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Investigation of Heat Flow, Thermal Shock Resistance and Electrical Conductivity of Al 6061-Silicon Carbide-Graphite Hybrid Metal Matrix Composites

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Abstract:- Metal matrix composites are regarded to be one of the most predominant classifications in composite materials. The measurement of the thermal properties of materials is fundamental for the better understanding of the thermal design. In this research paper, the determination of specific heat capacity, heat flow, thermal shock resistance and electrical conductivity have been accomplished for Al 6061, Silicon Carbide and Graphite hybrid metal matrix composites from room temperature to 300°C. Aluminium based composites reinforced with Silicon Carbide and Graphite particles have been prepared by stir casting technique. The thermal and electrical behaviour of hybrid composites with different percentage compositions of reinforcements have been investigated. The results have indicated that, the specific heat capacity, enthalpy and heat flow for different compositions of hybrid metal matrix composites decrease by the addition of Graphite with Silicon Carbide to the matrix alloy Al 6061.

Keywords:- Thermal measurement; specific heat capacity; heat flow; enthalpy; electrical behaviour; metal matrix composites.

I. INTRODUCTION

Metal Matrix Composites (MMCs) have fascinated the researchers in all perspectives. Metal matrix composites are the innovative materials that possess unlimited opportunities for modern material science and development. These materials satisfy the desired conceptions, objectives and requisites of the designer. The reinforcement of metals can have many different objectives. MMCs have greater advantage compared to other composites. These materials possess high temperature resistance, high yield strength and yield modulus and can be strengthened by different thermal and mechanical treatments. Metal matrix composites can be designed to process the thermal qualities viz., low Coefficient of Thermal Expansion (CTE), high thermal capacity and high thermal conductivity that are best suited for aerospace engineering, automotive components, thermal management of electronic equipment and electronic packaging applications. Aluminium Silicon alloys have extensive applications in industries due to their properties viz., high fluidity, low melting point, high fatigue strength, corrosion resistance, good castability characteristics, high tensile strength, high wear resistance and lower coefficient of thermal expansion. Hybrid metal matrix composites are regarded as one of the advanced materials that comprises of light weight, high specific strength, good wear resistance and low thermal expansivity [1] [2] [3]. Aluminium Matrix Composites (AMCs) possess better property of friction and excellent wear resistance due to the combined effect of the strength of Silicon Carbide influenced on the matrix and lubrication property of Graphite [2].

In the present scenario, thermal characterization and analysis of composite materials have been gaining greater impetus. This will help to understand the properties of materials as they change with temperature. It is often used as a term for the study of heat transfer through structures. The knowledge of the thermophysical properties has been mandatory for designing the effective heat transfer elements, heat sinks, heat shields and opto-electronic devices. The need for the thermal analysis of hybrid metal matrix composites should be comprehensively discussed. Most of the thermal properties are mainly concerned with Aluminium matrix composites but minimum information is available on hybrid composites. The behaviour of hybrid composite materials is often sensitive to changes in temperature. This is mainly because, the response of the matrix to an applied load is temperature-dependent and changes in temperature can cause internal stresses to be set up as a result of differential thermal contraction and expansion of the constituents [4].

Though the research work pertaining to mechanical, tribological and fatigue behaviour of composites is effectively accomplished, due emphasis needs to be given to the work related to the measurement of prominent thermal properties viz., thermal conductivity and thermal diffusivity. The main property considered in thermal analysis of metal matrix composites is thermal conductivity. The increase in thermal conductivity of composites will depend on strength and porosity, which finds this property in aerospace and automobile applications extensively [4]. Thermal diffusivity is an important property for materials being used to determine the optimal work temperature in design applications referred under transient heat flow. It is the thermophysical property that determines the speed of heat propagation by conduction during changes in temperature with time. The heat propagation is faster for materials with high thermal diffusivity [5] [6]. The assessment of thermal properties will benefit to evaluate heat capacity, variation in the intensity of heat, heat diffusion and heat release rate [7]. For aerospace and automotive applications, low coefficient of thermal expansion, moderate thermal conductivity, specific heat capacity and high electrical conductivity of the composites will enhance the efficiency in all perspectives. The technique that has been adopted in the experimental investigation of thermal conductivity and thermal diffusivity is laser flash apparatus. Some of the most important papers concerning the thermal properties of Aluminium-Silicon Carbide-Graphite hybrid composites have been presented.

