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Investigation of Mechanical Properties of Aluminium Based Powder Metallurgical Composites Reinforced With Sic& Al2O3

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Abstract: *Present study is focused on the fabrication of Aluminium 2024 based Powder Metallurgical composites, Reinforced with silicon carbide and Al2O3 by Powder Metallurgical technique. The percentage of one reinforcement particulate is kept constant and varying other and vice versa, namely types I and type II composites. The various mechanical tests like Density test, Porosity test, hardness test and Compressive strength performed on the samples obtained by Powder Metallurgical technique for comparison purpose. The result indicated that the developed method is quite successful and there is an increase in the value of hardness value and Decreased in Corrosion, Density and Compressive Strength*

Keywords: *Aluminum 2024, SiC, Al2O3, Powder Metallurgical technique, Mechanical properties*.

I. Introduction

Aluminum alloys are widely used in automobile industries and aerospace applications due to their Great mechanical properties, low density, low coefficient of thermal expansion, better corrosion resistance and wear as compared with conventional metals and alloys. The low production cost and better mechanical properties of composites makes them very useful for various applications in many areas from technological point of view. The reinforcements Al2O3 and SiC enhance the density of the base alloy when they are added to the base alloy to form the composite. Moreover, the theoretical density values match with the measured density values of these composites. Further, Miyajima et.al. [1] Reported that the density of Al2024-SiC particle composites is greater than that of Al2024-SiC whisker reinforced composites for the same amount of volume fraction. From the above the increase in density can be reasoned to the fact that the ceramic particles possess higher density. Further, the increased volume fraction of these particles contribute in increasing the density of the composites, also they have stated that the theoretical and measured density values of these composites match to each other. Additionally, the above discussions can be reasoned to the fact that the ceramic particles possess higher density. The Al6061-SiC and Al7075-Al2O3 particulate reinforced composites were developed by Powder metallurgy technique. The cast alloy and composite specimens were subjected to density test by using Archimedes ‘Principle and another being the rule of mixture, the obtained results [2]. Among the variants of reinforcements, the low aspect ratio particle reinforcements are of much significant in imparting the hardness of the material in which they are dispersed (the hardness of fiber reinforced PMC < whisker reinforced PMC < particle dispersed PMC) [1]. The particulate reinforcements such as SiC, Al2O3 and aluminide [3-4] are generally preferred to impart higher hardness. The coating of reinforcements with Ni [4] and Cu [5], also leads to good quality interface characteristics and hence contribute in improving hardness. TiC when dispersed in Al matrix, increases the hardness to weight ratio. Moreover, it imparts thermodynamic stability to the composites [6-7]. Abdulhaqq et.al. [10-13], explored the significance of hard ceramic particles in increasing the bulk hardness of Al- PMCs. Howell et.al. [12] Reasoned the improvement of the hardness of the composites to the increased particle volume fraction. [15-16] attributed this increase in hardness to the decreased particle size and increased specific surface of the reinforcement for a given volume fraction. Deuis et.al. concluded that the increase in the hardness of the composites containing hard ceramic particles not only depends on the size of reinforcement but also on the structure of the composite and good interface bonding [16]. The micro-hardness is a direct, simple and easy method of measuring the interface bonding strength between the matrix and reinforcement [17]. From the application point of view, the mechanical properties of the composites are of immense importance. The modified rules of mixture proposed by several researchers [18] are effective in predicting upper and lower bound values of the modulus and strength properties of the composites. An optimized combination of surface and bulk mechanical properties may be achieved, if Al-PMCs are processed with a controlled gradient of reinforcing particles and also by adopting a better method of manufacturing [19]. Although there is no clear relation between mechanical properties of the composites, volume fraction, type of reinforcement and surface nature of reinforcements [14], the reduced size of the reinforcement particles [20] is believed to be effective in improving the strength of the composites.

The structure and properties of the reinforcements control the mechanical properties of the composites. Increase in elastic modulus and strength of the composites are reasoned to the strong interface that transfers and distributes the load from the matrix to the reinforcement [18]. Further, the improved interface strength and better dispersion of the particles in the matrix can also be achieved by preheating the reinforcements [17]. The strength of SiC, Al2O3, TiC [9], and TiB2 particulate reinforced Al-PMCs is found to increase at the cost of reduced ductility, by increasing the volume percentage of ceramic phase and by decreasing the size of the reinforcement in the composite [19-20]. In general, the particle reinforced Al-PMCs are found to have higher Hardness[21].

