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Skin Instabilities in Honeycomb Structures of an Aircraft Wing

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Abstract - *The surface of a wing is used to initiate an aerodynamic force. This force is normal on the way through when it proceeds in the air or any other gassy media for smooth aviation. This is a discrete configuration of the control surface. An airplane wing is well planned, systematic, structured mechanism to bring about uplift. The aerodynamic status is evidence of sum of lift produced by an airfoil compared to its drag somewhat less thrust force is put in to get moving the wing via air in sequence pick up designated lift. Wing is used to fly by side tracking air downwards to generate lift. Also, wings are generally used upside down to create down force and grip things bring to the ground. The sandwich complex fabrication gives outstanding structural regulation along with the rigid strength of weight relationship. Benefits considered in this type of structures abolishment of weld, the best insulation quality along with flexible design. The reason to adopt non strength type of structures in history because a lot of problematic issues to conquer when complicated construction is applied to create dynamic stacked structures. It is crucial for understanding the strength of individual structural panels. At this moment in time we are going to compare sandwich composite honeycomb structures in the wing box to help of finite element procedure. To create a three- dimensional model in CATIA software along with Static, Dynamic and linear analysis to identify the initial frequency and modes in Ansys software.*

Key Words: **CATIA, Wing Box, Honeycomb structures**

1. INTRODUCTION

The wing surface generates an aerodynamic force in the usual direction during flying air or some other gas medium, which facilitates the takeoff. It's a special kind of airfoil.

Many experiments and study have been carried out to maximize the scale and weight of aircraft. They based primarily on the structural mass by modifying the material properties. During these studies, parameters such as shell scale, shell thickness have been varied but geometry remains consistent in wing structure growth. The aircraft wing structure mainly consists of ribs, spars which acts supporting member to provide rigidity to the aircraft wing. Before the designers were mainly focused on structural design as the advanced design came into existence nowadays the designers also focused on fail-safe, corrosion, fatigue, maintenance and inspect ability, and predictability.

The wing loading can be defined as, weight of aircraft divided by area of the reference wing. It depends on the thrust to weight ratio, the term “wing loading” is usually refers to the take-off wing loading and also to combat and other flight condition. Wing loading effects on the following parameters like stall speed, climb rate, take-off, landing distances and turn performance. It determines the design lift coefficient which impacts drag through its effect upon wetted area and wing span. Wing loading has an effect on sized aircraft take off gross weight. As the wing loading reduces, wing will be larger which improves the performance whereas with additional drag and empty weight due to the larger wing than it will increases the take-off gross weight to perform the mission.

The key objective of the architecture is to mitigate tension, maximize power, prevent cracking, conceal undetectable cracks and reduce weight.

1.1 Honeycomb Structure

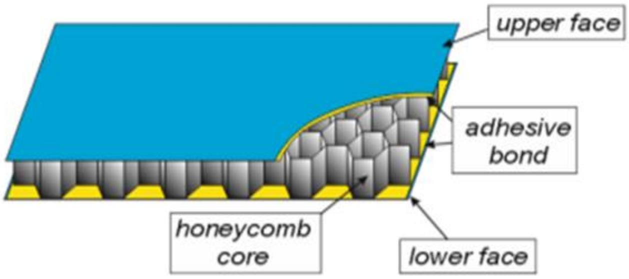

Fig-1: Honeycomb composites

In manufacturing of light weight transportation system, the idea of honeycomb structure are used the structure namely satellite, missiles. The high speed trains with which needed to be light in weight in order to gain a speed. Another major highlight of honeycomb structure is that it provides excellent structural efficiency, it provides high strength to weight ratio. With the use of honeycomb structure the welding can be eliminated. It has high insulating qualities and provides the versatile design option. The idea of honeycomb is not new it has be used from since long time, has we can see honeycomb structure is adapted for non-strength parts structure during last few decades, with help of honeycomb structure the variety of problems areas can be minimized. The characteristic strength of individual sandwich panel has to be better understood to enhance the uses of honeycomb structure. The honeycomb structure is a hexagonal type cell of thin foil perpendicular to the facing. Honeycomb structure provides added structural weight savings in the structure.

