DEVELOPMENT OF AL-SiC MMCs FOR MAKING VALVES

D. R. Patel[1], N. S. Patel[2]

[1]*Post Graduate Student, Mechanical Engineering (Machine Design), I.I.E.T., Gujarat, India.*

[2] *Head & Professor, Mechanical Engineering Department, I.I.E.T., Gujarat, India.*

ABSTRACT

Material science and Engineering has experienced a tremendous growth in the field of micron and Nano composites developed with enhanced chemical, mechanical and physical properties. Aluminum based Metal matrix composites (MMCs) are appropriate material for engineering sector which are prepared by powder metallurgy and casting method. The present work describe that Al-SiC composite as possible alternate materials with its unique capacity to give required properties for different engineering applications. In this paper, describe the microstructure of Al-6061-T6 (Aluminum alloy) and SiC- 1200 mesh (Silicon carbide powder) composites having 0, 5 & 15 volume percentage are produced by Stir casting method (Liquid metallurgy Route). Mechanical Tests like microstructure, Hardness, Strength etc. will be conducted.

Keywords: - *MMCs, Stir casting method, Valves, Properties*

1. INTRODUCTION

Aluminum alloy with SiC MMCs have drawn immense interest in various application. AMMCs by using Al-6061 with SiCp with 60-90µm size with 0, 5, and 10 % weight ratio and using stir casting method. Results concluded mechanical properties like Microstructure, hardness, surface roughness and chemical analysis. Optical micrographs showed uniform distribution, Hardness increases with increase weight percentage of SiC reinforced particles. So Developed Al-MMCs improves mechanical and physical properties compared to pure aluminum alloy 6061 [1]. R. S. Rana et. Al. [2] has fabricated Al-5083-35µm SiC particles with 0-10 volume percentage by using stir casting process. Result revealed that tensile strength, compression strength and hardness increase with increasing volume percentage of SiC particles. Porosity of composite material decreased due to ultrasonic treatment and N2 degassing. Al-5083-35µm and 40nm size particles MMCs cam made by ultrasonic assisted stir casting process. Al-SiC MMCs with 4% weight of nano silicon carbide shows hardness which is higher than 10% weight of micron silicon carbide [3]. Dinesh Kumar Koli et. al. [4] has discovered that as the reinforcement content increased in the matrix material hardness, tensile strength increased and decreased its elongation. Al-SiC MMCs for Spur gear which are subjected to continuous loading fabricated by using stir casting method analyzed by using CATIA and ANSYS [5].

K. R. Padmavathi et. al. [6] has represented Al-SiC-MWCNT hybrid metal matrix composite with Al-6061, SiC-15% and MWCNT-0.5% and 1.0% by using die casting through stir casting method. A.A. El-Daly et. al. [7] has developed MMCs with Al-60µm-99.7% and SiC-70nm-99.9% by employing high energy ball milling with cold pressing and sintering technology at 550^0 C for 1 hour. The wear resistance of Al-6061-T6 reinforced with SiC & Al_2O_3 Hybrid MMCs tested by using pin on disc wear tester [8]. It has been Discovered overview of stir casting process, process parameters, and preparation of MMCs material by using aluminum as matrix and SiC, Al_2O_3, graphite as reinforcement by varying properties [9]. By this paper must be noted that data for other critical properties such as fatigue and fracture toughness were not available. It gives a review on reactivity of matrix and reinforced material, fabrication processes, volume fraction of the reinforced materials [10].

