Experimental Investigation of tribological and mechanical properties of AL5052/SiC MMCs processed by powder metallurgy technique

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Abstract - ***Metal matrix composites have created distinct interest as of late adding to the strength to weight proportion, stiffness, good ductility, excellent corrosion resistance, availability & fatigue properties over that of conventional engineering materials. This is the reason past the extended requirement for advancement of composites with unique properties. Powder metallurgy is one such ideal method for production of MMCs because of the capability of process to produce near net shapes with minimal material waste associated with production. Tribological and mechanical properties have a noteworthy part in production of mmc's utilized extensively in automotive and aviation industries.***
Present investigation is an attempt made to disperse nano sized silicon carbide particles in Al 5052 base alloy by powder metallurgy technique and study its effect on wear properties of Al 5052 alloy. Addition of silicon carbide particulate reinforcement has been varied from 5% 10% & 15% by weight of base alloy. Powder metallurgy composite specimens fabricated were machined according to test standards the tribological and mechanical properties has been examined and compared with that of base material Al5052 alloy significant improve in wear properties, hardness is noticeably with increased volume wt% of silicon carbide. Compression strength were better for 5% SiC reinforced AL5052 and 15% SiC reinforced AL5052 showed better wear resistance properties. the mechanical and tribological behaviour of prepared composites showed better characteristics than that base of base material.

Key Words: *Metal matrix composites, powder metallurgy, Aluminium 5052 , Silicon carbide, wear characteristics, taguchi approach*.

1. INTRODUCTION

Composites are combination of two or more diverse materials, the property resulted by combination of these materials are not obtained by individual or conventional materials. There are many types of composite materials, out of all these MMCs fabricated by powder metallurgy principle have seen lot of advancements in its research due to their superior properties which can be used for engineering applications where there is need for light weight, good strength, stiffness with less density etc. in comparison with poly matrix and ceramic matrix composites.

The interaction of two ingredients results a composite material which is significantly stronger than altogether or one . Many of the shaping of metal objects without melting i.e, powder metallurgy principle of forming the metals were found to be practiced in the earlier civilizations. Egyptian iron components were found to be in use as early as from 300 bc. in Greece production of iron parts were broad in 800 - 600 BC. The significant development of adapting powder metallurgy principle to manufacture composite were advanced during the earlier years of 19th century the credit of advancements in adopting powder metallurgy technique is to be given for industries in England and Russia. These advancements ultimately led to revolution in powder metallurgy technique by the introduction of different types of fabrication methods in the prior years of 20th century with production of tungsten filaments which was used in incandescent lamp production sectors.
Composites industries are consistently evolving, The utilization of MMCs achieved by processing of garnets, piezoelectric materials& shape memory alloys for electronic industries. Aluminium alloys,
super alloys, beryllium and titanium alloys are used in spacecraft, high temperature missile applications of aerospace industries and in production brake pads and brake shoes in automobile applications due to their specific properties and strength set to replace commercially available metal parts in many applications.

2. FABRICATION OF MMCs BY PM TECHNIQUE

Based on literature review, it is concluded that powder metallurgy method of the solid phase processing methods serves better than other process The matrix material Al5052 powder was commercially available in fine powder form size varying from 70µm to 100µm and reinforcing material silicon carbide is subjected to ball milling technique to get nano scale reinforcement material

The fabrication of components by powder metallurgy procedure involves the following steps in sequence

- Production of metallic powders
- Blending of powders
- Compaction of powders
- Sintering
- Secondary machining operations
- Finishing and inspection

2.1 Die Design & Fabrication

In order to fabricate the specimen by powder metallurgy technique its required to fabricate die. Based on calculations of pressure to be applied and specimen dimension die was designed, calculations reveals that required pressure is 600Mpa which accounts for 250kN load. therefore designed die and punch assembly should have capacity has mentioned. As per the analysis made the results shows that Die design is good and it is safe for conducting.

