A Decision Support Study on Thermal Coupling Analysis of Inserts used in Hexagonal Honeycomb Plates for Satellite Structural Design.

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ABSTRACT: With advancements in Science and Space related Technologies, the necessity of materials which would sustain the extreme mechanical constrains have become evident and is of paramount importance. The material which is to be used in the outer space must carry many mechanical properties with respect to Structural Loads, Thermal Loads, Acoustics disturbances, Shock Waves etc. Apart from the above mentioned material characters, Strength to Weight Ratio of the material is regarded as one of the prominent virtue in selecting the materials for space application. The material needs to be light in weight, while it is capable of carrying huge loads, huge thermal radiation and huge thermal load developed by the sub systems inside the system. Technological advancements brought to light numerous materials which fulfil all the requirements so as to be used in outer space. Honeycomb Thermal is one of the most sorted out material in this regard. Honeycomb has high weight to density ratio. Its structure is in hexagon shape like Bee's house. It has highest crush strength to weight ratio. Its main use in Thermal application because of it has extremely efficient in Thermal with respect to the solid components. It is one of the orthotropic materials. This Project aims at Rate of heat transfer for a solid component to the performance of the Honeycomb Thermal and its characteristics.

Keywords: Honeycomb; Thermal; Orthotropic materials; Structural Loads; Acoustics disturbances; Shock Waves.

I. INTRODUCTION

The study of the project is to perform insert potting process for aluminium honeycomb structure materials used for mounting of different critical payload elements and to carry out performance evaluation of the of honeycomb structure and inserts by mechanical testing. HONEYCOMB materials are known to be tailor made in making satellites and payloads. Performance of the Honeycomb materials .The demand for lightweight materials for different structural and Thermal applications is increasing continuously and lightweight materials are opening enormous opportunities to the designers. Honey comb materials are one of the best innovations for using in space where the high stiffness is required at the same time weight shall be as low as possible. Honeycomb materials are good members for satellite structures but for mounting the hardware element it is required to have structural inserts. Honeycomb consists of an array of open cells, formed from very thin sheets of material attached to each other. Usually the cells form hexagons but there are other cell configurations that will be described and discussed.

II. PREPARATION OF HONEYCOMB CORE

Honeycomb sandwich are fabricated by various method such as adhesive bonding, resistance welding, brazing, Diffusion and thermal fusion. These methods are based on how the nodes are attached. Moreover 95% honeycomb is made by adhesive bonding. Corrugation process is original technique used to fabricate the honeycomb core.

In corrugation process the sheets are first corrugated, then applied the adhesive on the nodes and the sheets are stacked and cured in an oven. Honeycomb core has different shapes; hexagon, reinforced hexagon, over expanded, square cell, under expanded and flex core.

This component is used for fastening other subsystems on honeycomb sandwiches. Directly cannot fasten in Honeycomb core because of its not solid. Honeycomb is made of no's of cells in hexagon shape. Different types of inserts planned for testing are:

1. M6 through insert
2. M6 Blind Insert
3. M4 Blind

Insert all inserts are made of Al 2024 T81 material and chromic acid anodised. Insert Potting process is critical. This process requires more attention and proper knowledge about adhesive curing timing and pouring process. This process involves different steps. Each process step described in the following.

III. HONEYCOMB MACHINING

Honeycomb machining is required for insert potting. High speed milling machine will be used for making the required holes for placing the inserts for different tests. Honeycomb specimen post bonding drawings for the through and blind holes. ASHLAND makes PLIOGRIP® 5760 B adhesive systems will be used for insert potting. Appropriate quantities of black epoxy based resin and catalyst will be mixed thoroughly. The mixture will be dwelled for 30 minutes. Insert will be placed appropriately in the position using clamp. Approximate volume of the adhesive will be taken in adhesive filling gun and adhesive will be pressed though the runner hole till it will come out from the riser. Excess adhesive will be wiped off. The same setup will be kept at room temperature for 4 Hrs. of curing. Same process will be carried out for M6 blind insert and M4 blind inserts.

