GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

IMPORTANCE, NEED AND SCOPE OF THERMAL ANALYSIS AND CHARACTERIZATION OF COMPOSITE MATERIALS

S A Mohan Krishna[*1], T N Shridhar[2] & L Krishnamurthy[3]

[*1]Department of Mechanical Engineering, Vidyavardhaka College of Engineering,Mysore-570002, Karnataka, India

[2,3]Dept. of Mechanical Engineering, The National Institute of Engineering, Mysore-570 008, Karnataka, India

ABSTRACT

Metal Matrix Composites (MMCs) are the cutting edge materials that possess uninhibited opportunities for modern material science and development. Thermal studies of composite materials are gaining greater impetus in the present scenario. This will help to comprehend the properties of materials as they change with temperature. The thermal characterization of hybrid metal matrix composites has been progressively more important in a wide range of applications. The coefficient of thermal expansion, thermal conductivity, specific heat capacity, latent heat and thermal diffusivity are the most important properties of Metal Matrix Composites (MMCs). Since nearly all Metal Matrix Composites are used in various temperature ranges, measurement of Coefficient of Thermal Expansion and thermal conductivity (CTE) as a function of temperature is necessary in order to know the behaviour of the material. Thermal characterization and analysis of hybrid MMCs will depend on the factors that influence on the prominent thermo-physical properties presents a major challenge since they are sensitive to the type of reinforcement and method of manufacture. This research paper emphasizes the importance, need, applications and scope of thermal analysis of composite materials. Important thermal analyzers with their significance are discussed.

Keywords- *Metal Matrix Composites, thermal studies, thermal characterization, coefficient of thermal expansion, thermal conductivity and thermo-physical properties.*

I. INTRODUCTION

A composite material is a macroscopic combination of two or more dissimilar materials having an identifiable interface between them. A composite material exhibits a significant proportion of the properties of both constituent phases such that a superior combination of properties is realized. Composite materials comprises of two phases: one is the matrix, which is continuous and surrounds the other phase, often called the dispersed phase or reinforcement [1]. The main purpose of the reinforcement is to offer strength and stiffness to the composite. A matrix is used to bind the reinforcement together by virtue of adhesive and cohesive characteristics, and provides a solid form to the composite material. The matrix strongly holds the reinforcements in proper orientation and position and distributes the loads consistently among the reinforcements. The matrix material surrounds and supports the reinforcement materials by maintaining their comparative proportions. The reinforcements impart their exceptional mechanical and physical properties to augment the matrix properties. A synergism produces material properties unavailable from the individual constituent materials, while the wide assortment of matrix and intensifying materials allows the designer of the product or structure to choose a most favourable condition [2].

Metal Matrix Composites have emerged as a category of productive materials for advanced structural, electrical, thermal management, electronic packaging and wear applications. MMCs exhibit noteworthy improvement in physical and mechanical properties compared with unreinforced Aluminium alloys. Aluminium is the most popular matrix for MMCs. Aluminium alloys are attractive due to their low density, their capability to be strengthened by precipitation, good corrosion resistance, high thermal and electrical conductivity and damping capacity. MMCs based on Aluminium alloys have received greater interest since they combine with low weight, high mechanical strength, excellent wear properties, and becoming potential as a material for many engineering applications [3].

Metal Matrix Composites are normally distinguished by characteristics of the reinforcement namely particle reinforced MMCs, short fiber or whisker reinforced MMCs and continuous fiber or layered MMCs. Metal Matrix Composites (MMCs) covers an extensive range of materials to simple reinforcements of castings with low cost refractory wool, to complex continuous fires lay-ups in foreign alloys. The properties of MMCs are controlled and supported by the matrix, the reinforcement and the interface. The characteristics of metal matrix composites are determined by their microstructure and internal interfaces, which are influenced by their production and thermal mechanical prehistory. The microstructure covers the structure of the matrix and the reinforced phase. The chemical composition, grain or sub-grain size, texture, precipitation, behaviour and lattice defects are important to the matrix. The second phase is characterized by its percentage of volume, variety, size, distribution and orientation. Local varying internal tension due to the thermal expansion behaviour of the two phases is an additional influencing factor [2]. The reinforcement is very significant because it is accountable for the estimation and optimization of mechanical properties, cost and performance of a given composite. In particular, many of the considerations arising due to fabrication, processing and service performance of composites are related exclusively to the metallurgical aspects that take place in the interfacial region between matrix and reinforcement [3, 4, and 5].

