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INVESTIGATING NUMERICAL AND EXPERIMENTAL ANALYSIS ON CONVECTION HEAT TRANSFER OF ALUMINIUM BASE METAL MATRIX COMPOSITE REINFORCED WITH IRONOXIDE

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Abstract - *In a world where there is ever increasing demand for new materials, composite materials find the topmost spot. Knowledge of history and basic physical properties of these materials enables a better understanding of why they are used in specific applications. Composite materials find use in various fields like spacecraft, construction, automobile etc. The metal matrix composites (MMC's) are being used in many engineering and structural application in the recent years due to their high strength to weight ratio. In this present work an attempt has been made to fabricate a new composite with Al7075 as the base metal matrix and Magnetite also known as ferrous oxide (Fe_3O_4) as reinforcement. The Magnetite reinforcement was added to Al7075 in different proportions (2%, 6% and 10%) by weight and composites were prepared by liquid metallurgy (stir casting). Casted composite specimens were machined as per ASTM standards. The test which was carried out is convection heat transfer using pin-fin apparatus and compared the results with the Numerical analysis using ANSYS software. The applications of this composite material are aeronautical, automotive parts, kitchen utensils & fins etc.*

Key Words: Al7075, Magnetite, Fin Pin apparatus, Ansys.

1. INTRODUCTION

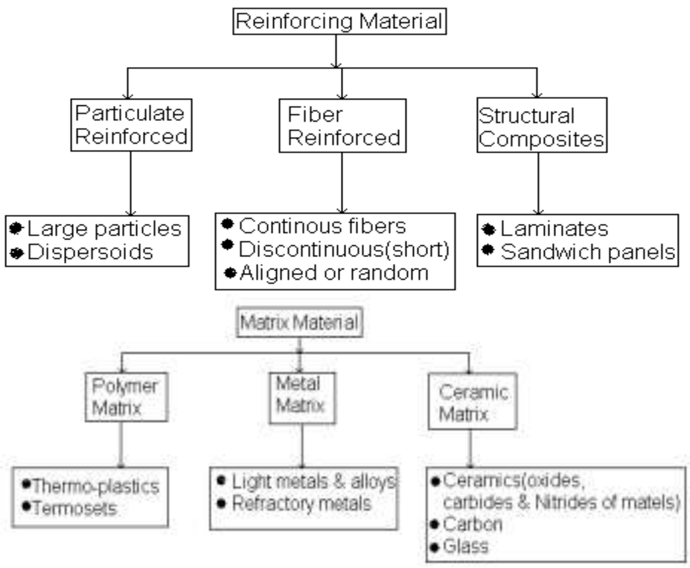
A composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. In contrast to metallic alloys, each material retains its separate chemical, physical, and mechanical properties. The two constituents are reinforcement and a matrix. The main advantages of Aluminium as base material is their high strength and stiffness, combined with low density, when compared with bulk materials, allowing for a weight reduction in the finished part.

The composite is obtained by mixing two or more materials of different densities of which one is called reinforcing state such as fibers, sheets, or particles, and is combined with another material called matrix state. The reinforcing and the matrix can be metal, ceramics or polymer. Reinforcement of composites usually may be a fiber particle size i.e. stiffer and stronger than the continuous matrix phase and it serves as the principal load carrying element.

Particles embedded in matrix of another material are the best example of modern-day composite materials, which are mostly structural. Laminates are composite material where different layers of materials give them the specific character of a composite material having a specific function to perform. Reinforcing materials generally withstand maximum load and serve the desirable properties. In matrix-based structural composites, the matrix serves two paramount purposes viz., binding the reinforcement phases in place and deforming to distribute the stresses among the constituent reinforcement materials under an applied force.

1.1 Classification of Composites materials

Classification of composites is done based on both geometry of reinforcing materials & the type of matrix material. Classification scheme for the composite is as illustrated in the flow diagram.



Composite materials are commonly classified at following distinct levels:

• The first level of classification is usually made with respect to the matrix constituent. The major composite classes include polymer Matrix Composites (PMCs), Metal Matrix Composites (MMCs) and Ceramic Matrix Composites (CMCs).

• The second level of classification refers to the reinforcement form - fiber reinforced composites, laminar composites and particulate composites. Fiber Reinforced composites (FRP) can be further divided into those containing discontinuous or continuous fibers.

• Laminar Composites are composed of layers of materials held together by matrix. Sandwich structures fall under this category.

• Particulate Composites are composed of particles distributed or embedded in a matrix body. The particles may be flakes or in powder form. Concrete and wood particle boards are examples of this category.

Matrix

The matrix is the monolithic material into which the reinforcement is embedded and is completely continuous. This means that there is a path through the matrix to ant point in the material, unlike two materials sandwiched together. In structural applications, cobalt and cobalt-nickel alloy matrices are common.

