Theoretical Analysis Of Coefficient Of Thermal Expansion By Thermo Mechanical Analyzer Of LM13/Mgo Composites.

Ananda.G. K, Ramesha. H

Abstract: This paper describes a study of the thermal characteristics of LM13 Al based MMC's with various amounts of magnesium oxide (MgO) particulates.MMCs are having some excellent properties such as high hardness, high strength, low thermal expansion & high thermal conductivity at elevated temperatures.In the present investigation, the effects of thermal expansion & thermal conductivity of LM13/MgO_p MMC's.The as-cast and heat treated LM13 alloy were fabricated using stir-casting method by varying the reinforcement. The specimens were prepared as per ASTME standards. These composites may be the alternate materials for aero-plane components, automobile parts like piston rod, connecting rod & cylinder head.

Key words: LM13-Light Metals, MgO_P-Magnesium oxide particulate, MMCs- Metal Matrix Composites, ASTME-American Society Tools & Manufacturing Engineering.

1 INTRODUCTION

The innovative materials open up unlimited possibilities for modern material science and development, the characteristics of MMCs can be designed into the materia, custom-made, dependent on the application. From this potential, MMCs fulfill all the desired conceptions of the designer. This material group becomes interesting for use as constructional and functional materials, if the property profile of conventional materials either does not reach the increased standards of specific demands. However, the technology of MMCs is in competition with other modern material technologies, for example powder metallurgy. The advantages of the composites materials are only realized when there is a reasonable cost-performance relationship in the component production. The use of a composite material is obligatory if a special property profile can only be achieved by application of these materials. MMCs are engineered combinations of two or more materials where tailored properties are achieved by systematic combinations of different constituents. The nature and morphology of the composites are mainly depends on the shape & size of individual constituents, their structural arrangement & distribution, the relative amount of each contribute to the overall performance of the composites. The properties such as friction & wear resistance in lubrication

condition are importance for the development of engine parts.Al alloy found widespread in transportation engineering applications because of its high strength to weight ratio. Al based MMC's refer to the class of light weight Metals with high performance Al centric material systems. The reinforcement on Al MMC's could be in the form particulate, whiskers, continuous and discontinuous fibers in weight 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.

2 LITERATURE REVIEW

Nowdays, the world wide upsurge in MMCs research and development activities is focusing mainly on Al alloys. These Al Matrix Composites are unique combination of properties like good wear resistances, lowdensity, & excellent mechanical properties.The unique thermal properties of Al Matrix Composites such as High metallic conductivity with lower coefficient of thermal expansion which can be tailored down to zero and its use in aerospace & aviniocs applications.The LM13/graphite, LM13/zricroium & LM13/quartz were respectively studied by A.K Gupta,Norman Tommis,& Joel Hemanth.They were explore the properties of LM13 Alloys and its composites.

3 EXPERIMENTAL WORK

The Matrix Material selected was LM13 and reinforcement material was MgO_p and particles were dispersed in the matrix material and chemical composition as shown in below Table1 . The size of the MgO particulates dispersed varies from 5 to 8 µm.

Elements	Al	Si	Mg	Mn	Ti	Cu	Fe
%Wt	Bal	12	1.2	0.8	0.02	0.9	0.8

Table1 Chemical Composition of LM13 alloy

The MgO particulates were kindly provided by the chemical laboratory, Bangalore with an average particle size of 6 µm. the properties of MgO/LM13 was fabricated by stirrer die casting method with maximum 10% weight fraction by step of 2%. A perform comprising MgO particulates was made firstly. Then the perform preheated MgO particulates on the crucible surfaces up to 400^0c and molten metal of LM13 composites melted at 800^0c then stirrer is followed by 10-15 mins.in order to proper mixing of MgO particulates to the hot molten metal LM13 alloy composites, So molten metal pouring to the molten dies, then followed by the solidification for few hrs.The CTE measurement and thermal cycling test were performed by thermal expansion measurement equipment(Model TMA-400, ASTME831-04) Thermo Mechanical Analyzer. This test was carried out in central power research institute, Bangalore. The specimen standard dimensions are Φ8mm &12mm lengths are respectively. All the specimens were tested from 50^0c to 500^0c at 5^0c/mins temperature rise & supply nitrogen inert gas 50ml/mins for heated specimens instantly. The data were obtained in the form of PLC(percent linear change) v's temperature rise. The CTE of the composites testes & determined CTE value at every interval of 100^0c.