Metal Matrix Composites are greatly beneficial compared to other composites. Hybrid MMCs are the distinctive materials that are fabricated by reinforcements of at least two types of materials into a tough metal matrix. These hybrid composite materials are expansively used in structural, aerospace and automotive industries. Hybrid MMCs have greater relevance to automotive engineering concerning with piston rods, piston pins, braking systems, frames, valve spring caps, disk brake caliper, brake disks, disk pads and shaft [6]. Presently, MMCs have the tendency to cluster around two peculiar types. The first type consists of high performance composites reinforced with expensive continuous fibers and requires sophisticated processing methods. The second type consists of comparatively inexpensive and low performance composites reinforced with moderately reasonably priced particulate or fibers. The cost of the first type is expensive for any military or space applications, whereas the second type is economical.

II. LITERATURE REVIEW

The literature concerning with mainly thermal properties have been included, that comprehensively focuses on aerospace and automotive applications. The research efforts and directions related to the present work have been identified through literature survey. The research papers concerning with the various thermal properties of composite materials has been discussed in this section.

L.C. Davis et al. [7] in their research thesis have explained the thermal conductivity of metal matrix composites, which are potential electronic packaging materials, has been calculated using effective medium theory and finite element techniques. It has been found that Silicon Carbide particles in Al must have radii in excess of 10 μm to obtain the full benefit of the ceramic phase on the thermal conductivity. Comparison of the effective medium theory results to finite element calculations for axisymmetric unit cell models in three dimensions and to simulation results on disordered arrays of particles in two dimensions confirms the validity of the theory.

S Cem Okumus, Serdar Aslan et al. [8] in their paper have studied on Thermal Expansion and Thermal Conductivity behaviours of Al/Si/SiC hybrid composites. It clearly highlights that 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 behaviours of hybrid composites with various graphite contents (5.0; 7.5; 10 wt.%) and different silicon carbide particle sizes (45 μm and 53 μm) has been investigated. Results indicated that increasing the graphite content improved the dimensional stability, and there was no obvious variation between the thermal expansion behaviour of the 45 μm and the 53 μm silicon carbide reinforced composites.

Na Chen, Zhang et al. [9] have reviewed on metal matrix composites with high thermal conductivity for thermal management applications, it emphasizes that the latest advances in manufacturing process, thermal properties and brazing technology of SiC/metal, carbon/metal and diamond/metal composites has been presented. Key factors controlling the thermo-physical properties were discussed in detail. The problems involved in the fabrication and the brazing of these composites were elucidated and the main focus was put on the discussion of the methods to overcome these difficulties. This review shows that the combination of pressure-less infiltration and powder injection molding offers the benefits to produce near-net shape composites.

J M Molina, M Rheme et al. [10] have investigated that thermal conductivity of Al-SiC composites demonstrates that the thermal conductivity of aluminium matrix composites having a high volume fraction of Silicon Carbide particles 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 and 16 μm). For composites based on powders with a monomodal size distribution, the thermal conductivity increases steadily from 151 W/m K for particles of average diameter 8 μm to 216 W/m K for 170 μm 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 W J, Jenkins R J 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.

Weidenfeller, Hofer et al. [12] have summarized thermal conductivity, thermal diffusivity and specific heat capacity of particle filled polypropylene. It has been investigated that, composites samples of polypropylene (PP) with various fillers in different fractions has been prepared with an injection moulding process to study the evolution of the properties as a function of filler content. Standard filler materials like magnetite, barite, talc, copper, strontium ferrite and glass fibres were used. Thermal diffusivities, specific heat capacities and densities of the prepared composite samples have been measured, and thermal conductivities were derived.

Hohenauer et al. [13] have carried out an experiment on flash method to examine diffusivity and thermal conductivity of metal foams. A finite element model has been generated to study the influences of the preparation method to the measurement results.

R Arpon, E Louis et al. [14] have analyzed that thermal expansion behaviour of Aluminium/SiC composites with bimodal particle distributions. The thermal response and the coefficient of thermal expansion (CTE) of aluminium matrix composites having high volume fractions of SiC particulate have been investigated. The composites were produced by infiltrating liquid aluminium into preforms made either from a single particle size, or by mixing and packing SiC particulate of two largely different average diameters (170 and 16 μm, respectively). The experimental results for composites with a single particle size indicate that the hysteresis in the thermal strain response curves is proportional to the square root of the particle surface area per unit volume of metal matrix, in agreement with current theories. This result is in full agreement with published numerical results obtained from finite element analyses of the effective CTE of aluminium matrix composites. The results also indicate that the CTE varies with particle volume fraction at a pace higher than predicted by theory.