Davis et al. [8] in their research paper have explained the thermal conductivity of metal matrix composites, which are potential electronic packaging materials and have been calculated by using effective medium theory and finite element techniques. The thermal boundary resistance, which occurs at the interface between the metal and the included phase (typically ceramic particles), has a large effect for small particle sizes. It has been found that, Silicon Carbide particles in Aluminium must have radii in excess of 10 µm to obtain the full benefit of the ceramic phase on the thermal conductivity.

Cem Okumus et al. [9] in their paper have studied on thermal expansion and thermal conductivity behaviour of Al/Si/SiC/Graphite hybrid composites. Aluminium-Silicon based hybrid composites reinforced with Silicon Carbide and Graphite particles has been prepared by liquid phase particle mixing and squeeze casting. The thermal expansion and thermal conductivity behaviour of hybrid composites with various Graphite contents and different Silicon Carbide particle sizes (45 µm and 53 µm) have been investigated. Results have indicated that, increasing the Graphite content improved the dimensional stability, and there has been obvious variation between the thermal expansion behaviour of the 45 µm and the 53 µm silicon carbide reinforced composites.

Molina et al. [10] have investigated the behaviour of thermal conductivity of Aluminium-Silicon Carbide (SiC) composites based on high volume fraction of Silicon Carbide particles. It has been investigated by comparing data for composites fabricated by infiltrating liquid aluminium into preforms made either from a single particle size, or by mixing and packing SiC particles of two largely different average sizes 170 µm and 16 µm. For composites based on powders with a monomodal size distribution, the thermal conductivity increases steadily from 151 W/mK for particles of average diameter 8 µm to 216 W/mK for 170 µm particles. For the bimodal particle mixtures the thermal conductivity increases with increasing volume fraction of coarse particles and reaches a roughly constant value of 220 W/mK for mixtures with 40 or more vol.% of coarse particles. It has been shown that all present data can be accounted for by the differential effective medium (DEM) scheme taking into account a finite interfacial thermal resistance.

Parker et al. [11] have explained the flash method of determining thermal diffusivity, heat capacity and thermal conductivity. A high-intensity short-duration light pulse is absorbed in the front surface of a thermally insulated specimen a few millimeters thick coated with camphor black, and the resulting temperature history of the rear surface has been measured by a thermocouple and recorded with an oscilloscope and camera. The thermal diffusivity has been determined by the shape of the temperature versus time curve at the rear surface, the heat capacity by the maximum temperature indicated by the thermocouple, and the thermal conductivity by the product of the heat capacity, thermal diffusivity and the density.

Chen et al. [12] have reviewed on metal matrix composites with high thermal conductivity for thermal management applications. The latest advances in manufacturing process, thermal properties and brazing technology of SiC/metal, carbon/metal and diamond/metal composites have been presented. Key factors controlling the thermophysical properties have been discussed in detail.

Hohenauer et al. [13] have experimented on flash methods to examine thermal diffusivity and thermal conductivity of metal foams. The results of thermal conductivity have been obtained by using a laser flash device. In particular, a Magnesium alloy has been investigated. To meet the requirements of flash technique, coplanar samples have been prepared. A finite element model has been generated to study the influence of the preparation method and measurement techniques.

S X Xu, Y Li et al [14] have investigated the temperature profile and specific heat capacity in temperature modulated Differential Scanning Calorimeter with a low sample heat diffusivity. The paper explains about a specific numerical model that is used to analyze the effects of thermal diffusivity on temperature distribution inside the test sample and specific heat measurement by TMDSC. The sample test results are presented to demonstrate the effects of material thermal diffusivity.