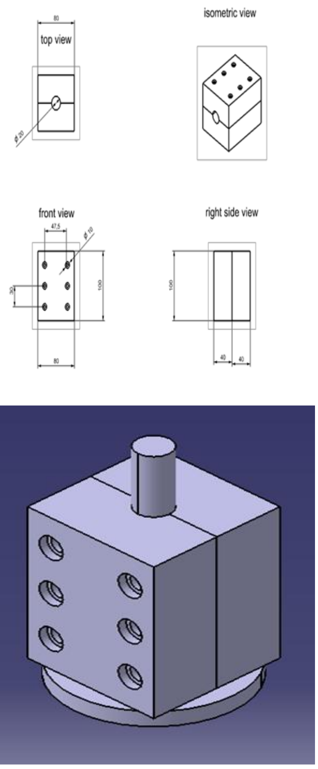

Figure 1: Design of die

2.2 Blending of powders

The MMC test specimens are fabricated by the powder metallurgy technique by implementing the standard mixing and solid state sintering .Total four categories of mixtures were prepared with varied wt% of silicon carbide in 5% , 10% & 15% in AL5052 wt% powder respectively. The powders were mixed according to the required volume fraction.

2.3 Preparation of green compact

Powder is filled in to the die cavity and punch is placed in top of cavity and the die punch assembly is placed in compression testing machine. Compacting of powders done by uniaxial compression testing machine as shown in below figure. The blended powders are compacted by applying load up to 200 KN. After compacting the load is released. The die assembly is displaced from the CTM and the die is dissembled in to two halves and the compacted specimen (Green compact) is ejected from the die cavity carefully.

2.4 Sintering

In present study compacted specimen was sintered by setting sintering temperature to 500˚c which was about 80% of melting temperature of AL5052 (base material). temperature of furnace starts increasing from 0 to 500^{0}c at the rate of 3^{0}C/ min. It takes approximately 2 and a half hours to reach 500^{0}C and compacts are holded for 2 hours & cooled to room temperature. In this time period and at this temperature bonding between powders takes place by inter diffusion and this provides necessary strength for specimen. The sintered specimen is harder and denser than the previous one.

Then thus prepared specimens were machined according to ASTM standards to conduct various type of tests.

3. RESULTS & DISCUSSIONS

3.1. Hardness test

Hardness may be defined as resistance to bending, scratching, abrasion or cutting. Hardness test was carried out using Rockwell hardness testing machine. Instrument has diamond indentation.

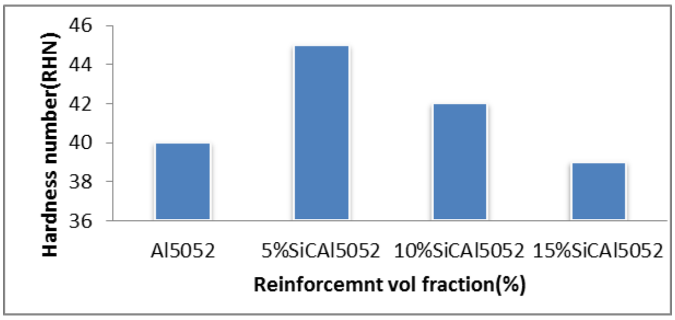

Figure 2 : Variation of Hardness number with volume fraction

Surface hardness value goes on varying from utilized Al 5052 alloy to the different percentage of SiC particles filled composite and these composites shows higher results than base material hardness value in certain percentage reinforced and shows lower hardness value when we goes on increasing from certain volume fraction percentage. The reason for variation in hardness value is mainly due to the presence of ceramic particles. In present test hardness value increases till 5% SiC-AL5052 with successive decrement in hardness value followed by 10% SiC-AL5052 & 15% SiC-AL5052. This results shows that optimum percentage of SiC can be used as reinforcement is 5% above this material may become ductile showing lesser hardness value. Base material without filler that is Al 5052 alloy is more brittle than 15% SiC-AL5052.

3.2 Compression test

Compression test for fabricated specimen was carried out using servo hydraulic testing machine. Compression plate fixtures are used to do compression test having crosshead speed of 0.5mm/min and test specimens are prepared according to the ASTM E9-89 standard. Figure shows machine and specimens.

