THEORETICAL ANALYSIS AND CFD SIMULATION ON THE CERAMIC MONOLITH HEAT EXCHANGER

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Abstract: The main objective of this research is heat transfer analysis in the monolithic heat exchanger; the monolithic heat exchangers are made up of ceramic materials, the heat exchanger has the hot air flow and cold air flow, airflow passage have the variable shapes, in our research we go to find the best ceramic materials and suitable air passage shape Al_2O_3, SiC and $CrCO_3$ ceramic materials are choose for this research, Circular, oval and hexagonal shape air passages are choose for this research from the heat transfer analysis we go to find the Suitable ceramic material and suitable air passage to find, from the result of heat transfer and temperature results Oval shape and $CrCO_3$ ceramic material is suitable for monolithic heat exchanger, The heat transfer analysis done in ANSYS-Fluent CFD Software.

Key words: Monolithic heat exchanger, Al_2O_3, SiC, $CrCO_3$, CFD, ANSYS

1. INTRODUCTION

Hard, typically ionic or bonded covalently and might be amorphous or crystalline in structure are the ceramic materials. Presently ceramic CHEs are chiefly brought up by material replacement for existing CHEs parts with ceramic. Predominant parts preferred to be replaced are fins and tubes. Procedures for manufacturing comprise forming chief components out of raw materials, succeeding machining, joining, bonding, and assembling. Ceramic heat exchangers are generally categorized as;

- Monolithic Assembly.
- Non-Monolithic Assembly.

In monolithic assembly, separated components are together bonded lastingly excluding internal joint, without any problem of sealing but concentrations of stress could shoot up beyond tremendous conditions to operate. Few predominant pros for ceramic materials compared to conventional metallic materials in compact heat exchanger construction are;

- It possesses tremendously elevated temperature stability.
- Low cost of material compared to traditional metallic materials.
- It has excellent corrosion resistance.

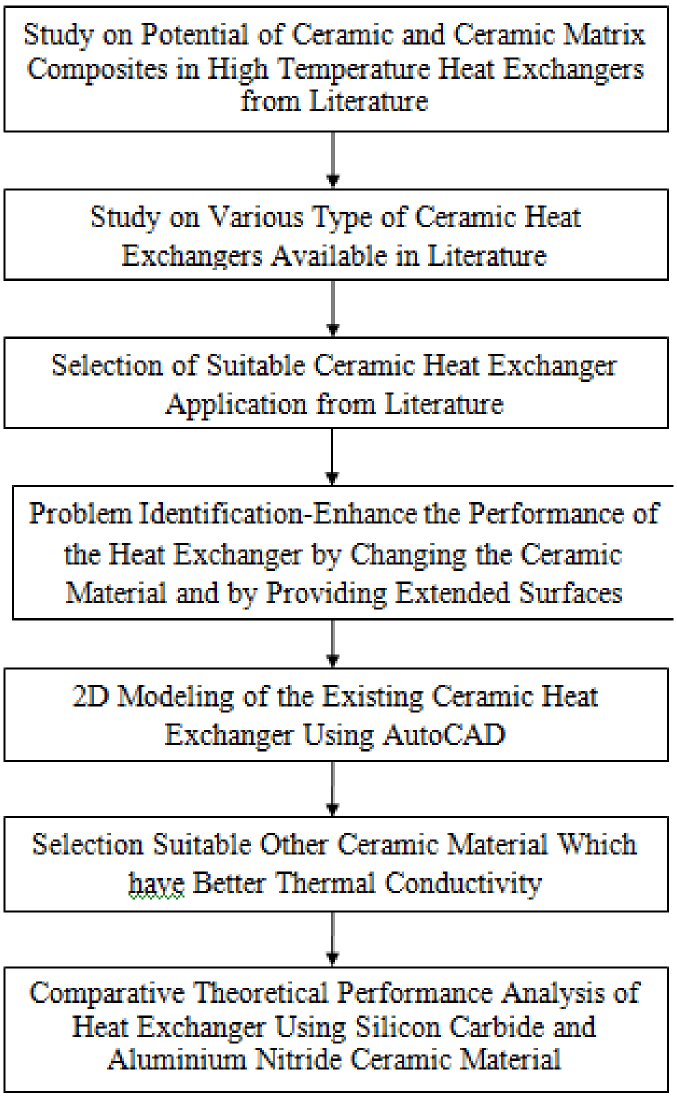
At high range of operating temperatures it possesses greater fouling resistance and chemical erosion.