K. L. Meena et. al. [11] was fabricated Al-6063/ SiCp MMCs by metal stirring technique. The MMCs bars and circular plates are prepared with varying the reinforced particles by weight fraction ranging from 5, 10, 15, 20 %. The average particle size of SiC are 220, 300, 400 mesh respectively, The microstructure and mechanical properties

like tensile strength, ultimate tensile strength, braking strength, elongation%, hardness, density, impact strength, are investigated on prepared specimen of MMCs. It was observed that tensile strength, Impact strength, hardness are increase with rising SiC particles. K. K. Alaneme et. al. [12] has fabricated As-cast and Age-hardening Al-6063-SiC MMCs using Borax additives and two step stir casting method which Result revealed that aging treatment improve in the tensile strength of the composites and double stir casting processing parameters utilize in this work. It has been developed Al-6061-T6-SiC MMCs by liquid metallurgy because among several series of Al-alloy, heat treatable 6061-T6 excellent extricable in nature, exhibit moderate strength, finds many applications in the fields of construction, automobile and marine engineering [13]. Micro-structural features, mechanical properties and improving the dry sliding wear behavior of MMCs reinforced with SiC particles has been investigated and manufactured by squeeze casting techniques. Results shows that the composites have homogeneously distributed porosity free SiC particles [14]. T.P.D. Rajan et. al. [15] revealed that max 45% SiC particles are obtained at outer periphery which has maximum hardness up to 150 BHN of MMCs of Cast-365 and Wrought 2124 Al-SiC by liquid metallurgy stir casting followed by horizontal centrifugal casting which is suitable for making engineering components which require high surface hardness and wear resistance with high specific strength.

The effect of particle size, forging and ageing effect on the mechanical and fatigue properties of the cast, forged and age-hardened Al-6082-SiC MMCs were studied and results revealed that forging process improves mechanical properties as well as forms a shape of the final product. Age hardening process improves strength and ductility [16]. Rajesh purohit et. al. [17] was developed Al-SiC composite with 5-30 weight percentage of SiC particles were fabricated using powder metallurgy as well as casting method. The hardness and radial crushing load was measured for the MMCs poppet valve guides and were found better than the cast iron poppet valve guides presently used in engines. Manoj Singha et. al. [18] develop Al-MMCs by using aluminum (98.41% C.P.) and SiC (320 grit) with two step mixing method of stir casting techniques with 5, 10, 15, 20, 25, 30 percentage weight of SiC powder. Discuss is that to improve the particle distribution, the second mixing step is needed, heat the slurry to a temperature above the liquids and then stir for 10 min at 600 rpm. R. Sagar et. al. [19] has fabricated MMCs valve seat insert through powder metallurgy and gravity die casting method. The Rockwell hardness, density, radial crushing load and surface roughness of the Al-SiCp MMCs and steel valve seat inserts presently used in engines were measured and compared. Results conducts like hardness and impact test, relived that with increase in composition of SiC an increase in hardness and impact strength. This literature considers gives the review for aluminum and silicon carbide metal matrix composite because its high strength to weight ratio, low density and good wear and corrosion resistance. It has been presented finite element analysis of poppet valve and two major techniques are powder metallurgy and solidification process (liquid metallurgy) to develop metal matrix composite material [20].

[21] This paper presents 2024 aluminum alloy metal matrix composite reinforced with three different sizes and weight fraction of Al_2O_3 particulate up to 30 weight percentage were fabricated by a vortex or stir casting method and subsequent applied pressure. J. Hashim et. al. [22] was discussed on effects of processing variables such as holding temperatures, stirring speed, size of the impeller, and the position of impeller in the melt are among the important factors to be considered in production of cast metal matrix composites as these have an impact on mechanical properties because currently to produce high quality composite is mostly required the expensive processing technique which has been relatively high cost and the stir casting method technique is evaluated production of MMCs with low cost. Room temperature tensile test have been carried out on MMCs Al-7075 and the particulate reinforcements used were SiC in three nominal sizes 5, 13, and 60μm. Three matrix ageing conditions were studied like peak aged, under aged and over aged matrix based on the micro hardness measurements [23]. In this paper, valve failures occur due to mechanical fatigue, thermal fatigue and thermo-mechanical fatigue due to cyclic loading and stresses. Failure due to high temperature, Failure of valve due to erosion and corrosion, Failure due to wear, and failure due to fatigue were explained. The frequency of exhaust valve failure is more than the intake valve failure [24].

