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DESIGN AND ANALYSIS OF WING RIB OF TWO SEATED AIRCRAFT

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i. ABSTRACT

In an aircraft, ribs are forming elements of the structure of a wing, especially in traditional construction. By analogy with the anatomical definition of "rib", the ribs attach to the main spar, and by being repeated at frequent intervals, form a skeletal shape for the wing. CATIA offers a solution to shape design, styling, surfacing workflow and visualization to create, modify, and validate complex innovative shapes from industrial design to Class-A surfacing with the ICEM surfacing technologies. CATIA supports multiple stages of product design whether started from scratch or from 2D sketches. Nastran is Multidisciplinary Structural Analysis which is widely used Finite Element Analysis (FEA) solver to simulate stress, dynamics, or vibration of real world, complex systems. Today's aircraft manufacturers are using Nastran for structural analysis from parts to complex assemblies. Patran is the world's most recommended used pre post processor software for Nastran. It provides solid modeling, meshing, analysis, set up and post processing. It provides a rich set of tools that streamline the creation of analysis ready models for linear, non-linear, explicit dynamics, thermal, other finite element solutions.

ii. INTRODUCTION

Constant need for more cost efficient and environmentally friendly aircraft is the driving force in developing lightweight structures. Composites have succeeded in decreasing the structural weight and therefore their proportion as a structural material has increased. For example in the world's largest passenger aircraft, Airbus A380, the structural weight proportion of composites is over 20%. All-composite wings have been used in military planes already in the early 1970's. For example already in 1974 flown Harrier AV-8B/GR5 has an all-composite wing. In civil aircraft carbon fibre reinforced plastics (CFRP) are used mainly in the wing skins with a metallic substructure [1]. As a result of increased knowledge of materials, composites are nowadays replacing also metallic substructures such as the wing ribs.

The rib foot corner has been the determinant for strength in composite ribs. The purpose of this thesis is to find simple analytical calculation tools for strength evaluation of the composite rib foot corner and to develop test methods to support these analyses. The parameters affecting the strength of the composite rib foot corner are studied through the analysis and tests. This information can be used for composite wing rib design and sizing. The rib foot corner is particularly difficult from the composite design point of view because both the lateral and normal loads to the bolt central axis cause out-of-plane tensile and shear stresses.

Failure load of a composite rib foot corner is usually tested with a curved laminate. The angle in the laminate is 90˚ and it is bolted to a rigid plate. This element level test is referenced as L-pull test. In the finite element method analysis (FEM) the bolted joint is commonly approximated with proper boundary conditions to avoid laborious modelling. Boundary conditions are later verified by comparing analysis results with test results. This means that the influence of certain parameters cannot be varied in analysis without time consuming modelling.
As mentioned earlier the L-pull test arrangement provides the failure load of a specific assembly. It does not separate the out-of-plane tensile and out-of-plane shear failure. The fracture mode is hard to define because both of these stresses cause delimitation between layers around the corner. This thesis intends to find out the failure modes of specific rib foot corner specimens and to provide information how different parameters affect the failure mode. Different failure criteria are considered in order to find out which criterion gives the most accurate failure load predictions. Comparison of different failure criteria also provides information of possible interaction between failure modes.

iii. LITERATURE SURVEY

In their paper focuses on the effects of structure, mechanical properties, and morphology of dragonfly wings on their fly ability, followed by the implications in fabrication and modelling. Dragonfly wings possess great stability and high load-bearing capacity during flapping flight, glide, and hover. Scientists have been intrigued by them and have carried out research for bio mimetic applications. The mechanical properties of dragonfly wings need to be understood in order to perform simulated models.

They studied the influences of uncertainties in the structural parameters on the flutter speed of wing. These uncertain factors are described by interval numbers. With the help of first-order Taylor series expansion, expansion, the interval finite element model for the flutter analysis of wing with certainties is presented, which can give an approximate interval estimation of the varying range of the flutter speed caused by uncertainties.