N R Pradhan, H Duan et al [15] have examined the specific heat and effective thermal conductivity of composites containing single and multi wall carbon nanotubes. The specific heat and effective thermal conductivity in anisotropic and randomly oriented Multi-wall Carbon Nanotube (MWCNT) and randomly oriented Single-wall Carbon Nanotube (SWCNT) composites from 300 K to 400 K has been studied. The specific heat of randomly oriented MWCNTs and SWCNTs exhibited similar behavior to the specific heat of bulk graphite powder.

Bedrich Smetana, Monica Zaludova et al [16] have summarized the possibilities of heat capacity measurement of metallic system. The paper deals with the study possibilities of heat capacities, mainly of metallic systems (alloys) on the basis of Fe (Fe-C). Possibilities of theoretical calculations dependencies of heat capacities on temperature are presented in this work in a wide temperature region. Theoretical basis of heat capacities determination using Neumann-Kopp rule has been discussed comprehensively. Experimental possibilities of heat capacities acquisition are determined by the experimental base.

E Morintale, A Harabor et al [17] have described the use of heat flows from DSC curve for calculation of specific heat of the solid materials. On the basis of the second law of thermodynamics, they have established a procedure for calculating the specific heat of solid materials using heat flow in the sample studied, and the rate of heating of the sample.

R Androsch [18] has explained about the determination of specific heat capacity using a saw-toothed type modulated differential scanning calorimeter. Heat capacities have been calculated based on the amplitudes of the first and second harmonics of Fourier series of the heat flow and heating rates.

Teresa M V R De Barros, Anabela C [19] has described the accuracy and precision of heat capacity measurements using heat flux differential scanning calorimeter. The measurement of heat capacities of solids has been tested using Sapphire and Benzoic acid.

B Karthikeyan, S Ramanathan et al [20] have elucidated specific heat capacity measurement of Al/SiC_P composites by Differential Scanning Calorimeter. Good thermal control systems have been considered for various materials applicable for spacecraft applications. Differential Scanning Calorimeter has been employed to determine the specific heat capacity of 7075 Al /SiC_P composites.

It has been evident from the literature review that, thermal characterization and analysis of Aluminium Matrix Composites (AMCs) have to be given greater emphasis. However, investigations concerning the thermal characterization and analysis of composite materials of AMCs are scarce. Many experimental investigations have been carried out pertaining to thermal characterization of Aluminium Silicon Carbide composites, but limited work has been accomplished concerning Aluminium-Silicon Carbide-Graphite hybrid MMCs. The literature review has indicated the need for further investigations on thermal characterization and analysis of Aluminium matrix composites. If these materials are to be used for many engineering applications, the thermal aspects of AMCs need to be given more emphasis. Hence it becomes important that the evaluation of thermal aspects and characteristics of hybrid composites cannot be ignored in order to transform the material from design stage to manufacturing stage.

In the present scenario, research has been accomplished on mechanical and tribological properties of hybrid composites substantially, but limited research has been carried out on Aluminium-Silicon Carbide-Graphite hybrid composites relating thermal characterization and analysis. It has been reported in the literature that, the experimental investigation on thermal characterization and analysis of Aluminium and Silicon Carbide has been carried out concerning low and high weight fraction [9]. But, research on thermal characterization and analysis of Al 6061 with Silicon Carbide (SiC) and Graphite (Gr) hybrid metal matrix composites pertaining to low and high weight fraction have been very deficient. The pertinent thermal properties of Aluminium based hybrid MMC reinforced with Silicon Carbide and Graphite have to be investigated in terms of varying weight fraction and smaller particle sizes. Casting techniques viz., stir casting, centrifugal casting and squeeze casting have been extensively used.