In this work, developing of MMCs for the Valve which is a device that controls, regulates, and directs the flow of a fluids like Gases, liquids, fluidized solids or slurries by opening, closing of partially obstructing various passage ways. Valves which are found in every industrial process like water processing & sewage processing, power generation process, processing of oil, gas and petroleum industries. Food manufacturing industries, and various other fields. Ball valve, Gate valve, Globe valve, Butterfly valve, Poppet valve are the main valves which are used in engineering areas. Now days these are valves are developed by casting and forging process by using various stainless steel materials like SAE 316, SAE 410, SAE 416, Carbon steel, Cast iron, Alloy steels like EN 18, EN 24. In this work, compared MMCs properties with these materials and revealed that after developing MMCs by stir casting, can manufacture the valves by casting and forging process.

2. Materials and Experimental details

2.1 Selection of matrix material

Aluminum alloy 6061-T6 has been selected as matrix material for synthesis of MMCs. Aluminum alloy was supplied by Choudhary enterprise, Makarpura, Vadodara. The chemical composition of aluminum alloy are shown in the following table. Al-6061 is a precipitation hardening alloy, containing magnesium and silicon as its major alloying elements. It has significant application in aircraft, marine and automobile industries.

Element	Si	Fe	Mn	Mg	Cu	Zn	Ti	Cr	Al
% Percentage	0.52	0.14	0.05	1.1	0.30	0.03	0.015	0.20	97.645

Table-1 Composition of Aluminum alloy 6061-T6

Properties	Values
Density	2.7 g/cm3 (169 lb/ft3)
BHN (500kg_10mm Ball)	95
Rockwell B Hardness	60
Vickers Hardness	107
Ultimate tensile strength	260-310 MPa
Yield tensile strength	240-270 MPa
Shear strength	210 MPa
Modulus of Elasticity	70 GPa
Poisson's ratio	0.33
Melting point Temp.	580-650ºC
Elongation (%)	10-12 %

Table-2 Properties of Aluminum alloy 6061-T6

2.2 Selection of reinforcement particles

The reinforcement may be Fibers, particles or whiskers which increases strength, stiffness, temperature resistance, wear resistance, hardness, etc. Particulates are most common reinforcement materials. The SiC particulate reinforcement Al-MMCs have good combination for use as wear resistance and also lead to a favorable effect on properties such as hardness, strength, fatigue resistance, surface roughness, radial crushing load. In the present work 1200 mesh silicon carbide particulates were used as reinforcement material. 1200 mesh silicon carbide was supplied by Parshwanath hardware store, Ahmedabad.

Product Name	Grit size (Mesh)	SiC	Free Carbon	Fe2o3
F200-F400	200-400	98.5	0.3	0.5
F400-F600	400-600	97.5	0.4	0.7
F800-F1200	800-1200	96.5	0.4	0.7
F1600-F1800	1600-1800	95.5	0.5	0.7

Table-3 Composition of Silicon carbide black powder

Properties	Values
Density	3.2 g/cm^3
Color	Black
Melting point Temp.	2700º C

Table-4 Properties of SiC Powder

2.3 Preparation of Aluminum-SiC MMCs

The following steps has been followed for stir casting Process:

1. Heating and melting of Al-6061-T6 Alloy by around 750°C which is above the melting point temperature of the alloy which is shown in Fig-1 (A)
2. Fig-1 (B) illustrates the feeding process of preheated silicon micron particles (0, 5 and 15% of micron SiC) for the preparation of the composites.
3. When the alloy reaches to a semi-pasty stage, the surface is covered with flux agent coverall-11 about 5 grams of the flux was added to the molten metal for the degassing process.
4. Fig-1 (C) describes mechanical stirring at 200rpm for 20 min for the uniform distribution of the particles. Before the mechanical stirring manual stirring is required for better distribution of silicon carbide particles in the molten metal.
5. Degassing of melt with N2 gas for removing the air inclusion in the material.
6. In Fig-1 (D) sand mold is ready for the making specimen components for MMCs.
7. Pouring of molten metal of aluminum alloy 6061 and 1200 mesh SiC powder to the pre prepared sand mold
8. .Removal the specimen of composite material.