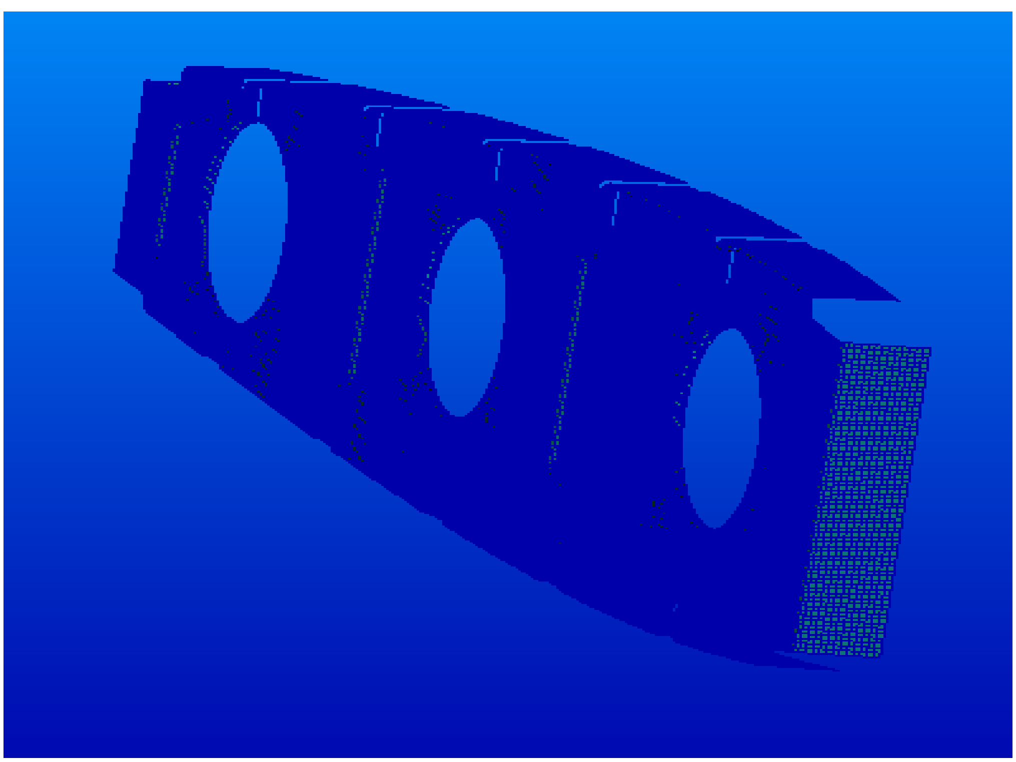
iv. FEM DESCRIPTION

MSC Nastran is a general purpose finite element analysis computer program. "General purpose" means that MSC Nastran addresses a wide range of engineering problem-solving requirements (i.e. beam versus plate structures and various types of response such as statics or dynamics) as compared to special type programs, which concentrate on particular types of analysis. MSC Nastran is written primarily in FORTRAN and contains over one million lines of code. MSC Software's clients lease or purchase executable-only versions of the program. MSC Nastran is available on a large variety of computers and operating systems ranging from Windows/PC to large Linux clusters. Regardless of the computer system used, MSC Nastran is optimized to run efficiently and provide identical results on every system.

The MSC Nastran program has evolved over many versions. Each new version contains significant enhancements in analysis capability and numerical performance. In addition, many errors from previous versions are corrected. (No computer program of any degree of sophistication is free of errors-MSC Software Corporation maintains a detailed and frequently updated list of known errors, including suggestions for alternate approaches.)

MSC Nastran is composed of a large number of building blocks called modules. A module is a collection of FORTRAN subroutines designed to perform a specific task-processing model geometry, assembling matrices, applying constraints, solving matrix problems, calculating output quantities, conversing with the database, printing the solution, and so on. The modules are controlled by an internal language called the Direct Matrix Abstraction Program (DMAP). Each type of analysis available in MSC Nastran is called a solution sequence, and each solution sequence is a pre-packaged collection of hundreds or thousands of DMAP commands. Once a solution sequence is chosen, its particular set of DMAP Commands send instructions to the modules that are needed to perform the requested solution. All of this happens automatically with no effort on your part beyond choosing a solution procedure (sequence)

Global finite element modal (GFEM)



The Global meshing model

V. WING RIB MODELLING AND STRESS ANALYSIS

Computer-Aided Design (CAD) has wide applicability in the design and development process of an aircraft [1,3]. CAD is the use of computer software and systems to design and create 2-D and 3-D virtual models, the benefits of which are increasing rapidly, ranging from shape visualization to its analysis, machining, layout designing and considerable cost reduction. Availability of CAD models reduce the experimentation considerably and aid in quick changes to design with initial estimates hence reducing the design and development cycle[2,4]. Creating drawings, preparing reports of assembly and part drawings, preparing bill of materials, etc. become much easier and faster with the use of CAD systems.