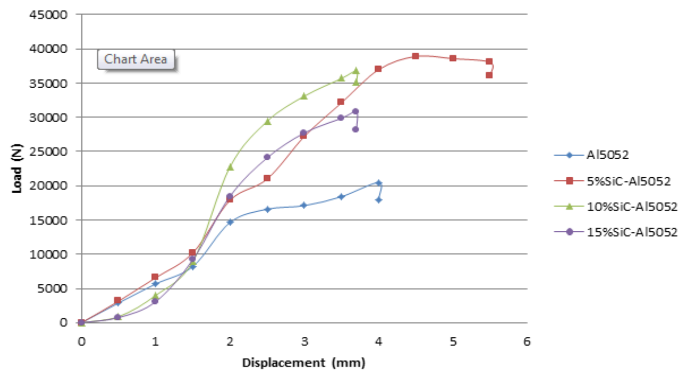

Figure 3: Variation of load with displacement

Figure 3 shows the variation of displacement with increase in load on the specimen for different specimens. The results and plot shows the variation in compressive strength of Al 5052 with different percentage of SiC. Up to 5% of SiC reinforcement its strength is high and strength is steady slightly decreased for 10% of SiC reinforcement had more strength than unreinforced Al5052. Then at at 15% ofSiC reinforced composite shows lesser compressive strength in comparison with all compositions. Increasing the reinforcement leads to decrease in its strength after 5% to 10% of reinforcement, therefore the results reveals that Al 5052 with 5% SiC possess the better compressive nature compare to other compositions.

3.3 Tribological test

In the present study we are concentrated just on the wear conduct of MMC. Consequently the test directed was two body abrasive wear test and Taguchi test method is selected for the specimen. Wear is portrayed as mischief to a strong surface, all around including dynamic loss of material, as a result of relative movement between that surfaces and relating to substance or substances. Hence the test conducted was two body abrasive wear test and taguchi test on the selected samples

3.3.1 Two–Body Abrasive Wear test behavior

Two–Body Abrasive Wear test behaviour was carried out to determine the wear characteristics. The wear test was conducted for different compositions of reinforcement and the wear volume results are evaluated and listed in table1

Abrading Distance(m)	Wear volume (mm³)			
	Al 5052	Al 5052+ 5%SiC	Al 5052+ 10% SiC	Al 6061+15%S
250	0.0354	0.0301	0.0287	0.0259
500	0.0552	0.0519	0.0492	0.0456
750	0.0925	0.0898	0.0876	0.0798

Table 1: Wear volume results

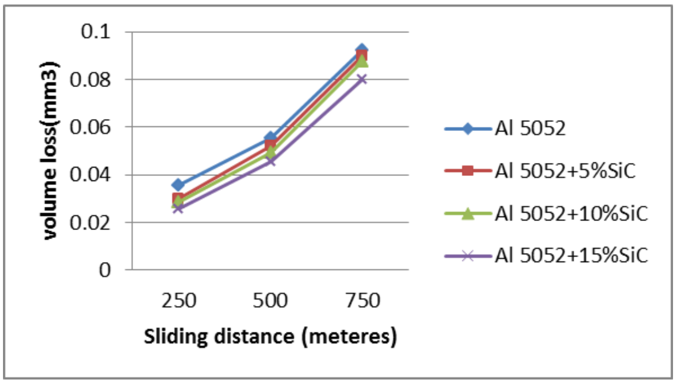

Figure 4: Specific wear rates for 20N load

The above results shows that with increase in the reinforcement volume fraction consequently wear resistance increases and is better than that of base material AL5052 & 15% SiC shows the better wear resistance properties in comparison with other composition and base material because of relatively lesser specific wear rate.

3.3.2 Taguchi approach

Taguchi started to generate new methods for optimization of engineering experimentation. He obtained that the suitable method to enhance quality was to create and produce it into the product. He introduced the unique methods which are now called as Taguchi Methods. His main conclusion does not lie in mathematical formulation of creating experiments but was his different method of approach. His method of approach produced unique and superlative quality results that changed from rational approach. He produced a component which rigid and does not changes with environmental factors. He derived to conclusions from his three different thought.

The wear behaviors of components are determined by conducting different set of experiments. The parameters chosen are speed of the rotating disc, Pan loading, material combination; wear distance traversed by the specimen. The variations of the wear results for the conducted specimens are as shown in the table below

The experiments were performed based on the levels and factors chosen for orthogonal array. In experiments conducted an L_9 orthogonal array was chosen. The condition of wear factors are material with three different levels and load and three different speed levels and different abrading distance. The results for the experiments conducted are as shown in the tables below.