S X Xu, Y Li et al [15] 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 [16] 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 behaviour to the specific heat of bulk graphite powder.

Bedrich Smetana, Monica Zaludova et al [17] 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 [18] 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.

III. IMPORTANCE OF THERMAL ANALYSIS OF COMPOSITE MATERIALS

Thermal studies of composite materials are gaining greater impetus in the present scenario. 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 assessment of thermal parameters of composites will benefit to evaluate heat capacity, variation in the intensity of heat, heat diffusion and heat release rate. It is usual to control the temperature in a predetermined way either by continuous increase or decrease in temperature at a constant rate by means of linear heating or cooling processes. For aerospace and automotive applications, low CTE, moderate thermal conductivity and high electrical conductivity of the composites will enhance the efficiency in all perspective. Thermal characterization and analysis of hybrid MMC will depend on the factors that influence on the prominent thermo-physical properties presents a major challenge since they are sensitive to the type of reinforcement and method of manufacture. The knowledge of the thermo-physical properties is compulsory for designing the effective heat transfer elements, heat sinks, heat shields and opto-electronic devices.

The experimental investigation on mechanical, tribological, fatigue, machinability and thermal characterization of metal matrix composites have become very important for the researchers to explore and exploit its properties comprehensively. In the present research work, it has been proposed to carry out thermal characterization and analysis of hybrid metal matrix composites. Thermal Analysis is also often used as a term for the study of heat transfer to measure heat capacity and Thermal Conductivity. Thermal Analysis of Metal Matrix Composites is required to clearly examine the thermal properties viz., Thermal Conductivity, Temperature Difference, Thermal Capacity or Heat Difference, Coefficient of Thermal Expansion, Thermal Stresses, Thermal Strain, Thermal Flux, and Heat Generation Rate. The determination of the effective thermal properties of composite materials is of paramount importance in effective design and application.

The main parameter considered in thermal analysis of 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. 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 is faster for materials with high thermal diffusivity. Metal Matrix Composites can be customized to provide good Coefficient of Thermal Expansion (CTE) matching for thermal management and thermal conductivity applications. It is essential to evaluate new materials for the thermal stability and to measure properties including CTE and thermal conductivity for specialty products [8].

IV. NEED FOR THERMAL ANALYSIS OF COMPOSITE MATERIALS

The need for the thermal analysis of hybrid metal matrix composites should be comprehensively discussed. The behaviour of 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. The thermal expansion coefficients of matrices and reinforcements behave as the function of temperature. The friction coefficient and coefficient of thermal expansion can be successfully measured with a high-precision thermal mechanical analyzer. The observed behaviour of the composites can be discussed in terms of particle size and thermal stresses developed as a result of the coefficient of thermal expansion between the reinforcement and the matrix.

A methodical approach for precise, competent and profitable thermal investigation and characterization of composite materials has to be discussed. It exclusively includes test prediction, validation tests and validation analysis. In the design and development of aircraft structures, the major requirements namely safety, cleanliness, production and manufacturing costs are the imperative issues for the fundamental intangible decisions. Generally, the temperature field is also very important for the assessment of stresses induced by thermal expansion. In the design process, the best method to acquire pertinent thermal data is by analytical or numerical simulations of the various missions that are required for the documentation of aircraft structures [19].

Metal Matrix Composites are exceedingly useful for industrial applications, such as aerospace and automotive streams, due to its enhanced thermal and physical properties. Finite Element Method (FEM) supplies an institutional analysis taking advantages of graphical and numerical post-processes. It helps systematic analysis of material behaviours and properties, including the investigation of local stress and strain distribution. Nevertheless, there are reports of FEM study on the thermal properties of Al/SiC system compared to that of the experimental research. Finite Element Analysis (FEA) has been used extensively to simulate the thermal and mechanical behaviour of Metal Matrix Composites. Aluminium is well known as a matrix material that possesses high magnitude of CTE. Thus Silicon Carbide particles in Aluminium matrix have been considered as a role of CTE reduction in Al/SiC system. The results of various finite element solutions for different types of composites can be compared with the results of various analytical models and with the available experimental investigation. Computational simulations on the thermal analysis of metal matrix composites composed of Aluminium and Silicon Carbide (SiC) has been performed in extended areas of SiC volume fraction [20]. Few empirical or mathematical models can be validated for the validation of thermal expansivity and thermal conductivity of the composites.