II. Material Used

Aluminum alloy 2024 is a medium to high strength heat-treatable alloy with strength higher than 2005. It has very good corrosion resistance and very good weld ability although reduced strength in the weld zone. It has good cold formability in the temper T4, but limited formability in T6 temper. Not suitable for very complex cross sections.

. **Table2.1** Chemical Composition of AA2024

Elements	Al	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn	Remaining
AA2024	94.7	0.1	4.9	0.5	1.8	0.9	0.5	0.15	0.25	0.20

2.1.Reinforcing material:

In the present investigation Silicon Carbide and alumina were used as reinforcing elements. Alumina or Al2O3 (Young's Modulus = 375 GPa, poison ratio = 0.21) is easily available, cost effective ceramic reinforcement, having good thermal properties so that it could be used as refractory material. The strong ionic inter-atomic bonding imparts excellent dielectric properties and higher hardness, higher strength and higher stiffness. Silicon Carbide or SiC (Young's Modulus = 410 GPa, poison ratio = 0.19) Al2O3 has moh's hardness of 9-9.2, nearly equal to that of SiC. It remains inert to many chemical solutions and does not have any sharp melting point, although it softens at a temperature range of 1140-1280 °C. Among many ceramic materials, SiC and Al2O3 are widely in use, due to their favorable combination of density, hardness and cost effectiveness. When these reinforcements are combined with Al-PMCs, the resulting material exhibits significant increase in its elastic modulus, hardness.

III. Experimental Methodology

The Aluminium 2024 alloy based ceramic reinforced composites were designed as per Table 3.2, amounting to 100% by weights and prepared using Powder Metallurgical technique Powder compaction is the process of compacting metal powder in a die through the application of higher Loads. Typically the tools are held in the vertical orientation with the punch tool forming the bottom of the cavity. The powder is then compacted into a shape and then ejected from the die cavity. In a number of these applications the parts may require very little additional work for their intended use; making for very cost efficient manufacturing. The density of the compacted powder is directly proportional to the amount of Load applied. Loads 40KN to 100KN are commonly used for metal powder compaction. In this Al2024 Alloy Powder consist of Grain size 40 microns

Table 3.1 Design of fabricated ceramic particulate filled Al6061 alloy composites

Composites	Material	%wt of Reinforcement		
PMMCs-I	AA2024	49.2	51	52.8
	SiC	4.5	3.6	2.7
	Al_2O_3	1	1	1
PMMCs-II	AA2024	54.6	56.4	58.2
	SiC	1	1	……..

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Fig 3. Shows applying a load 40KN by using UTM

3.1 Sintering:

Sintering is thermal treatment of fine-grained material at a temperature below the melting point of the main constituent, for the purpose of increasing its grain size and strength by bonding together the particles. Theories about what happens exactly during sintering have provided the subject matter of innumerable conferences and learned scientific papers. Suffice to say that atomic diffusion takes place and the welded areas formed during compaction grow until eventually may be lost completely. Re-crystallization and grain growth may follow, and the pores tend to become rounded and the total porosity, as a percentage of the whole volume, tends to decrease. We have maintained a sintering temperature range 480^0c. During this process we have used Argon Gas Cylinder to avoid In-Organic Gases are formed in Muffle Furnace. When material reaches to 480^0c we are waiting for 1hr.setup shown in figure

