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Design and Analysis of Horizontal Tail - Fuselage Attachments

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***Abstract* - The objective of the project is to Design and Analyze a fitting for adjustable horizontal tail for sports utility aircraft. In designing the fittings the modeling strategy adopted is “Relational Design”, so that every part is made relational with the aerodynamic datum surfaces provided by the organization. The designing of the parts is done in the CATIA V5.After the designing, analysis of the fitting has been carried out in Msc. NASTRAN/PATRAN. The loads applied are the reactions acting on the fitting as resultant of the aerodynamic loads acting on the whole horizontal tail for fail proof design 2-sigma loading conditions are considered. The FEM analysis also been validated by classical methods and the margin of safety are calculated and ensured that they clear ‘0’.Finally drafting is done in CATIA V5 after concluding the dimensions.**

***Key words* - CAD modeling of the product, static analysis, Finite element analysis, strength**

***Nomenclature* -**

1. **FEA – Finite element analysis**
2. **Lbs - pounds force**
3. **in: Inches “: Inch**
4. **Mpa – Mega pascal.**
5. **Gpa – Giga pascal.**
6. **MDS – Master Dimensional Surface**

I. INTRODUCTION

The objective is to design a fitting for an adjustable horizontal stabilizer.

- The fitting should satisfy the required mechanism, and have to withstand the load reactions acting on it.
- Shapes of the fittings are designed after thorough literature survey.
- Proper materials are selected considering the functionality, such that their allowable provide sufficient margin of safety (>1).
- The product includes single lug, double lug, and rib bracket for the attachment.
- The double lug is fixed to ribs of the tail wing.
- The single lug is attached to the double lug which is movable.
- The rib bracket is fixed in between the fuselage frames.

The objective is to learn and obtain a properly sized and analyzed Hinge fitting for adjustable Horizontal tail of the sports utility aircraft; loads at 150 degrees angle of attack for the elevator are considered to be acted on the hinge fitting.

The scope of this report is to design the Horizontal Tail Fitting and analyze it through Classical and FEA methods, thus includes

- Modeling in CATIA V5
- Analyzing by both Classical & FEA (MSC PATRAN/NASTRAN) approaches
- Resizing if required
- Drafting in CATIA V5

In designing the fittings the modeling strategy adopted is “Relational Design”, so that every part is made relational with the aerodynamic datum surfaces provided by the organization. The designing of the parts is done in CATIA V5. After the designing, analysis of the fitting has been carried out in Msc. NASTRAN/PATRAN. The loads applied are the reactions acting on the fitting as resultant of the aerodynamic loads acting on the whole horizontal tail for fail proof design 2-sigma loading conditions are considered.

The FEM analysis also been validated by classical methods and the margin of safety’s are calculated and ensured that they clear ‘0’.

II. EXPERIMENTAL DETAILS

A. Design Methodology

The modeling of the product has done on the philosophy of Datum Based Design approach. Utilizing work planes in a skeleton structure to control the shape and position of components in an assembly. This is like placing all the crucial information in a high-level location and communicating that information to the lower levels of the product structure. The Datum based approach offers the ability to maintain design intent and minimize rework due to relational modeling. On operation it has been revealed that the datum method had a smaller total and per part files size, despite containing a greater number of parts. The design has started with in the same approach. All the parts are maintained in relation with master datum surfaces, with the help of their publications in RLM.The Master Geometry referred here are, three ribs of Horizontal Tail and 3 fuselage frames of aircraft.

B. *Problem Definition*

The working surface is known as a Master Dimensional Surface (MDS). The MDS is driven by the aerodynamics of the Aircraft; therefore this surface is crucial to defining the structure/shape of airframe models. An exact recreation of the skin was not required initially because of the relational nature of this design. The key to modern aviation design, in this strategy, is relational design. The parts were generated dynamically depending on the contour of the HT box and the positioning of the skeletal planes along the HT. Each part was created as a separate instance of a fully linked version Assembly. Since existing links were maintained between the MDS and each part, amendments are to be done based on a datum and the center axis of the aircraft.

C. *Material Selection*

One of the key design decisions of our fitting that greatly increases the safety, reliability and performance in any aircraft design is material selection. To ensure that the optimal material is chosen, extensive research was carried out and compared with materials from multiple categories. Material selection is predominantly concluded beyond the scope of this report. For high strength applications, the 7075 alloy is widely used. 7075 is alloyed with zinc, magnesium, and copper.

The aerodynamic loads acting on the HT are provided by Garuda Engineering Solutions. The Reactions at the station 1 where the front actuator is attached and at left and right station 2’s the aft hinges are located.

Table 1: Material specification chart

S.NO.	Material, aluminum	Density, lb/in3	Temp. limit, ^{0}F	FTU, 103 psi	FTY, 103 psi	FCY, 103 psi	FSU, 103 psi	E, 106 psi	G, 106 psi
1.	Clad,7075-T6-(sheet)	0.101	250	72	64	63	43	10.3	3.9
2.	Clad,7075-T6-(forgings)	0.101	250	749	63	66	43	10.0	3.8
3.	Clad,7075-T6-(extrusions)	0.101	250	81	72	72	42	10.4	4.0

The loads for Horizontal tail of Garuda 101 are evaluated at density (ρ) =1.225kg/mm3, Free stream velocity (V∞) = 100 Kmph for 150 maximum deflection of the elevator and 00 angle of attack of horizontal tail.