One of the major advantages of Aluminium-Silicon Carbide-Graphite hybrid metal matrix composites is that, these composites are self-lubricating materials comprising Graphite, yet their strength can be improved by the presence of Silicon Carbide ceramic phase. These AMCs possess better property of friction and excellent wear resistance due to the combined effect of the strength of Silicon Carbide influenced on the matrix and lubrication property of Graphite [9] [12]. Silicon Carbide exhibits mechanical and thermal properties and has been used extensively as a prominent reinforcement. Graphite represents an optimal combination of strength, ductility and thermal properties for pertinent engineering applications. Graphite has superior characteristics viz., tensile strength, improved castability, damping capacity and machinability. From literature review, Graphite has been used scarcely. Hence in this research work, Graphite has been used as reinforcement concurrently with Silicon Carbide and Aluminium matrix alloy considering low weight fraction of hybrid composites.

II. FABRICATION OF HYBRID COMPOSITES

Aluminium-Silicon Carbide-Graphite hybrid metal matrix composites specimens have been stir cast by using Aluminium alloy Al 6061 as the matrix material and reinforcements Silicon Carbide and Graphite particulates containing different percentage compositions (2.5%, 5%, 7.5% and 10%). Hybrid metal matrix composites specimens have been cast by mixing equal proportions of Silicon Carbide and Graphite reinforcements maintaining the total percentage of reinforcements same (2.5%, 5%, 7.5% and 10%). A specimen of matrix alloy Al 6061 has been cast without the inclusion of any reinforcements. The powders of Silicon Carbide and Graphite have been added by direct mixing and top pouring stir casting system has been adopted. In this research paper, the evaluation of thermal properties viz., thermal conductivity, thermal diffusivity and specific heat capacity have been accomplished. Different specimens have been considered as per American Society for Testing and Materials (ASTM) standards. The specimen size for determination of specific heat capacity is powder form or pellets, approximately 20 mg. The hybrid composite specimens have been fabricated commercially. Also, from room temperature to 800^0C, the atmosphere for fabrication process has been maintained.

The composite specimen having Aluminium matrix reinforced with Silicon Carbide and Graphite reinforcements have been stir cast. A known amount of Al 6061 alloy pieces in the sintering furnace has been heated and allowed the same to melt at 780^0C. Complete melting of Aluminium has been ensured while preparing the specimen. The alloy pieces have been kept in the crucible and preheated the mould at the required temperature range 750^0C-800^0C. The reinforcements Silicon Carbide and Graphite have been preheated at the above mentioned temperature range. Magnesium (about 3 to 5 g) has been added to the molten alloy of Aluminium to increase the wettability. Slag has been removed by using scum powder to avoid poor quality casting. In order to remove moisture content in the casting the melt has been maintained at the above mentioned temperature for about 20 minutes. Approximately 5% mass of solid dry hexachloro-ethane tablets or degassing tablets have been used to degas the molten metal at 780^0C. Stirring of the molten metal maintained at around 750^0C, has been accomplished using a mechanical stirrer, to create vortex. The molten metal has been stirred at a speed range of 400-750 rpm for about 10 minutes. The stirring of the mixture has been carried out to ensure uniform dispersoid concentration of reinforcements in the matrix material. After the process of solidification, mould is cooled to avoid shrinkage of casting metal for about 3 hours to complete the process [1] [2] [3]. Then the casting has been separated from the mould which is subsequently cleaned. The required test specimens were 22 mm diameter and 220 mm length. They have been machined thoroughly. The dimensions chosen agree well with the available literature. The samples are fabricated to the required sizes. Five specimens have been separately considered for the determination of specific heat capacity with different specimen sizes.