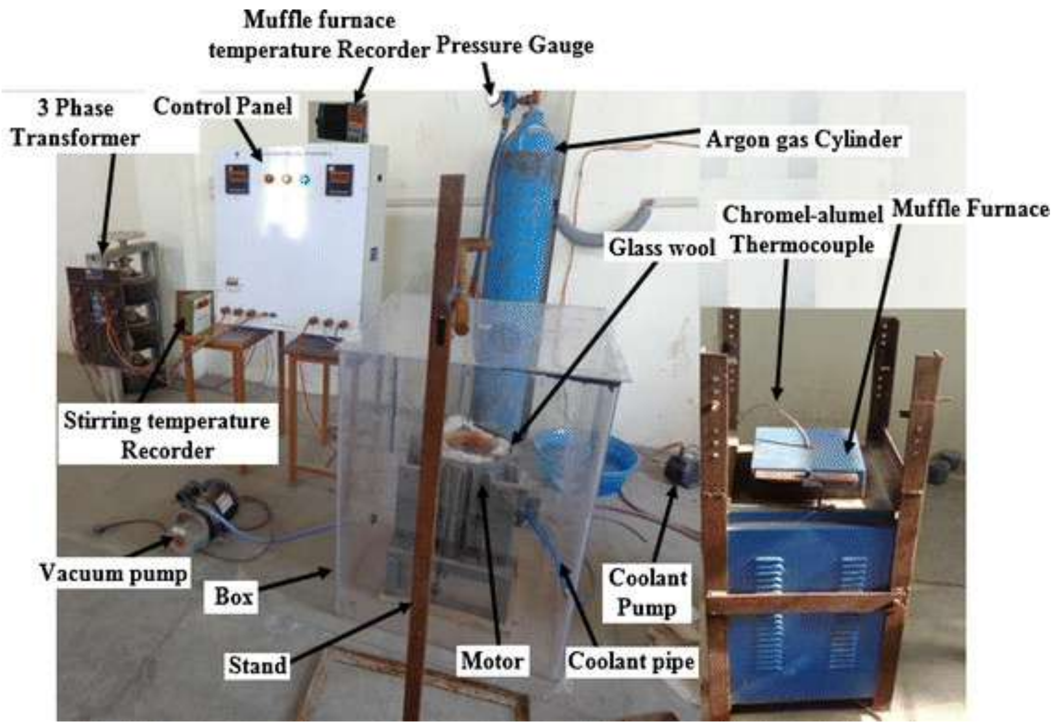


Fig3.1 Shows Muffle Furnace Setup

IV. Mechanical Testings

4.1 Hardness Test

The term micro hardness test usually refers to static indentations made with loads not exceeding 1 kgf. The indenter is either the Vickers diamond pyramid or the Knoop elongated diamond pyramid. The procedure for testing is very similar to that of the standard Vickers hardness test, except that it is done on a microscopic scale with higher precision instruments. The surface being tested generally requires a metallographic finish; the smaller the load used, the higher the surface finish required. Precision microscopes are used to measure the indentations, these usually have a magnification of around X500 and measure to an accuracy of +0.5 micrometres. Also with the same observer differences of +0.2 micrometres can usually be resolved. It should, however, be added that considerable care and experience are necessary to obtain this accuracy Specimens are prepared as per ASTM ISO2811.

A

B

Fig 4.1 A) Samples B) Micro-Vickers Hardness Tester

4.2 Density& Porosity

Density is measure of mass per unit volume .it is measured by using Archimedes principle, the object is prepared by using ASTM ISO2811 Standards. When object is immersed in liquid, difference between two masses (in grams) will equal (Almost Exactly)the volume(in ml)of weighted, knowing the mass and object allows us to calculate the density test carried out with a setup and specimen shown in figure 4.2A &B.

Formulae used for Density test is Density= (Mass/Volume) g/cc

Porosity: PMMC= (m)/ ((m-m1) × ($\rho H2o$)

m :Mass of composite in Air in grams

m1=Mass of same composite in distilled water and density of distilled water 0.998g/cm^3 .

According to rule of mixture theoretical calculations can be done by using formulae $\rho c = vr\ \rho r + (1-vr)\ \rho m$

Where

ρc =Density of composite

vr =Weight ratio of reinforcement

ρr =Density of reinforcement

ρm =Density of Unreinforced AA2024

Porosity= (1-(measured/calculated)) × 100

A

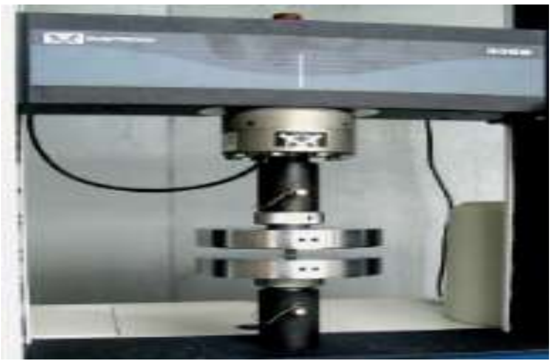
B

Fig4.2 .A) Samples B)Density Test Setup

4.3 Compressive Test:

Compressive test carried out by using UTM (Universal Testing Machine) and sample is prepared ASTM ISO2811 as shown in fig.4.3 A&B, when a sample is placed in between two plates and compression done up to 9mm then load is applied in upward direction then sample is shorten in the direction of applied forces and expands in the direction perpendicular to the force. Compression test is essentially the opposite of the more common tension test.