Overall distribution of Right Hand Horizontal Tail loads along the semi span is shown in appendix B.

D. *Phases of design*

Relational modeling technologies are crucial in the control of complex surface-driven models in the aviation industry. This Relational Modeling is applicable to the vast majority of design projects which do not proceed linearly from beginning to end. It is especially suited to conceptual design and to creation of parametric series of models as part of a design optimization process.

The same approach has been adopted to design this fitting based upon the aerodynamic datum surfaces and Master axis location, provided by the organization.

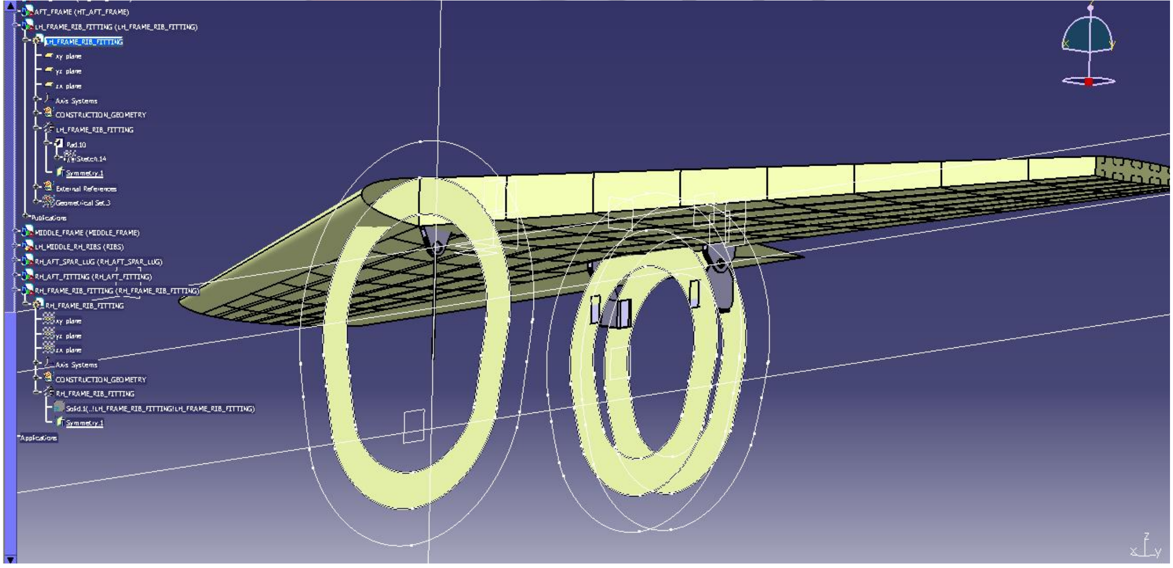


Figure 1 MDS and MDF’s

To create a relational design all the detail level parts (FWD and AFT fittings) along with master geometry (MDF, MDS, RLM) should belong to a single product only.

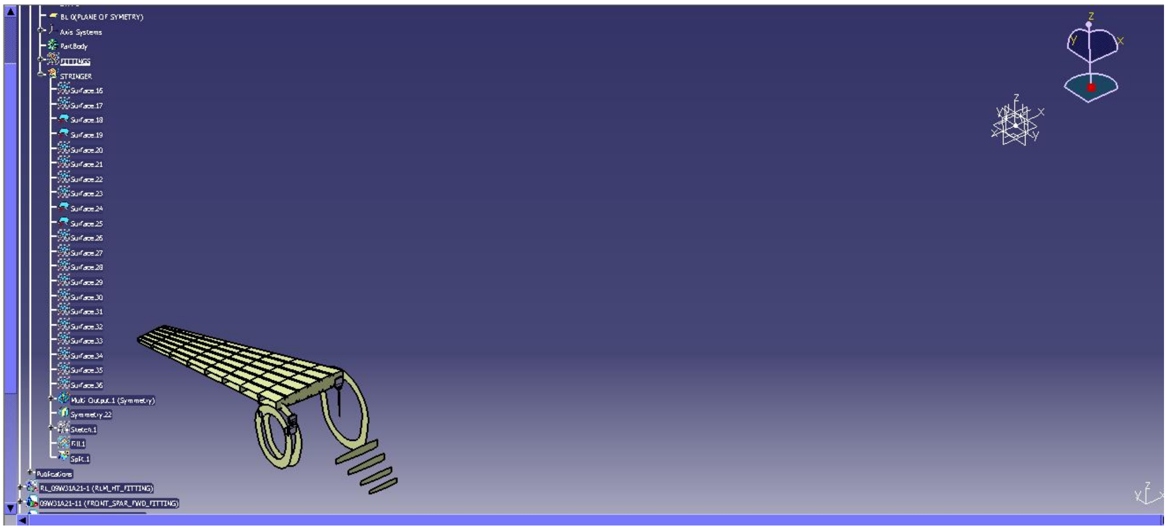


Figure 2 Showing Published RLM

Following the same approach the total product was split into two assemblies, including parts individually and are named with part ID's based on their location in the design