III. EXPERIMENTAL INVESTIGATION ON SPECIFIC HEAT CAPACITY OF HYBRID COMPOSITES

Specific heat capacity is a thermophysical property describing the energy required to induce a certain change in the temperature of a unit mass of the material. Generally all materials depict the increase in specific heat capacity with an increase in temperature. Differential Scanning Calorimeter (DSC) is used to measure specific heat capacity and heat flow of composites. Differential Scanning Calorimeter exhibits the temperature dependent heat capacity quickly over a wide range of temperature with utmost accuracy. Hence it is used to measure the difference in the heat flow of a sample which is a direct function of time or temperature subjected under the processes of heating, cooling or isothermal conditions [18] [19] [20].

In this research work, the determination of specific heat capacity of hybrid composites has been carried out by using NETZSCH DSC Q200 F3 Maia. The experimental investigation depicts the measurement of specific heat capacity over the range of temperatures. For the determination of specific heat or thermal capacity and enthalpy of hybrid composites, usually the sample should be either in powder form (approximately 20 mg) or in pellet form. Fig. 1 and 2 illustrates the variation of specific heat capacity and enthalpy with temperature for the different compositions of hybrid metal matrix composites. From fig. 1 and 2, it can be observed that, Al 6061 has high specific heat capacity of 980 J/kg K and enthalpy of 560 kJ/kg respectively at 300°C. It can be observed that, by the addition of reinforcements Silicon Carbide and Graphite there has been a gradual decrease in specific heat capacity. Al 6061 + 5% SiC + 5% Gr hybrid MMCs reveals low specific heat capacity and enthalpy of 900 J/kg K and 460 kJ/kg respectively at 300°C.

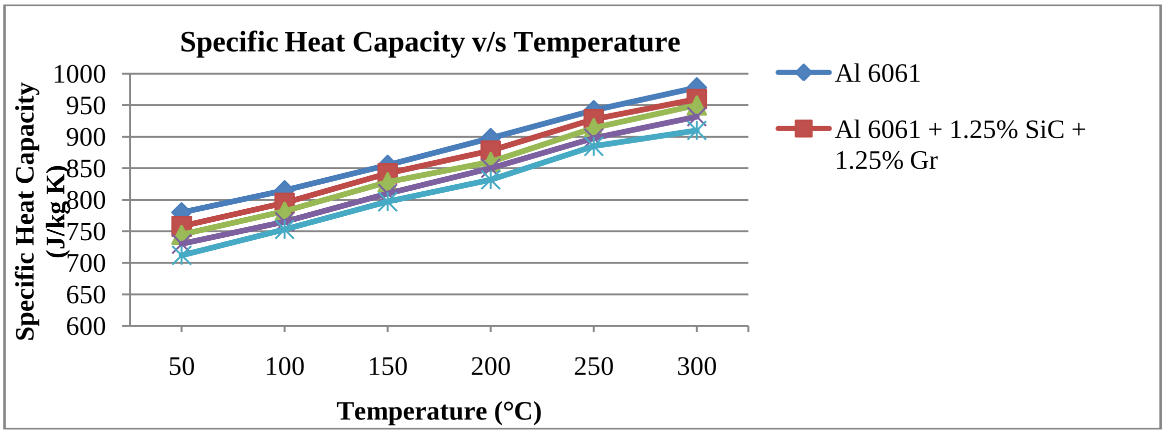

Fig. 1. Variation of Specific Heat Capacity with Temperature of Hybrid Composites

