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Design and Performance Validation of Wing and Fuselage

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ABSTRACT

The problem of optimizing the efficiency of a Wing and Fuselage across a wide range of altitudes for the development of an Aircraft thas has been a long time subject of special dedicated efforts within the research and development of advanced Aircraft. Wing and Fuselage is the one such Wing and Fuselage considered to have better performance at off design altitudes compared with that of conventional High wing shaped Wing and Fuselage. It is a type of Wing and Fuselage with capacity of continuous altitude compensation. Engine characterized by small scale, light weight, high performance during all altitudes and better utilization of the vehicle base is the promising candidate for the propulsion device of future advanced Aircraft. Spike truncation is a common measure to avert the thermal and structural problems in ideal Wing and Fuselages. On the other hand Wing and Fuselages with larger amounts of base truncation tend to suffer loss of thrust especially in over-expansion conditions.

This thesis develops a general purpose ANSYS AND CATIA code which uses the Method of Characteristics and the Stream Function to define high efficiency Wing and Fuselage contours for isentropic, in viscid, irrotational supersonic flows of any working fluid for any user-defined exit Mach number.

This thesis aims to design linear Wing and Fuselages with varying truncation percentages using contours developed by ANSYS AND CATIA code and validate the design by numerical simulation using commercial Computational Fluid Dynamics (CFD) code ANSYS FLUENT. The Wing and Fuselage flow-field is obtained and studied using ANSYS FLUENT. The exit Mach numbers obtained through numerical simulation were compared with design conditions. For this purpose Wing and Fuselages with truncation lengths of 25%, 40%, 50% are designed. Simulation of the flow is carried out at three different altitude conditions representing Under-expansion, Ideal, and over-expansion conditions of the flow. Exhaust flow analysis is carried out to investigate the effects of amount of truncation on performance of the Wing and Fuselage. Optimum percentage of the truncation is selected by the comparison of Wing and Fuselages with different lengths of truncation under various altitude parameters.

Introduction

The purpose of aerodynamic analysis of an airplane is to optimize aerodynamic performance. That is to maximize lift for a given amount of drag, and conversely to minimize drag for a given amount of lift. Shapes and contours of individual components and parts on aircraft affect the amount of total aircraft drag. Nevertheless, the total drag further rises when combining these parts into an airplane. This increment in drag is called interference drag. The performance of the aircraft depends on the life span of the different components. At some number of cycles each and every component undergoes damage. Structure of an aircraft will resist different types of loads in different conditions.

Weight also plays an important role in performance and life span of the aircraft. All of these investigations indicate that there is a possibility that the drag-rise characteristics can be improved by taking advantage of a favorable interference between two components and that the drag-divergence Mach number can be increased. Aircraft structure damages due to the application of different cyclic loads at different segments of its Flight. The interference effects that occur for several wing-body geometries that are considered candidates for a design of an airplane intended to operate at low subsonic speeds at high altitude.

Due to continuous applications of loads the structure degrades. This degradation of structure due to application of cyclic loads is called fatigue analysis. Each and every component of an aircraft undergoes fatigue damage. Now our next step is to select the component which undergoes fatigue damage. Fatigue is a type of fracture that occurs in materials that are subjected to changing or varying stresses over time. Fatigue occurs when a material is subjected to repeat loading and unloading. If the loads are above a certain threshold, microscopic cracks will begin to form at the stress concentrators such as the surface, persistent slip bands (PSBs), and grain interfaces. Eventually a crack will reach a critical size, and the structure will suddenly fracture The Advancement in technology made the structure of composite materials stronger than they actually needed to be, so when the damage occurs it will less likely to be catastrophic. This can be equally required for a composite material if thecrack is detected that could heal itself, without the help of human interaction, these composite materials have made a good impact on automobiles and aircraft structures. Crack formatted due to the heavy aerodynamic flow and gust loads areas which highly effected in aircraft structures are wings, control surfaces and rudder.

Fatigue is progressive failure mechanism and material degradation initiates with the first cycle. The degradation/damage accumulation progresses until a finite crack is nucleated, then the crack propagates until the failure process culminates in a complete failure of the structures. The total life from first cycle to the complete failure can be divided into three stages: Initial life interval, Life interval, Final Life interval. The fatigue damage is mainly based on two designs: FAIL-SAFE and SAFE-LIFE. The objective is to design a Fail-Safe Structural component.

