# Modeling and Static Structural Analysis of an Aircraft Wingbox

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***Abstract-*** *An Aircraft Wings are an important part which produces lift. Depending on type and usage Aircraft Wing design may vary. Aircraft can have Wing structure comprising of spars, ribs or can have honeycomb structure.In present work, the wing box is analyzed for its strength with honeycomb structure as well as without honeycomb structure. The wing box is modeled using Unigraphics. Further the wing box is tested for its compressive and tensile strength using appropriate FEA tools. The outcome of the analysis reveals that the honeycomb structure wing box has high strength.*

***Keywords***- FEA,Honeycomb structure, Unigraphics, Wing box.

## I. INTRODUCTION

An aerodynamic force is created in the direction normal to motion by wing surface during travelling air or any other gaseous medium, enabling the flight. It's a specific form of airfoil. Many studies and research has been carried out for the design of aircraft to optimize the size and weight. They have mainly concentrated on the structural mass by changing the material properties. During these, researches have varied the parameters like shell size, shell thickness but keeping the geometry as a constant for the development of wing structure. The main goal of design is to minimize the stresses, to increase strength, to avoid fretting corrosion, hidden undetectable cracks and to reduce weight.

Many research works had been carried out to analyze aircraft wings to increase their strength to weight ratio. Few of them are discussed here. **Poonam Harakare.et.al [1]** in this paper, FEA was carried out on wing box using MSC Nastran. Studies were done on stresses induced and buckling strength for various modes of wing box. Maximum stress observed was 21.7kg/mm$^2$ and buckling factor was 6.8302.

**Graeme J Kennedy.et al [2]** in this paper, metallic wings and composite wings were assured with respect to structural height and drag. They showed composite wings is 30-40% lighter than metallic wings due to this 5-8% of fuel can be saved.**Venugopal.et al [3]** has done analysis through FEA for composite sandwich panel in static bending load condition. Comparison of models was done with experimental data for sandwich panel. Bending properties assisted in establishing a trustful modeling approach, in this paper Nomex flex core is used as core materials of about 15mm thickness and carbon fiber reinforced polymer composite of about 1.2mm thickness is used for face sheet material.

## II. PROBLEM DEFINITION AND OBJECTIVE

Aircraft wing box structure consists of spars and ribs. Wing structure has to withstand high loads during flight operation. Generally these structures are bulkier and of higher weight. Any method which increases its strength with lesser weight is added advantage. Wing box with honeycomb structure promises to increase the strength with minimal weight. Thus an attempt is made to optimize the wing by incorporating the honeycomb structure and analyzing the same. The main objective is Comparison of wing box with and without honeycomb structures for linear static analysis at different load conditions.

## III. MATERIAL SELECTION:

Material selection is key factor in design of an aircraft structure. Some of the important criteria for selection of material are weight to strength ratio, high corrosive resistance and machinability. As the structure is subjected to different loads, the material should comply with the design requirements.

The Materials that are considered for analysis are,

- Aluminum alloy and
- CFRP (carbon fiber reinforced polymer)

Now a day manufacturing of aircraft industries uses advanced material technology carbon fiber is used. CFRP has the high strength to weight ratio. It is a composite material, comprising of several carbon fibers and thermosetting resins.

Table 3.1: Properties of aluminium alloy

| Properties of aluminium alloy 7075 | |
|---|---|
| Density | $2.7\times10^3$kg/m$^3$ |
| Modulus of elasticity | $71.7\times10^3$Mpa |
| Tensile yield strength | 503Mpa |
| Poisson's ratio | 0.34 |
| Tensile ultimate strength | 572Mpa |

Table 3.2: Properties of CFRP

| Properties of CFRP | |
|---|---|
| Density | $1.5\times10^3$kg/m$^3$ |
| Modulus of elasticity | $1.5\times10^3$Mpa |
| Tensile yield strength | 200Mpa |
| Poisson's ratio | 0.28 |
| Tensile ultimate strength | 550Mpa |

## IV. GEOMETRICAL MODELING AND FEM ANALYSIS

### 4.1 THREE DIMENSIONAL WING BOX MODELS:

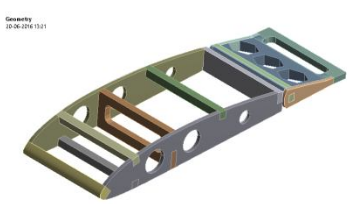

Figure 4.1: Three dimensional model of wing box without honeycomb structure

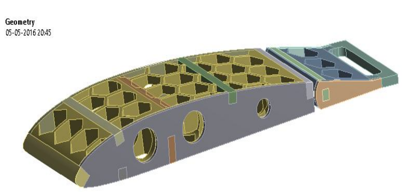

Figure 4.2: Three dimensional model of wing box with honeycomb structure

### 4.2 MESHED WING BOX WITH AND WITHOUT HONEYCOMB STRUCTURES:

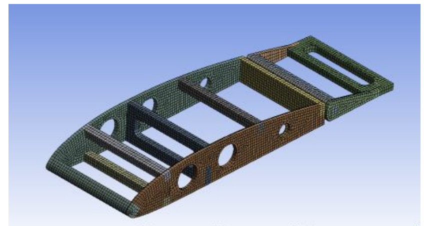

Figure 4.3: Meshed wing box model without honeycomb structure

Mesh matrix is hexa dominant method with edge size and body size with having 69708 nodes and 11905 elements are formed in meshing process.