The development of numerical tools for the computational mechanical testing of materials and carrying out numerical experiments will lead to the development of recommendations for the improvement of mechanical structures. The design of materials on the basis of numerical testing of microstructures can be realised if big series of numerical experiments for different materials and microstructures can be carried out quickly, systematically and automatically. To extend experimental information, the computational FEM method on a variety of composite materials systems allows MMC fabrication to be fruitful with empirical results and computational investigation. For the analysis of metal matrix composite, many researchers have suggested the analysis of unit cell of composite. Generally, there are computational difficulties to obtain reasonable results based on a small single unit owing to a lack of interaction between reinforcement and matrix. On the contrary, the computation with multiple unit cells allows reliable results due to considerable material interaction [20].

The techniques of numerical or computational simulation are the prominent components or the reduction of development costs. In the present scenario, the availability of computational resources and simulation techniques are beneficial to achieve accuracy and speed that consecutively saves production cost and computation time. Certain simulation tools can save the development costs and is envisaged to validate the numerical methods by means of small scale materials for parameter identification. Hence it is necessary to focus on maximum effort for both experimental testing and validation analyses. The prerequisite of using homogenization techniques in thermal analysis is caused by a different selection of problems. It can be performed to simplify certain mechanisms in heat transfer by suing specific simulations tools. The application of homogenization to the thermal material properties will help to predict the temperature profile of a structure concerning with aircraft systems. Any technique concerning with the thermal analysis of composites can be implemented and executed using Finite Element Method [19].

V. SCOPE FOR THERMAL ANALYSIS OF COMPOSITE MATERIALS

The scope of the research is to evaluate the effective thermal conductivity, CTE and other main thermal parameters of composite materials by experimental and numerical or computational analysis and to investigate their proximity relations with the assistance of thermo-elastic or empirical models that have been developed for the prediction for the thermal analysis of metal matrix composites. The thermal properties of composites will help for design applications mainly for materials selection criteria, thermo-mechanical analysis for structural component design for extreme temperatures, prediction of alloy properties based on unalloyed metal properties and evaluation of thermally induced stresses and degree of thermal cycling that leads to material fracture or thermal shock resistance.

The development, specification, and quality control of materials often require the measurement of thermophysical properties. This data can be critical to a successful design, especially with the rapidly increasing cooling requirements that result from the packaging of higher performance devices. A variety of methods, involving both steady state and transient techniques, are available for measuring thermal diffusivity, specific heat, thermal conductivity and thermal resistance. Information of the thermo physical properties of materials and heat transfer optimization of final products is becoming more and more vital for industrial applications. Over the past few decades, the flash method has developed into the most commonly used technique for the measurement of the thermal diffusivity and thermal conductivity of various kinds of solids, powders and liquids. Application areas are electronic packaging, heat sinks, brackets, reactor cooling, heat exchangers, thermal insulators and many others.

Trouble-free sample preparation, small required sample dimensions, fast measurement times and high accuracy are only a few of the advantages of this non-contact and non-destructive measurement technique.

VI. THERMAL ANALYZERS FOR THE ANALYSIS OF COMPOSITE MATERIALS

Thermal analysis of composites can be carried out effectively using various thermal analyzers namely Differential Thermal Analysis (DTA), Differential Scanning Calorimetry (DSC), Laser Flash apparatus (LFA), Horizontal Platinum Dilatometer, Dynamic Mechanical Analyzer and Thermogravimetric analyzer (TGA). Laser Flash method is regarded as the most popular method of measuring thermal conductivity and thermal diffusivity of solids. The magnitude of density, thermal capacity and specified temperature range are the salient factors for the estimation of thermal diffusivity of homogeneous materials. Horizontal Dilatometer is mainly used for the evaluation of thermal expansion coefficient based on the changes in volume or length of the sample. Differential Scanning Calorimeter is predominantly used in the determination of intensity of heat flow, specific heat capacity and enthalpy of isotropic materials. In the research, Laser Flash apparatus, Dilatometer and Differential Scanning Calorimeter are used prominently is the determination of thermal properties of hybrid metal matrix composites.

