EFFECT OF SIC PARTICLES ON THE COEFFICIENT OF THERMAL EXPANSION OF AL 6061 METAL MATRIX COMPOSITE

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ABSTRACT

Aluminium metal matrix composite (Al – MMC) finds extensive application in the field of electrical contacts, rocket nozzles, bearings and pistons. The coefficient of thermal expansion of this alloy with various percentage of SiC particles has not been studied in details. An investigation has been made for the change in coefficient of thermal expansion (C T E) of SiC reinforced Al 6061 metal matrix composite. The composite were prepared by the liquid metallurgy technique with varying percentages of SiC in steps of 10,20 and 30% by weight. This paper tries to bring the relationship between CTE and the temperature. An attempt has been made to study the CTE behavior of Al 6061-SiCp in the temperature range of 50^0 C to 500^0 C. The results shows the CTE significantly increased with increasing temperature.

Key Words*:* MMC, CTE

1. Introduction

Reinforced composites not only have high specific strengths and modulus at high temperatures but also have excellent wear resistant, high thermal conductivity, dimensional stability and low coefficient thermal expansion[1].Metal matrix composite have several other applications especially in automobile - piston,cylinder,drive shaft and rotor brakes[2].A diesel engine shows temperature profile of the piston area where the temperature has reached the higher level in the regions of the piston[3].The difference in the CTE between reinforcement and metal matrix has a predominant effect[4]. The linear CTE is defined as [5].Some authors[6-8]. have interpreted, a reduced CTE and increased thermal conductivity of metal matrix composite with addition of ceramic particle. The objective of the present investigation to study the thermal characteristics of MMC reinforced with SiC particles.CTE of MMC measured between the range of 50^0 C to 500^0 C by Thermal Mechanical Analyzer (TMA) model Q-400

2. Experimental Procedure

The castings has been prepared using liquid metallurgy technique. The Al 6061 –SiCp exhibits excellent casting properties with a good base metal characteristics. The chemical composition of the Al 6061 is given table 1. Silicon Carbide particles of 15μ m with a lower coefficient of thermal expansion,(4.5 X 10^{-6} / K) lower density and high strength (Mohr's hardness of 6 – 6.5) has been used in the present study. The chemical composition of SiC is given table 1. In the present study casting has been subjected to forging and heat treatment. The heat treatment cycle with 500^0 C for 5 hours with precipitation hardness of 160 – 170^0 C for 4 hours. The specimens for CTE tests were prepared with a dimension of 11 x 5 x 5 mm and the surface were polished with 1μ m diamond paste. Figure 1 shows Thermal Mechanical Analyzer (TMA) Q-400.Four samples of Al 6061-SiCp metal matrix composite were tested under the same the parameters to compare the reproducibility of the data[9]. CTE measurement has been performed from 50^0 C to 500^0 C at 5^0 C per minute using TMA Q-400.The test has been conducted as ASTM 831 – 03. CTE test was conducted under Nitrogen atmosphere and flow rate of 50 ml / min. Type of probe: expansion and force 0.02N.

Table 1: Chemical Composition of Al 6061 alloy (weight percentage)

Si	Mg	Cu	Fe	Mn	Zn	Cr	Ti	Al
0.68	0.85	0.22	0.32	0.07	0.005	0.06	0.02	Bal

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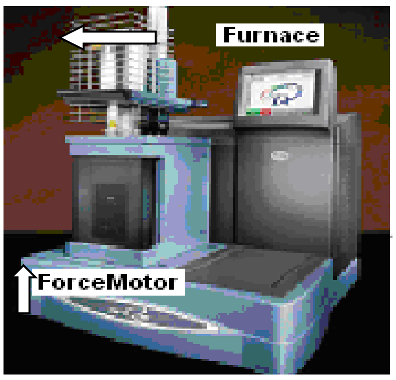


Fig.1 shows Q-400 Thermal Mechanical Analyzer (TMA)

3.Results and Discussions

The coefficient of thermal expansion of metal matrix composite have been expressed by different researchers[10 - 12]. Figure 2 shows the microstructure of Al 6061 with various percentage of SiCp. The base metal is cut to a size of 20 x 20 mm.The sections were prepared for optical metallography.Keller's reagent has been used.Figure 2a represents microstructure of Al 6061.Figure 2b shows 10% SiCp which are formed across the boundary line with a thin line formation. Figure 2c shows 20% SiCp which are uniformly distributed across area. The difference in CTE between aluminium and SiCp have yielded low CTE in case of Al 6061-20% SiCp.Figure 2d shows 30% SiCp which thickens the grain boundary.

