ISSN 2347 - 3983
Volume 3, No.11 November 2015
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter023112015.pdf

Numerical Investigation of Thermal Conductivity on Al-12Si/MgOp Composites

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ABSTRACT
The present study focuses on the effect of thermal behavior in the aluminum alloys especially Al-12Si with MgO particulate metal matrix composites. The as-cast Al-12Si alloy and its composites were fabricated using liquid metallurgy method by varying 2 to 10% volume fraction by steps of 2 of particulate of magnesium oxide reinforcements. Guarded heat flow meter test method is used to measure the thermal conductivity of Al-12Si with magnesium oxide composites using an instrument as per ASTME-1225-99. In the numerical study, the finite element package ANSYS is used to calculate the thermal conductivity of the composites.The three-dimensional Solid cylinder coordinates lattice array models are used to simulate microstructure of composite materials for various compositions of reinforcements. This study reveals that the incorporation of aluminum particles results in enhancement of thermal conductivity of magnesium oxide reinforcement particulate and thereby improves its heat transfer capability. The experimentally measured conductivity values are compared with the numerically calculate ones and it is found that the values obtained for various composition composites models using finite element analysis (FEA) are in reasonable agreement with the experimental values.

Key words: American Society of Testing Materials, Finite Element Analysis, Magnesium Oxide, Thermal Conductivity

1. INTRODUCTION
The demand of today's and future aluminium alloys are best suitable materials in engineering applications.These needs for new materials able to match increasingly strength in engineering requirements have led to the development of Metal Matrix Composites for automotive applications. Al based MMC's are having some excellent properties such as high hardness, high strength & high thermal conductivity at elevated temperatures. Other characteristics are low coefficient of thermal expansion & wear resistances. The objective of the present paper is to give an overview of the current understanding of particle reinforced light metal composites, identify some of the key factors which need to be controlled which may be specific to the mode of manufacture or processing and consider some of the main problem areas which need to be overcome if these materials are to reach their full commercial potential. There is variety of alternatives being explored by the automobiles industry, hence the automobiles of the future will continue to be mix of materials of which the candidate materials will be Al based MMC's The reinforcement on Al MMC's could be in the form particulate, whiskers, continuous and discontinuous fibers in volume fraction ranging from 15% up to 70%. Properties of Al based MMC's can be tailored to the demands of different industrial applications of matrix, reinforcement and processing route **[1-4].**

2. LITERATURE REVIEW
Pradeep.K.Rothatgri et al, has explained the metal matrix composites research & development activities with particular emphasis on cast metal matrix composites **[5].** W Kim et al, has found out the thermal conductivity by EMC for microelectronic encapsulation **[6].** L E Sung et al, enhanced thermal conductivity of polymer matrix composites in solid loading of Al nitride in epoxy resin **[7].** S Peng et al, has determined the conductivity for anisotropy of polymer solids under large strains **[8]**. R C Progelhof et al, has described the thermal conductivity method for predictions **[9].** R Nayak et al, has found out thermal conductivity by computational approach **[10].** I Tavanam et al, has explained about thermal conductivity on experimental heat transfer functions **[11]**.

3. METHODOLOGY
3.1 Experimental work
In this research MgO were dispersed in Al alloys (Al-12Si, Properties shown in Table 1) by stirrer die casting followed by Liquid metallurgy process. The size of the MgO particulates dispersed varies from 50 µm to 80 µm and the amount addition varies from 2 to 10%wt in steps of 2.

