Fatigue Analysis and Life Prediction of Honeycomb Structures

Ajit Lohote[1], Prof.S.S.Kelkar[2]
[1, 2] Department of Mechanical Engineering
[1, 2] JSCOE, Pune University, Maharashtra, India.

Abstract- *The use of honeycomb composite structure continues to increase rapidly due to the variety of their application, for example: satellites, aircraft, ships, automobiles, transportation rails, etc. The sandwich composites are multi-layered materials made of bonding stiff, high strength skins facings to low density core material. In structural components high stiffness to weight ratios is the major benefit of the honeycomb sandwich concept. In this study a honeycomb structure is evaluated. Static behavior of sandwich are investigated for permissible load. Then a fatigue analysis is carried out to investigate for its life prediction. The objective of the project is to find number of cycles a structure sustains at a particular load. If a structure fails at early stage, efforts will be taken to increase its stiffness and strength as design parameters.A Finite element analysis of honeycomb structures is to be carried out with ANSYS Workbench as both preprocessor and post processor. The finite element analysis results compared with the experimental results.*

Keywords- Finite element analysis, Honeycomb, fatigue analysis.

I. INTRODUCTION

Sandwich panels are used for design and construction of lightweight transportation systems such as satellites, aircraft, and missiles. Structural weight saving is the major consideration and the sandwich construction is frequently used instead of increasing material thickness, honeycomb are made of very thin material. They reduce the weight, while providing the structural rigidity. This type of sandwich construction consists of two thin facing layers separated by a core material. Potential materials for sandwich facings are aluminum alloys, high tensile steels, titanium, inconel-617 and composites with composites with honeycomb cores and a suitable matrix depending on the specific mission requirement. Several types of core shapes and core materials have been applied to the construction of sandwich structures. Among them, the honeycomb core that consists of very thin foils in the form of hexagonal cells perpendicular to the facings is the most popular.

The facing sheets of a honeycomb sandwich panel can compared with the flanges of I-beam, as they carry the similar bending stresses to like the beam is subjected. With one facing sheet is in compression, the other is in tension. Similarly honeycombcore corresponds to the I-beam web. The core resists the shear loads and increases the structure stiffness by holding facing sheet apart, improving on I-beam and it gives constant support to flanges or facing sheets to make a uniformly stiffened panel. The core to skin adhesive rigidly joins honeycomb sandwich components and permits them to act as single unit with a bending rigidity and high torsion.

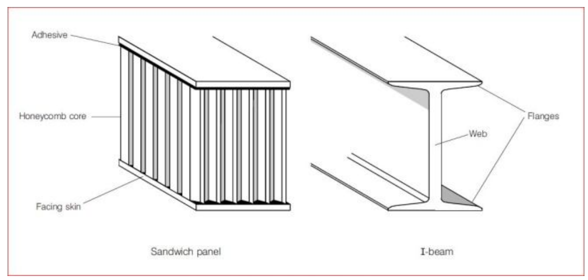


Fig.1 Honeycomb Sandwich panel compared with I-beam [10]

S. Belouettar et.al. [1] Presented work is related to static and fatigue behaviours of honeycomb composites using four point bending test, in this they found the effects of core density and the cell of orientation on the maximum load and on the damage processes. Craig A et.al.[2] proposed the study of Analytical predictions are made for the three-point bending collapse strength of sandwich beams with composite faces and polymer foam cores.Hualin Fan et.al. [4] Presented work is related to study compression behaviours of the lattice composites and sandwich columns with different skin thicknesses.Isaac M et.al. [5] Presented work is related to determine experimental the flexural behaviour of composite compare the result with theoretical models.

The proposed work is to determine fatigue life of honeycomb composite panel having honeycomb structure sandwich between glass fiber panel. Fatigue life is determined by FEA analysis and validated with experimental results.

II. HONEYCOMB STRUCTURE

Honeycomb sandwich construction is mostly used in various structures, as the concept is most suitable with lightweight structures for high in- plane and flexural stiffness. Honeycomb sandwich panels consist of two thin sheets (skins) and Da lightweight thicker core. Usually materials used for face sheets are composite laminates and metals, while cores are made by metallic and non-metallic honeycombs, cellular foams, balsa wood or trusses. The flexural stiffness and out-of-plane shear and compressive strength is provided by the core. Important issues in honeycomb sandwich structures are failure mechanisms, the quality of structure that are developed under different loading conditions and effects of geometric nonlinearities, effects of nonlinear material behavior.