Hence honeycomb structure has been widely adopted for large weight critical structures. Honeycomb structures have been used as strength members of satellites or aircraft, thus efficiently reducing their structural weight.

1.2 Definition Problem and Objectives

Design and analysis of Structure of the wing box with honeycomb structure using linear static analysis, dynamic analysis of a wing box design model is carried out and life evaluation is performed to find the life cycle of design model. The sandwich construction recognized as a promising concept for structural design of light weight systems, for wings of aircraft; purpose to design a light-weight sandwich panel for trailers. Strength calculations, skin instability and selection of materials were carried out in order to find a new solution for specific application.
[1] Static liner structural analysis of wing box with honeycomb structure and without.
[2] Dynamic analysis to find modes and corresponding frequency.
[3] Fatigue life estimation of wing box.

2. MATERIAL SELECTION

As the weight strength ratio is important criteria for selection in aircraft material and have high corrosive resistant and machinability. Aircraft structure undergoing tension load, compressive load, bending load and buckling load. So we consider material should have to capacity obeyed our design requirement.
Materials used for analysis are,

[1] The aluminum alloy and
[2] The CFRP (carbon fiber reinforced polymer)

Table -1: Properties of aluminum alloy

Properties of aluminum alloy 7075	
Density	2.7×10^6kg/m^3
Coefficient of thermal expansion	33×10^{-6}/c
Modulus of elasticity	71.7×10^3Mpa
Shear modulus	28×10^3Mpa
Tensile yield strength	503Mpa
Poisson's ratio	0.34
Tensile ultimate strength	572Mpa

Table-2: Properties of CFRP

Properties of CFRP	
Density	1.5×10^6kg/m^3
Coefficient of thermal expansion	12×10^{-6}/c
Modulus of elasticity	1.5×10^3Mpa
Shear modulus	53×10^3Mpa
Tensile yield strength	200Mpa
Poisson's ratio	0.28
Tensile ultimate strength	550Mpa

3. FEM ANALYSIS

Finite element Method based upon discritization of component into Finite number of blocks (elements), Finite element method (FEM) is a numerical technique for finding approximate solutions to boundary value problems for partial differential equations. It uses subdivision of a whole problem domain into simpler parts, called finite elements, and variational methods from the calculus of variations to solve the problem by minimizing an associated error function.

3.1 Meshed Wing Box Honeycomb Structures

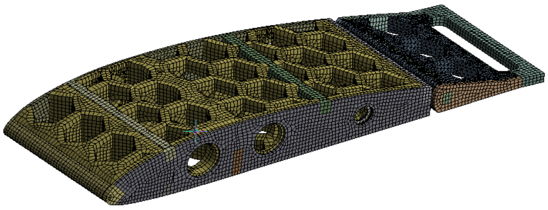

Fig-2: meshed model for without honeycomb structure

Fig-2 shows the meshed model for without honeycomb structure. 3D model is imported from unigraphics and is meshed in ANSYS. The mesh type is the hexa-dominant method of meshing with edge size and body size with 69708 knots and 11905 elements which showed in table. Fine mesh option were take it as default.

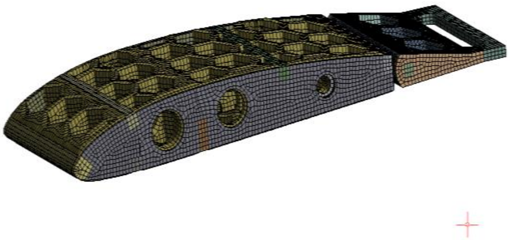

Fig-3: meshed model for honeycomb structure
Fig-3 shows the meshed model for honeycomb structure. 3D model is imported to and is meshed in ANSYS. Mesh matrix Hexa dominant method with edge size and body size were used for meshing, 125791 nodes and 54017 elements are

formed in meshing process which is shown in table. Fine mesh option were take it as default.