Table.1 Chemical composition of Al alloy (Al-12Si)

Elements	Al	Si	Ni	Mg	Fe	Mn	Zn
Wt%	Bal	12	1.5	1.4	1.0	0.5	0.5

Table.2 Chemical composition of MgO particulate

Elements	Magnesium	Oxide structure	Crystalline
Wt%	60.30	39.70	octahedral

The primary process consists of synthesis of micro-sized MgO particulate reinforced Al composites containing three different volume % of MgO particulates was carried out using liquid metallurgy techniques. The processing of the composites involved heating of Al alloy in a graphite crucible up to 973°K using resistance furnace to which the preheated reinforcement (to 573°K) was added and stirred well by an impeller rotated at 400 rpm to create vortex to get uniform distribution of the reinforcement. In secondary processing, the deposited monolithic and MgO particulate containing Al-12Si alloy matrix are heated up to molten metal state. The molten metal is then poured into the preheated cast iron dies. The castings were tested to know the common casting defects using ultrasonic flaw detector. The specimens were prepared as per ASTME (American Society for Testing Material Engineering) standards and the specimens dimensions are diameter 25 mm and 80 mm length. The thermal conductivity apparatus as instruments standards (1225-99) state that's the surface of the specimens were cleaned by alcohol and then by acetone to remove the dust particles. After the specimens are mounted in the testing column and the temperature is increased to 323^0K by heat input and once temperature attains equilibrium conditions. The procedure was repeated up to 573°K. The thermal conductivity of the specimens was calculated by using the principle of Fourier law of conduction at steady state operating condition with unidirectional heat flow condition **[12-13].**

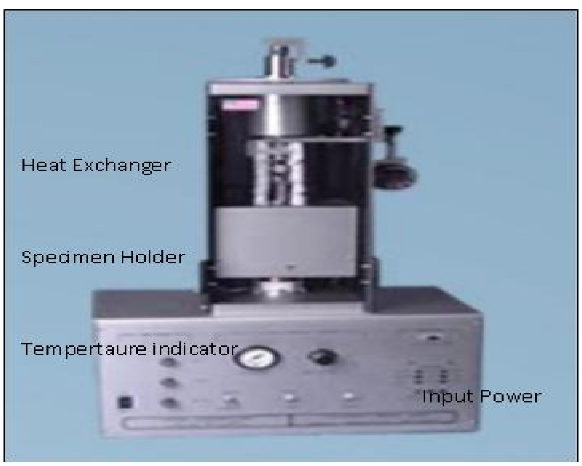

Figure.1 Guarded heat flow measurement apparatus (λ) [14]

$$\lambda = \frac{QxL}{AX\,\Delta T} \text{ ………………..Eq1}$$

3.2 Finite Element Analysis

The determinations of effective properties of composites are given importance for fundamental design and the application of effective properties can be controlled to an appreciable extent in the microstructure of the composite. In the analysis of this conduction problem, the heat flow direction and the boundary conditions for the particulate matrix composite body are shown in figure 2. The temperature at the nodes along the surfaces is prescribed as T_1=323°K and the ambient convective heat transfer coefficient is assumed to be 25 $W/m^2/K$ at room temperature of 298°K. The other surfaces parallel to the direction of the heat flow are assumed to be adiabatic. The temperatures at the radius in the interior region and on the other boundaries are unknown. These temperatures are obtained with the help of finite element program package ANSYS Solver for thermal analysis.

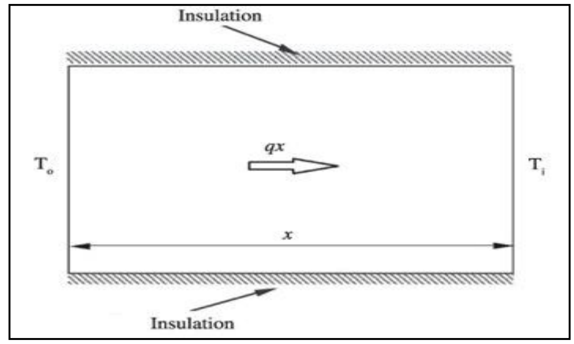

Figure.2 Thermal Boundary Conditions for FEA

3.3 Assumptions

In the analysis of the ideal case it will be assumed that,
The composites are macroscopically homogeneous.
Both matrix and reinforcement are homogeneous.
The thermal contact resistance between the reinforcement and the matrix is negligible.
The composite matrix is free of voids.
The problem is based on 3D physical models.
Using ANSYS, thermal analysis is carried out for the conductive heat transfer through the composite body. In order to make a thermal analysis, three dimensional physical models with solid-in-cylinders coordinates and lattice arrays have been used to stimulate the microstructure of composite materials for five different percentage volume factions for the reinforcements of MgO particulates. Furthermore, the effective thermal conductivities of these Al-12Si composites containing MgO particulate up to 10% by volume fraction are numerically determined **[15-16].**