Table 2 Product Part Id's

PRODUCT	ID
HT_FITTING.PRODUCT	12W31D41-1
FRONT_HINGE_ASSEMBLY	12W31D41-14
FRONT_DOUBLE_LUG	12W31D41-11
ACTUATOR_ROD	OUT OF SCOPE
LH_AFT_ HINGE_ASSEMBLY	12W31D41-13
LH_AFT_DOUBLE_LUG	12W31D41-15
LH_AFT_RIB_BRACKET	12W31D41-16
LH_AFT_SINGLE_LUG	12W31D41-17
RH_AFT_HINGE_ASSEMBLY	12W31D41-14
RH_AFT_DOUBLE_LUG	12W31D41-18
RH_AFT_RIB_BRACKET	12W31D41-19
RH_AFT_SINGLE_LUG	12W31D41-20

Cad Sketches and Models

PART_ID: 12W31D41-11 (FWD_DOUBLE_LUG)

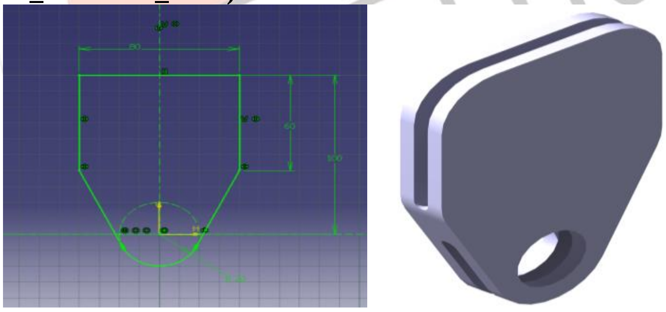


Figure 3 Part 11

The publications used here are the FWD_RIB_PLANE and FWD_HINGE_AXIS, and all the features are related with these references only, so that any updating in the rib plane or hinge axis can automatically update the part geometry as well as feature geometry.

PART_ID'S: 12W31D41-15&16(LH_AFT_DOUBLE_LUG & RH_AFT_DOUBLE_LUG)

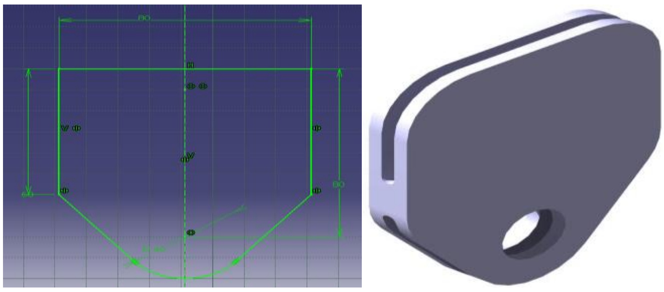


Figure 4 Part 15, 16

The sketch support lied on the publications of LH_RIB_PLANE and RH_RIB_PLANE which are in the RLM.

PART_ID'S: 12W31D41-17 & 18 (RH_AFT_SINGLE_LUG & LH_AFT_SINGLE_LUG)

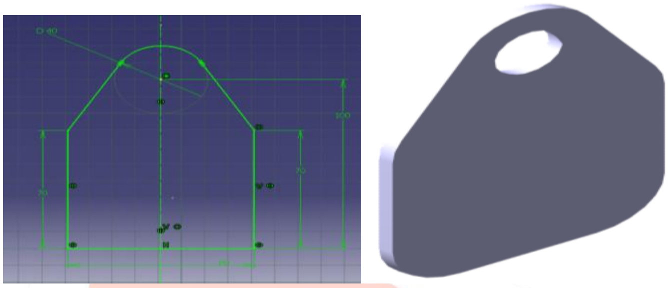


Figure 5 Part 17, 18

This part has to be attached with the two fuselage frames with the help of a C-Bracket and has to be fitted in between the fork ends of the double lug designed above.

Therefore the sketch support of this part has also been derived from the same entities as above which are LH_RIB_PLANE and RH_RIB_PLANE.In order to maintain perfect alignment the two pin holes of the both lugs are needed to maintain concentricity with the AFT_HINGE_AXIS projection point.

PART_ID'S: 12W31D41-19 & 20 (LH_AFT_RIB_BRACKET & RH_AFT_RIB_BRACKET)

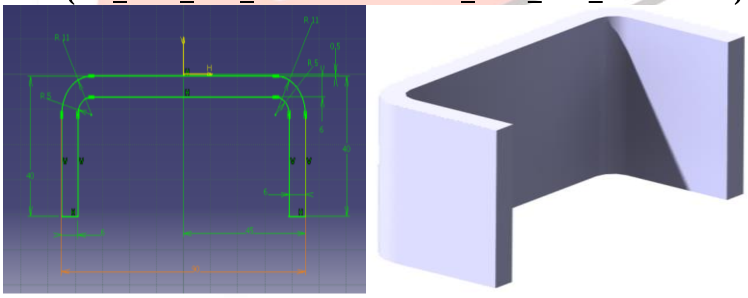


Figure 6 Part 19, 20

The brackets location and size are decided by considering the area of contact with fuselage frames and the single lug designed as the purpose of the bracket is to transfer loading from the lug to the frame.As inter-part relationship is not encouraged in Relational design, the sketch support is again a plane offset-ed from either LH_RIB_PLANE or RH_RIB_PLANE.