A



B

Fig 4.3: A) Compressed Samples B) Compression of Sample under UTM

4.4 Corrosion Test:

Salt spray testing was conducted in accordance with ASTM ISO2811. This practice provides a controlled corrosive environment that has been utilized to produce relative corrosion resistance information for specimens of metals exposed in a test chamber. After Spraying samples are immersed in CUSO45H2O(Copper Sulphate Pentahydrate) solution and the we are going to see the samples after 7 days and 21 days as shown in figure 4.4A & B.

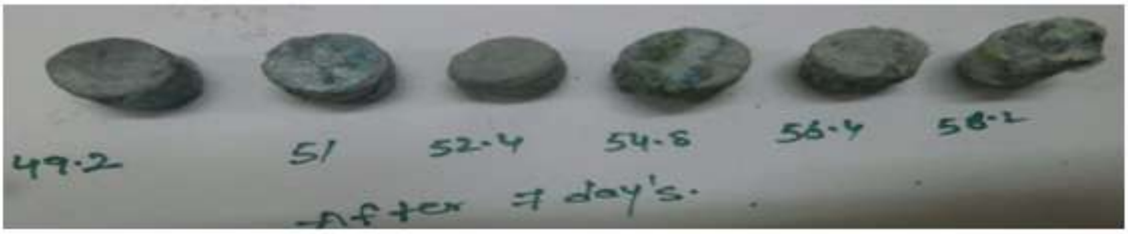


Fig4.4A. Corrosion Test Samples after 7 Days

Fig4.4B.Corrosion Test Samples after 21 Days

V. Results & Discussion

5.1 Effect of Type-I AA2024 composites on density & void fraction

From the Table 5.1 below, it can be observed that the density of the composite is higher than the base matrix. Also, the density of the composites increased with increase in filler content by addition 3.6%SiC & 1% Al2O3. Further, the theoretical and experimental density values are in line with each other. The increase in density of composites can be attributed to higher density of reinforcement particles. The results of the several investigations regarding the density of the Al2O3/ SiC particle reinforced AA2024 and other aluminum alloys can be summarized as follows: the reinforcements Al2O3 and SiC enhance the density of the base alloy when they are added to the base alloy to form the composites.

Table 4.1 Density & Void of composites using by experimental and analytical result

SiC+Al2O3 Filled AA2024 Composites	ρth (gm/cc)	ρexp (gm/cc)	Void
AA2024+ 4.5%SiC+1%AL_2O_3	2.78	2.73	0.01798
AA2024+ 3.6%SiC+1%AL_2O_3	2.89	2.82	0.0248
AA2024+ 2.7%SiC+1%AL_2O_3	2.972	2.92	0.0178

5.2 Effect of Type-I AA2024 composites on hardness

The Table 5 .2 presents hardness characteristics of said composites as evaluated experimentally. The hardness reveals that its magnitudes improve (linearly) appreciably with appreciation in the content of silicon carbide and alumina ceramic reinforcement relative to AA2024. It can be observed that the hardness of composites were 4.2 %, 17.6% and 22% greater than that of its base alloy. This may be attributed to presence of harder silicon carbide and alumina ceramic phases then AA2024 phases in the composite. Abdulhaqq et.al. , Hutchings and Lloyd et.al. , explored the significance of hard ceramic particles in increasing the bulk hardness of Al-PMCs. Vencl et.al. reasoned the improvement of the hardness of the composites to the increased particle volume fraction.