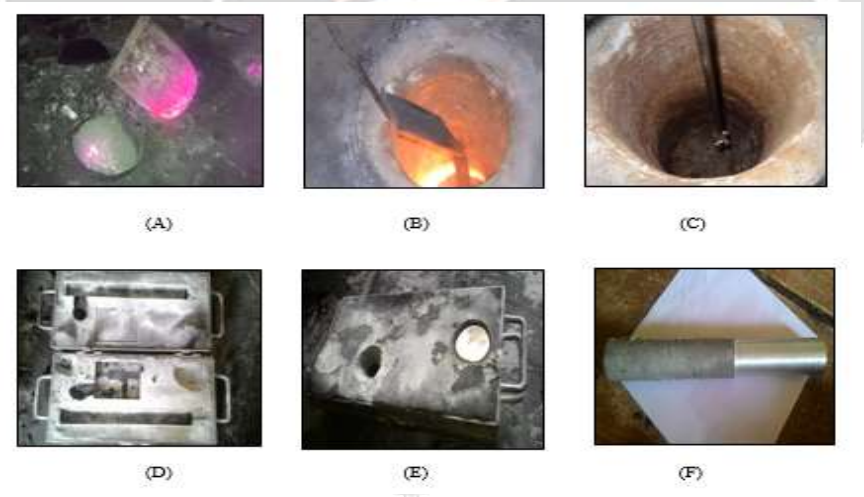

Fig-1 Synthesis of development MMCs

3. RESULTS AND DISCUSSION

3.1 Microstructure test

Microstructural examination were doing scanning electron microscope for testing the microstructure of sample, its surface and distribution of Micron particles in aluminium alloy 6061. The specimen for the scanning microscopy were polished using a series of ranging grit sizes emery papers. A 0.5% HF solution was used for etching process for 3-6 min before experimental testing. All samples were developed by using stir casting technique by taking 5 & 15 % weight fraction. Figures shows micrographs of samples containing different weight fractions. It clearly shows the

resulting homogeneous distribution of particles in the samples.