PART_ID's: 12W31D41- 13, 14 (LH_AFT_ HINGE_ASSEMBLY & RH_AFT_ HINGE_ASSEMBLY)

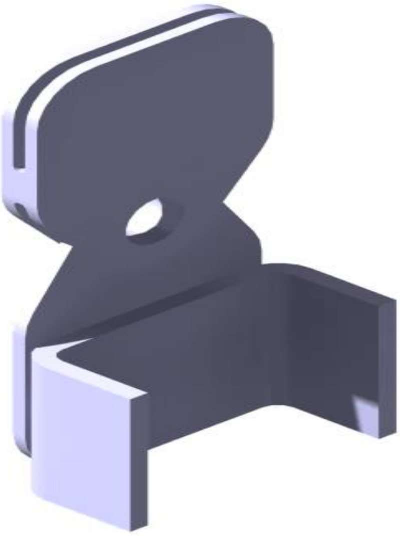


Figure 7 Part 12w31d41-13, 14

The two part assemblies are shown. Thus all the parts are modeled in CATIA

E. *Finite Element Analysis*

The finite element method is a proven technique for using computers to model a wide variety of engineering problems. The Finite element method (FEM) is a powerful technique originally developed for numerical solution of complex problems in structural mechanics, and it remains the method of choice for complex systems.

MSC/PATRAN is software developed to provide a systematic approach towards making FEA modeling fast and accurate. It uses a simple step-by-step approach that helps to create, analyze and interpret a mathematically realistic model of the structure. This approach is built around geometric modeling, interactive computer graphics, and current finite element theory. The same approach is followed for all the parts. The screens and plots are provided for all the parts followed by validation through classical methods.

PART ID: 12W31D41-15, 16

FEA METHOD

Modeling:

The modeling of the fitting begins by importing the CAD model from CATIA in .IGES format

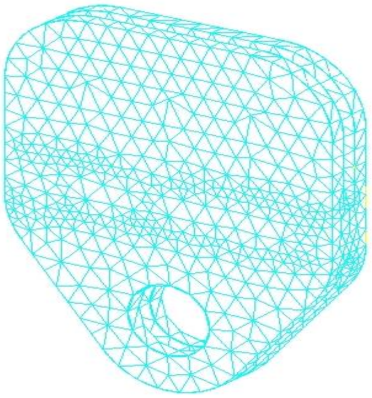


Figure 9 Part 15, 16 Surface

Break the model and post them into separate groups for feasible handling.

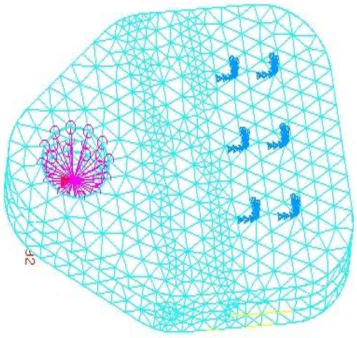


Figure 10 Part 15, 16 Fem

Element properties are to be chosen with proper knowledge keeping conscious

Figure 1 part 15, 16 fem with constraints

Define the boundary conditions and apply on identified grid points. Apply loads in given orientation.

Solution Sequence

Create MSC.Nastran Input File to start solution phase, analyze the complete model and perform analysis up to desk. Run NASTRAN by opening this .BDF file. This will generate .F06 file (Results). Check .F06 file for any solving errors. Translate the Results into MSC.Patran for Results Post processing, by attaching the solution file (.xdb) this will enable us to plot the contours or fringe plots read necessary values form the analysis.