Typical ceramic materials and their temperature limits

Material	TemperatureLimit
➢ Silicon Carbide (SiC)	1400°C
➢ Silicon Nitride (Si3N4)	1900°C
➢ Alumina (Al_2O_3)	1500-1700°C
➢ Aluminium Nitride (ALN)	1300°C

2. METHODOLOGY

The work presented here starts with a study on potential of ceramic and ceramic matrix composites in high temperature applications from literature



3. FLUENT CODE:

Fluent is a computational fluid dynamics computer code developed and marketed by Fluent Inc. The code solves the equations for conservation of mass, momentum, energy and other relevant fluid variables using a cell-centered finite-volume method. First the fluid domain is divided into a large number of discrete control volumes (also known as cells) using a pre-processor code which creates a computational mesh on which the equations can be solved. Once the fluid domain has been meshed, the governing equations (in integral form) are applied to each discrete control volume and used to construct a set of non-linear algebraic equations for the discrete dependent variables. Fluent then offers the user a number of choices for the algorithm used to solve these equations, including coupled explicit, coupled implicit, and segregated solvers. In all the calculations reported here only the segregated solver has been used. In this approach the governing equations are solved sequentially. Since these equations are non-linear they are first linearized using an implicit method. This produces a scalar system of equations containing only one equation per computational cell per degree of freedom. A point implicit (Gauss-Siedel) linear equation solver is then used in conjunction with an algebraic multigrain (AMG) method to solve the resultant scalar system of equations for the dependent variable in each cell. Since the equations are non-linear several iterations of the solution loop must be performed before a converged solution is obtained.

4. DESIGN USING CATIA

The design of the Solid Structural Cross Flow Monolithic Heat Exchange for Three Shape

- Oval
- Circle
- Hexangular

The below Table 1 show that the Design the Monolithic Cross Flow Heat Exchanger for three different shape with same dimension and also the Mesh show in the table for three shape with Node and Element is show in table present below to design the Heat Exchanger is first step to going into project next is to mesh both design and mesh is show below

Table 4.1: Design and Mesh heat exchanger

DIFF SHAPE	HEXANGOL	OVAL	CIRCLE

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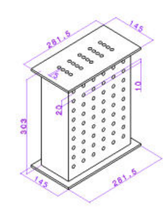
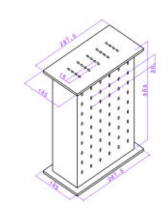
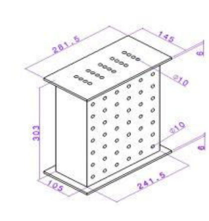
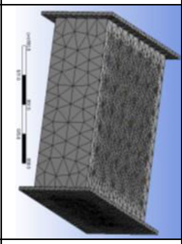
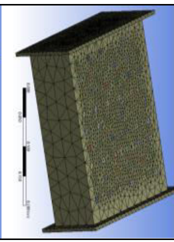
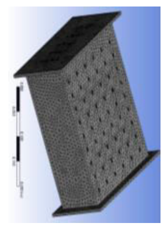
DESIGN			
MESH			
MESH condition	Statistics Nodes 28399 Elements 121139 Mesh Metric None	Statistics Nodes 26913 Elements 101948 Mesh Metric None	Statistics Nodes 85478 Elements 345241 Mesh Metric None

5. ANALYSIS USING ANSYS WORKBENCH

Import the design and load value in the Ansys and the Temperature analysis of the Heat Exchange for different Shape and Different Material to identify the results are,