In this project we have designed a Wing-Bracket interaction which was not yet designed by any of the industry. And we have estimated the fatigue life of our Wing-Bracket attachment model. Here we compared the fatigue life of our model with three materials such as Managing Steel, Titanium and Structural A36 steel. Among this three we have proved that Managing steel gives more fatigue life compared to other two materials. For estimating the fatigue life we have made some hand calculations. Finally we have represented the fatigue life with the help of Goodman Curve. The Structural Component is designed and analyzed using CATIA and ANSYS Software's. In analysis the maximum stress at which the component undergoes degradation/damage is calculated for different End Conditions (loadings and stresses), which determines the fatigue life of the component.

Introduction to ANSYS & CATIA

ANSYS:

Ansys, Inc. is an engineering simulation software (computer-aided engineering, or CAE) developer headquartered south of Pittsburgh in the South pointe business park in Cecil Township, Pennsylvania, and United States. One of its most significant products is Ansys CFX, a proprietary computational fluid dynamics (CFD) program.

ANSYS Mechanical is an intuitive mechanical analysis tool that allows geometry to be imported from a number of different CAD systems. It can be used to verify product performance and integrity from the concept phase through the various product design and development phases.

The use of ANSYS Mechanical accelerates product development by providing rapid feedback on multiple design scenarios, which reduces the need for multiple prototypes and product testing iteration

CATIA:

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Assault Systems directed by Bernard Charles. Written in the C++ programming language, CATIA is the cornerstone of the Assault Systems software suite.

Initially, CATIA name is an abbreviation for Computer Aided Three-dimensional Interactive Application We had already said in the introduction of historical, that the French Assault Systems is the parent company and IBM participates in the software's and marketing, and cattie is invades broad industrial sectors, and has been explained in the previous post position of CATIA between 3d modeling software programs.

Now we will speak about another point which is whether there is a drawing program better than the other?... we must know, that drawing programs provides us drawing tools while not any of them can provide you the ability to design, You should, thinking and looking and imagine then building a design in your mind, either drawing program will help you to transform these designs graphics on papers, for that, we prefer CATIA because it provides us with all the tools that we need.

Before we come to learning any 3d modeling software's, you must know their classification as a drawing program, Where CATIA classified under the following software packages:

- CAD (Computer Aided Design)
- CAM (Computer Aided Manufacturing)

Wings:

This are highly effected due to aerodynamic flow and fatigue, gust loads have a great impact on the wing structure. The first of these is the heating up and cooling down of the Aircraft surface during each supersonic flight which induces a thermal stress cycle contributing to the general Fatigue damage and critically affecting design at some locations. Same with the control surface and rudder.

Safe-life design:

Safe-life design is based on the assumption that the part is initially flaw-free and has a fine life in which to develop a critical crack size. Like the infinite-life methodology, safe-life assumes an initial flaw-free component. This methodology was developed to account for parts that were subjected to higher loads that produced plastic strains.

Under these conditions, the description of local events in terms of strain made more sense and resulted in the development of assessment techniques that used strain as a determining quantity, that is, log strain (e) versus log number of cycles (N). The failure criterion is usually the detection of a small crack or some equivalent measure related to a substantial change in load-deflection response, although failure may also be defined as fracture.

1. The practice of designing for a finite life is known as "safe-life" design.
2. It is used in many industries, for instance automotive industry, in pressure vessel Design, and in jet engine design.
3. The calculations may be based on stress-life, strain-life, or crack growth relations.
4. Ball bearings and roller bearings are examples of safe-life design.

Fail-safe design:

The fail-safe design philosophy assumes that fatigue cracks will be detected and repaired before they lead to failure.

This methodology was developed in the aircraft industry where large safety margins were weight prohibitive. Fail-safe designs incorporate multiple load paths and crack stoppers in the structure. In other words, if a primary load path fails, the load will be picked up by an alternate load path to prevent the structure from failing. A major part of this methodology is rigid certification criteria along with the capability to detect and inspect cracks.

1. Fail-safe design requires that if one part fails, the system does not fail.
2. Fail-safe design recognizes that fatigue cracks may occur and structures are arranged so that cracks will not lead to failure of the structure before they are detected and repaired.
3. Multiple load paths, load transfer between members, crack stoppers built at intervals into the structure and inspection are some of the means used to achieve fail-safe Design.

Mean Stress Consideration:

The standard S-N Curve used for fatigue calculations is based on pure alternating load. Mean stress for this test is zero. Mean stress would be present for all the loading conditions other than pure alternating. It is also generated due to processes like rolling or heat treatment, bolt pre stresses or constant loading applications.