3.2 Compression Load for With and From Honeycomb

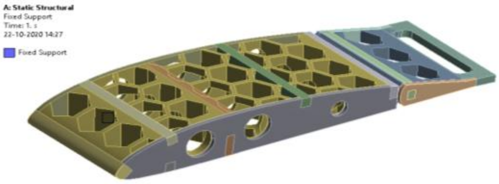

Fig-4: Honeycomb fills wing box

The load is seen in Fig-4 without the arrangement of the honeycomb wing package. Pressure of 50 Mpa on wing surfaces was applied. The wing box was fixed on the fuselage side and the other side was left open. On both with and without a wing box structure study, the same boundary conditions were used.

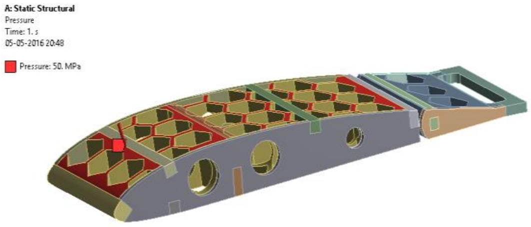

Fig-5: compressive loads on with honeycomb wing box

Fig-5 plays compressive load on the construction of the honeycomb wing package. Pressure of 50 Mpa on wing surfaces was applied. The wing box was fixed on the fuselage side and the other side was left open. The same boundary conditions were implemented both with and without a wing box structure study.

3.3 Tension Load for With Honeycomb Structure

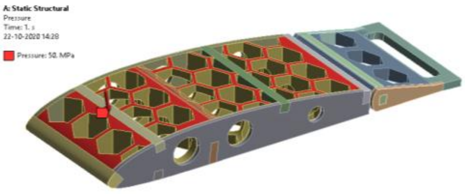

Fig-6: tension loads on without honeycomb wing box

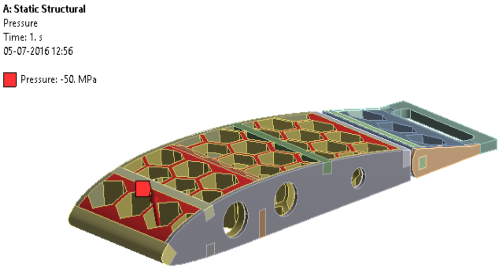

Fig-7: Tension loads on the wing box

The stress load with and without a wing box arrangement as seen in Fig-6 and Fig-7. Inputs such as -50 Mpa pressure is placed on wing surfaces. The wing box was fixed on the fuselage side and the other side was left open. On both with and without a wing box structure study, the same boundary conditions were used.

4. RESULT AND DISCUSSION

4.1 Compressive Stress Analysis

4.1.1 Equivalent stresses for without and with honeycomb structure

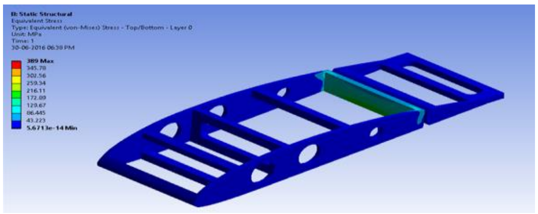

Fig-8: equivalent stresses for without honeycomb wing box

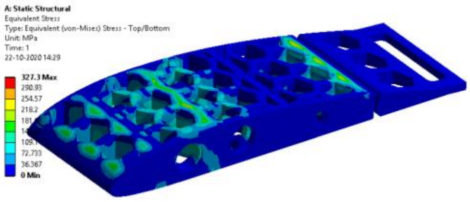

Fig-9: equivalent stresses for with honeycomb wing box

Fig-8 and 9 demonstrate FEA findings for equivalent stresses without and with honeycomb frame structure. Given the compressive load and its boundary constraints, the equivalent stress was 389 Mpa for the framework wing box without a wave-box and 327.3 Mpa were obtained for the structure study with a wing box.

