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MODELLING AND ANALYSIS OF 2D DOUBLE U AUXETIC HONEYCOMB STRUCTURE IN RADIATORS FOR INCREASING HEAT TRANSFER

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ABSTRACT

The purpose of present work is to explore experimentally the study of thermal conductivity of auxetichoneycomb structure and use them in a thermal heat transfer application such as a radiator. The structure is evaluated using finite element analysis model and the results are discussed. The honeycomb structure features a unit cell geometry allowing in-plane auxetic (negative Poisson's ratio) deformations, and geometry parameters tobe used to design the honeycomb configurations for multifunctional applications. The design model is designed with the help of CATIA v5 software and the analysis work is performed using ANSYS 17.0 software. In this, the design of the normal conventional radiator is modified andthe fins are replaced with auxetic honeycomb structure to understand and propose the thermal conductivity of the auxetic honeycomb structure. The obtained results are compared with the normal conventional fin designs and the results are discussed. The main objective of the proposed idea is to explore and determine the implementation of auxetic materials in heat transfer component such as radiator.

Keywords *- Conventional radiator, ANSYS 17.0, CATIA V5*

1. INTRODUCTION

Auxetic materials are unique structured components which possess negative Poisson's ratio, which are mainly used for their impressive mechanical behavior when an external load is applied. The auxetic materials are known for their complex mesh design which act as an energy absorption medium when an external physical load is applied. The mesh design is well inter connected with each other and their area of exposure is also high. So, thereby using these auxetic mesh design in a heat transfer component to increase its thermal dissipation to its atmosphere and also increasing the components mechanical rigidity when an unexpected sudden load is applied on the component in its working atmosphere.

2. LITERATURE SURVEY

1) Pardeep, Harvinder, et al., (2014) had made the design and analysis of fins with variousshaped extensions. Comparetheheat transfer performances between the various extensions fins that designed. Fin with different extension such as rectangular extensions, triangular extensions, trapezium extensions and circular segmental extensions. By using the extension in the heat transfer is increased as compare to fin without extensions. The range of performance of fin with extension achieves 5% to 13% than fin without extensions. Here, the rectangular extensions result higher heat transfer than the other extensions and the effectiveness of rectangular extensionsfin have ahigher ascompareto other extensions onfin.

2) K. Sathish Kumar, K. Vignesh et al., (2017) had made analysis of fins with various types of notches to enhance theheat transfer. Three types of notches were analyzed such as holes V- shaped notch and rectangular notch. The efficiency and effectiveness of the three notched fins are analyzed. This analysisresultsthat rectangularnotchhasgreaterheattransferrate compared to that of the fins without holes, fins with holes and V shaped fins. Here the modelling of the structural design and analysis of the fins with notches carried out by CREO 2.0 and CFD– fluent software.

3) Nasir, Bhushan, Nitish et al., (2019) had made a review about a Pin fin efficiency enhancement. The heat transfer rate is increased by changing the various number of parameters on pin fins. The parameters like fin spacing, fin geometries and temperature distribution. The theoretical analysis done based on Newton's law of cooling. The convection heat transfer enhanced either by increasing the values of convective heat transfer coefficient (h) or surface area of thematerial (As).

4) J.S. Hu, B.L. Wang et al., (2021) had made an enhancement of fatigue behavior for auxetic honeycomb structure under thermalcycling. The theoretical model is carried out to analysis the service life of the auxetic structure based on Paris's law. Here the analysis carried out for both Auxetic and Non – auxetic honeycomb structure. The result shows that auxetic structure have longer service life time than the non – auxetic

structure due to the lower interfacial thermal stress intensity factor (ITSIF) level of auxetic honeycomb structure. It also proven that auxetic structure is good enough for thermal protection purposes.

5) P. Innocenti, F. Scarpa et al., (2009) had made an analysis of thermal conductivity properties and heat transfer of Multi – re – entrant (material causes a local increase in stress) Auxetic honeycomb structure. The thermal conductivity of the multi- re-entrant unit cell is calculated using a theoretical approach based on Fourier's law and electric-thermal analogy. This theoretical analysis is compared with FE analysis under steady state thermal conditions. Here it results the both theoretical and FE (finite element) analysis perfectly matched each other. The both analysis shows that the auxetic honeycomb configurations show higher out – of – plane conductivity, strong in-plane thermal anisotropy, and the lowest peak temperatures during heat transfer between the bottom and top faces of honeycomb panels. The FE analysisdoneby ANSYS software.