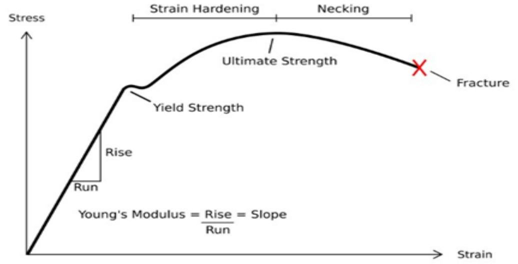

Figure 1.1: Stress Vs Strain Graph

Designs and Modeling of Wing-Fuselage Interaction Bracket.

Airfoil Design:

For designing an airfoil key points are mandatory. We have chosen NACA 2412 airfoil for our project Purpose. NACA 2412 airfoil is a semi-symmetric and has maximum lift values around 1.93.

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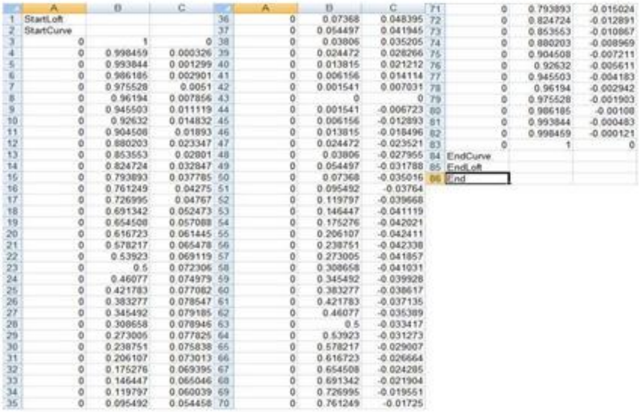
The step by step procedure for designing NACA 2412 airfoil is as follows.

Step 1: Importing key points into CATIA using EXCEL sheet:

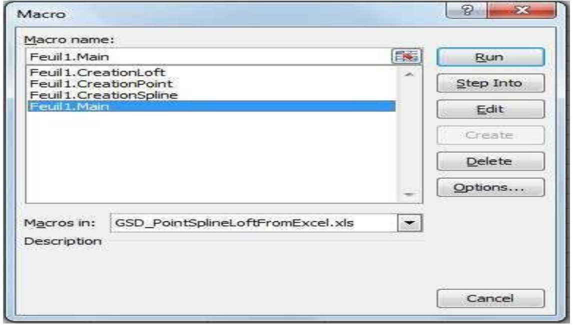
CATIA has a flexibility of providing us EXCEL sheet with "GSD_Spline from loft From Excel". Open the sheet and paste the key points in EXCEL sheet as shown in figure 3.1



	A	B	C
1	StartLoft		
2	StartCurve		
3	0	1	0
4	0	0.998459	0.000326
5	0	0.993844	0.001299
6	0	0.986185	0.002901
7	0	0.975528	0.0051
8	0	0.96194	0.007856
9	0	0.945503	0.011119
10	0	0.92632	0.014832
11	0	0.904508	0.01893
12	0	0.880203	0.023347
13	0	0.853553	0.02801
14	0	0.824724	0.032847
15	0	0.793893	0.037785
16	0	0.761249	0.04275
17	0	0.726995	0.04767
18	0	0.691342	0.052473
19	0	0.654508	0.057088
20	0	0.616723	0.061445
21	0	0.578217	0.065478
22	0	0.53923	0.069119
23	0	0.5	0.072306
24	0	0.46077	0.074979
25	0	0.421783	0.077082
26	0	0.383277	0.078547
27	0	0.345492	0.079185
28	0	0.308658	0.078946
29	0	0.273005	0.077825
30	0	0.238751	0.075838
31	0	0.206107	0.073013
32	0	0.175276	0.069395
33	0	0.146447	0.065046
34	0	0.119797	0.060039
35	0	0.095492	0.054458
36	0	0.07368	0.048395
37	0	0.054497	0.041945
38	0	0.03806	0.035205
39	0	0.024472	0.028266
40	0	0.013815	0.021212
41	0	0.006156	0.014114
42	0	0.001541	0.007031
43	0	0	0
44	0	0.001541	-0.006723
45	0	0.006156	-0.012893
46	0	0.013815	-0.018496
47	0	0.024472	-0.023521
48	0	0.03806	-0.027955
49	0	0.054497	-0.031788
50	0	0.07368	-0.035016
51	0	0.095492	-0.03764
52	0	0.119797	-0.039668
53	0	0.146447	-0.041119
54	0	0.175276	-0.042021
55	0	0.206107	-0.042411
56	0	0.238751	-0.042338
57	0	0.273005	-0.041857
58	0	0.308658	-0.041031
59	0	0.345492	-0.039928
60	0	0.383277	-0.038617
61	0	0.421783	-0.037135
62	0	0.46077	-0.035389
63	0	0.5	-0.033417
64	0	0.53923	-0.031273
65	0	0.578217	-0.029007
66	0	0.616723	-0.026664
67	0	0.654508	-0.024285
68	0	0.691342	-0.021904
69	0	0.726995	-0.019561
70	0	0.761249	-0.01725
71	0	0.793893	-0.015024
72	0	0.824724	-0.012891
73	0	0.853553	-0.010867
74	0	0.880203	-0.008969
75	0	0.904508	-0.007211
76	0	0.92632	-0.005611
77	0	0.945503	-0.004183
78	0	0.96194	-0.002942
79	0	0.975528	-0.001903
80	0	0.986185	-0.00108
81	0	0.993844	-0.000483
82	0	0.998459	-0.000121
83	0	1	0
84	EndCurve		
85	EndLoft		
86	End		