The production of many metals namely cast iron, ductile iron and series of Aluminium alloys are aided by a production technique called thermal analysis. Thermocouple is used to measure and monitor temperature, where chemical composition of the metal can be estimated based on the phase diagram obtained. Sample Controlled Thermal Analysis analyzes the cooling curves, where the cooling rate of the sample is dependent and the sample volume is normally a constant. To detect phase evolution and corresponding characteristic temperatures, cooling curve and its first derivative should be considered simultaneously. The examination of cooling and derivative curves are done by using appropriate data software analysis called "Computer Aided Cooling Curve Thermal Analysis." More advanced temperature profiles have been developed which uses an oscillating sine or square wave or modify the heating rate in response to changes in the properties of the system. This is referred as Sampled Controlled Thermal Analysis.

Thermal expansion is the tendency of matter to change in volume in response to change in temperature. The degree of expansion to the change in temperature is called the material's coefficient of thermal expansion and generally varies with temperature. Coefficient of Thermal Expansion is one of the most important properties of MMCs. Since nearly all Metal Matrix Composites are used in various temperature ranges, measurement of CTE as a function of temperature is necessary in order to know the behaviour of the material. Several different systems for measurement of CTE can be used depending on the temperature conditions. One of the most common systems used is a dilatometer. A dilatometer measures the length or the volume changes of the sample, when the sample follows a temperature program and submits a small force. In a push rod dilatometer the change in length of the sample is detected by an inductive displacement transducer. Calibration and corrections of measurements are done by using various standards and comparison with materials of known expansion. The measurement of the coefficient of thermal expansion (CTE) can be carried out in the temperature range from approximately – 150 deg C to 1500 deg C.

A horizontal Dilatometer comprises of Thyristor controlled unit, Linear Variable Differential Transformer (LVDT), automatic pressure control unit, variety of sample holders and RCS (Rate Controlled Sintering) software. The coefficient of thermal expansion (CTE) can be controlled by two parameters simultaneously namely wall thickness and volume fraction comprehensively. The CTE values have a stronger dependence on particle volume fraction than the wall thickness in the range of temperatures explored. The thermal expansion results with the variation of temperature for the composites and the matrix are shown for different percentage composition. It is obvious that the CTE of the composites and matrix increases with increase in temperature [21].

Many different methods and variants for measuring thermal expansion have been developed to satisfy the needs of measurement problems. The choice of methods may depend upon the material to be measured, the amount of material available, the temperature range of interest and the precision or accuracy that is needed. The methods of measuring thermal expansion that are most widely used include Interferometry, Pushrod Dilatometry, X-ray diffraction and high-precision three-terminal capacitance cell [21].

The pushrod dilatometer method for measuring thermal expansion is experimentally simple, reliable and easy to automate. In this method, the relative expansion of the specimen is transmitted referring to cooled or heated zone to a measuring device (an extensometer) by means of tubes and/or rods of a stable reference material. In this technique, the specimen is placed at the end of a tube and a smaller rod is placed in the tube in contact with the specimen. An extensometer has the capability to detect the difference in expansion between the specimen and an equal length of the tube. The most widely used extensometer is the LVDT (Linear Variable Differential Transformer). For the evaluation of CTE, the validation of thermo-elastic models namely Rule of Mixture, Kerner's model, Schapery's model and Turner's model is highly beneficial for validation that can give greater impetus for research.

Laser Flash technique is highly resourceful for the evaluation of Thermal Conductivity and Diffusivity. The sample is positioned on an electronically controlled and programmable robot located in a furnace. The furnace is then held at a predetermined temperature. At this temperature, the sample surface is then irradiated with a programmed energy pulse (laser or xenon flash). This energy pulse results in a homogeneous temperature rise at the sample surface. The resulting temperature rise of the rear surface of the sample is measured by a high speed infrared detector and thermal diffusivity values are computed from the temperature rise versus time data. The resulting measuring signal computes the thermal diffusivity, and in most cases the specific heat (Cp) data. Both power and the pulse length can be easily adjusted by the software.