L_9 array with output results

*Material 1- Al5052-5%SiC, 2- Al5052-10SiC%, 3- Al5052-15%SiC

Level	material	load	speed	distance
1	15.11	16.31	16.25	17.76
2	16.79	16.54	17.91	15.81
3	17.82	16.86	15.55	16.15
Delta	2.71	0.55	2.36	1.95
Rank	1	4	2	3

Signal to noise: Smaller is better

Table 2: Wear response for signal to noise ratio

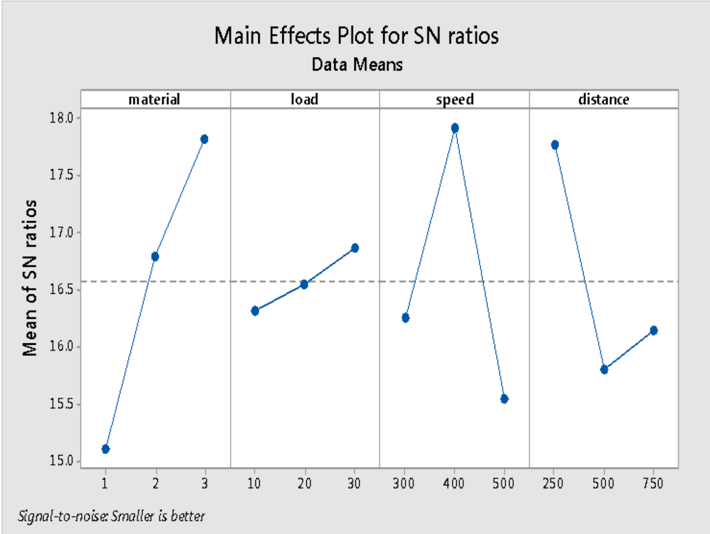

Figure 5 :Wear response plot for Signal to Noise ratio of test specimens

Wear parameters were analyzed using the software Minitab version 17 to find out predominant parameters that control the wear. The parameters selected were speed of the rotating disc, Pan loading, material combination; wear distance traversed by the specimen based on the plots of signal to noise ratio and the ranked components on those values for each parameter. From the analysis of the wear parameters based on the results from Taguchi technique it concludes that material of the component is primary factor that play important role in wearing of the specimen next important role is played by speed followed by load on pan, the distance traversed by the specimen shows least effect on the wearing of the component. From the plots of SN ratio we can observe that for material condition 3, speed of rotating disc 400rpm, the traversing distance of 250m and pan loading of 30N shows the least wear.

4. CONCLUSIONS

The fabrication and experimentation of aluminium alloy Al5052 reinforced with varied volume fractions of silicon carbide (SiC) succesfully synthesised by using powder metallurgy technique. The results of the test conducted were tabulated and results are compared.

The following conclusions can be drawn from this attempt

1.Al 5052 alloy MMCs reinforced with different volume fractions or weight percentages of SiC particles (5%, 10% & 15%) have been commendably fabricated by powder metallurgy method. The optimum condidtions of production process were that compacton load accounted is 200 KN with sintering time of 90 minutes at temparature of 500°c.

2.The hardness test results reveal that with slight increase in the reinforcement weight fractions. i.e., For 5% SiC volume fraction of reinforcement material hardness has increased considerably to that of base alloy metal and with additional increase in SiC volume fraction hardness has been decreased in comparison with 5% weight percentage.

3. The compression tests results reveal that compression strength increase in weight fractions in comparison with compressive strength of Al5052 base material. Compression strength for 5% SiC is more and it was approximately same till 10% SiC volume fraction and compression strength is reduced for 15% SiC may the material become brittle during this composition.

4. From two body wear test results it can be concluded that hhigher wear resistance was found in 15% Silicon carbide (SiC) filler as to that of base alloy may be due to existence hard reinforcement particle SiC in the matrix.
From Taguchi wear response it is evident that material plays a significant role followed by speed, load and the role played by the distance parameter on wear is very less. From plot wear loss against SN ratio, material condition 3(15% SiC) , speed of rotating disc 400rpm, the traversing distance of 250m and pan loading of 30N shows the least wear.

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