Figure 3.1 Key points of NACA 2412

Use MACRO'S in view option and choose as shown in figure 2 below. Then click RUN. Select option 2 for plotting key points with spline. Key points will be plotted in the CATIA work bench. Before this command we have to open CATIA in sketcher workbench. Figure 3 shows the image of airfoil with key points.



Macro

Macro name:

Feuil1.Main

Feuil1.CreationLoft
Feuil1.CreationPoint
Feuil1.CreationSpline
Feuil1.Main

Macros in: GSD_PointSplineLoftFromExcel.xls

Description

Figure: 3.2 Macro Dialogue box

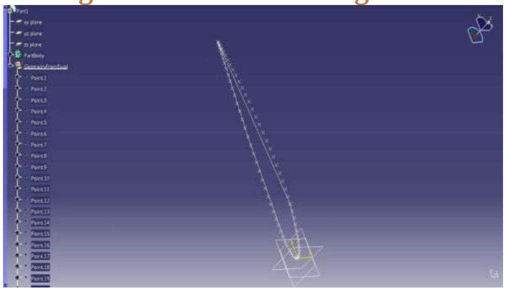


Figure: 3.3 2D NACA 2412 Airfoil

Step 2: Extruding key points:

Next exit the work bench and use PAD option to add material along perpendicular direction (EXTRUDE). Thickness of the airfoil we have chosen here is 0.2mm. Figure 4 show the image of solid NACA 2412 airfoil.

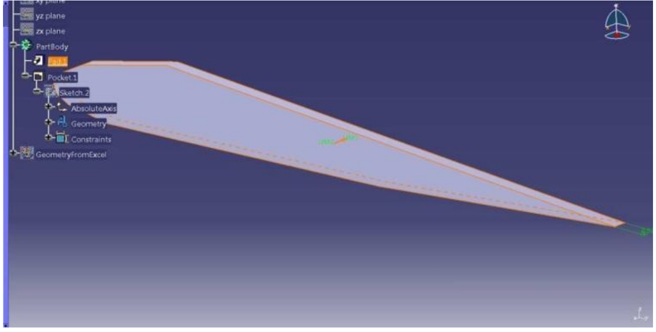


Figure: 3.4 Airfoil with Thickness 0.2mm

Step 3: Giving Holes:

In sketcher, using circle and constraints three circles are drawn on airfoil. Figure 5 gives clear idea of dimensions. Distance between holes is maintained 0.25mm. Whole diameter is 0.05mm, 0.04mm, 0.03mm respectively.

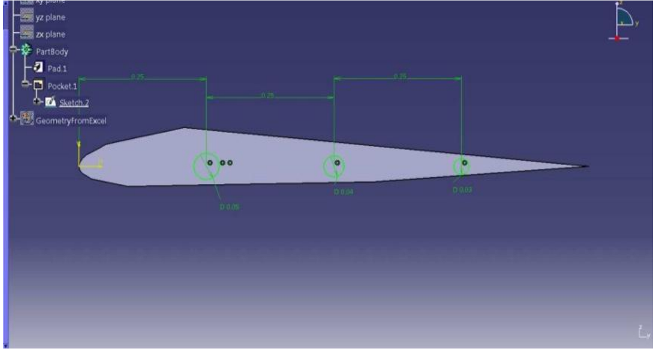


Figure: 3.5 Creating Holes

Exit the work bench and select pocket to give holes with respective diameter. Figure 6 gives the complete picture of NACA 2412 airfoil with holes.