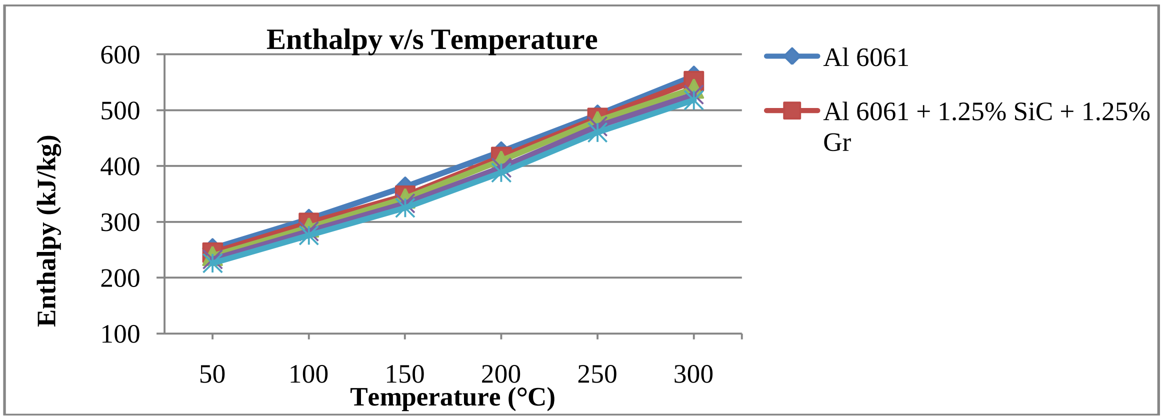

Fig. 2. Variation of Enthalpy with Temperature of Hybrid Composites

It can be observed that, as the temperature increases, there has been a decline in specific heat capacity of hybrid composites. Experimentally, it has been observed that, by the addition of Graphite and Silicon Carbide with Aluminium matrix alloy Al 6061 with varying weight fraction at lower proportions, resulted in the considerable reduction in specific heat capacity of hybrid metal matrix composites.

It has been reported in the literature that, the specific heat capacity of hybrid MMCs considerably increases by reinforcing Silicon Carbide over the different ranges of temperature [15] [18]. But in this research work, Graphite has also been used as a reinforcement and from the experimental investigation, it is clear that, by the addition of Graphite with Silicon Carbide and Al 6061 at lower weight fraction there has been no much variation in specific heat capacity of hybrid composites. This is due to fact that, the specific heat capacity of Graphite (720 J/ kg K) is low compared to Aluminium 6061 (900 J/kg K) and Silicon Carbide (750 J/kg K). The addition of Silicon Carbide and Graphite with Al 6061 has insignificant influence in the increase of specific heat capacity at low weight fraction. It has been examined that, by the addition of reinforcements Silicon Carbide and Graphite at high weight fraction or volume fraction resulted in increase in specific heat capacity of composites [19, 15]. In the literature, it has been reported that, the addition of Graphite with any Aluminium alloy do not exhibit much variation in thermal behaviour of hybrid composites [21]. Based on these investigations, it has been concluded that, the specific heat capacity of hybrid composites reduces due to the enrichment of Graphite.

Using DSC, it is also possible to determine the heat flow based on the specific heat capacity of hybrid composites. Heat flow is regarded to be one of the most important thermal properties of composite materials. Heat flow can be determined by using the equation (1).

$$\text{Specific Heat Capacity} = \frac{\text{Heat flow}}{\text{Heating rate}} \qquad \text{-----------} \ (1)$$

From equation (1), heat flow is the product of specific heat capacity and heating rate. Heating rate is the ratio of temperature difference to time taken to test a particular sample. In this research work, the heating rate for a particular sample is 10°C/min and maintained constant for all the samples. The total duration to test a particular sample is 30 minutes. Fig. 3 illustrates the variation of heat flow with temperature for hybrid metal matrix composites.

