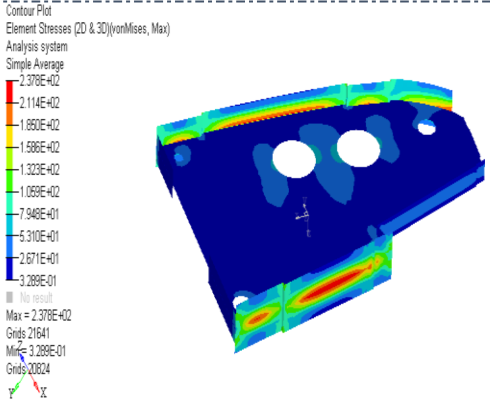


Fig.12. The value of Stress is $2.378*10^2$ Mpa

The value of stress in base model is $2.378*10^2$ is converted into is 237Mpa. After visualizing the static results optimization will come I the picture to get innovative shape of wing rib. Optimization techniques are shown below, different techniques are explained in brief.

5.2 Re-Design of the Optimized Model and Pre-Processing Methodology

Basic reference model is changed to the above design after applying the OptiStruct application to that. Design changes had been generated in Hypermesh using osssmooth option.

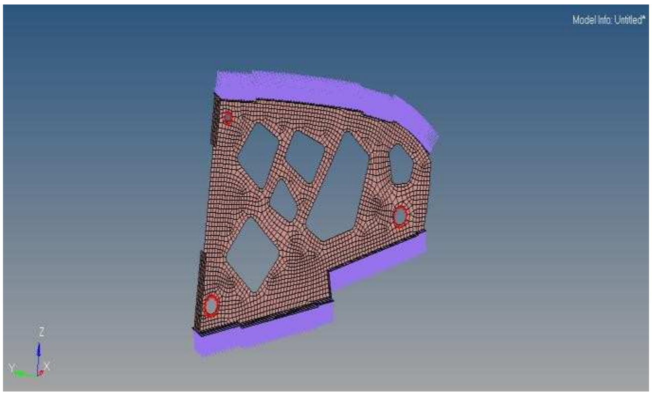


Fig.13. New design of optimized result is meshed in hyper mesh.

5.3 Results of Base Model Aircraft Rib Wing Displacement:

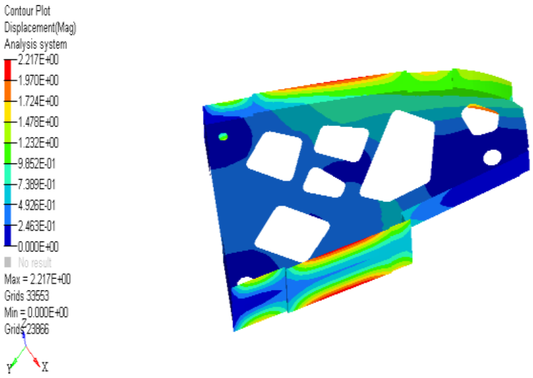


Fig.14. displacement for optimized model is 2.217 mm. Stress:

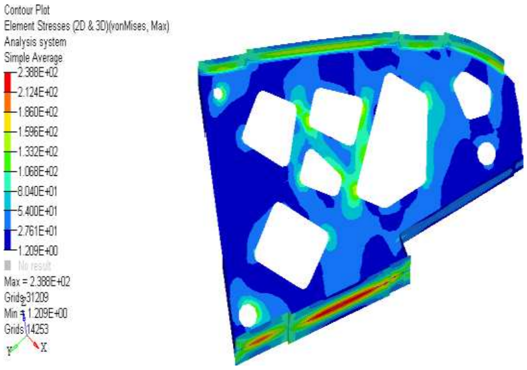
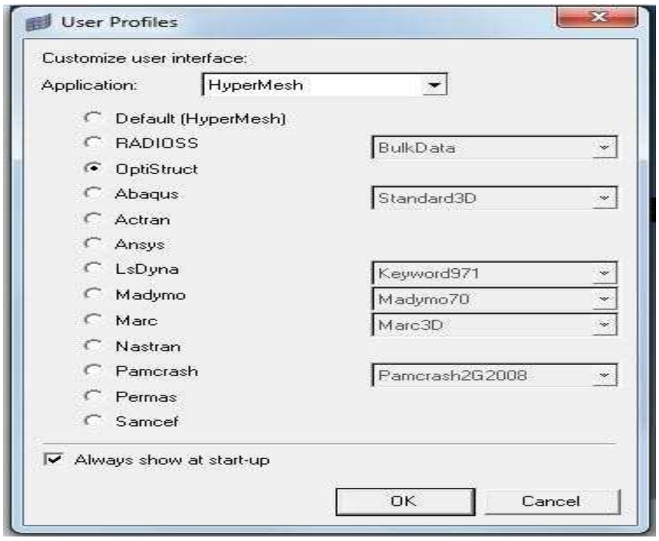


*Fig.15. Stress for optimized model is 2.355*10^2 tones.*

The value of stress in optimized model is $2.355*10^2$ is 238 Mpa.

5.4 Optimization Process

Optimization is done to the control arm model the steps of optimization technique are mentioned below. First step is user profile should change to Optistruct in hypermesh interface.



User Profiles

Customize user interface:

Application: HyperMesh

○ Default (HyperMesh)
○ RADIOSS — BulkData
● OptiStruct
○ Abaqus — Standard3D
○ Actran
○ Ansys
○ LsDyna — Keyword971
○ Madymo — Madymo70
○ Marc — Marc3D
○ Nastran
○ Pamcrash — Pamcrash2G2008
○ Permas
○ Samcef

☑ Always show at start-up

Fig.16. User profile to solve Optistruct.