- Hot air outlet Temperature
- Cold air outlet Temperature
- Hot air Inlet Temperature
- Cold air Inlet Temperature
- Overall Temperature Difference

All the Result for Three Shape and Three Material

5.1 Boundary conditions for CFD Analysis

Table 5.1 Inlet condition for Hot and Cold Flow

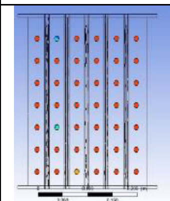
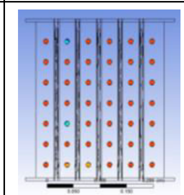
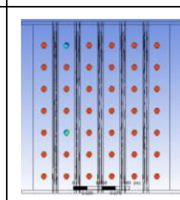
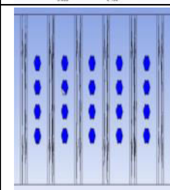
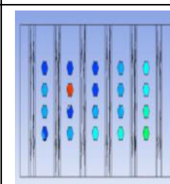
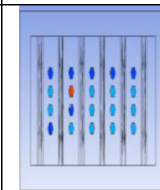
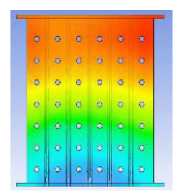
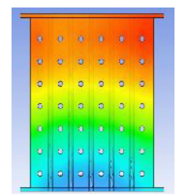
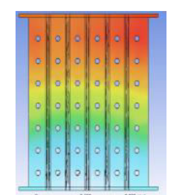
	INLET TEMPERATURE
HOT AIR	1000^0C
COLD AIR	25^0C

The Table 5.1.a is show that the Intel condition for Hot and Cold Flow. The Intel Flow is common for the three shape and three material

5.2 RESULTS FOR CIRCULAR SHAPE:

The Analysis is done by Ansys 15 for circular shape and the three material

Table 5.2 Analysis results for Circular shape

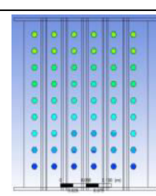
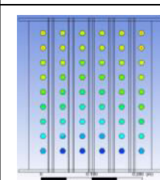
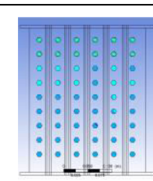
DIFFERENT MATERIALS	Alumina	Silicon Carbide	Chromium Carbide
Hot air outlet Temperature			
Cold air outlet Temperature			
Overall Temperature Difference			

The table 5.2 shows that the Analysis results for Circular Shape and the three material

5.3 RESULTS FOR HEXAGONAL SHAPE:

The Analysis is done by Ansys 15 for Hexagonal shape and the three material

Table 5.3 Analysis results for Hexagonal shape

DIFFERENT MATERIALS	Alumina	Silicon Carbide	Chromium Carbide
Hot air outlet Temperature			

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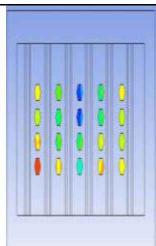
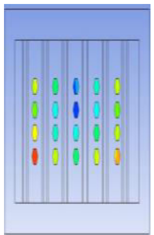
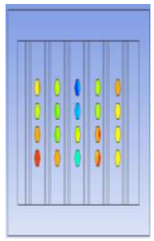
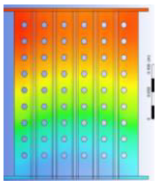
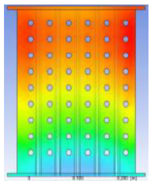
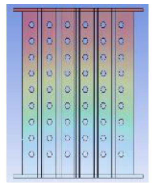
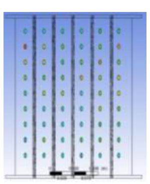
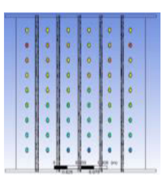
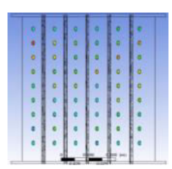
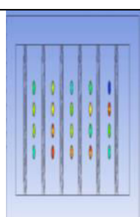
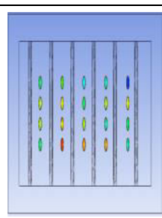
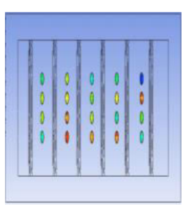
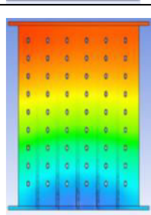
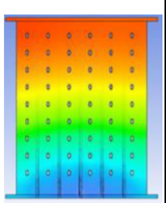
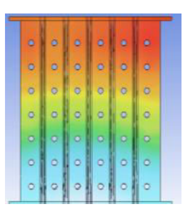
Cold air outlet Temperature			
Overall Temperature Difference			