- *Ananda.G.K is currently pursuing masters degree program in Thermal power engineering in Sri Siddartha higher academy of education under UGC, India, PH-8050033180.E-mail: ananda_gk@rocketmail.com*
- *Ramesha.H is currently pursuing master degree program in thermal power engineering in Siddartha higher academic education under UGC, india,, Ph-.9845718319, E-mail: hmtramesh@gmail.com*

4 RESULT & DISCUSSION

4.1 Composite characterizations

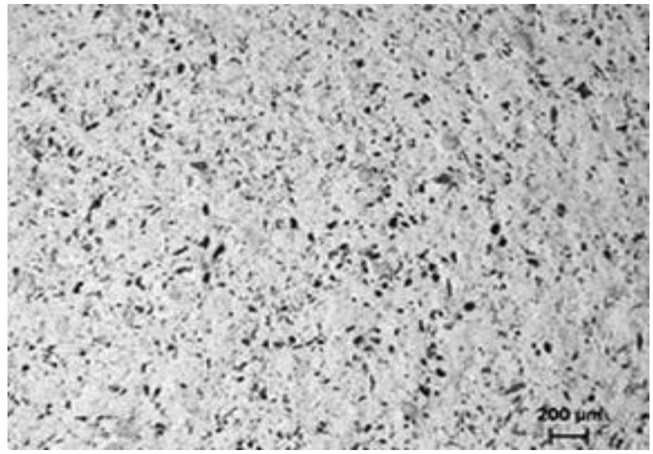

Fig.1 Microstructure of polished LM13/MgO composite

The representative SEM Micrograph of polished section of LM13/MgO particulates composites are as shown in below fig.1. It can be found that MgO particle clustering.However,some coarse particles were observed. Due to the high temperature employed during fabrication, the molten metal Al filled in the particle perform completely. So the composite material appeared to be free of porosity and macroscopically homogeneous.

4.2 Coefficient of thermal expansion

The thermal expansion results with the variation of temperature for the composites & matrix are shown in below fig.2. Its obvious that the CTE of the composites was only a half of that of matrix due to the addition of reinforcement with an increase in temperature. The LM13/MgO particulate composite is a two phase system composed of continuous LM13 Matrix & isolated MgO particulate each having different mechanical and thermal properties. So the thermal expansion behaviour of the composites *is* the results of the interaction between LM13 Matrix and MgO particulate through interfaces. Because of the tightened restriction of the particles, the CTE of the composites is much lower that of Matrix. The Matrix expands with increasing tem-

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perature on the other hand; the rise of temperature would reduce the transferring abilities of interface which makes the constraints of particles weaken. In the end, the CTE of the composites increases as the temperature goes up.

4.3 Comparsion of CTE among experimental & theoretical results

In order to understand the thermal expansion behaviour of the composite well, its important to compare quantitatively theoretical predictions with experimental results. But the CTE of Metal Matrix Composites is relatively difficult to the predict precisely because several factors. Such as volume fraction, morphology & distribution of the reinforcement, Matrix plasticity, interfacial bondage & internal structure of the composites may influence the results. In the case of particulate composites many researchers have given expressions for the CTE of composites. Among these expressions, the typical ones are rule of Mixtures (ROM), Turner's model & experimental work.

4.3.1 According to ROM, the CTE of the Composites is expressed as below

$$\alpha_c = \alpha_m v_m + \alpha_p v_p$$

4.3.2 Turner's model

The turner's model is based on the fact that only uniform hydrostatic stress exists in the phase & the CTE of a composites can be given below are

$$\alpha_c = \frac{\alpha_m V_m K_m + \alpha_p V_p K_p}{V_m K_m + V_p K_p}$$

K is the bulk modulus, which is calculated by the standard relationship is given by

$$K = \frac{E}{3(3 - \frac{E}{G})}$$

4.3.3 Experimental work

According to the thermal stress induced in the CTE of the composite bar is expressed as given below

$$\frac{\Delta L}{L_o} = \alpha . \Delta T$$

4.3.4 Physical properties of matrix & reinforced phasse

The numerical values of parameters needed in the computation of the CTE composite are extracted from relative references and summarized in the below Table.2.

Physical property	LM13 Alloy	MgO_p
Density (kg/m^3)	2.71	3.21
Thermal conductivity (w/m^0c)	141-167	38-45
Thermal expansion($\mu/^0c$)	22.5	11.5
Young modulus(Gpa)	72	249
Bulk modulus (GPa)	68	165

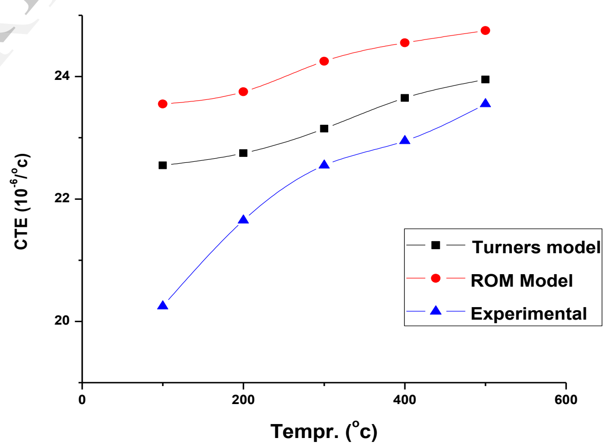

Fig.2.Comparison of CTEs among Experimental & Theoretical (ROM & Turners Model) results for MgO/LM13 Composites.