Results Post-Processing

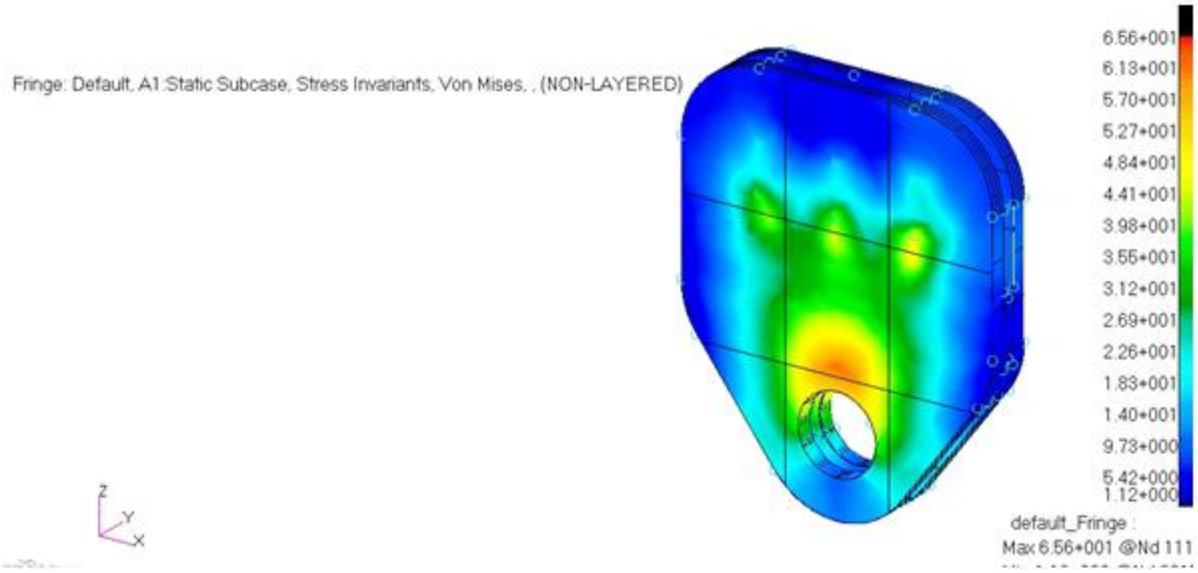


Figure 12 Part 15, 16 Results

Margin of safety, MoS = $1 / (R_A^{1.6}+R_{TR}^{1.6})^{0.625} - 1 = 0.12$

Allowables are multiplied with Fatigue factor (0.38) for wrought aluminum for 5*10^8 cycles. Referred from

All the allowables are referred from Bruhn

PART_ID:09W31A21-11:

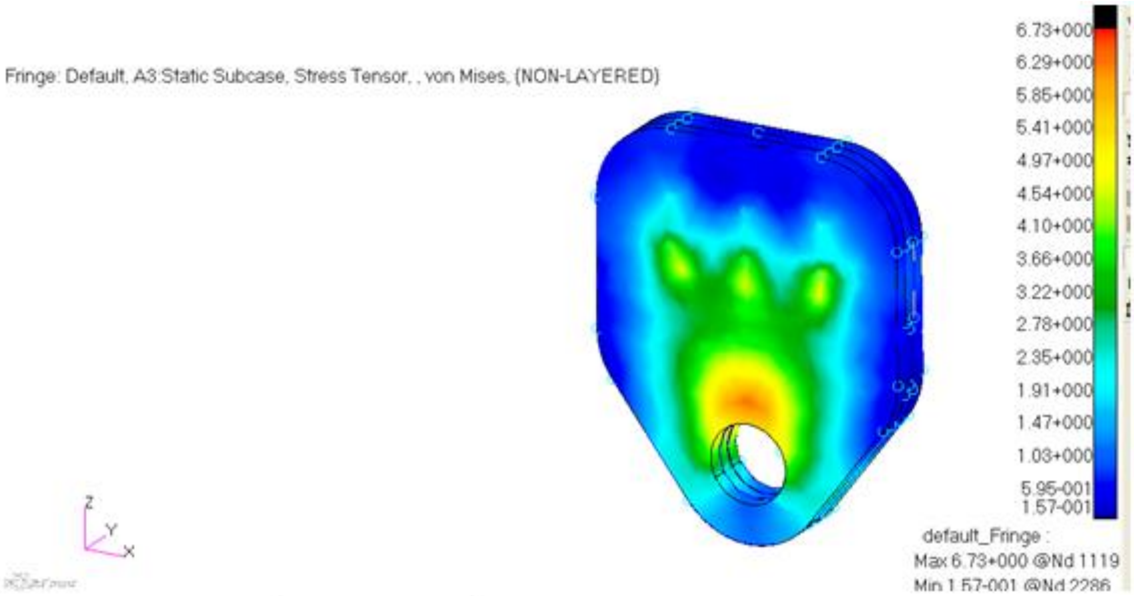


Figure 17 Part 11 Results

The procedure of analysis in both FEM and Classical ways are same as PART_12W31D21-15&16. The margin of safety for the part is thus obtained in the same way and the values are

Table 4 Part 11 Results

Load	MoS for Ultimate load analysis	MoS for limit load analysis
25516	0.2002	0.079382

Part ID: 12W31D21-19, 20

FEA METHOD

Modeling:

The modeling of the C- bracket is done in 2D by importing the geometry from CATIA by extraction of the middle surface.

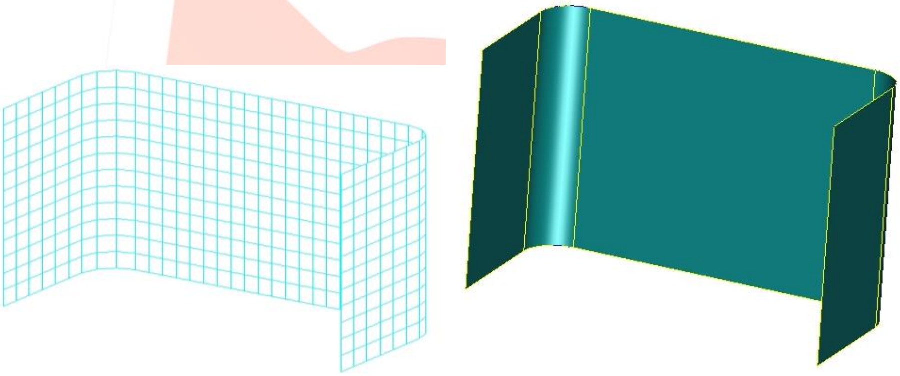


Figure 22 part 19, 20 surfaces

Do create necessary geometry for simplifying the mesh. In this case the 3D model is idealized as 2D surface and meshed, for making it 3D, thickness is assigned in the property set.