The thermal conductivity of metals, alloys or composites can be measured by comparative method with steady state longitudinal heat flow in a temperature range room temperature up to about 1000°C. The comparative instrument measures heat flow based upon the known thermal properties of standard reference materials. The test specimen is sandwiched between two identical reference samples. This stack is placed between two heating elements controlled at different temperatures. A guard heater has been placed around the test stack to ensure a constant heat flux through the stack and no lateral heat flow losses. As heat flows from the hot element to the cold element the temperature gradient across the stack is measured with thermocouples. In a laser flash method, laser fires a pulse at the sample's front surface and the infrared detector measures the temperature rise of the sample's back surface. The software uses literature-based analysis routines to match a theoretical curve to the experimental temperature rise curve. To determine specific heat, the infrared detector measures the actual temperature rise of the sample [21].

The technique recommended for the experimental investigation of heat flow distribution, specific heat capacity and enthalpy of hybrid metal matrix composites is Differential Scanning Calorimeter (DSC). DSC is one of the versatile thermal analysis techniques employed for measuring the energy necessary to establish a nearly zero temperature difference between a substance and an inert reference material, as two specimens are subjected to identical temperature regimes in an environment heated or cooled at a controlled rate. It can be used with composites and composite precursors to study thermodynamic processes and kinetic events such as cure and enthalpic relaxation associated with physical aging or stress [22]. Differential Scanning Calorimeter (DSC) is one of the most periodically used techniques in the field of thermal characterization of solids and liquids. Its main advantages are the modest requirements in terms of sample size (~20 mg) and its ability to provide quantitative data on overall reaction kinetics, with relative speed and ease. Fundamentally the DSC measures the heat capacity of a sample by recording the heat flow rate into the sample and comparing it to a reference sample.

In DSC, when the two pans are heated, the computer plots the difference in heat flow against temperature. The differential heat flow rate depends on the differential heat capacity and heating rate. The true specific heat capacity is related to the quantity of heat required to raise the temperature of a specified mass of material by a specified temperature. Normally, specific heat capacity can be determined by depending on the values of heat flow and heating rate. The characteristic feature of this measuring system is that the main heat flow from the furnace to the sample and reference containers passes symmetrically through a thermally conductive disk. The sample containers are positioned on this disk symmetrical to the centre, and the temperature sensors are integrated. Each temperature sensor covers more or less the area of support of the respective container (crucible, pan) so that calibration can be carried out independent of the sample position inside the container. The purge gas is Nitrogen which is impinged at 50 mL/min and pan type is crimped Aluminium. The nominal program rate is 10°C/min.

When a sample material is subjected to linear temperature program, the heat flow rate into the sample is proportional to instantaneous specific heat. By recording the heat flow rate which is a function of temperature, and comparing the same with the heat flow rate into a standard material under the same conditions, the specific heat capacity of the sample is determined as a function of temperature. To measure the magnitude of specific heat capacity of a sample, the sample holder temperature is programmed. To accomplish a base line, the program is carried out with the absence of sample; however, empty Aluminium foil sample containers are placed in sample holders. Isothermally, the base line indicates the differential losses the sample holders at the initial temperature. When the program commences, small offset from isothermal base line, caused by the thermal capacity mismatch between the two sample holders and their contents is observed. When the temperature program terminates, the isothermal base line disappears. This procedure is then repeated, with a weighed sample added to the sample holder. The isothermal base lines are unaltered, since the sample has no impact on the power dissipation of the sample holder. However, there is an additional offset from the programming base line, owing to the absorption of heat by the sample [22].

VII. CONCLUSIONS

Thermal studies of composite materials are gaining greater impetus in the present scenario. The assessment of thermal parameters of composites will benefit to evaluate heat capacity, variation in the intensity of heat, heat diffusion and heat release rate. It is usual to control the temperature in a predetermined way either by continuous increase or decrease in temperature at a constant rate by means of linear heating or cooling processes. For aerospace and automotive applications, low CTE, moderate thermal conductivity and high electrical conductivity of the composites will enhance the efficiency in all perspective.

In future, composite materials will produce significant changes both in aircraft manufacture and industries. Because they provide structural efficiency at lower weights than equivalent metallic structures. Advanced composites are rapidly emerging as the primary material for the use in next-generation aircraft structures. The technology of advanced composites has already well advanced, where all newly emerging military aircraft systems have a number of composite components in production. For next-generation aircraft system, high-volume production should make use of composites that are highly competitive with metals. Thus, to expand the existing production base and prepare for the projected high-volume, cost competitive production, airframe manufacturers must re-evaluate and upgrade their requirements and facilities significantly.