4.1.2 Maximum Principal Stresses for Without and With Honeycomb Structure

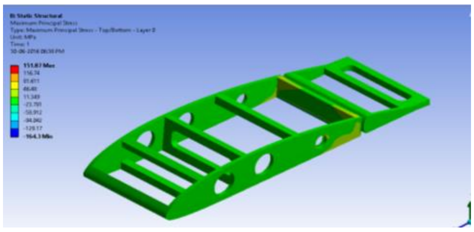

Fig-10: maximum principal stresses for without honeycomb wing box

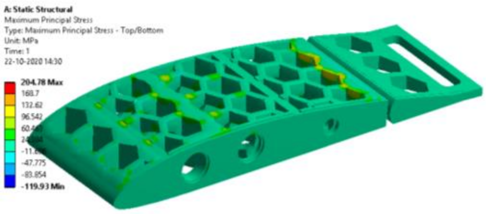

Fig-11: maximum principal stresses for with honeycomb wing box

Fig-10 and 11 shows maximum principal stresses for FEA results without and with the wing box arrangement honeycomb. Due to the compressive charge and its boundary conditions, the overall key stress 151.87 Mpa were obtained for the structure without a honeycomb wing and 204.78 Mpa were obtained for the structural study of a honeycomb wing box.

4.1.3 Minimum Principal Stresses for Without and With the Composition of Honeycomb

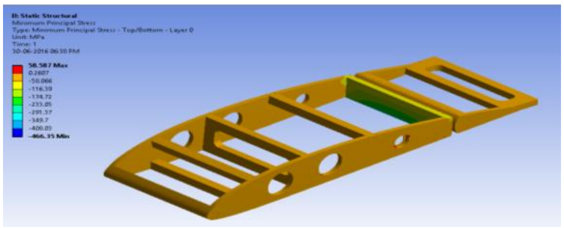

Fig-12: Minimum Principal Stresses for without Honeycomb wing box

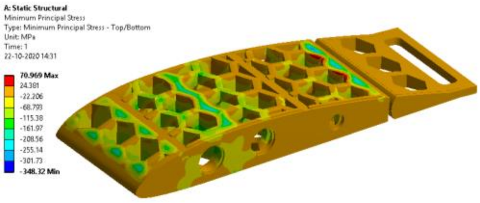

Fig-13: Minimum Principal Stresses for with Honeycomb wing box

Fig-12 and 13 indicate minimum key stresses for FEA outcomes without and with wing box layout. Given the compressive load and boundary parameters, the minimum key stress was 58.587 Mpa and the 70.969 Mpa were obtained for structure-structure-box honeycomb analysis.

4.1.4 Complete Deformation for Structure Without and With Honeycomb

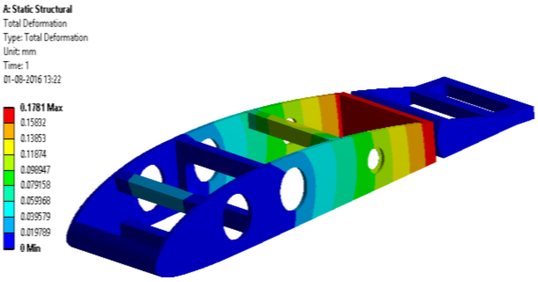

Fig-14: Total systemic deformations without wax

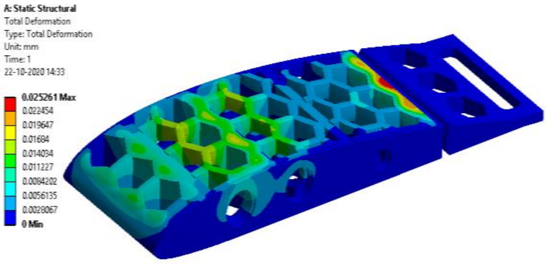

Fig-15: Total systemic deformations with wax

Fig-14 and 15 demonstrate complete deformation for the effects of the FEA wing box structure without and with honeycomb. In view of its compressive load and boundary conditions, the overall deformation was 0.01781mm and 0.02526mm was obtained for honeycomb-free structure wing-box structure analysis.