Metal Matrix Composites (MMC)

Metal matrix composites, at present though generating a wide interest in research fraternity, are not as widely in use as their plastic counterparts. High strength, fracture toughness and stiffness are offered by metal matrices than those offered by their polymer counterparts. They can withstand elevated temperature in corrosive environment than polymer composites. Most metals and alloys could be used as matrices and they require reinforcement materials which need to be stable over a range of temperature and non-reactive too. However, the guiding aspect for the choice depends essentially on the matrix material. Light metals form the matrix for temperature application and the reinforcements in addition to the aforementioned reasons are characterized by high moduli.

Most metals and alloys make good matrices. However, practically, the choices for low temperature applications are not many. Only light metals are responsive, with their low density proving an advantage. Titanium, Aluminium and magnesium are the popular matrix metals currently in vogue, which are particularly useful for aircraft applications. If metallic matrix materials have to offer high strength, they require high modulus reinforcements. The strength-to-weight ratios of resulting composites can be higher than most alloys.

The melting point, physical and mechanical properties of the composite at various temperatures determine the service temperature of composites. Most metals, ceramics and compounds can be used with matrices of low melting point alloys. The choice of reinforcements becomes more stunted with increase in the melting temperature of matrix materials

3. AIM AND OBJECTIVE OF STUDY

In the present work an attempt has been made to fabricate a new composite with Al 7075 as matrix material and Iron oxide as reinforcement. The need for higher strength and higher hardness of the composite has initiated the present investigation. The Iron oxide reinforcement was added to Al7075 in different proportions (2%, 6% & 10%) by weight and composite were prepared by Liquid Metallurgy (stir casting) technique through the vortex method. The casted composite specimens were machined as per ASTM standards.

- To study the feasibility, formation and structure of mixed oxide by varying weight percentage.
- Test the convection Heat transfer coefficient for the prepared specimen.

4. FABRICATION AND EXPERIMENTAL DETAILS.

Selection of mould

The effect of shrinkage during cooling must be considered while fabrications of composites by stir casting method. Other important factors like metal flow and porosity will also be considered.

Some mainstream rules are

- Sharp corners should be avoided, which can show hot tearing during cooling.
- Uniform cross section should be used to maintain the cooling rate comparatively uniform and avoid stresses.
- Avoid more flats-more flat areas tend to warp.
- 1% to 2% shrinkage allowances should be given.
- Machining allowances- allows extra material for later machining of critical dimensions.
- Internal features should be avoided – these will require extra steps in mould making and may create metal flow problems.

Casting procedure

- Weighed aluminium alloy 7075 was kept in a crucible and crucible was heated by keeping the same in furnace at a temperature 477-635^{0}C.
- Weighed percentage of Magnetite (2%, 6% & 10%).
- Moulding dies were also preheated.
- Add degasifying agents to avoid blow holes, to reduce porosity.
- Once temperature reaches to prescribed value add the calculated percentage of Magnetite to the molten metal and stir thoroughly.
- Remove slag.
- Pour the molten metal to die and allow it to cool.

Fig-1: electric arc furnace

5. EXPIREMENTS

- **Thermal properties test**

After the preparation of the required size specimens from casted material, they were subjected convection testing.

To determine the temperatures of the pin fin for free and forced convection to find the heat transfer rate and heat transfer coefficient.

Procedure: -

i) Connect the equipment to electric power supply.
ii) Keep the thermocouple selector switch to zero position.
iii) Turn the dimmer stat clockwise and adjust the power input to the heater to the desired value. For forced convection we need to switch on the blower.
iv) Set the air–flow rate to any desired value by adjusting the difference in water levels in the manometer and allow the unit to stabilize.
v) Note down the temperatures, T1 to T6 from the thermocouple selector switch. For forced convection note down the manometer readings.

- **Numerical Analysis using Ansys Software**

GENERAL STEPS
Step 1: Ansys Utility Menu File – clear and start new – do not read file – ok.
Step 2: Ansys Main Menu – Preferences select – STRUCTURAL – h-method ok
Step 3: Pre-processor Element type – select type of element from the table and the required options Real constants – give the details such as thickness, areas, moment of inertia, etc. required depending on the nature of the problem. Material Properties – give the details such as thermal conductivity
Step 4: Modelling – create the required geometry such as nodes elements, area, and volume by using the appropriate options.
Step 5: Generate – Elements/ nodes using Mesh Tool if necessary (in 2D and 3D problems)
Step 6: Apply boundary conditions/loads such as ambient temperature & convection.
Step 7: Solution – Solve the problem
Step 8: General Post Processor – plot / list the required results.