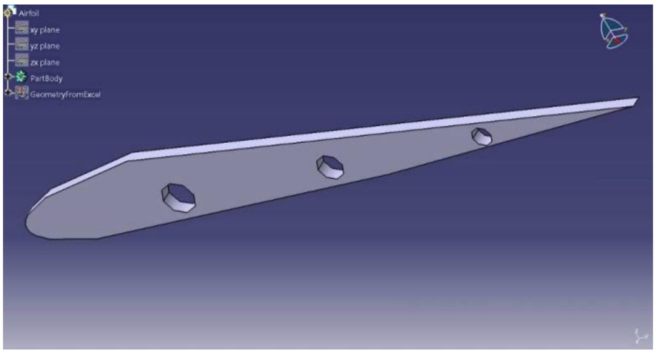


Figure: 3.6 Airfoil with Holes

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The above figures clearly give the design criteria we have chosen in this project for wing fuselage interaction. This ends up airfoil design. Next step is modeling of 0.05 mm, 0.04mm, 0.03mm cylinders.

ANALYSIS OF WING –BRACKET INTERACTION

Once the modeling part of the bracket is completed in CATIA we move ahead with the analysis part and the analysis of this wing-fuselage intersection bracket will be done in ANSYS.

ANSYS is very useful software for the analysis purpose of such problem definition and highly preferred in such cases of analysis and studying the characteristics of a model.

We first induce the model designed in CATIA into ANSYS and apply the boundary conditions .The boundary condition of this would be fixing all the degrees of freedom of the wing from one side and leaving one end free and then the load is applied on the free end of the wing .The wing is subjected to a load from one the effect of it is studied all along the wing various stress distribution patterns are studied and analyzed.

The various stress studied in our project are:

1.Von-Misses

2.Total deformation stress

3.Maximum principle stress

4.Directional stress (x-direction)

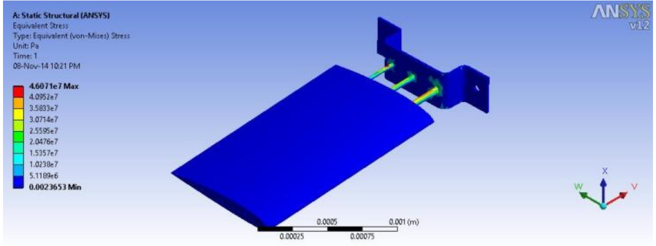

Figure 4.1 Von misses stress analysis of wing-fuselage interaction bracket

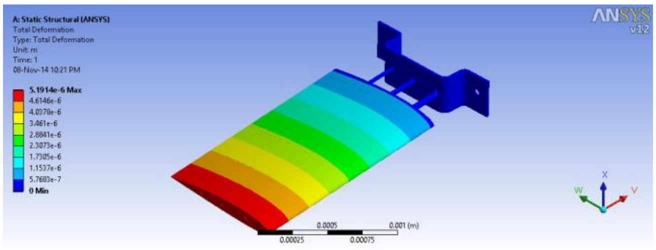

Figure 4.2 Total deformation analysis of wing-fuselage interaction bracket

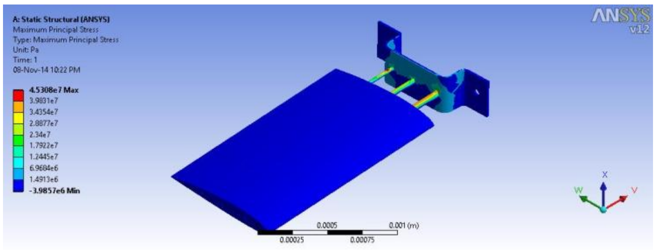

Figure 4.3: Maximum principal analysis of wing-fuselage interaction bracket

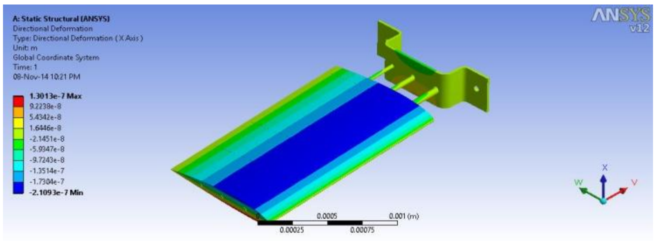

Figure 4.4: Directional deformation analysis of wing-fuselage interaction bracket

This model is imported into ansys for analysis which will be discussed in the next chapters. The complete model is solid model made using “sketcher, part design, Assembly work benches. The results of the above wing-fuselage interaction bracket are seen further in next section of our project.