Figure 3 shows the representation of graph with various percentage of SiC particle and the change in the dimension of metal matrix composite with respect temperature raise. The CTE has been noticed at a temperature range of 275^0 C, further as the temperature increases , there CTE decreases and α will be 16.01 μm / (m^0 C) as shown in figure 3 a for Al 6061 with out SiCp.

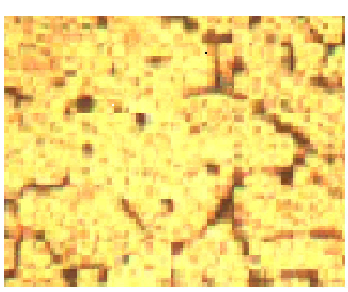


Fig.2 a Microstructure of Al 6061 MMC (Magnification 100x),

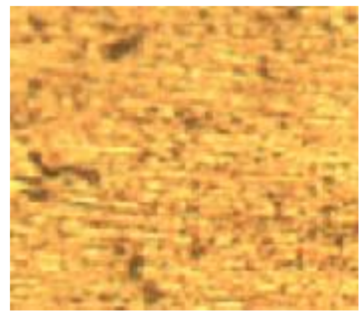


Fig. 2b Microstructure of Al 6061 MMC 10 % SiC particles, (Magnification 100x)

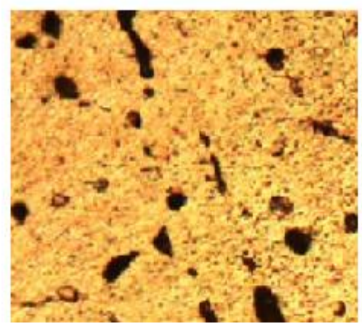
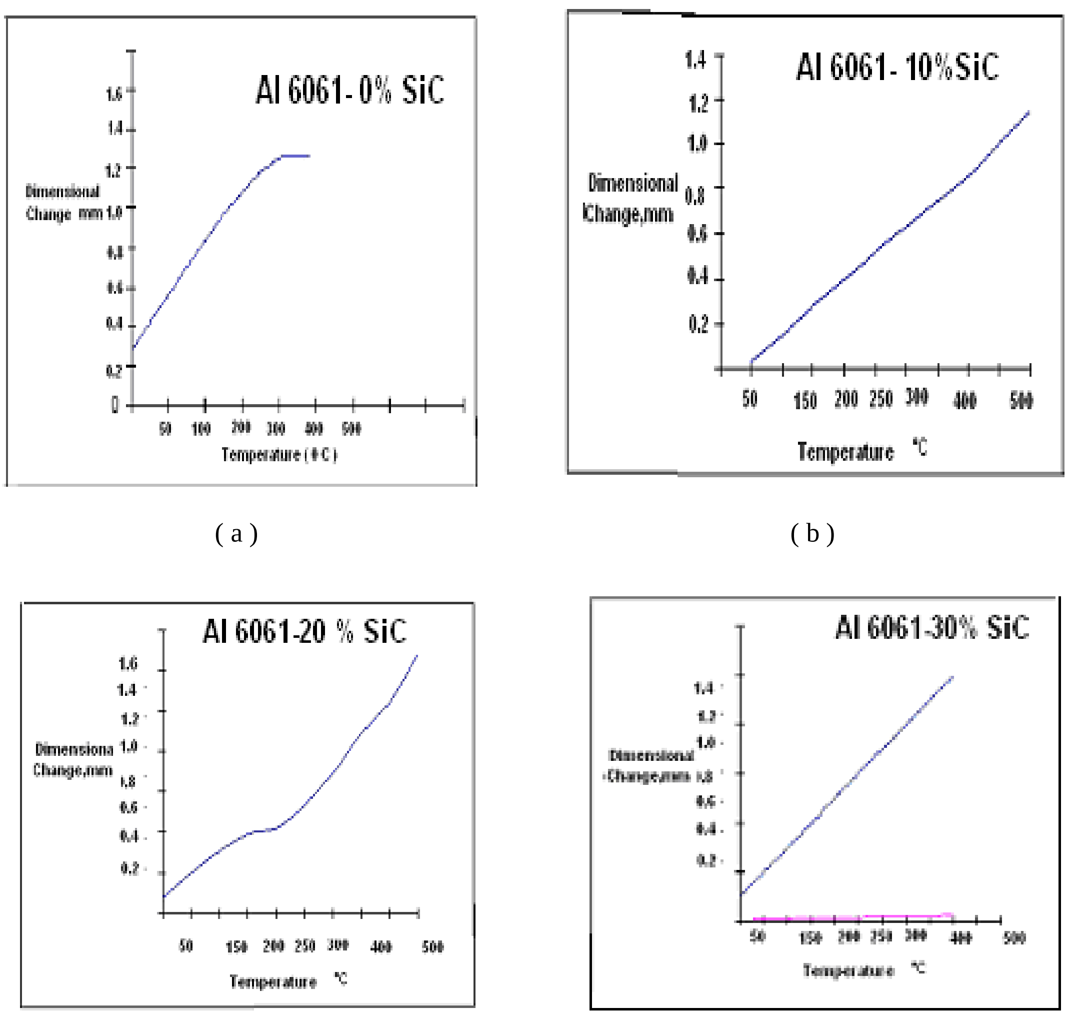