The table 5.3 show that the Analysis results for Hexagonal Shape and the three material

5.4 RESULTS FOR OVAL SHAPE:

The Analysis is done by Ansys 15 for Oval shape and the three material

Table 5.4 Analysis results for Oval shape

DIFFERENT MATERIALS	Alumina	Silicon Carbide	Chromium Carbide
Hot air outlet Temperature			
Cold air outlet Temperature			
Overall Temperature Difference			

The Table 5.4 show that the Analysis results for Oval Shape and the three material

6. RESULT AND DISCUSSION

The performance of the ceramic monolith heat exchanger is analyzed using

- Al_2O_3
- SiC
- $CrCo_3$

Materials with different cross sectional

- CIRCULAR,
- HEXAGONAL
- OVAL

Results are discussed.

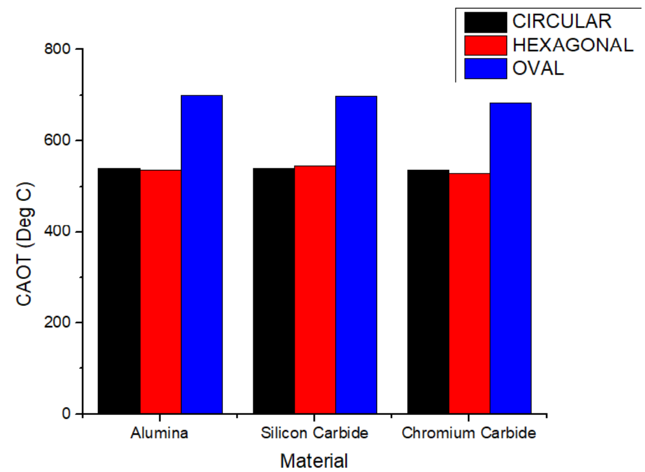


Figure 6.1 : Comparision of cold air outlet temperature Vs Materials properties with different cross sectional

From the above figure absorbed that Al_2O_3 as higher cold air outlet temperature with oval cross sectional. The Oval Cross section gives the best performance for the all materials in Cold air outlet temperature. The Hexagonal and Circular Cross section gives almost similar result for all materials in cold air outlet temperature.

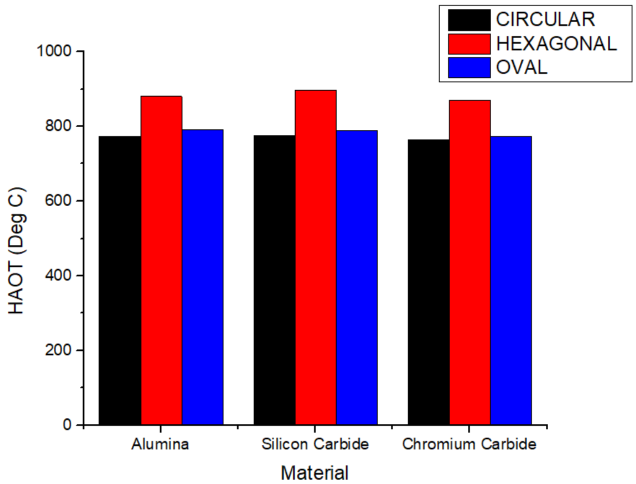


Figure 6.2: Comparison of Hot air outlet temperature Vs Material properties with different cross sectional,

From the above figure absorbed that SiC as higher cold air outlet temperature with hexagonal cross section .The Hexagonal cross Section gives the best performance for the all materials in Hot air outlet temperature. The Oval and Circular Cross Section gives almost similar results for all materials in hot air outlet temperature.