4. RESULT AND DISCUSSION

4.1 Microstructural Characterization

Microstructural characteristics of micro-size of Al alloy composites are discussed in terms of distribution of reinforcement and matrix interfacial bonding. Microstructural studies conducted on the as-cast and its composites are uniform distribution of the reinforcement as shown below (Figure.3 & Figure 4), good reinforcement matrix interfacial integrity significance of grain reinforcement with minimal porosity. This is due to gravity of MgO particles associated with judicious selection of string parameters (vortex route) preheated reinforcement by the matrix material. Metallographic studies of the specimens revealed that the matrix is recrystallized completely. Grain reinforcement in case of Al-12Si alloys and its composites can be attributed to capability of MgO particulates to nucleate Al grains during solidifications and restricted growth of recrystallized Al grains because of the presence of finer reinforcement was assessed using scanning electron microscopic to analyze the interfacial deboning at the particulate matrix interface. Here also the results revealed that a strong bond exists between the interfaces as expected from Al-12Si/MgO particulates.

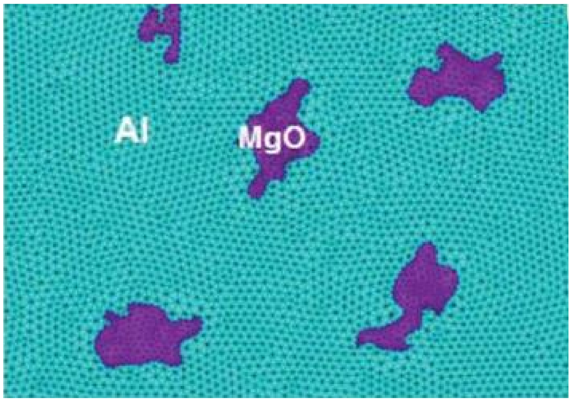

Figure.3 Optical microstructure of the matrix (Al-12Si)

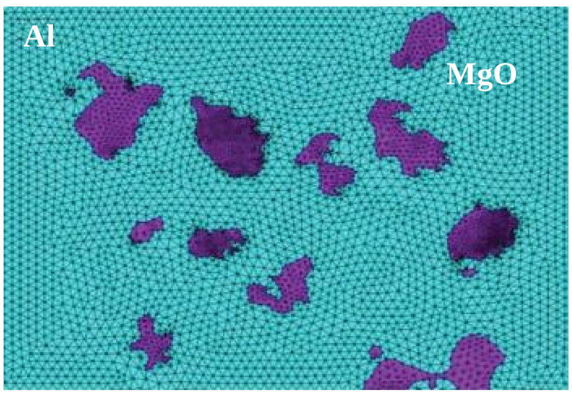

Figure.4 Optical microstructure of 10%MgOp / Al-12Si alloy

4.2 Numerical Analysis

The temperatures at various nodes within the composite body are obtained with the help of finite element program.