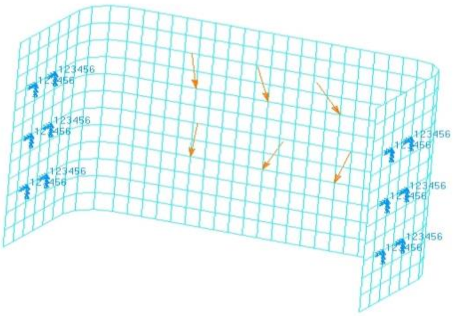


Figure 23 part 19, 20 surfaces

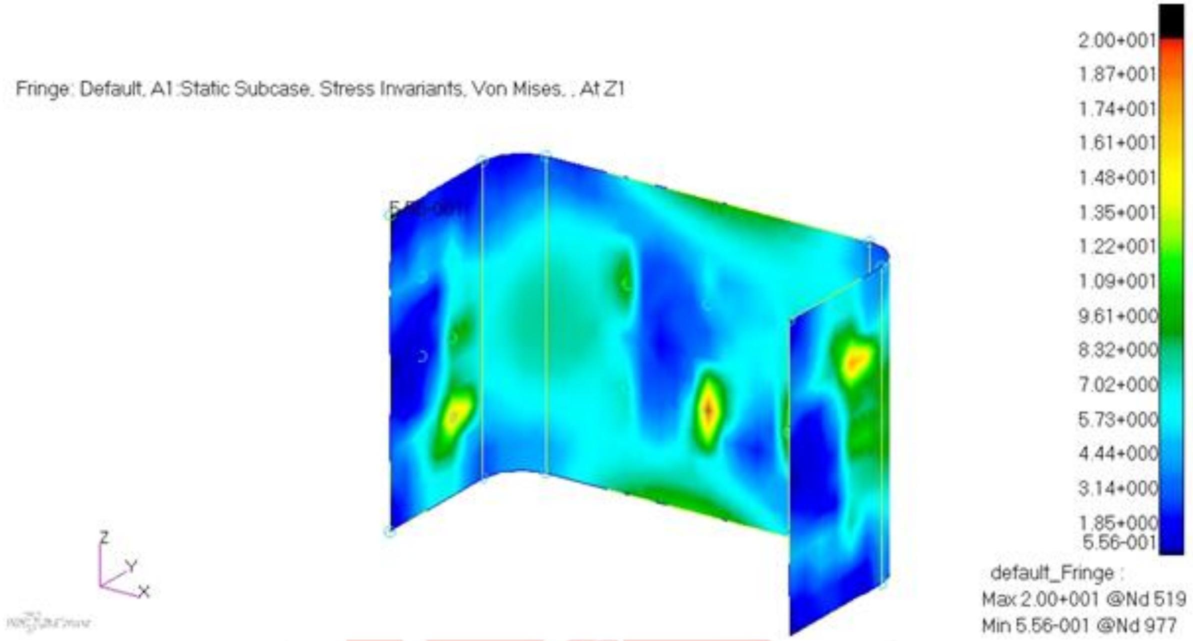
Figure 24 part 19, 20 surfaces with constraints

Solution Sequence

Create MSC.Nastran Input File to start solution phase, analyze the complete model and perform analysis up to desk. Run NASTRAN by opening this .BDF file. This will generate .F06 file (Results). Check .F06 file for any solving errors.

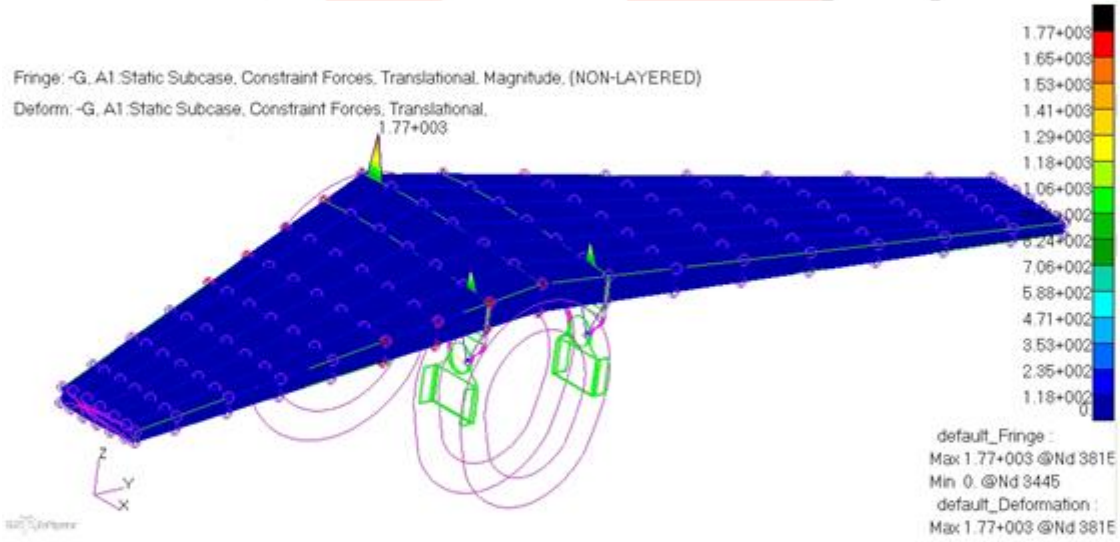
Translate the Results into MSC.Patran for Results Post processing, by attaching the solution file (.xdb) this will enable us to plot the contours or fringe plots read necessary values form the analysis.