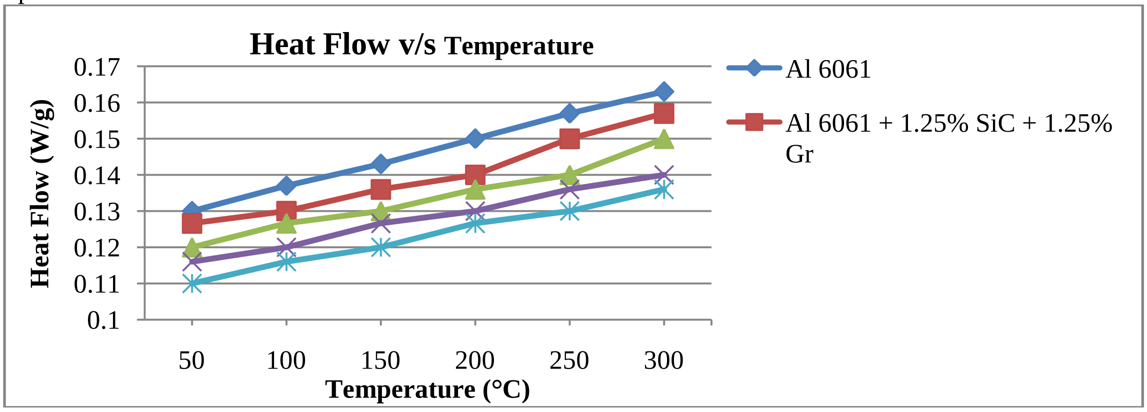

Fig. 3. Variation of Heat Flow with Temperature of Hybrid Composites

It has been observed that, Al 6061 has high heat flow and Al 6061 + 5% SiC + 5% Gr reveals low heat flow at all temperatures. It has been noticed that from fig. 3 that, Al 6061 has high specific heat capacity and Al 6061 + 5% SiC + 5% Gr reveals low specific heat capacity at all temperatures. Also, it can be noticed that, the rate of increase of specific heat capacity is decreasing, as a result heat flow decreases progressively.

IV. DETERMINATION OF THERMAL SHOCK RESISTANCE AND ELECTRICAL CONDUCTIVITY OF HYBRID COMPOSITES

Thermal resistance is the capacity of materials to maintain their internal structure and strength subjected under sharp transformations pertaining to temperature. Thermal resistance of materials is generally characterized by a number of cycles of temperature where a material maintains their internal structure and strength under successive freezing and melting processes [21] [22]. Mathematically, thermal resistance (T_R) is the ratio of the length of the specimen to the product of thermal conductivity and area of the specimen. It has been noticed that, the thermal resistances of hybrid MMCs gradually increases over the range of temperatures. It has been observed that, as the value of thermal conductivity decreases, there has been increase in thermal resistances of hybrid composites. Thermal shock occurs when a thermal gradient causes different parts of a material to expand by different amounts. This differential expansion can be comprehended in terms of stress and strain. At some point, this stress can exceed the length of the material, causing a crack to form. Mathematically, thermal shock resistance (TSR) is the ratio of the product of thermal stress and thermal conductivity to modulus of elasticity and thermal expansivity of the materials. Equation (2) has been used for the determination of thermal resistance (T_R). Equation (3) depicts the relation for thermal shock resistance.

$$T_R = \frac{1}{K} \qquad \text{-----------(2)}$$

$$TSR = \frac{\sigma \times K\,(1-\nu)}{\alpha \times E} \qquad \text{-----------(3)}$$

Presently, thermal shock resistance of hybrid metal matrix composites have been calculated at higher temperature 300°C with varying weight fraction 2.5%, 5%, 7.5% and 10%. Based on thermal expansion and thermal conductivity behavior of hybrid metal matrix composites, thermal shock resistance can be determined. It has been observed that, there has been a decrease in thermal shock resistances of hybrid metal matrix composites. As thermal conductivity, thermal stresses, thermal expansivity and Poisson's ratio varies, there has been a decrease in TSR. Table 1 illustrates the determination of T_R and TSR based on the values of thermal stress, thermal conductivity, moduli of elasticity and thermal expansivity that have been determined at higher temperature 300°C.