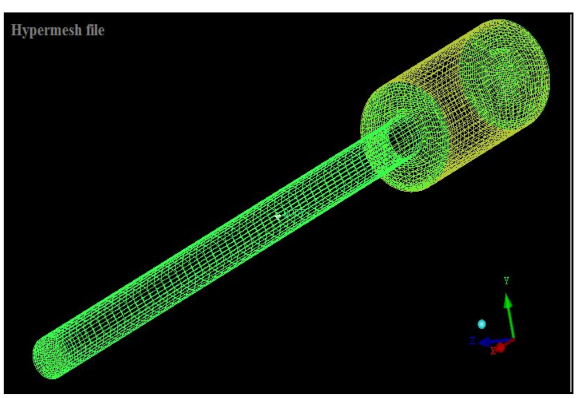

Figure.5 Typical 3-D solid cylinder coordinates with meshing

Typical 3-D models showing arrangement of solid cylinders coordinates with MgO_p of 2%wt within the solid shaped matrix body are illustrated in the Figure.5 are respectively. hermal conductivities of Al-12Si alloy with MgO_p up to 10%vol fraction are numerically estimated by using the solid cylinders co-ordinates model. The temperature profiles obtained from FEA for the composites with 2 to 10% volume fraction are shown in Figure.6 to Figure.10 respectively.