Honeycomb closely resembles the bee's honeycomb found in nature, from which it gets its name. It can be made from any thin flat material, and in the past over 500 different kinds of honeycomb have been manufactured. Paper honeycomb was first made about 2000 years ago by the Chinese, who used it for ornaments and not structurally as it is today. Even now, however, we still see ornament tissue paper honeycomb turkeys being used as decorations for Thanksgiving, and tissue paper honeycomb bells and stars during the Christmas season. The first honeycomb core patent, covering a manufacturing method for the production of Kraft paper honeycomb, is probably the Bud wig Patent, issued in 1905 in Germany. One of the earliest man-made sandwich structures of which we have a record was a tubular railroad bridge in Wales, built in 1845. It consisted of a large rectangular tube, the floor of which supported railroad tracks, and through which trains ran. The tube's top compressive panel had two flat plates connected to a square cell egg crate type wood core.

IV. WHY HONEYCOMB?

Why and when should a honeycomb sandwich structure be used? The basic reason is to save weight; however, smooth skins and excellent fatigue resistance are also attributes of a honeycomb panel. A sheet and stringer air foil with thin skins under load. If the skins are thin. And the stringer spacing large, the skins will deform and cause additional unwanted drag on the air foil, while the honeycomb air foil retains a smooth surface even under load. Shows a DC-I0 honeycomb sandwich vane with a man's reflection on the mirror like surface. Honeycomb panels are used in classified space mirror projects and even over some beds in Las Vegas hotel suites! Another real plus for sandwich construction is its fatigue resistance.

The results of sonic fatigue tests comparing a honeycomb panel with a skin-stiffened structure. Notice that the honeycomb panel lasted 460 h at 167 dB while the conventional structure only lasted 3 min. The honeycomb panel therefore lasted 9200 times longer. The reason for the greater fatigue resistance of the honeycomb panel is that the sheet and stringer construction uses rivets which are stress risers and cause premature failure. The honeycomb panel facings are continuously bonded to the core and therefore no stress concentrations are present.

But the main reason for using honeycomb is to save weight. Compares the strength and stiffness values of different honeycomb structures made using a 0.064 in. (1.6mm) thick piece of aluminium split in half as the top and bottom facings of the sandwich. The sandwich on the far right is 37 times stiffer than the flat aluminium sheet and 7 times stronger in bending strength, yet it only weighs 9% more than the solid plate. However, it does cost more. When light weight is a design criterion, honeycomb should be used if the skins have a buckling problem. If the loads are very high and thick skins are required (no buckling problems) a sheet and stringer or extruded shape may be the most economical solution. Another situation where honeycomb may not be the best alternative is when the loads.

V. WEB MATERIALS AND MANUFACTURING METHODS

Since the 1940s honeycomb has been made from many different web materials, as honeycomb can be made from just about any thin flat sheet material. Some of the more common web materials currently in use are:

- Metallic - aluminium, stainless steel, titanium
- Non-metallic - fiberglass, Nomex, Kraft paper.

A few of the more unusual web materials are copper, lead, asbestos, Kapton, Mylar and Kevlar. One new material is carbon fabric, which produces honeycomb that has extremely high mechanical properties, especially for a non-metallic core. In fact, it is the first non-metallic core that has shear moduli as high as the aluminium honeycomb. The aluminium alloys commonly used are 3003 for commercial grade honeycomb and 5052, 5056 and 2024 for the specification grades with 5052 being the most common. The 2024 alloy is used when higher service temperatures are encountered. It can withstand 420 °F (216°C) service temperatures while the other aluminium alloys cores. have a service temperature of 350 °F (177°C). Nomex paper also comes in a commercial grade, E-78 (now T-722), and a specification grade 412. The E-78 Nomex paper produces honeycomb with only slightly lower mechanical properties, but it does not pass the FAR 25.853 flammability afterglow requirement. Fiber glass honeycomb cores are made from the following plain weave fiber glass fabrics: 106, 108, 116, 117 and 1526. The 106 fabric is the lightest and thinnest; therefore, it is used for the small cell light density cores. Kraft paper comes untreated or resin impregnated from 11 to 25% by weight in paper weights of 60, 80 and 90lb per ream; one ream equals 3000 square feet (27, 36 and 41 kg per ream; one ream equals 279m^2). Flame retardant salts may be added to allow the Kraft paper honeycomb to meet UL flame spread requirements of being self-extinguishing. The alloys used in stainless steel cores are 17- PH, PH 15-7, AM 350, AM 355, 316L and 347. Titanium cores are made from commercially pure 6AI-4V, 6AI-2Sn-4Zr-2Mo and 3AI-2.5V foil. Inconel and Hastelloy-X are two nickel based alloys that are also used to make honeycomb cores.