Results Postprocessing



F. *Load Data*

The aerodynamic loads acting on the HT are provided by Garuda Engineering Solutions. The Reactions at the station 1 where the front actuator is attached and at left and right station 2's the aft hinges are located.



The loads for Horizontal tail of Garuda 101 are evaluated at density (ρ) =1.225kg/mm3, Free stream velocity (V∞) = 100 Kmph for 150 maximum deflection of the elevator and 00 angle of attack of horizontal tail.

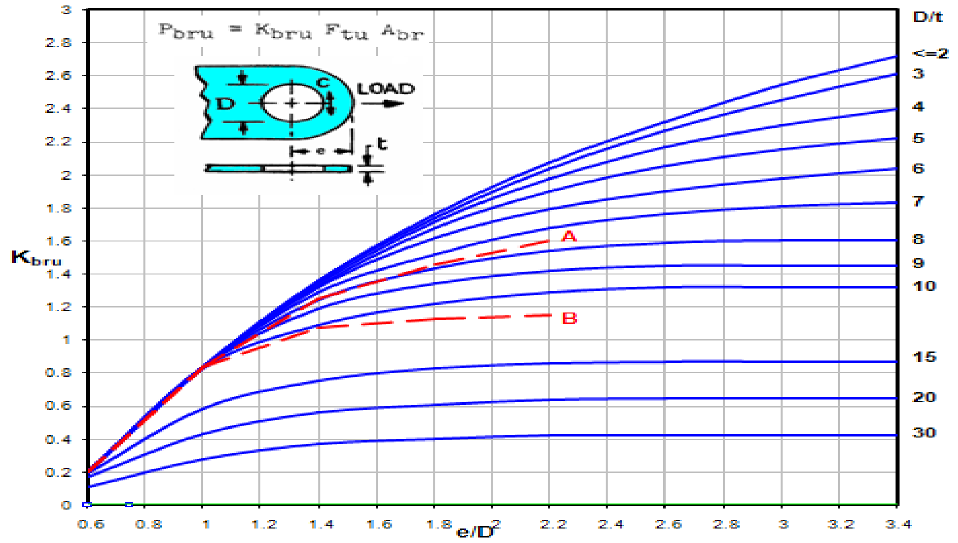
Overall distribution of Right Hand Horizontal Tail loads along the semi span is shown in appendix B.