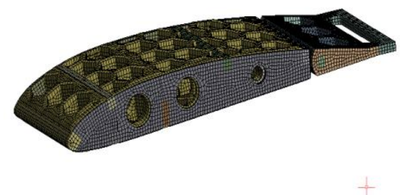

Figure 4.4: Meshed model wing box with honeycomb structure

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

### 4.3 BOUNDARY CONDITIONS

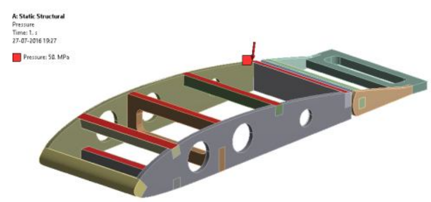

Figure 4.5: Compressive loads on wing box without honeycomb structure

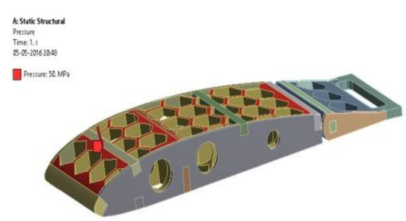

Figure 4.6: Compressive loads on wing box with honeycomb structure

Figure 4.5 and 4.6 shows compressive load on without honeycomb wing box structure. Pressure of 50 MPa was applied on wing surfaces. Fuselage side of Wing box and tip side was fixed and flaps side was kept free. Same boundary conditionswere used for both with and without honeycomb structure wing box analysis.

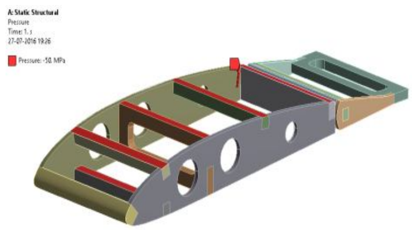

Figure 4.7: Tension loads on wing box without honeycomb structure

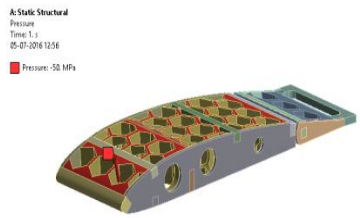

Figure 4.8:Tension loads on wing box with honeycomb structure

The above same boundary conditions were applied and Pressure of -50 Mpais applied on wing surfaces.

## V. RESULT AND DISCUSSIONS

### 5.1 COMPRESSIVE STRESS ANALYSIS

Wing box experiences the compressive load during its operation because of which compressive stress is developed in the wing box structure. For proper design and analysis of wing box determining it compressive is necessary, hence by using appropriate FEA tool. An effort to estimate equivalent compressive stress and thus compressive strength for wing box with and without honeycomb structure are presented in this section.

### 5.1.1 EQUIVALENT STRESSES WING BOX WITHOUT AND WITH HONEYCOMB STRUCTURE

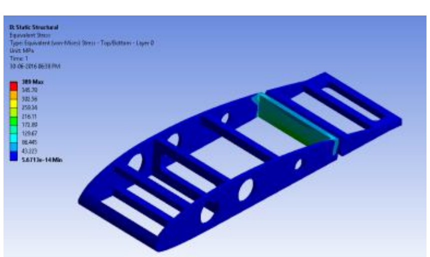

Figure 5.1: Equivalent stresses of wing box without honeycomb structure

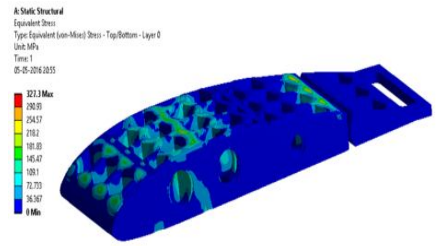

Figure 5.2: Equivalent stresses of wing box with honeycomb structure

Figure 5.1 and 5.2 shows equivalent stresses with and without honeycomb wing box structure FEA results respectively. Given Compressive load and its boundary conditions, the equivalent stress 389 Mpa were obtained for without honeycomb structure wing box and 327.3 Mpa were obtained for with honeycomb wing box structure analysis.