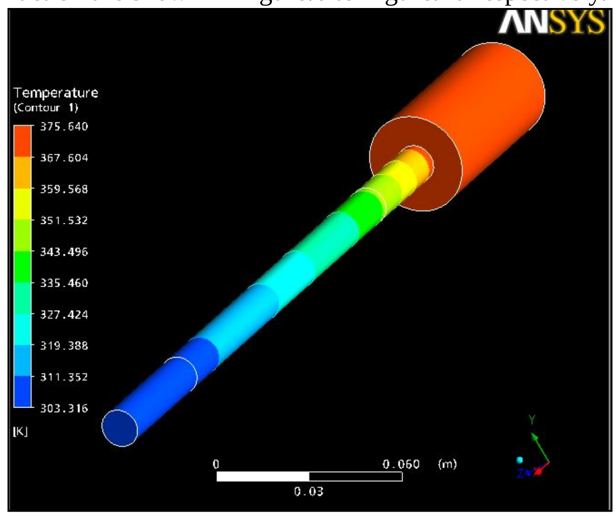

Figure.6 Temperature profile of Al-12Si alloy with 2%vol of MgO_p

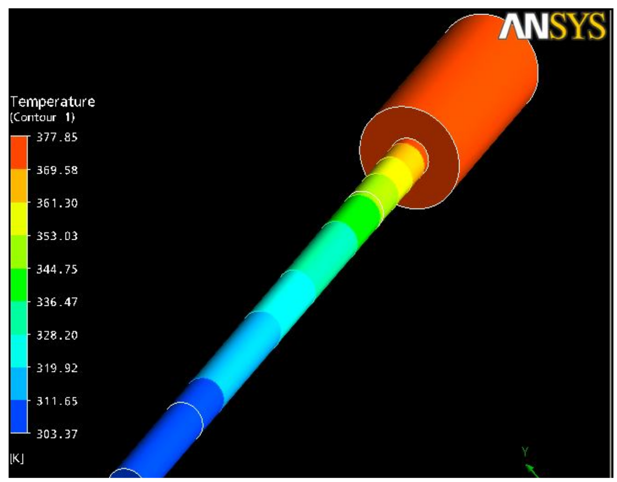

Figure.7 Temperature profile of Al-12Si alloy with 4%vol of MgO_p

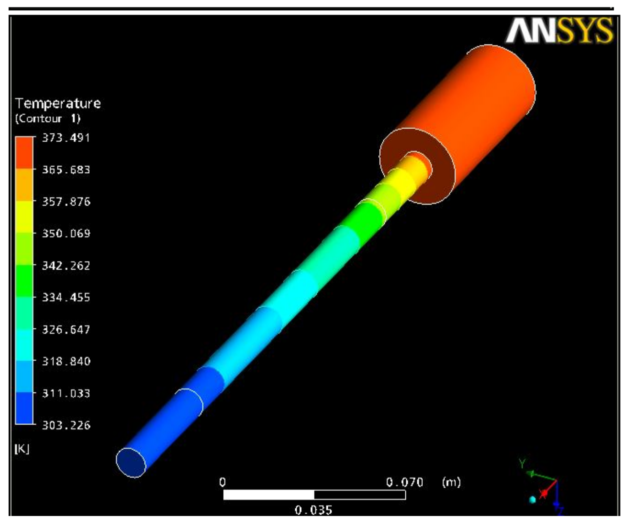

Figure.8 Temperature profile of Al-12Si alloy with 6%vol of MgO_p

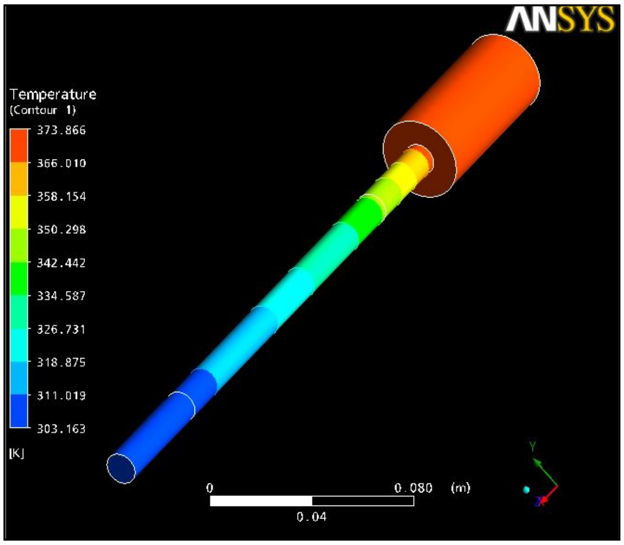

Figure.9 Temperature profile of Al-12Si alloy with 8%vol of MgO_p

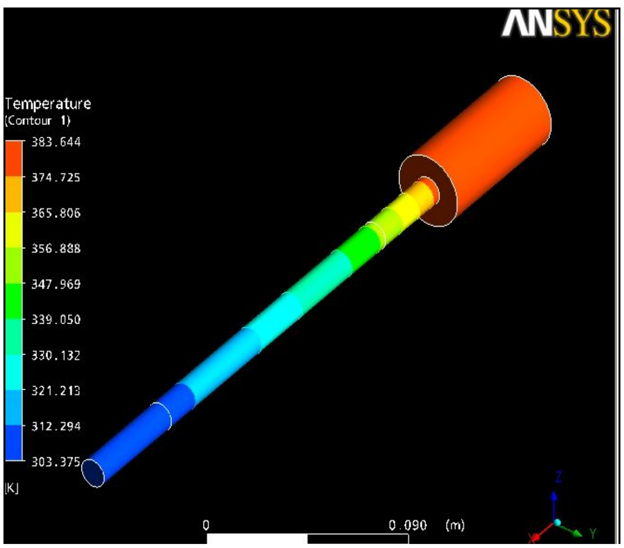

Figure.10 Temperature profile of Al-12Si alloy with 10%vol of MgO_p

Table.3 Comparison study of Experimental & FEA

MgO_p %Vol	Thermal Conductivity of Composites(w/m/K)	
	Finite Element Analysis	Experimental Work
2	149	145
4	145	142
6	143	139
8	139	134
10	136	130
Matrix (141- 156)		Reinforced(38-41)

Table.4 Percentage Errors associated with Experimental Work and FEA

MgO_p %Vol	Percentage errors estimated with FEM & Experimental
2	2.75
4	2.11
6	2.87
8	3.73
10	4.56

5. CONCLUSION

Finite Element Analysis can be gainfully employed to determine effective thermal conductivity of Al-12Si with MgO particulate composites with different composition of reinforcement. Incorporation of MgO particulate results in increase of thermal energy transfer capability. With an addition of 2 to 6% vol MgO particles improves by about 45.46% with the light weight and improves insulation capability of MgO particulate. With base Matrix (Al-12Si) alloy composites can be used for automobile applications such as Piston, Cylinder head, Crankpin, etc.

ACKNOWLEDGMENT

The authors grateful thanks to the support of this work by Central Power Research Institute, and Indian Institute of Science and Management ,Bangalore.