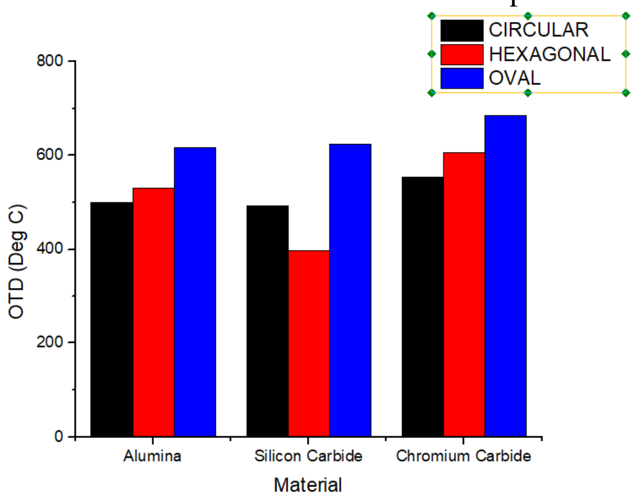


Figure 6.3 : comparison of outlet temperature differenc Vs Materials properties with different cross sectional

From the above figure absorbed that $CrCo_3$ as higher outlet temperature difference with oval cross-section. The Circular Cross section gives the best performance for the all materials in Overall Temperature Different. The Circular Shape is second best in Overall temperature difference. In Silicon carbide give low performance in the Hexagonal shape

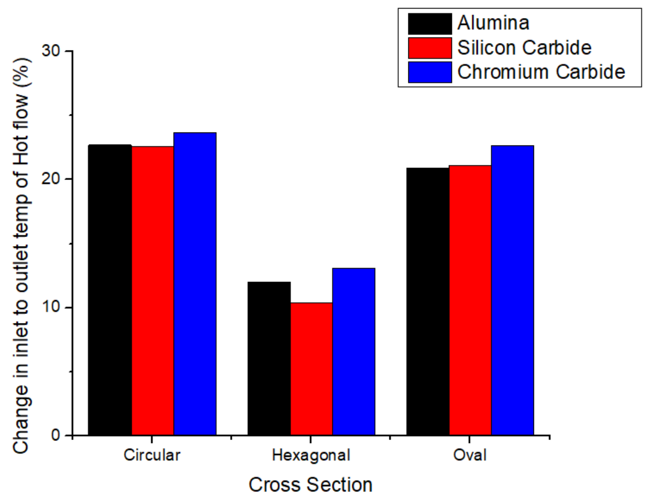


Figure 6.4: Comparison of change in inlet to outlet temperature of hot flow Vs Materials properties with different cross sectional

From the above figure 6.4 absorbed that $CrCo_3$ is higher change in inlet to outlet temperature of hot flow (%) with oval cross sectional. The Results show that low performance in Hexagonal Cross Section for Hot Flow. The Oval and Circular Best Performance for all materials Conditions.

VII. CONCLUSION:

The results obtained from the ceramic monolithic heat exchangers with various cross sectional shape of circular, hexagonal and oval shapes for ceramic monolithic heat exchanger Al_2O_3, SiC, $CrCo_3$ materials are used for this analysis CFD methodology is used for analysis 3D modeling of ceramic heat exchanger done in CATIA V5 software and CFD analysis done in ANSYS Fluent software from this results $CrCo_3$ ceramic core will produce the better thermal performance compare to hexagonal circular shape will produce 12% efficiency, compare to oval shape 1.36% efficiency is improved.

VIII. REFERENCES

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