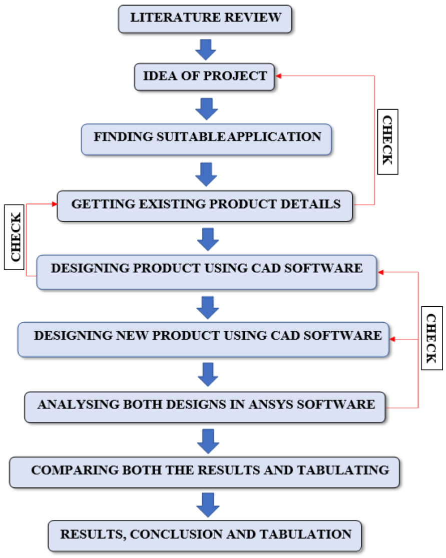
6) M. Almutairi, M. Othman et al., (2018) had made an investigation of thermal behavior of auxetic honeycomb structure by theoretical and experimental techniques and it is also compared with finite element analysis method using ANSYS workbench. All these analysis parts are carried out for three different types of auxetic honeycomb structures such as Re – entrant Splined and Stiffened. It results that stiffened honeycomb structure has a good Thermal insulation characteristic for the highest instantaneous temperature, whereas re – entrant honeycomb structure has a good heat transmission.

7) Ankit, Rajvinder et al., (2016) had designed and analysis using ANSYS 12 workbench for different thermal conductivity of extended surface (also known as fins). The design of the fin and fin material are used as a parameter to increase the heat transfer rate of any surface using FE analysis. Here the various materials with different thermal conductivity are used for analysis and the materials such as Aluminum, Copper and Stainless steel. It concluded that thermal conductivity increases with increases in heat transfer rate as Fourier's law states and the nodal temperature is reduces. Finally, the analysis shows that copper with highest conductivity gives better heat transfer.

8) Akbar A, Asaad, Raziyeh et al., (2011) had made optimized design of the microstructure of auxetic material.The methodology was applied to design of microstructure of 2Dand 3D materials and it was shown that it is possible to design a large number of new auxetic materials, with different values of negative Poisson's ratio. The advantagesofthis methodarethat it gives choice from a set of feasible solutions, rather than a single solution, in design of auxetic materials. These materials with their improved properties have proved their efficiency in several practical fields. The proposed methodology is based on a combinationof FE method.

3. METHODOLOGY

The design and analysis of auxetic honeycomb fin structure is performed to understand the heat transfer rate and to knowabout the efficiency of the structure which will be used for radiators. The 3D Double U auxetic structure is designed using CAD software, the software used is CATIA v5. To study the effectiveness of the double U auxetic structure fins in its heat dissipation, the other type of auxetic Structured fins such as double U auxetic concave and convex structure and Diamond shape auxetic structure are compared with the existing fin design structure. Then, the existing fin typed core structure and other different types of auxetic honeycomb structures are designed and analyzed to understand about the mechanical and thermal advantages. The fins are analyzed in ANSYS software and the results are noted for study. The Static structural analysis is performed on the designs first to observe the total deformation and equivalent stress which is developed o the structure then the Steadystate thermal analysis is performedon the designs next to observe the heat transfer rate. Then, the observed details are compared and resulted for different fins to finalize the efficient mesh design for fins used in Radiator. By keeping the material property same as that of the existing product and the base design of the radiator is kept same, but only the structural design of the mesh is modified.



Flow chart.1 Methodology of the project

4. PROPOSED SOLUTION

In our project the fins have an expanded-metal structure and corrugated form. Air flows over them. The corrugated fins are arranged between flat tubes of the radiator. They may be located inside the flat tubes. The expanded metal structure includes diamond-shaped openings, and bridges. These openings extend over the height of the fins. The fins are formed into hills and valleys interrupted by openings in the direction of air flow.

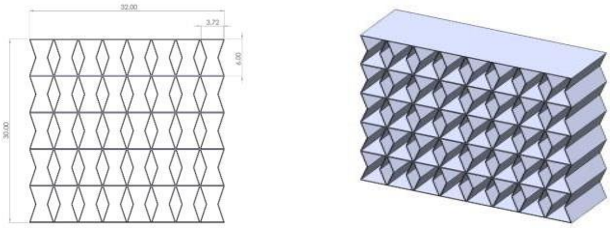


Figure.1 2D & 3DDouble U auxeticdiamondhoneycombextrudedpart

The Double U auxetic concave honeycomb structure is the proposed alternate for the normal conventional fin type core structure which is used in most of the radiators. The auxetic design is has its own advantages like more exposed area to the atmosphere and complex design structure which provides mechanical advantage. Each fin structure is dimensioned as 6x4x13.5mm with the foil thicknessof0.1mm.