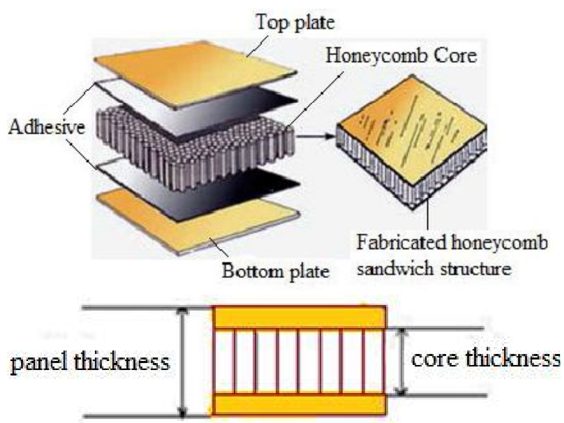


Fig.2 Exploded view of honeycomb core sandwich structure [11]

Fatigue failure of Honeycomb Structures

One of the common causes of Honeycomb Structures failure is due to fatigue. Repeated cycling of the load causes fatigue. It is continuous damage due to both fluctuating stresses as well as strains on material. Cracks are initiated and propagated in the regions where strain is more severe.

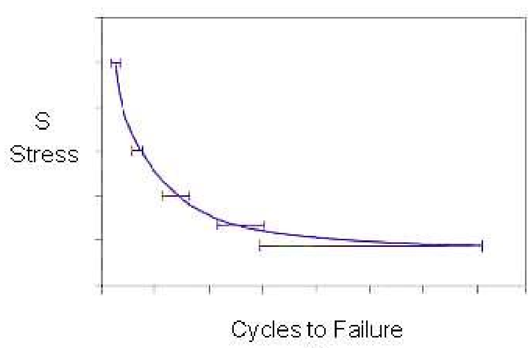


Fig.3 S-N curve

The concept of fatigue is not difficult, when motion is repeated; the object becomes weak. For example, while you are running, your leg and other muscles of your body become weak, not always to the point where you can't move them anymore, but there is aconsiderable decrease in quality output. This same principle is seen in materials. When the material is subject to alternating stressesfor a long period of time fatigue occurs. e.g. airplane wings, turbine blades and bones.

There are three steps that can be viewed in material failure because of fatigue on a microscopic level:

1. Crack Initiation: Initial crack occurs in this stage. That crack may be caused by surface scratches caused by handling, or tooling of the material; threads as in a screw, slip bands /dislocations intersecting the surface as an effect of previous cyclic loading or work hardening.
2. Crack Propagation: Crack continues to grow atthis stage due to continuous application of stresses
3. Failure: Failure is occurred when the material that hasn't been affected by the crack can't withstand the stress. This happens very quickly.

III. FATIGUE ANALYSIS

In materials science, fatigue is the weakening of a material caused by repeatedly applied loads. It is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. The nominal maximum stress values that cause such damage may be much less than the strength of the material typically quoted as the ultimate tensile stress limit, or the yield stress limit.

Fatigue is generally understood as the gradual deterioration of a material which is subjected to cyclic loads. In fatigue testing, a specimen is subjected to periodically varying constant amplitude stress. The applied stresses may alternate between equal positive and negative value from zero to maximum positive or negative value, or between equal positive and negative values or between unequal positive and negative values.

A series of fatigue tests are made on a number of specimens of the material at different stress levels. The stress endured is then plotted against the number of cycle sustained. By choosing lower and lower stresses, a value may be found which will not produce failure, regardless of the number of applied cycle. This stress value is called the fatigue limit of the material or the endurance limit. The plot of the two terms is called stress-cycle diagram or S-N diagram. The fatigue limit may be established for most steels be-tween 2 and 10 million cycles. Non-ferrous metals such as aluminum usually show no clearly defined fatigue limit. Survey of the various aspects of fatigue of structures.