Fig. 2c Microstructure of Al 6061 MMC 20 % SiC particles, (Magnification 100x)

Fig. 2d Microstructure of Al 6061 MMC 30 % SiC particles, (Magnification 100x)

Figure 3 b indicates reasonable higher CTE and the vale of α at 275^0 C is recorded as 23.45 μm / (m^0 C).

Figure 3c implies higher CTE in the temperature of 50 - 200^0 C,at 275^0 C it was observed that a slightly lower CTE[13] and a tendency of consistency has been noticed, this attributes to the percentage of SiC particles in MMC.



(a) (b) (c) (d)

Fig. 3 shows the graph of dimensional change and Temperature of (a) Al 6061, (b) Al 6061- 10% SiCp, (c) Al 6061-20 % SiCp and (d) Al 6061-30 % SiCp

Table 2 : Coefficient of Thermal Expansion of Al 6061/ SiCp MMC

Temperature (^{0} C)	0% SiC (10^{-6} K^{-1})	10% SiC (10^{-6} K^{-1})	20% SiC (10^{-6} K^{-1})	30% SiC (10^{-6} K^{-1})	CTE of SiC 10^{-6} □ K
50	20.51	16.88	18.22	19.88	4.5
100	21.56	17.56	17.65	20.11	4.5
150	22.34	18.56	17.98	22.32	4.5
200	23.66	20.22	18.65	23.59	4.5
250	18.09	22.55	21.00	24.78	4.5
300	24.87	23.01	23.07	24.90	4.5
350	25.00	24.45	24.54	25.10	4.5
400	26.22	25.32	26.18	27.63	4.5
450	27.09	27.06	28.02	26.00	4.5
500	27.61	26.54	26.00	28.30	4.5

Operating at higher temperature the CTE in case of Al 6061-20% SiC has shown slower rate of dimensional change as seen in figure 3 c. As the percentage of SiC increases to 30%,the value of CTE increases linearly as shown in figure 3 d.Table 2 shows the coefficient of thermal expansion of Al 6061/ SiCp metal matrix composite.The results of the CTE of various weight percentage of SiC reinforced composites are shown in Table2. It has been observed that a drastic reduction in CTE of the composite in comparison with that of the matrix alloy, which indicates a good interfacial bonding due to the existence of macroscopic strain. CTE of SiC particles are lower than Al 6061,hence contributes for lower tendency of CTE in MMC.

4. Conclusions

The Al 6061 – SiCp metal matrix composite with various weight percentage from 10 – 30% could be successfully produced by liquid metallurgy technique. The rate of increase in the coefficient of thermal expansion is gradual up to 300^0 C and rapid till 500^0 C.The CTE decreases with increase in SiC (10 and 20%) and increases in 30% SiC, the reason being the lack of wettability during the casting process and thermal strain increases with increase in temperature.

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