Modelling of rib:

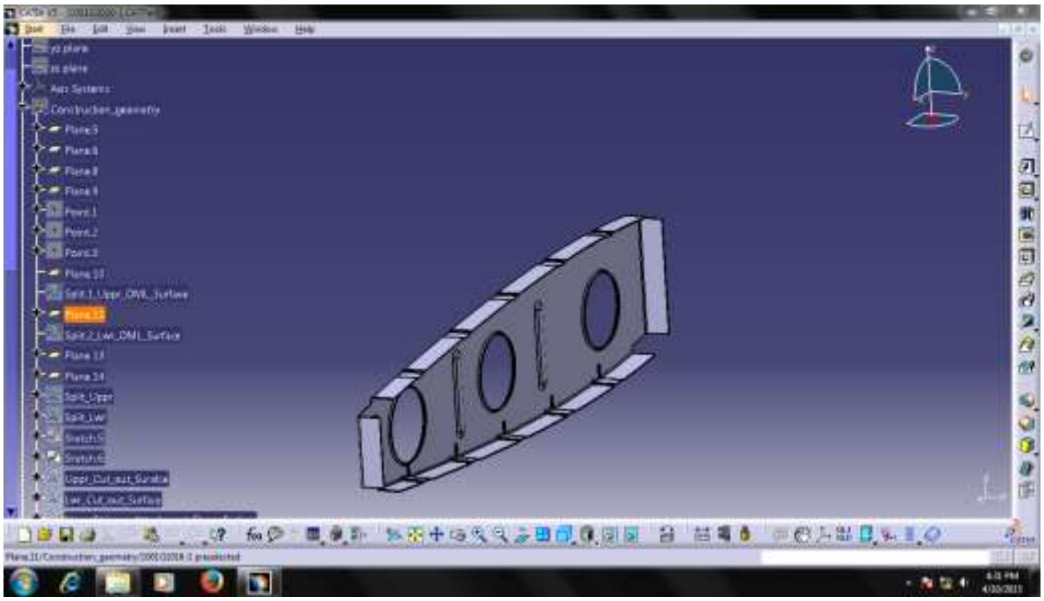


Figure Rib model 1

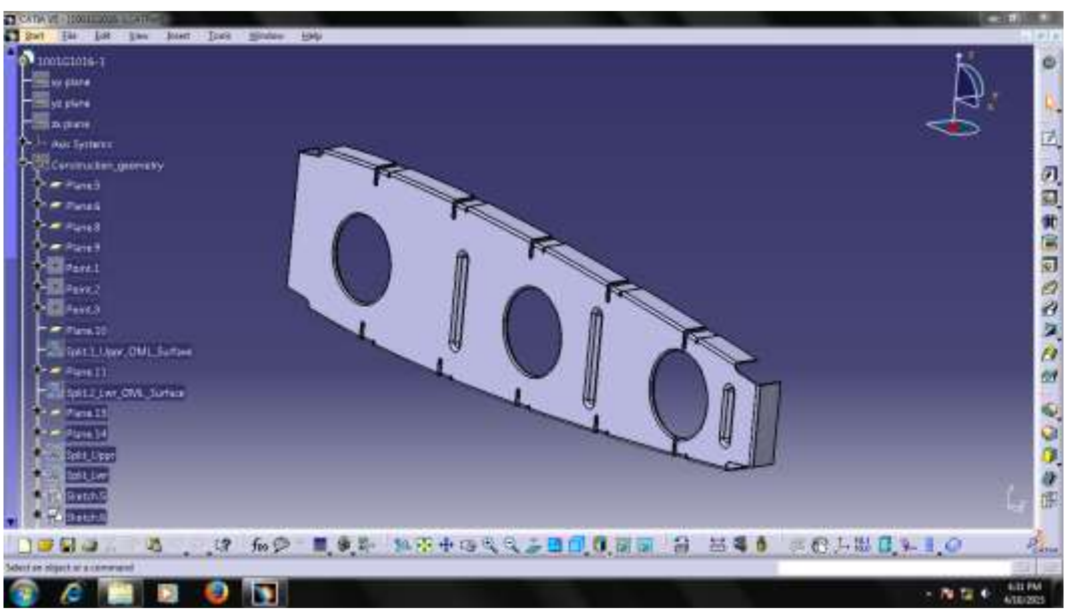


Figure Rib model

Wing Rib Stress Analysis:

The aircraft is constructed primarily from thin metal skins which are capable of resisting in plane tension and shear loads but buckle under comparatively low values of in-plane compressive loads. The skin therefore is stiffened by longitudinal stringers which resist the in-plane compressive loads and at the same time resist small distributed loads normal to the plan of the skin. For aerodynamic reasons the wing contours in the chord wise direction must be maintained without appreciable distortion. Therefore to hold the skin-stringer wing surface to contour shape internal structural support units are presented which are referred to as wing ribs. Figure 3.3 shows the internal construction of the historical aircraft 727, where the lower skin is not installed, showing the wing ribs between the lower and the front spars and their extension in the leading edge.In addition to the wing rib main function of maintaining the wing aerodynamic shape, the ribs also are presented for many other purposes that can be summarized as:

1- Limiting the length of the stringers to an efficient column compressive strength which increases the skin-stringers stability under compressive loads.