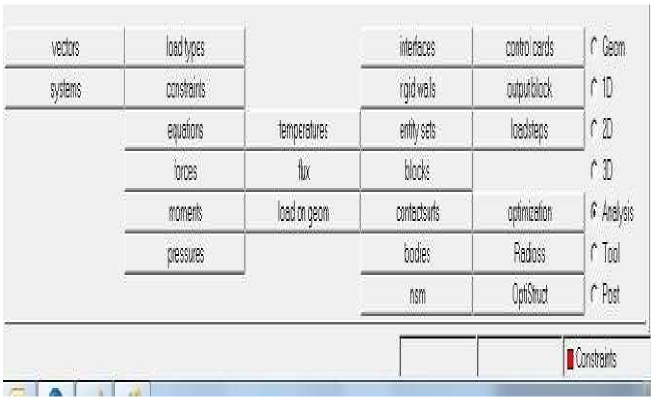


Fig.17. Optimization problem setup in Analysis page.

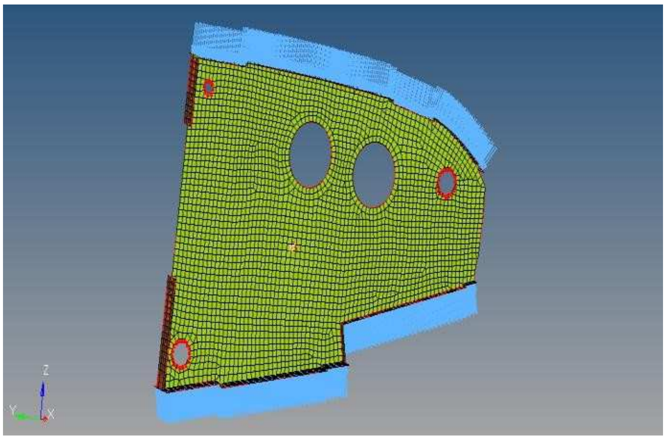


Fig.18.Design area is green colour area and non design area is flanges

5.5 Optimized Model Results

Optimization is completed and results are taken 6 iterations to complete the thickness and topology optimization.

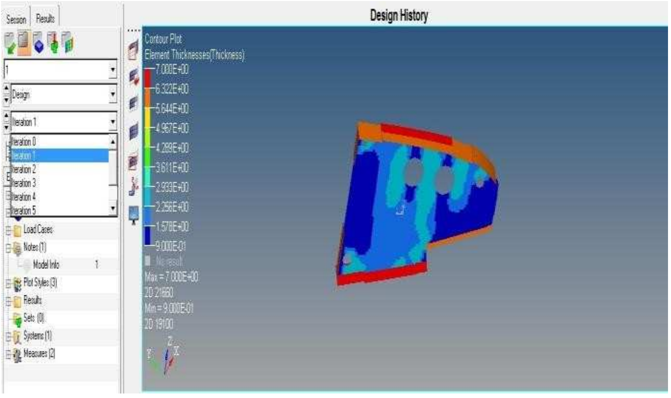


Fig.19. Iterations for free Size optimization.

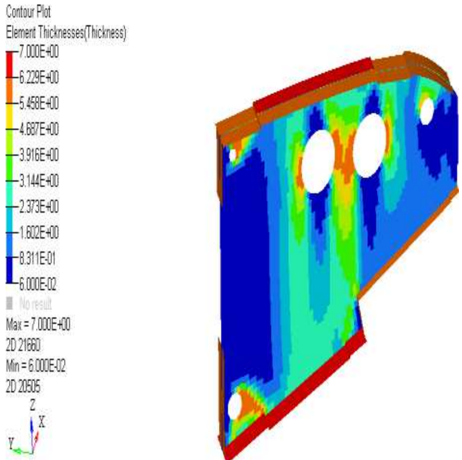


Fig.20. Thickness optimization is given perfect results for the given loads.

Topology method using Optistruct is shown in above figure, steps are involved is same like free size optimization. Response is given for volume fraction as 0.3% from the total volume and weight compliance as a objective which will reduce the weight of the component by giving innovative shape to wing.

Fig.21. Present Dummy and trail prototype for Viewing the thickness and optimized model.

6. CONCLUSION

The present work illustrates how topology, sizing and shape optimisation tools may be used in the design of aircraft components. The technology has been successfully used in an industrial environment with short industrial time scales and has on a single application proved to be able to provide efficient stress and stability component designs. Initial studies have shown that care should be taken in the modelling of the load and boundary conditions of the components. For aircraft component design it is also important to be aware of the impact of changing loading situations. The truss type designs obtained using the topology optimisation is highly specialised designs optimised for certain loading situations. Load definitions generally change as the design of an aircraft mature, and this could seriously affect the optimality of the structure. It could therefore prove important to carefully select applications for topology optimisation and only use the technology on structures with well efined loading conditions. The varaiation of pressure is induced in optimized model ompared to base model as per the requirement of below yield point stress which is 325 Mpa and as well as the variation of displacement is induced in optimized model compared to base model which is lower than the 3 mm as per the requirement. As per the given requirement the reduction of weight is 16% decreased compared to reference model. Hence the cost analysis also reduces by using the base model and optimized model readings.

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