4.2 Tension Stress Analysis

4.2.1 Equivalent tensions for the formation of honeycomb

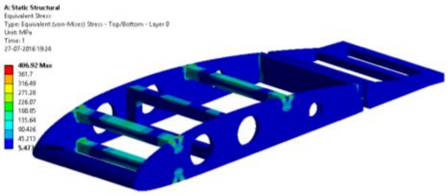

Fig-16: Equivalent Stresses for Aluminum Wing Box

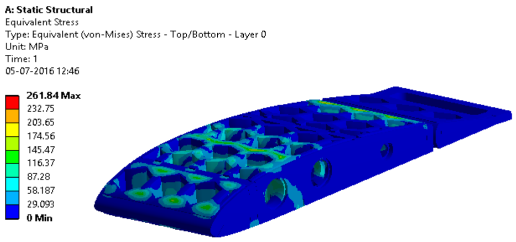

Fig-17: Equivalent Stresses for Composite Wing Box

Fig-16 and 17 demonstrate FEA findings for equivalent stresses with and without honeycomb structure. Provided strain load and border constraints, the equivalent stress 406.92Mpa was obtained for the structure wing box without honeycomb and the structure study of honeycomb wing boxes obtained 261.84 Mpa.

4.2.2 Maximum Principal Stresses for Without and With Honeycomb Structure

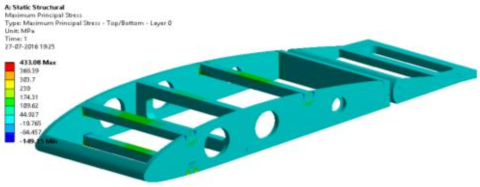

Fig-18: maximum stresses for aluminum wing box

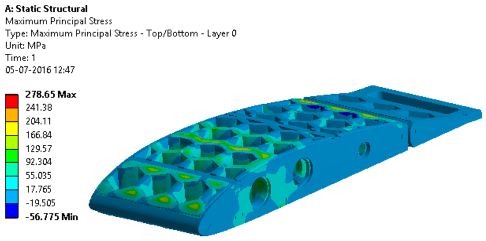

Fig-19: maximum stresses for composite wing box

Fig-18 and 19 indicate the full key stresses of the FEA performance, with and without honeycomb wing box arrangement. Due to the tension load and its boundary constraints, the maximum principal stress was 433.08 Mpa and 278.65 Mpa were obtained for the structural study of the wing box honeycomb.

4.2.3 Minimum Principal Stresses for Without and With Honeycomb Structure

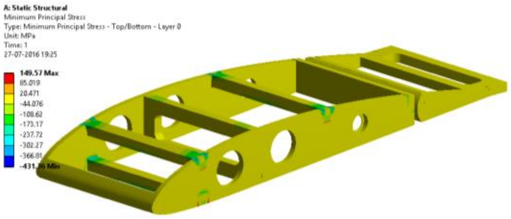

Fig-20: minimum stresses for aluminum wing box

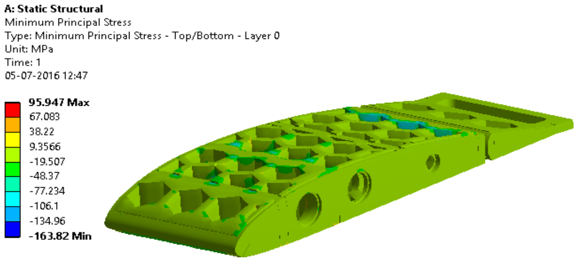

Fig-21: minimum stresses for composite wing box

Fig-20 and 21 indicate minimum key stresses for the effects of FEA with and without wing-box arrangement. Because of the tension load and limit factors, the major minimum stress was 149.57Mpa in the case of a honeycomb framework wing box, and 95.947 Mpa in the case of a honeycomb wing box study.