2- Transferring and distribution loads All the loads applied to the wing are reacted at the wing supporting points, thus these applied loads must be transferred into the wing cellular structure composed of skin, stringers spars,…etc and then react at the wing supporting points, these applied loads can be summarized as a- Aerodynamic loads acting on the skin-stringer panels are transferred to the rib webs, which by its roll transfer it to the spars. This function requires light ribs.b- Concentrated forces resulting from landing gears and power plants support points. These forces should be transferred to the wing cellular units in the form of distributed shear flows, this function is handled by the wing ribs which requires heavy ribs referred to as bulkheads.c- Between the forces mentioned in ‘a’ and ‘b’ there are medium forces Resulting from the flaps, ailerons, fuel tanks supporting points, armaments, etc.d- Body forces in the form of gravitational forces (wing structural weight) and inertia forces due to wing structural mass.

3- Redistributing shear forces at discontinuities in the wing in the form of cut outs for the landing gears, inspection holes, etc.

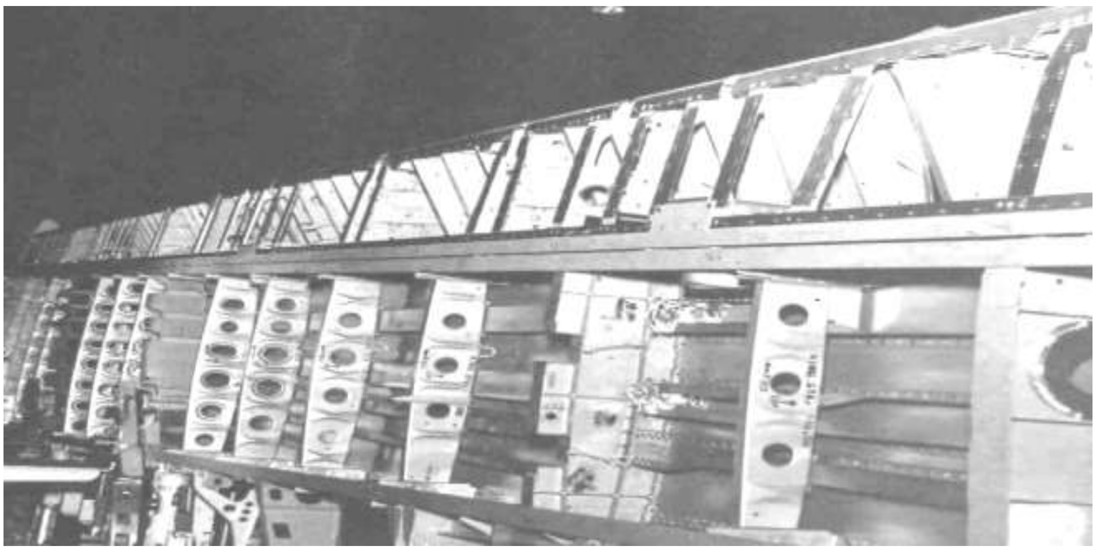


Figure 727 aircraft wing with lower skin not installed showing the wing rib

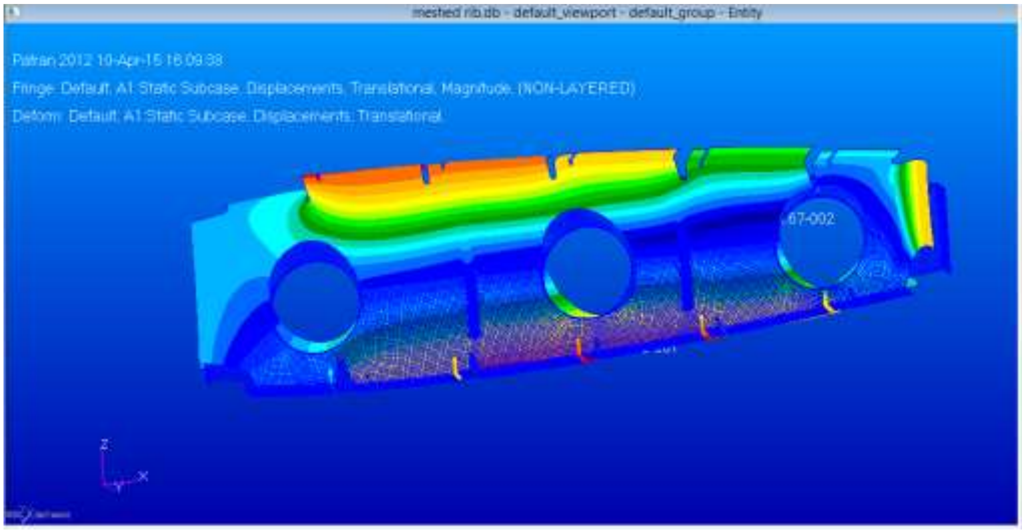
vi. ANALYSIS

This chapter contains the static and stability (buckling) analysis of the skin stringer panel in this we are using Nastran solution sequence 101 and 105.It contains an overview of the method and basic assumptions, geometrical information, derivation of loads and allowable. The wing rib analyses are derived from the following general requirements:

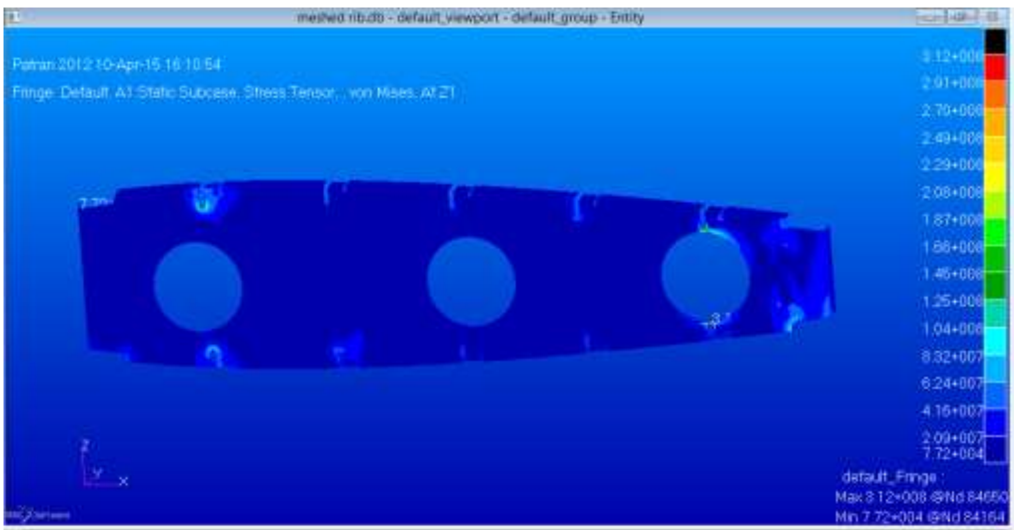