Table 5.2 Hardness of (SiC+Al2O3) filled AA-2024 composites

(SiC+Al2O3) filled AA-2024 Composites	Hardness (HV)
AA2024	60
AA-2024+ 4.5%SiC+1%Al_2O_3	70.56
AA-2024+ 3.6%SiC+1%Al_2O_3	80.89
AA-2024+ 2.7%SiC+1%Al_2O_3	84.57

5.3 Effect of Type-I AA2024 composites on Compression

The Table 5 .3 presents compression characteristics of said composites as evaluated experimentally. The compression reveals that its magnitudes improve (linearly) appreciably with appreciation in the content of silicon carbide and alumina ceramic reinforcement relative to AA2024 alloy. It can be observed that the compression of composites were 4.2 %, 17.6% and 22% greater than that of its base alloy.

Table 5.3 Compression of (SiC+Al2O3) filled AA-2024 composites

SiC+Al2O3) filled AA-2024 Composites	Compression (KN)
AA2024	6
AA-2024+ 4.5%SiC+1%Al_2O_3	6.5
AA-2024+ 3.6%SiC+1%Al_2O_3	7.28
AA-2024+ 2.7%SiC+1%Al_2O_3	8.02

5.4 COMPARISON OF MECHANICAL & PHYSICAL PROPERTIES BETWEEN PMMCSI AND PMMCS-II:-

It is observed that from the Figure 5.4.1 density of both AA2024 composites material increases with increasing volume fraction of ceramic particle in matrix materials. In PMMCs-II density of reinforcing AA2024 composite greater than the PMMCs-I.

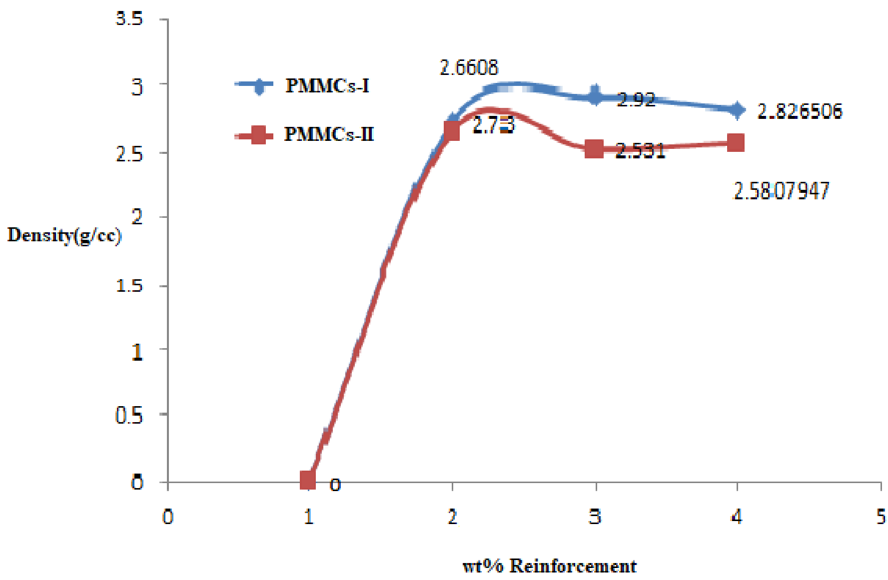


Fig. 5.4.1 Comparison of Density in both PMMCs-I and PMMCs-II

The results show in Figure 5.4.2 that the hardness varies linearly with volume fraction in both the PMMCs-I and PMMCs-2 conditions. However, the effect is about 44%greater for the material in the PMMCs-I as comparative to PMMCs-II addition of 22% and 4% ceramic particle addition respectively.