REFERENCES

1. *"Introduction to Composites", Composites ASM Hand Book, Volume 21, May 2002.*
2. *Karl Ulrich Kainer, "Basics of Metal Matrix Composites."*
3. *D. Hull, T.W. Clyne, "An Introduction to Composite Materials", Cambridge Solid State Science Series, Second Edition.*
4. *N. R. Habbu "Use of Aluminium Silicon Alloys in Automobile Application", Proceedings of one day Industry Institute Interactive Meet on Al-Si alloys, Development and Application for transport sector, IISC Bangalore, September 2000.*
5. *Jayashree P K, Gowri Shankar M C, Achutha Kini, Sharma S S and Raviraj Shetty, "Review on Effect of Silicon Carbide on Stir Cast Aluminium Metal Matrix Composites", International Journal of Current Engineering and Technology, ISSN 2277-4106, Volume 3, Number 3, 2013.*
6. *Daljeet Singh, Harmanjit Singh and Gurvishal Singh, "An Experimental Investigation of Mechanical Properties of Aluminium by adding SiC and Alumina", International Journal on Emerging Technologies, Pages 178 – 184, 2012.*
7. *L.C. Davis, B.E.Artz, "Thermal Conductivity of metal matrix composites", Journal of Applied Physics, Vol. 77, pp 4954-4960, July 2009.*
8. *S Cem Okumus, Sredar Aslan et al, "Thermal Expansion and Thermal Conductivity Behaviors of Al-Si/SiC/graphite Hybrid Metal Matrix Composites (MMCs)", Volume 18, No 4 (2012).*
9. *Na Chen, Zhang et al, "Effect of Thermal cycling on the expansion behaviour of Al/SiC composites", Journal of Materials Processing Technology, pp 1471-1476, 2009.*
10. *J M Molina, M Rheme et al, "Thermal conductivity of aluminum matrix composites reinforced with mixtures of diamond and SiC particles", Volume 58, Issue 5, Pages 393-398, 2008.*
11. *Parker W J, Jenkins R J, Abbott G L et al, "Flash method of determining Thermal Diffusivity, Heat Capacity and Thermal Conductivity", Journal of Applied Physics, Volume 31, Issue 9.*
12. *Weidenfeller, Hofer et al, "Thermal conductivity, thermal diffusivity and specific heat capacity of particle filled polypropylene", Applied Science and Manufacturing, Part A 35 (2004), 423-429.*
13. *Hohenauer et al, "Flash methods to examine diffusivity and thermal conductivity of metal foams", Pittsburg, 2009.*

14. *R Arpon, E Louis et al, "Thermal expansion behaviour of aluminium/SiC composites with bimodal particle distributions", Volume 51, Issue 11, Pages 3145-3156, 2003.*
15. *S X Xu, Y Li et al, "Study of temperature profile and specific heat capacity in temperature modulated DSC with a low sample heat diffusivity", Elsevier, pp 131-140, 2000.*
16. *N R Pradhan, H Duan, "The specific heat and effective thermal conductivity of composites containing single and multi wall carbon nanotubes", IOP Publishing, May 2009, USA.*
17. *Bedrich Smetana, Monica Zaludova, "Possibilities of Heat Capacity Measurement of Metallic systems", METAL 12, 23 – 25, Czech Republic, EU, 2012.*
18. *E Morintale, A Harabou, "Use of heat flows from DSC curve for calculation of specific heat of the solid materials", Physics AUC, Volume 23, 89-94, 2013.*
19. *Jan Tessmer. Tom Spreowitz and Tobias Wille, "Thermal Analysis of Hybrid Composite Structures", 25th International Congress of the Aeronautical Sciences, 2005.*
20. *Eusun Yu, Jeong-Yun Sun, Hee-Suk Chung, Kyu Hwag Oh, "Investigation on Thermal Properties of Al/SiC particles Metal Matrix Composite Based on FEM Analysis", School of Material Science and Engineering, 2008.*
21. *K D Maglic et al, "Compendium of Thermophysical Property Measurement Methods – Recommended Measurement Techniques and Practices", Volume 2, Springer Science Business Media, LLC.*
22. *M J O'Neill, "Measurement of Specific Heat Functions using Differential Scanning Calorimetry", The Parker-Elmer Corporation, Norwalk.*