Result discussion

Results of wing-fuselage interaction bracket’s stress analysis:

Von misses:

Max value: 4.6971e07 pa
Min value: 0.0263 pas
Max principal stress: 4.5308e7 Pa

Total deformation:

Max value: 5.191 e6 Pa
Min value: 0

Directional deformation:

Max: 1.301 e-7 Pa
Min: -2.109

CONCLUSION

The wing-fuselage configuration shows flow separation in front of the non-filleted junction withv-shape wing downwash on the fuselage after section. This certainly lowers lifting capability and increases drag due to separation. It is also highly beneficial for studying different characteristics of wing-body geometries. Effective arrangement of Carbon nano tubes in the aircraft structures should be in square grid cross-section, hence it reduces the diameter of the carbon nano tube and the healing agents are implanted in geometric points of the square grid. The carbon nano tubes are helping in increase the lifetime, safety, and cost effectiveness of structures. There is also evidence that carbon nano tubes play a passive role in suppressing the rate at which micro cracks grow in structures.

S-N curves are derived from tests on samples of the material to be characterized (often called coupons) where a regular sinusoidal stress is applied by a testing machine which also counts the number of cycles to failure. This process is sometimes known as coupon testing. Each coupon test generates a point on the plot though in some cases there is a run out where the time to failure exceeds that available for the test (see censoring). Analysis of fatigue data requires techniques from statistics, especially survival analysis and linear regression.

The progression of the S-N curve can be influenced by many factors such as corrosion, temperature, residual stresses, and the presence of notches. The Goodman-Line is a method to estimate the influence of the mean stress on the fatigue strength.

With projections indicating an increase in mobility over the next few decades and annual flight departures expected to rise to over 16 billion by 2050, there is a demand for the aviation industry and associated stakeholders to consider new forms of aircraft and technology. Customer requirements are recognized as a key driver in business. The airline is the principal customer for the aircraft manufacture. The passenger is, in turn, the airline's principal customer but they are just one of several stakeholders that include aviation authorities, airport operators, air-traffic control and security agencies. The passenger experience is a key differentiator used by airlines to attract and retain custom and the fuselage that defines the cabin envelope for the in-flight passenger experience and cabin design therefore receives significant attention for new aircraft, service updates and refurbishments. Decision making in design is crucial to arriving at viable and worthwhile cabin formats. Too little innovation will result in an aircraft manufacturer and airlines using its products falling behind its competitors. Too much may result in an over-extension with, for example, use of immature technologies that do not have the necessary reliability for a safety critical industry or sufficient value to justify the development effort. The multiple requirements associated with cabin design, can be viewed as an area for optimization, accepting trade-offs between the various parameters. Good design, however, is often defined as developing a concept that resolves the contradictions and takes the solution towards a win-win scenario. Indeed our understanding and practice of design allows for behaviors that enhance design thinking through divergence and convergence, the use of adductive reasoning, experimentation and systems thinking. This paper explores and defines the challenges of designing the aircraft cabin of the future that will deliver on the multiple requirements using experiences from the A350 XWB and future cabin design concepts. In particular the paper explores the value of implementing design thinking insights in engineering practice and discusses the relative merits of decisions based on optimization versus win-win scenarios for aircraft cabin design and wider applications in aerospace environments. The increasing densification of technological opportunities and shifting consumer demand coupled with highly complex systems may ultimately challenge our ability to make decisions based on optimization balances. From an engineering design perspective optimization tends to preclude certain strategies that deliver high quality results in consumer scenarios whereas win-win solutions may face challenges in complex technical environments.

Future scope:

Results indicate that the model we have designed is simple and can be used for both small as well as large aircraft as the materials can with stand different types of loads and weight balance is also perfect.

This type of fitting mainly will increase the life span of the material and study of fracture mechanics gives us the crack propagation. This deformation propagation can be obtained with the help a structural Analysis Software ANSYS Mechanical is an intuitive mechanical analysis tool that allows geometry to be imported from a number of different CAD systems. It can be used to verify product performance and integrity from the concept phase through the various product design and development phases.

The use of ANSYS Mechanical accelerates product development by providing rapid feedback on multiple design scenarios, which reduces the need for multiple prototypes and product testing iterations.

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