NOMENCLATURE

λ : The thermal conductivity (watts per meter per Kelvin scale)
Q: Rate of heat transfer per unit area per Kelvin rise
K: Kelvin temperature scale
L: Length of the specimens in term of meters
ΔT : Change in temperature in Kelvin

REFERENCES

1. Williams.D.Callister. **Aluminum Matrix composites,** *Material Science and Engineering an Introduction Wiley and Publications*,7th edition ,pp.420-454,September 2012.
2. Kauffman**, Characterstics of Composite Materials**, *Wiely publications*, ISBN0471268828, pp337-365,2013.
3. Pradeep.Rohatgi.K etal. **Metal Matrix Composite**, *Department of material Engineering*, *Defence Science Journals*, Vol 43, pp323-349, Oct 1993.
4. Evans. A. etal. **Light Weight Materials and Structures,** *Materials Science Engineering* ,pp790-820,2000.
5. Kim.K, Alokanya etal. **Thermally conductive EMC for MicroelectronicsEncapsulation,***Polymer.Engg,Science* , Vol.39,pp756-766, 1999.
6. L.E.Sung etal, **Enhanced Thermal Conductivity of**

Polymer matrix Composites via High Solids Loading of Al Nitride in Epoxy Resin, *American Ceraicmic Society*. Vol.91, pp1169-1174, 2008.

7. R.C.Progelhof etal**, Methods of predicting the Thermal Conductivity of Composites Systems**, *Polymer for engineering Science,* Vol.16 (9),pp 615-625,1976
8. R.Nayak, P.Seng etal, **Computational and Experimental Investigation on Thermal Conductivity**, Journal on *Composite for material science, Vol.48,pp.576*-581,2008.
9. R. S. Chandel etal, **Effect of welding parameters and groove angle on the soundness of root beads deposited by the SAW process,** *Proc. of Trends in Welding Research*, Gatlinburg, Tennessee, USA,Vol(7), pp 479-385,1986.
10. Kalpakjian.S etal, **Manufacturing Processes for Engineering Materials,** *Second Ed. Addison-Wesley Publishing Company*, New York, USA, pp456-475,1997.
11. G.kerb etal, **Thermophysical Properties of Metal Matrix Composites,** *Austrian Research Centers Scibersdorf,*Vol 7,pp11-19,2007.
12. E.l.Chaesley etal, **Thermal Analysis: Techniques and Applications**, *Springer*,ISBN: 0851863752, pp124-134, 1992
13. **Standards Test method for Thermal Conductivity of Solids using Guarded Heat Flow meter techniques**, *ASTM International west Conshohocken's, PA, www.atm.org.2013*
14. I.Tavman etal, **Thermal Anisotropy of Polymers as a Function of Their Molecular orientation,** *Experimental Thermodynamics, Elsevier*,pp1562-1568,1991.
15. Alok Satapathy etal **Study on Thermal Conductivity of Aluminum nitrate Filled Polymer Composites,** International Conference on Engineering and Technology, Phuket, pp755-788, May 2011.
16. Joel Hemanth, **Effect of Microstructure on Mechanical Behavior of Chilled Al-Al_2SiO_5** MMCs, *J.Microstrure Material Property*,pp65-74,2011.

APPENDIX-I

Ananda.G.K, who hails from Mandya, Karnataka State from India was born on 25th April 1986.The educational background is as follows. Bachelor of Engineering in Mechanical Engineering. Master of Technology in Thermal Power and Engineering. He is currently working as Assistant Professor in the Department of Mechanical Engineering, B.T.Laxman Institute of Technology and Management, India. He takes over the primary responsibilities on academic teaching, research and development activities. He recently joined as journal reviewer on international journal on advance research in science and engineering with impact factor: 1.142. He has joined professional membership bodies are American Society for Mechanical Engineering (ASME) and American Society for Testing Materials (ASTM).