Table 1. Determination of T_R and TSR of Hybrid Metal Matrix Composites with Varying Weight Fraction

Hybrid Composite Specimens	Thermal Stress (□) (N/m^2)	Thermal Conductivity (K) (W/m K)	Thermal Expansivity (□) (/°C)	Moduli of Elasticity □(Gpa)	TSR (W/m)	T_R ($m\,K\,W^{-1}$)
Sample 1	0.318×10^9	168	23.6×10^{-6}	70	22,637.3	0.0059
Sample 2	0.306×10^9	167.4	22.8×10^{-6}	71.5	22,040.8	0.00597
Sample 3	0.282×10^9	166.78	22×10^{-6}	73	20,658.1	0.006
Sample 4	0.281×10^9	165.3	21.6×10^{-6}	74.5	20,393.1	0.00604
Sample 5	0.279×10^9	163	20.8×10^{-6}	76	20,388.7	0.0061

Electrical conductivity of composite materials will usually be high and as a result, this property is best suited for aerospace and automotive engineering [23] [24]. Electrical conductivity of composite materials has been determined by using Weidemann-Franz law. It can be stated as "the ratio of thermal and electrical conductivities is directly proportional to the temperature (T)." Mathematically it can be interpreted in equation (4).

$$\frac{K}{\sigma} \propto T \qquad \text{or} \qquad \frac{K}{\sigma T} = C$$

C is Lorenz's constant = 2.45×10^{-8} W ohms/K^2 ----------- (4)

In this research work, electrical conductivity of hybrid composites has been determined for the varying weight fraction of hybrid composites. It has been observed in table 6.8 that, the electrical conductivity for Al 6061 is high and Al 6061 + 5% SiC + 5% Gr has lower value at higher temperature 300°C. The electrical conductivity of hybrid composites decreases as the thermal conductivity decreases gradually. But the electrical resistivity gradually increases. Electrical resistivity (E_R) is the ratio of electrical conductivity and is mathematically depicted in equation (5).

$$E_R = \frac{1}{\sigma}$$ -----------(5)

Table 2 illustrates the electrical conductivity and electrical resistivity of hybrid composites with varying weight fraction.

Table 2. Electrical Conductivity and Electrical Resistivity of Hybrid Composite Specimens

Serial Number	Hybrid Composite Specimens	Electrical Conductivity (ohm. m)$^{-1}$	Electrical Resistivity (ohm. m)
1.	Sample 1 (Al 6061)	11,928,571.428	8.38×10^{-8}
2.	Sample 2 (Al 6061 + 1.25% SiC + 1.25% Gr)	11,912,142.143	8.39×10^{-8}
3.	Sample 3 (Al 6061 + 2.5% SiC + 2.5% Gr)	11,891,428.57	8.41×10^{-8}
4.	Sample 4 (Al 6061 + 3.75% SiC + 3.75% Gr)	11,807,142.857	8.43×10^{-8}
5.	Sample 5 (Al 6061 + 5% SiC + 5% Gr)	11,642,857.142	8.45×10^{-8}

V. CONCLUSIONS

The following are the major conclusions drawn based on the experimental investigation for Aluminium 6061-Silicon Carbide-Graphite hybrid metal matrix composites with varying weight fraction.

- Al 6061 has higher values of specific heat capacity and heat flow, but Al 6061 + 5% SiC + 5% Gr hybrid composites reveal low specific heat capacity and heat flow. There has been a decrease in specific heat capacity at higher temperatures for varying weight fraction of hybrid MMCs by the addition of reinforcements Silicon Carbide and Graphite with Al 6061. Analogously, Al 6061 reveals higher value of enthalpy when compared to other hybrid composites with varying weight fraction. The decrease in enthalpy at all temperatures for different percentage compositions of hybrid metal matrix composites by the addition of reinforcements at low weight fraction resulted in the decrease in enthalpy. The addition of Silicon Carbide with Aluminium matrix alloy increases specific heat capacity, but specific heat capacity and enthalpy of hybrid composites have been reduced due to the enrichment of Graphite.

- It has been observed that, thermal resistivity or resistance and thermal shock resistance decreases due to the variation in thermal properties of hybrid composites at higher temperature. As thermal conductivity, thermal stresses, thermal expansivity and Poisson's ratio varies, there has been a decrease in thermal shock resistances. Similar behavior has been observed for electrical conductivity also.

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