1. The structure must be able to support Limit Load without detrimental permanent deformation.
2. The Load Factor of 1.5 must be applied to the Limit Load to obtain Ultimate Load
3. In demonstrating Static Strength for secondary structure, it is acceptable to use “B” basis equivalent material properties and design values
4. Aerodynamic contour and smoothness requirements must be satisfied.

Rib Strength Check

Portions of the upper rib of the wing rib are analyzed as simply-supported flat plates. The ribs are sized to be stable up to Design Ultimate Load (DUL) and therefore no secondary loads due to tension field effects are considered in the other analyses. Each rib is idealized as a rectangular plate .Although many of the rib flanges are skewed, each bay is idealized as a rectangular plate with an equivalent area. Idealized plates are typically defined from fastener to fastener and/ or to the centre of a stiffener. The long dimension of the plate is usually defined as the "a" dimension and the perpendicular distance to the other edge is defined as the "b" dimension.



Stress Tensor result



Displacement Result

Conclusion:

From the above results we can conclude that the margin of safety is greater than zero. That means that rib is safe in strength. Although all the results through PATRAN are approximate and one can get close to that approximate result by decreasing the mesh size. If the margin of safety of the body is less than zero there is a chance to material will fail. PATRAN and NASTRAN will not show that at what instant of stress, the material will break. Its users part to analysis the reading and compare it with some standard reference data and arrive at some reasonable conclusion with the help of some considerable assumptions.

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