IV. FINITE ELEMENT ANALYSIS

The CAD model is imported to ANSYS Workbench. The appropriate element size is selected according to the geometry features. Then using Shell element the aluminum honeycomb is meshed and then the composite plates maintaining the connectivity. The meshed model is checked for element criteria. Shell 63 element type is used for meshing. Number of nodes and elements are 50165 and 41630 respectively.

The composite panel is made of 6 layers of Glass fiber sheets arranged with different degree of orientation. The layers of thickness 0.2083 mm are arranged as 45o, -45o, 45o, -45o, 45o, -45o.The top and bottom layers are arranged as in the order by total 12 layers. The Aluminum core is sandwiched between the layers. Material properties of aluminum core and glass fiber are given in following tables.

Table 1: Material properties Aluminum core [10]

Property	Value
Young's Modulus, E	68.9 GPa
Poisson's Ratio ,ν	0.33
Density, ρ	2700 kg/m^3
Yield Stress, σ_{yield}	214 MPa
Ultimate Tensile Stress, σ_{uts}	241 MPa

Table 2: Material properties of Glass fibres [10]

Property	Value
Young's modulus in x-direction, E_x	40300 MPa
Young's modulus in y-direction, E_y	6210 MPa
Young's modulus in z-direction, E_z	40300 MPa
Poisson's Ratio ,ν	0.2
Density, ρ	1.9 x 10^{-9} tonne/mm^3
Shear modulus in XY plane	3070 MPa
Shear modulus in YZ plane	2390 MPa
Shear modulus in ZX plane	1550 MPa

Results of fatigue analysis of honeycomb structure with and without composite material for 1 kN load are shown in following figures.

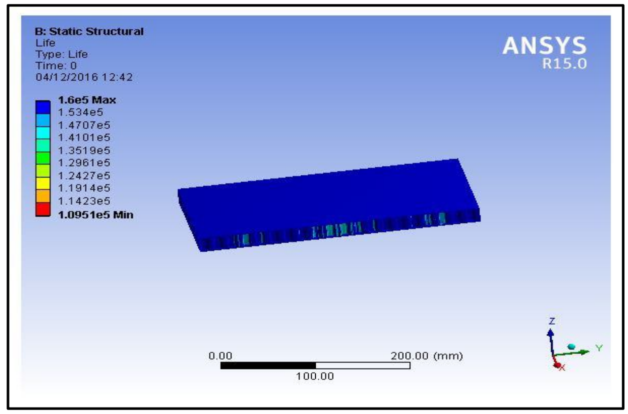
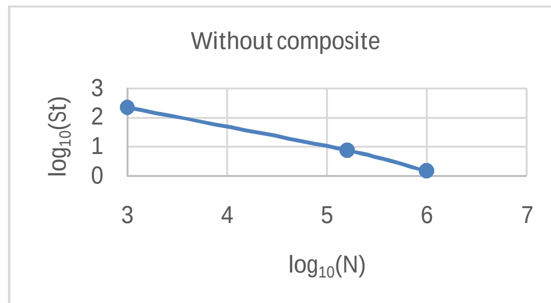


Fig.4 Fatigue life of specimen without composite for 1 kN load.



Graph .1 S-N Curve results of specimen without composite.

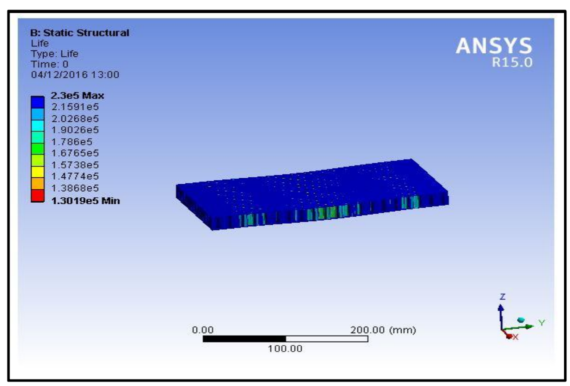
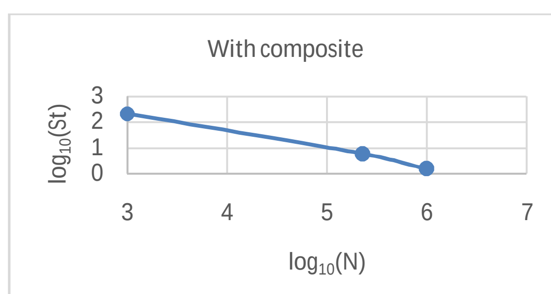


Fig.5 Fatigue life of specimen with composite for 1 kN load.