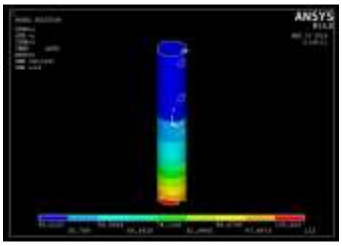


Fig -2: free convection 2% Fe_3O_4

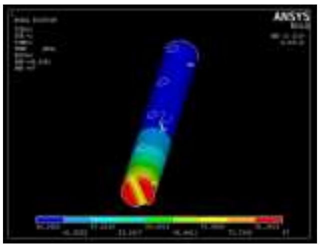


Fig-3: forced convection 2% Fe_3O_4

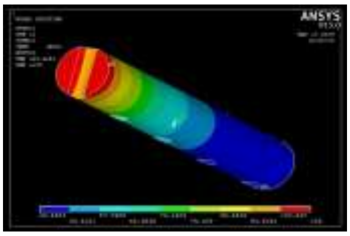


Fig-4: free convection 6% Fe_3O_4

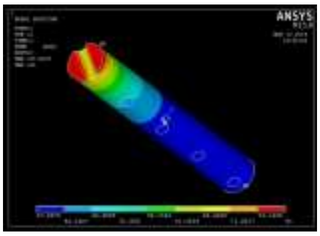


Fig-5: Forced convection 6% Fe_3O_4

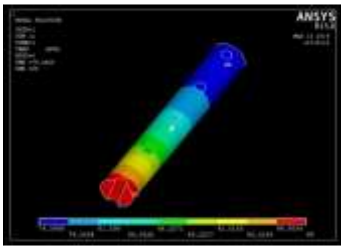


Fig-6: free convection 10% Fe_3O_4

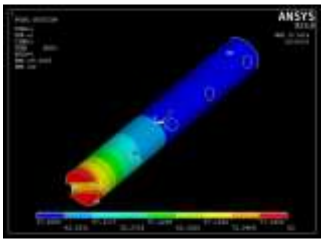


Fig-7: forced convection 10% Fe_3O_4

6 RESULTS

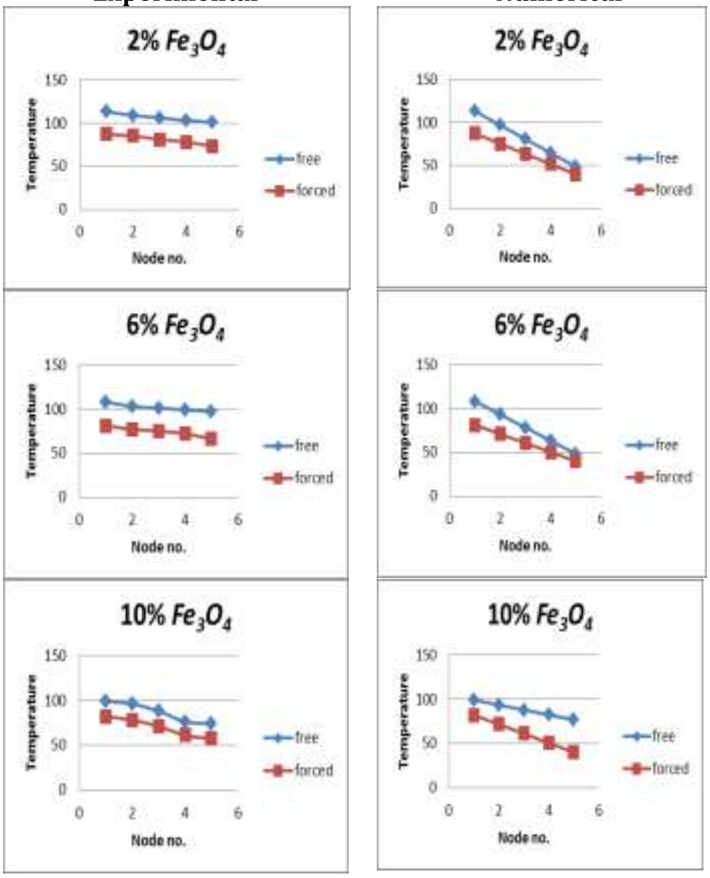
- **Convection test results**

	% of reinforcement		
Convection	2%	6%	10%
Free	10.24	10.28	10.39
	3.02	3.07	3.14
	89.56	90.15	93.25
forced	36.8	36.475	36.276
	7.37	6.862	4.423
	71.6	73.21	76.04

Table-1: convection results

- **Comparison between numerical and experimental results**

Experimental **Numerical**



7. CONCLUSION

Aluminium Al7075 matrix composite reinforced with iron oxide was successfully prepared by stir casting. Thermal analysis (Convection heat transfer) is carried out Experimentally using Pin-Fin apparatus and compared the Experimental results with the numerical method using ANSYS Software which shows Heat transfer coefficient and Heat transfer rate increases with increase in percentage of reinforcement in case of both Free and Forced Convection.

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