The Double U auxetic convex honeycomb structure is the second alternate design proposed for the normal conventional fin type core structure which is used in most of the radiators. The Double U auxetic convex honeycomb structure has its own advantages like more exposed area to the atmosphere gives us excess performance in heat dissipation and complex design structure which provides mechanical advantage, but comparatively lesser than the proposed concave structure. Each fin structure is dimensioned as 6x4x13.5mm with the foil thickness of 0.1mm.

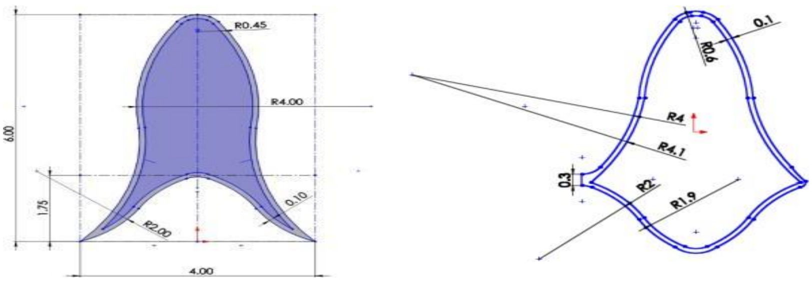
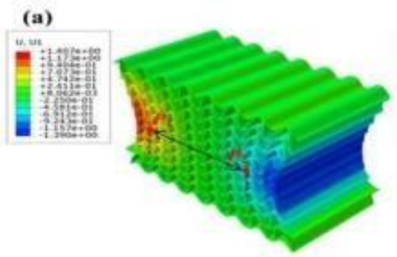


Figure.1 2D concave & convex honeycomb sketch

The designed components are converted into Parasolid format (.x_t) and are imported into the ANSYS software. Static thermal analysis and Structural analysis are performe during same values at different conditions. Then the imported design Figure [3.4] is meshed and in solver various parameters and conditions are given to define the problem and the analysis is done.



5. EXPERIMENTAL ARCHITECHTURE

Three auxetic designed fins and a normal fin type designed fin are considered first and the following analysis such as steady – state thermal analysis and static structural analysis are performed to understand which auxetic structure is best and which one will be a better replacement for fin type designedstructure.

Before we proceed with the testing, we considered a scenario, where we assumed that the radiator is experiencing 50kmph air flow over the component. This is done to understand and fix heat transfer co-efficient rate for proceeding with our experiment. The atmosphere temperature is set to 28°C and the 50 km/h is converted into m/s which is 13.88 m/s. The Air – Heat transfer coefficient graph Figure [8.1] is used her to find the heat transfer coefficient rate for varying air velocity rate. With the help of the graph, we found the air heat transfer coefficient is around 39 W/m^2K. The found Heat transfer coefficient value is used in further experiment.

- **STEADY STATE THERMAL ANALYSIS**: Steady state thermal analysis is performed on small piece of Fins in a radiator. Fin type design Diamond type auxetic honeycomb, Double U auxetic convex honeycomb structure mesh and Double U auxetic concave honeycomb structure mesh is taken in account for pre – analysis. A sample of cut section 30x30x13.5 mm is designed and analyzed.
- **ACTUAL DESIGN THERMAL ANALYSIS**: The DoubleU auxetic concave honeycomb structure mesh is designed on the actual radiator to find out its actual heat dissipation compared with the fin type radiator. A cut section of 50x23x25 mm is used as the sample here for performing analysis. The inlet coolant temperature varies from 100-120ºC, so a heat input of 100ºC is given.
- **MID TEMPERATURE TEST**: The Mid temperature test is performed mainly to understand about the heat sink effect which is produced at higher temperatures. Here, a cut section of 35x16x25mm is taken. Heat input of 100ºC is provided at both top and bottom Coolant carrying tubes. Steady state thermal analysis is performed on the design to understand about the mid temperature heat dissipation.

6. STEADY STATE THERMAL ANALYSIS

Steady state thermal analysis is performed on small piece of Fins in a radiator. Fin type design Figure [8.2], Diamond type auxetic honey comb mesh Figure [8.3] ,Double Uauxetic convex honey comb structure mesh Figure [8.4]and Double Uauxetic concave honey comb structure mesh Figure [8.5]is taken in account for pre– analysis. A sample of cut section 30x30x13.5mm is designed and analyzed.

7. CONCLUSION

Multiple analysis has been performed on the fin type radiator and the Double U auxetic concave honeycomb structure radiator. Which shows us the actual improvement in the efficiency of thermal dissipation to the atmosphere and structural strength between the two types of the designs. From the obtained results it is clear that the Double U auxetic concave honeycomb structure is a better alternate for the fin type radiator design. The implementation of the proposed design will improve the thermal dissipation of the radiator ad also improves the structural strengthof the component.

8. FUTURE WORK

In future we aim to build on the outcomes of this study and focus on the development of a auto functionality model.

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