A comparison of the experimental and theoretical CTE values is presented in Fig.2. The experimental CTEs for entire higher temperature range show significantly deviation from ROM and Turner's model. This is not surprising because Turner's model is based on the fact that only uniform hydrostatic stresses exist in the phases, while the stresses inside the composite are very complex. So Turner's model does not describe the actual stress state in the composite. The result of the finite element method (FEM) indicated that particles with higher aspect ratio would give stronger constraint on the matrix .Therefore ,the predictions by Turner's model is a better fit at high temperatures than those of other models. This may related to the facts that it takes into account both the normal and shear stress in the matrix.

4.3.5 Thermal cycling behvoiur

The thermal strain response of the composite during cycling between 100^0c to 600^0c is shown in the Fig.2. The distinct features can be found from the Fig.2 as mentioned below

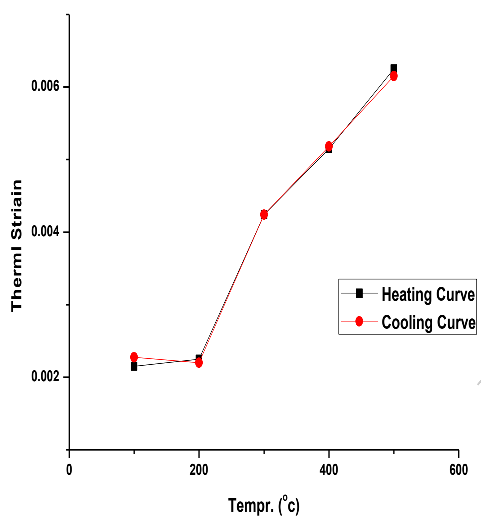

Fig.3.Thermal Strain response of the MgO/LM13 Composite during Cycling

(a)The existence of a distinct strain hysteresis can be found in the composite and the composite exhibits a large residual plastic strain after the cycle.

(b) There is a distinct inflexion in the heating curve of the composite. The strain hysteresis in the composites can be attributed to the stress state of the matrix. On cooling from the fabrication temperature, a tensile stresses exists in the matrix before the cycle because of the contraction mismatch between the matrix and reinforcement.During heating, the tensile stress present in the matrix helps to the expansion of the composites. With increasing temperature, the tensile stress is progressively relived. After complete relief of the tensile stress, a compressive stress starts to build up, opposing further expansion of the composite. This leads to a change in the heating curve, resulting in the existence of inflexion. However, because of the visco-plastic relaxation at the relatively high temperature, the build-up of a large compressive stress can be prevented. Upon cooling, the compressive stress, which assists in contraction, is relived quickly. Consequently, a tensile stress was engendered. When the tensile stress builds up sufficiently, tensile yielding occurs. So, the combined operation of the tensile and compressive stresses prevents superposition of the cycling curves, resulting in the observed strain hysteresis, and the effect of plastic and visco-plastic deformation is a tensile plastic strain at the end of the cycle.

4.3.6 UNITS FOR PHYSICAL QUANTITIES

Table 3

Symbol	Quantity	Units
α	*Thermal expansion of matrix,composite,particulate*	$1/^0c$
µ	*Micron*	10^{-6}mts
V	*Volume fraction of matrix,composite, Particulate.*	m^3
c,m,p	*Composite,matrix,particulate*	…..
T	*Temperature*	^0c
L_0	*Original length*	mts
ΔL	*Change in length*	mts
ϵ	*Thermal strain*	----
K	*Bulks modulus*	Gpa
E	*Young modulus*	Gpa
G	*Modulus of rigidity*	Gpa
ΔT	*Change in tempaerature*	^0c

5 CONCLUSIONS

(a) The CTE of LM13/MgO Composites is only a half of that of its Matrix.

(b) The CTEs of LM13/MgO Composites lie within the elastic bounds derived by Turner's

Model Analysis. At higher temperature, the CTEs agree well with Turner's Model, while the CTEs at elevated temperature are in the better agreement with the values predicted by (ROM) Rule of Mixtures.

(c)The composite exhibited strain hysteresis during cycling, which was attributed primarily to the anelastic behaviour of the matrix induced by thermal stresses, and the residual plastic strain after the cycle resulted from the combined effect of plastic & visco-plastic deformation.

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