There are five basic ways of making honeycomb: adhesive bonding, resistance welding, brazing, diffusion bonding and thermal fusion. These methods are based on how the nodes are attached. By far the most common manufacturing method is adhesive bonding; perhaps as much as 95% of the honeycomb cores are made this way. Resistance welding, brazing or diffusion bonding are only used on cores that must see high temperatures or severe environmental conditions as it is much more expensive to manufacture core by these processes.

The highest temperature adhesive bonded nodes can withstand is about 750 °F (399 °C), and that is with a polyimide node adhesive. Normally nylon epoxy and nitrile phenolic adhesives are used, and their maximum service temperatures are around 400°F (204°C).Some thermoplastic materials have their nodes heated so they are partially melted; then they are pressed together and the two ribbon sheets fused together at the nodes. In this method an adhesive is not required.

The corrugation method, illustrated, is the original technique used to fabricate honeycomb core. Although it is labour intensive, this method is still used for making high density metallic and some non-metallic cores. In the corrugation process the sheets are first corrugated, then adhesive is applied to the nodes and the sheets are stacked and cured in an oven. Since only light pressure can be applied to the stacked block the node adhesive is much thicker than the expanded core. In fact the corrugated node adhesive can be 10% of the total honeycomb weight while it is only about 1 % or less in the expanded core. Some non-metallic corrugated blocks must be brought up to final density by resin dipping to achieve the optimum resin-to reinforcement ratios. Instead of using adhesive to connect the nodes some metallic corrugated honeycomb cores have their nodes brazed, diffusion bonded or spot welded together. This allows some cores such as stainless steel and Inconel to be used at temperatures as high as 1300 °F (704°C).

VI. HONEYCOMB PROPERTIES

The honeycomb mechanical properties that are generally determined are the following: bare and stabilized compressive strength, stabilized compressive modulus, and Land W plate shear strengths and moduli. For energy absorption applications the crush strength is needed, which is approximately 50% of the bare compressive strength. All the honeycomb manufacturers have brochures with their core products properties listed. All of them would welcome the opportunity to send.

The sandwich is not a material having unique mechanical properties; rather, it is a structure which must be designed for the particular uses to which it will be subjected. The composition of the sandwich is limited only by the availability of materials and the engineer's ingenuity. In designing sandwich structures the following must be considered: the sandwich is a composite structure, the materials used may be anisotropic, and the core shear modulus is low; therefore, the shear deformations must be checked. The basic concept of sandwich construction is to use thin, dense, strong facing materials bonded to a thick, lightweight core. Each component by itself is relatively weak and flexible but when working together they provide an extremely stiff, strong and lightweight structure. In these designs it is assumed that the facings take the bending load (one skin in compression and the other in tension) and the core takes the shear load. It is usually assumed that the facing stresses are uniformly distributed and the honeycomb offers no resistance to bending. In other words, the core bending modulus E~ equals zero. This assumption also leads to a uniform shear stress throughout the core thickness.

The sandwich panel evolved. At first most structures were made from wood beams. Note that the highest bending stresses are at the outer surfaces and zero in the middle. Consequently, the center portion of the wood beam carries very little of the bending load. It mainly takes the shear load. Then came the wide-flange or I-beam. Here there are two flanges separated by a web. The flanges take the bending load, one in compression and one in tension, with the web taking all the shear loads. This concept works very well and is used extensively in building structures as weight is usually not a critical concern. However, in aircraft structures weight is extremely important. To cut the weight down on wide-flange beams the flange thickness is reduced. This can cause a local buckling problem of the flange tips. Thus the entire flange does not carry the full material yield stress. Here is where honeycomb sandwich is beneficial.