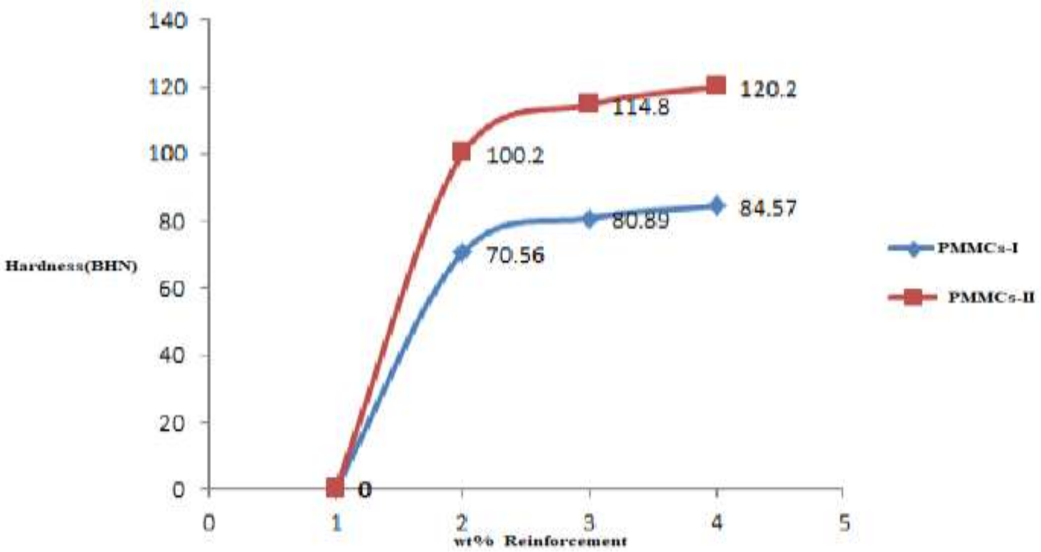


Fig. 5.4.2 Comparison of Hardness in both PMMCs-I and PMMCs-II

The results show in Figure 5.4.3 that the Compression varies linearly with volume fraction in both the PMMCs-I and PMMCs-II conditions. However, the effect is about 12%greater for the material in the PMMCs-I as comparative to PMMCs-II addition of 3% and 5% ceramic particle addition respectively.

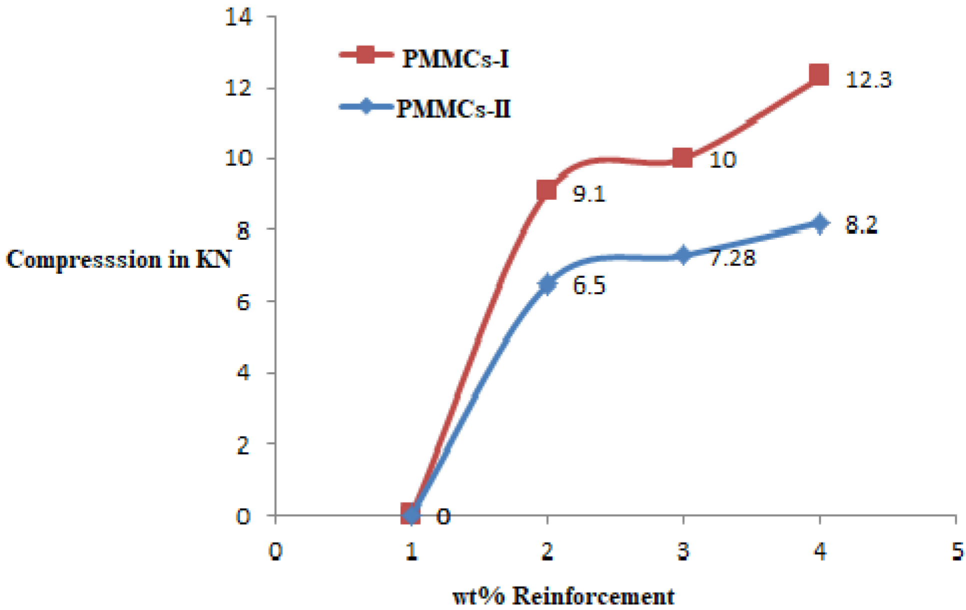


Fig. 5.4.3 Comparison of Hardness in both PMMCs-I and PMMCs-II

VI. Conclusions

The significant conclusions of the studies carried out on SiC & Al2O3 filled Al6061 alloy composites are as follows.

1. Cast SiC & Al2O3 filled AA2024composites were prepared successfully using conventional casting techniques. Density found increasing with increased SiC and Al2O3 content.
2. Hardness of the SiC & Al2O3 filled AA2024 composites found increased with increased ceramic particulates content. Finer the grain size better is the hardness.
3. Compression of the SiC & Al2O3 filled AA2024 composites found increased with increased ceramic particulates content. Finer the grain size better is the Compression.

Corrosion Resistance of Material is Fine by increasing the SiC & Al2O3 filled AA2024 composites found increasing with increased reinforcements in the composites.

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