4.2.4 Total deformation for with and Without Honeycomb Structure

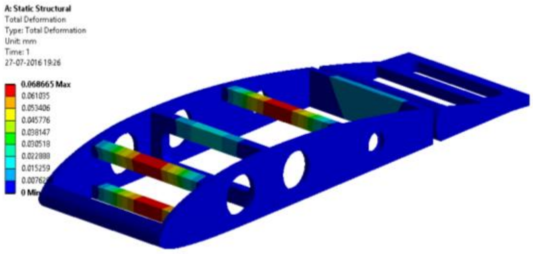

Fig-22: total deformation for aluminum wing box

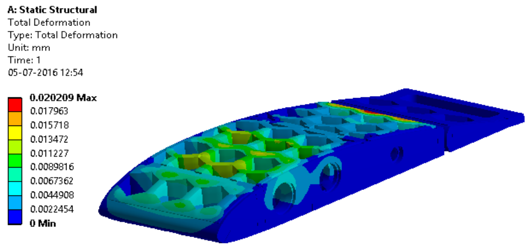

Fig-23: Total deformations for composite wing box

The cumulative deformation for FEA occurs with and without honeycomb wing box arrangement reveals in Fig-22 and 23 respectively. Complete deformity 0.068665mm for without honeycomb-structure wing box and 0.020209mm were obtained for honeycomb-wing box structure analysis provided voltage load and its boundary conditions.

Table-3: Comparison results of compressive static analysis

ANALYSIS	VARIABELS	WITHOUT HONEYCOMB STRUCTURE WING BOX	WITH HONEYCOMB STRUCTURE WING BOX
STATIC COMPRESSIVE ANALYSIS	Equivalent stresses (Mpa)	389	327.3
	Maximum principal stresses (Mpa)	151.87	204.78
	Minimum principal stresses (Mpa)	58.587	70.969
	Total deformation (mm)	0.01781	0.02526

Table-3 displays the contrast outcomes with and without the honeycomb wing arrangement box for static compressive study. Equivalent stresses derived from measurement are less than the final stress of the wing box content and are thus stable. There is more tension without a wave than with the honeycomb structure so the honeycomb structure has a strong power.

Table-4: Comparison results of static tension analysis

ANALYSIS	VARIABELS	WITHOUT HONEYCOMB STRUCTURE WING BOX	WITH HONEYCOMB STRUCTURE WING BOX
STATIC TENSION ANALYSIS	Equivalent stresses (Mpa)	406.92	261.84
	Maximum principal stresses (Mpa)	433.08	278.65
	Minimum principal stresses (Mpa)	149.57	95.947
	Total deformation (mm)	0.068665	0.020209

Table-4 plays the effects of the static tension study with and without the honeycomb wing structure box. Equivalent stresses derived from measurement are less than the final stress of the wing box content and are thus stable. There is more tension without a wave than with the honeycomb structure so the honeycomb structure has a strong power.

4.3 Modal Analysis

Inherent properties of structure are called modes and are determined by mass, damping, stiffness and boundary conditions of structure. Natural frequency, modes shapes and modal damping is used define modes. Modes are changing by mass, damping, stiffness or boundary conditions. Understanding this by the concept of degrees of freedom that is where the mass deflect only on vertical direction is called single degree of freedom and deflects both vertical x axes is called multi degrees of freedom.

Analysis of modes and deformation by FEM has two stages,

- Appropriate type of model identification(with viscous or structural damping)
- Appropriate parameters of the chosen model determination.

5. CONCLUSIONS

From the analysis, with honey comb structure has less deformation as compared to without honey comb in both cantilever and simply supported beam Equivalent elastic strain results are lesser in with honey comb structure as compared to without. Also as a result honeycomb is a preferred core material that is advantageous because of:

- High strength to weight ratio
- Good compressive strength
- Lightweight

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