III. APPENDICES

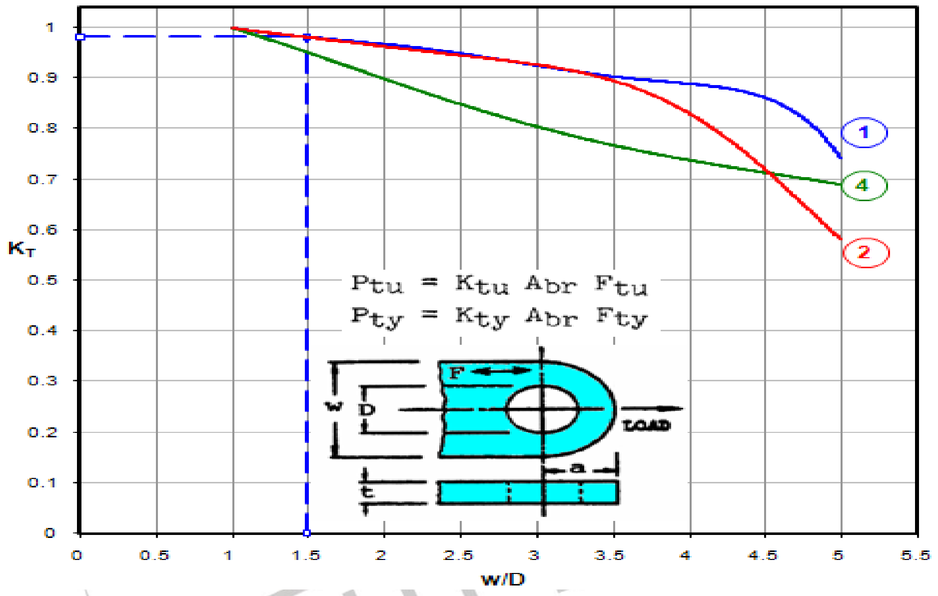
Appendix A

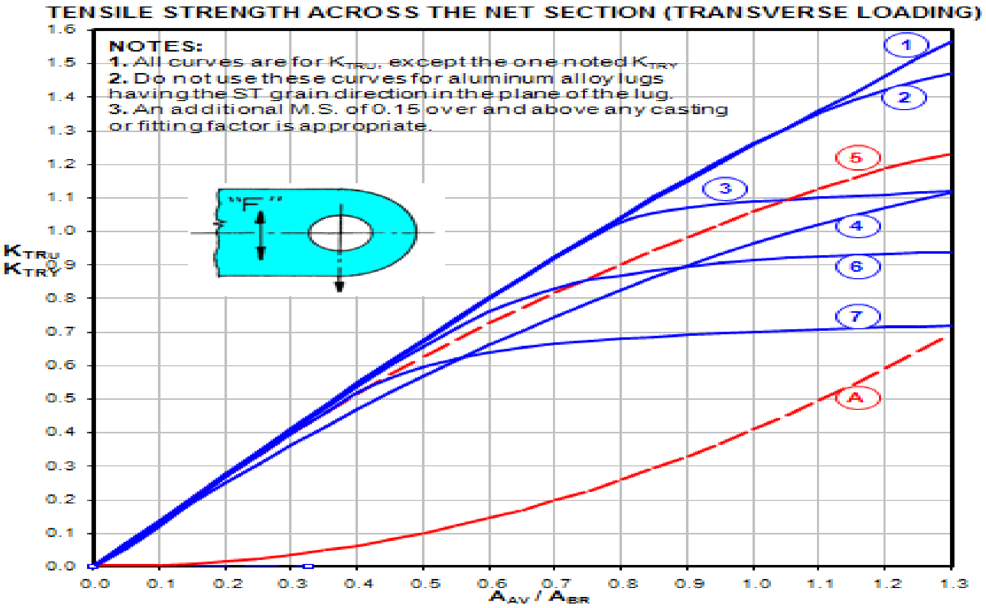
Graphs: Referred From Bruhn

SHEAR OUT BEARING ULTIMATE STRENGTH

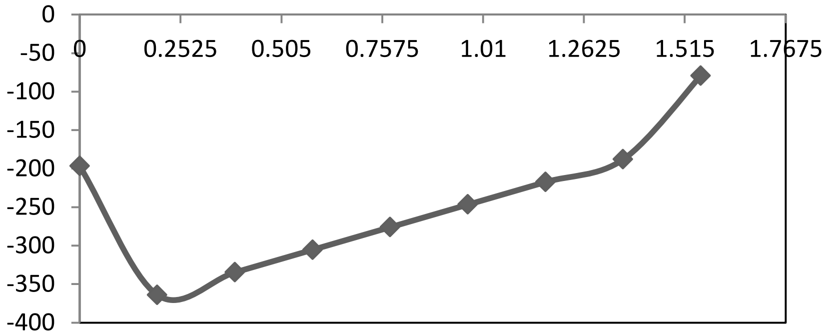


TENSILE STRENGTH ACROSS THE NET SECTION (AXIAL LOADING)



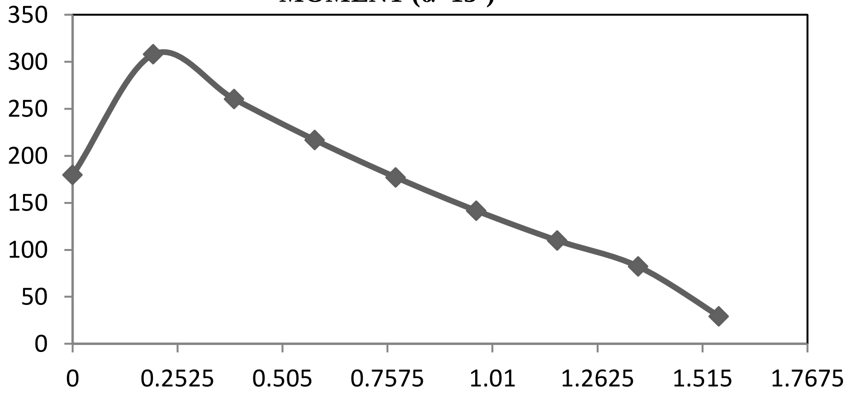


LIFT (α=15^0)

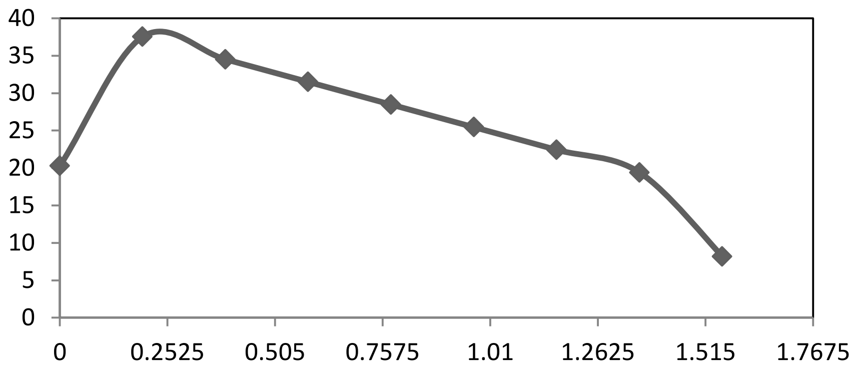


Appendix B
Aerodynamic Loads

MOMENT (α=15^0)



DRAG ($\alpha=15^0$)



IV. FUTURE SCOPE

As per the objective of the project, study of several parts is limited and can be continued as extension of the project in future, such areas are

- FEM analysis of pin
- Classical validation of C- Bracket
- Design and Analysis of Actuator rod.

V. INFERENCE

- The analysis on parts has cleared that assumed dimensions can withstand in the current loading conditions.
- With all margin of safety's being positive the parts are capable of withstanding the loading.
- The final dimensions are thus shown in the draftings attached in the appendix
- Note that in calculating margin of safety, material Fatigue factor is also considered thus giving the dimensions which can with stand up to 5e8 cycles.

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[3] Aircraft design by Ajoy Kumar Kundu.
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