Graph 2S-N Curve results of specimen with composite.

Fatigue analysis of honeycomb structure without composite has shows1,60,000life cycles and for honeycomb structure with composite shows 2,30,000 life cycles for 1kN load.

V. EXPERIMENTAL VALIDATION

Equipment Make : Instron Structural Testing System (Country-Germany)
Test Equipment used: Instron Actuator 25KN (AC/MC/059)
Controller : 8800 Instron Make

Fig.6 Experimental setup

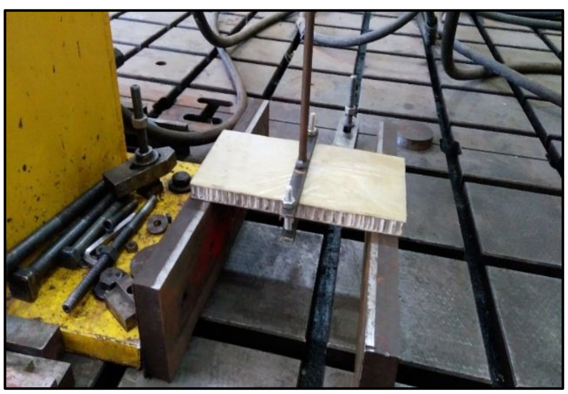
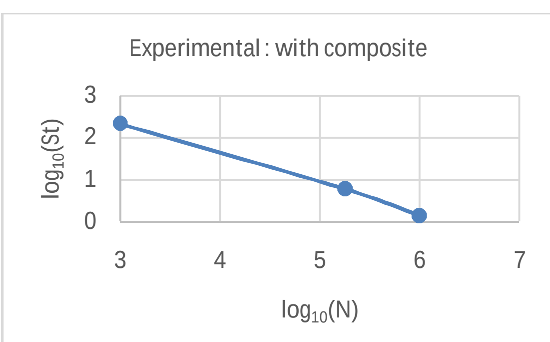


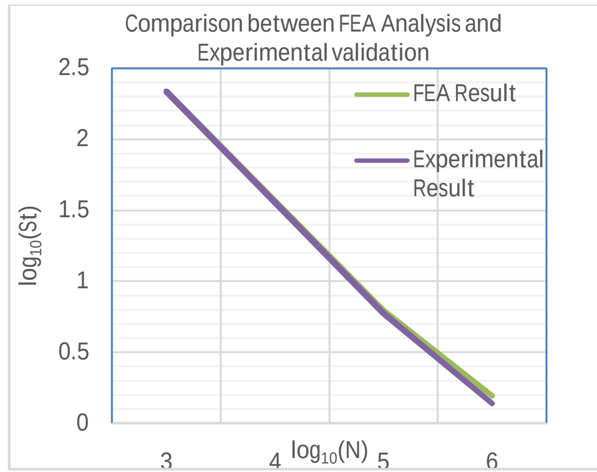
Fig.7 Testing specimen



Graph 3S-N Curve results for experimental validation of specimen with composite

VI. RESULTS AND DISCUSSIONS

Method of Analysis	No. of cycles
By Finite Element Analysis	2,30,000 cycles
By Experimentation	1,80,936 cycles – Crack observed.



Graph 4S-N Curve comparison between FEA Analysis and Experimental validation

From the above graph it can be seen that FEA results and experimental result are closely matching.

VII. CONCLUSION

1. Fatigue testing in three point bending were performed on honeycomb structure. It shows that at 1kN load & frequency 10Hz, Crack observed after 1,80,936 cycles of honeycomb structure with composite.
2. Fatigue analysis has been performed for honeycomb structure without composite life cycle is 1,60,000 cycles and honeycomb structure with composite life cycle is 2,30,000 cycles for 1kN load.
3. 3.Based on the results it can be used in some applications like automotive and aerospace where the structure can undergo repeated or complete reverse fatigue load.

APPENDIX

Journal Paper submitted

Ajit T. Lohote, Prof. S. S. Kelkar,"Fatigue Analysis and Life Prediction of Honeycomb Structure", MECHPGCON 2016.

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