### 5.1.2 TOTAL DEFORMATION WING BOXWITHOUT AND WITH HONEYCOMB STRUCTURE

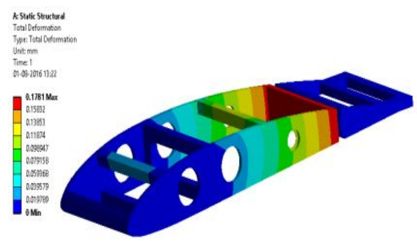

Figure 5.3: Total deformations wing box without Honeycomb

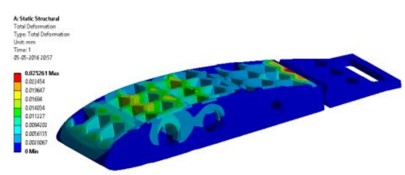

Figure 5.4: Total deformations wing box with Honeycomb structure

Figure 5.3 and 5.4 shows total deformation wing box with and without honeycomb structure FEA results respectively. Given compressive load and its boundary conditions, total deformation 0.01781mm were obtained for without honeycomb structure wing box and 0.02526mm were obtained for with honeycomb wing box structure analysis.

### 5.2 TENSION STRESS ANALYSIS

Wing box experiences the tensile load also during its operation along with compression load, because of which tensile stress is developed in the wing box structure. For proper design and analysis of wing box finding its tensile strength is essential, hence by using appropriate FEA tool, an effort to estimate equivalent tensile stress and thus tensile strength for wing box with and without honeycomb structure are presented in this section.

### 5.2.1 EQUIVALENT STRESS WING BOX WITHOUT AND WITH HONEYCOMB STRUCTURE:

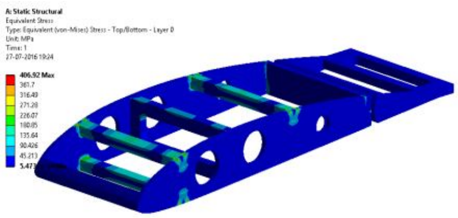

Figure 5.5: Equivalents Stresses Wing Box without Honeycomb Structure

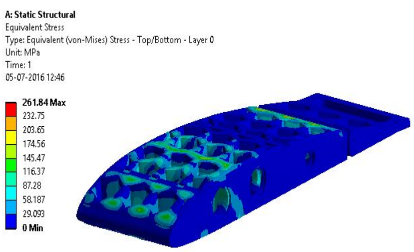


Figure 5.6: Equivalent Stresses Wing Box witht Honeycomb Structure

Figure 5.5 and 5.6 shows equivalent stresses with and without honeycomb wing box structure FEA results respectively. Given Tension load and its boundary conditions, the equivalent stress 406.92Mpa were obtained for without honeycomb structure wing box and 261.84 Mpa were obtained for with honeycomb wing box structure analysis.

### 5.2.2 TOTAL DEFORMATION WING BOX WITHOUT AND WITH HONEYCOMB STRUCTURE

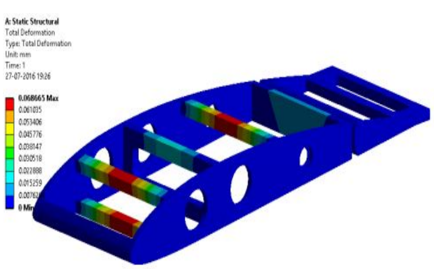

Figure 5.7: Total deformation wing box without Honeycomb Structure

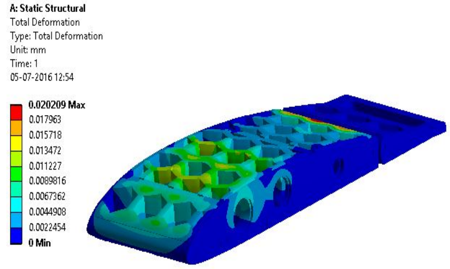


Figure 5.8: Total deformations wing box with Honeycomb Structure

Figure5.7and 5.8 shows total deformation with and without honeycomb wing box structure FEA results respectively. Given tension load and its boundary conditions, total deformation 0.068665mm were obtained for without honeycomb structure wing box and 0.020209mm were obtained for with honeycomb wing box structure analysis.

### 5.3 COMPARATIVE RESULTS:

Results obtained in static structural compressive and tension analysis are tabulated bellow

Table 5.1: Comparative 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 5.1 shows the comparison results of static compressive analysis for with and without honeycomb structure wing box. Equivalent stresses obtained from analysis less than the ultimate stress of the wing box material hence it is safe. Without honeycomb has more stress than with honeycomb structure hence the with honeycomb structure have good strength.

Table 5.2: Comparative results of tension static 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 5.2 shows the comparison results of static tension analysis for with and without honeycomb structure wing box. Equivalent stresses obtained from analysis less than the ultimate stress of the wing box material hence it is safe. Without honeycomb has more stress than with honeycomb structure hence the with honeycomb structure have good strength.

## VI. CONCLUSION

Based on analysis the following conclusions were drawn.

- The stresses obtained under static linear analysis for wing box without honeycomb structure are 389 MPa and 406.92 MPa for compression and tension loading respectively.
- Stresses induced with honeycomb structure wing box are 327.3Mpa and 261.84 MPa for compression and tension loading respectively. Hence for higher strength with honeycomb structure is preferred for the wing box design.
- Usage of the honeycomb structure avoids buckling of the outer skin of wing box.

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