The honeycomb core completely supports the facing so very thin facings can be used which will not buckle. These skins can work to their full material yield stress. The portions of the compressive flanges of a sandwich panel, wide-flange beam and extrusion that are at their maximum yield stresses. This, of course, assumes thin flanges. Only the sandwich panel is fully stressed. If the design loads are large and require thick facings, buckling will not be a problem and the wide-flange or I-beam concept may be the most economical and the better approach. However, whenever local flange buckling occurs the sandwich concept is the best.

VII. ASSEMBLY CONSTRAINTS

Use the Assembly Constraints command to define positions of components in the assembly. NX uses directionless positioning constraints, which means that either component can move to solve the constraint. You can use assembly constraints to:

- Constrain components so they touch each other or align with each other. The Touch Align constraint is the most commonly-used constraint.
- Specify that a component is fixed in place. This is useful when you want to control which components move when the software solves a constraint.
- Bond two or more components together, so they move together.
- Define a minimum distance between selected objects in components.

The following way can also be done:

- Use the Constraint Navigator to analyze, organize, and work on assembly constraints in your work part.
- Convert mating conditions to assembly constraints. Assembly constraints are usually faster to create and easier to use than mating conditions.
- Create constraint groups in the Assembly Navigator or the Constraint Navigator to organize the constraints in your assembly. A constraint group associates a set of assembly constraints, and is displayed as a single item in the navigator.

VIII. BOUNDARY CONDITIONS

Loads, constraints, and simulation objects are all considered boundary conditions. The Simulation Navigator provides tools that let you create, edit, and display boundary conditions. You can also create boundary conditions using icons on the Advanced Simulation toolbar. The options that appear on the boundary conditions dialog boxes are specific to the active solution and its associated solver. For example, if the active solution uses the NX Nastran solver, the Create Force dialog provides options that are specific to the NX Nastran FORCE card.

One can create boundary conditions before or after you create a solution:

- If you create a solution first, the loads, constraints, and simulation objects are stored in their respective containers in the Simulation: the Load Container, Constraint Container, and Simulation Object Container. You can also assign them to folders in these containers. New boundary conditions and folders are automatically added to the active solution or step.
- If you create the loads, constraints, and simulation objects first, they are stored in their respective containers in the Simulation. You can then drag and drop individual boundary conditions or folders into solutions you create.

Boundary conditions can be applied to both geometry (edges, faces, vertices, points) and FEM objects (nodes, elements, element faces, and element edges).

In particular, FEM-based boundary conditions are useful for imported meshes with no underlying geometry, locations that are not defined by geometry, and areas where small edges and faces were removed during abstraction. To define the magnitude of a boundary condition, you can use constant values, NX expressions, or fields to define how the magnitude varies with time, temperature, frequency, or spatially. For more information, see Fields. You can import boundary conditions from a source simulation to reuse in another simulation. For more information about importing modeling objects, see Importing simulation entities.

- Simulation Navigator → (Load, Constraint, or Simulation Object) Container → rightclick.
- Simulation Navigator → Solution →(Loads, Constraints, or Simulation Objects)→ right-click.
- Advanced Simulation toolbar → (icon for specific load, constraint, or simulation object)
- Select model object → right-click → Create (Load, Constraint, or Simulation Object).

IX. CONCLUSIONS

In light of this study, the thermal coupling problem between two adjacent inserts of a honeycomb plate was analysed. The clearance and thermal interference between the adjacent inserts has an important influence on the satellite equipment's (such as the electronics box), which can cause the satellite equipment's failures. The representation of adhesive model using finite elements analysis in this study proved to be a good approach and improves the quality of the results. From the results obtained in this paper, the position of the inserts and the assembly of the equipment into the honeycomb plate are very significant in order to avoid any risk failure. This study will help to guide the designers and manufacturing specialists in choosing the most effective parameters for improving the robustness of bonded joints using inserts and thus to improve its design by selecting optimum joint configurations.

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