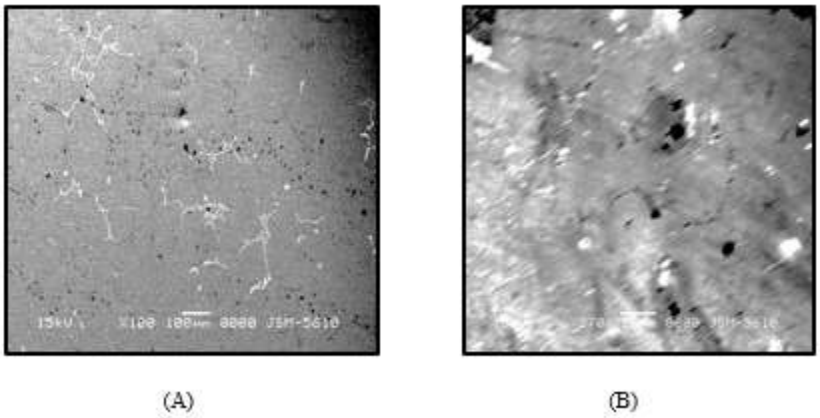

Fig-2 SEM micro graphs of Al6061-5% SiC

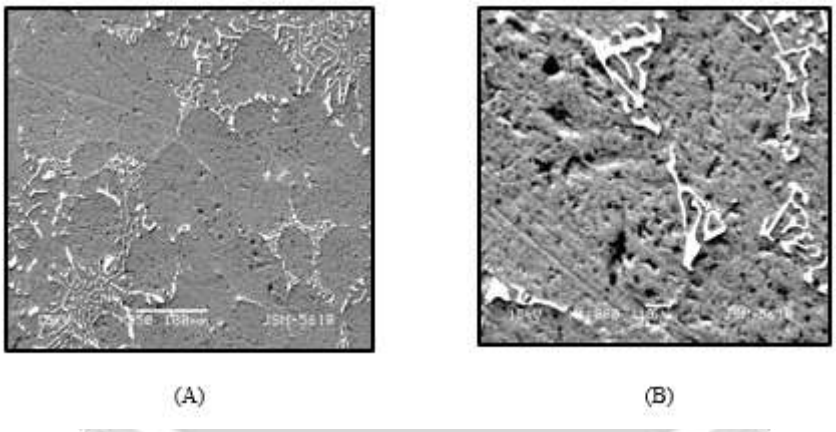

Fig-3 SEM micro graphs of Al6061-15% SiC

3.2 Chemical analysis

Chemical analysis of Aluminum alloy 6061 and Al6061-5% SiC and Al6061-15% SiC were measured by using chemical spectrometer. In this test, analysis of weightage percentage of magnesium and silicon which are main alloying elements of aluminum alloy. Test revealed that by increasing silicon powder contents weight fraction will be increase silicon contents in the metal matrix composite materials.

Elements	Al6061 0% SiC	Al6061 5% SiC	Al6061 15% SiC
Al + Other	98.38	95.706	87.382
Si	0.52	3.364	11.473
Mg	1.10	0.930	1.145

Table-5 Chemical analysis of MMCs

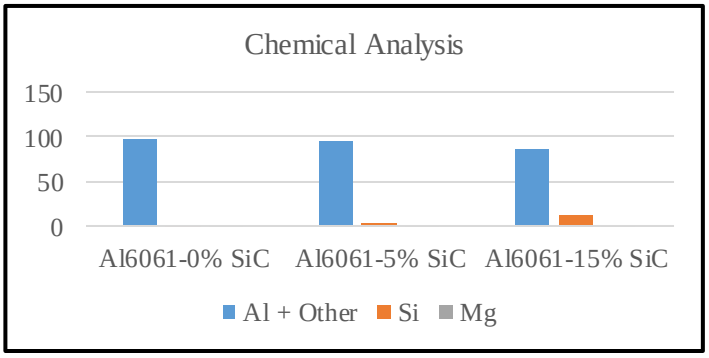

Chart-1 Chemical analysis comparison of MMCs

3.3 Density test

Density is the physical properties that reflects one of the important characteristics of composites. The theoretical densities were calculated in this study of Al-6061 aluminum alloy and cast MMCs with 5% SiC and 15% SiC reinforcement with Al-6061 matrix alloy. Following graph and table describes the value of calculated density of pure aluminum and metal matrix composite with 5% and 15% Silicon carbide MMCs. Density was increased with increasing weight fraction of the silicon carbide powder reinforcement.

	Al6061 0% SiC	Al6061 5% SiC	Al6061 15% SiC
Density(g/cm^3)	2.65	2.69	2.77

Table-6 Density of MMCs

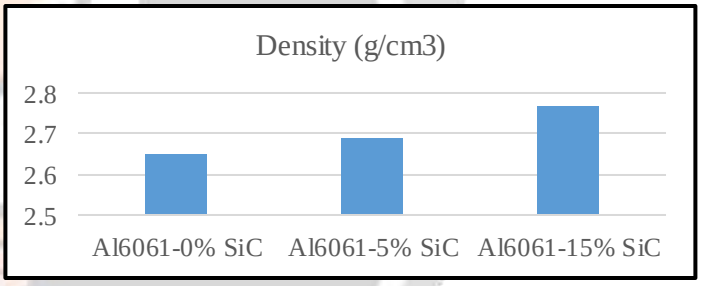

Chart-2 Density comparison of MMCs

3.4 Hardness test

In hardness test, first of all samples of 20mm diameter and 15mm length in cylindrical round bar were developed from manufacturing process. The specimens were fabricated by filing for making perfectly parallel before hardness testing. Samples were polished by using different types of emery papers and tests were carried out by using Rockwell hardness tester with load of 100kg at room temperature condition. Hardness values were obtained in three various sections are given in table and figure shows increase hardness with increasing SiC particles. Also observe that the hardness of the composite is greater than its cast matrix alloy.

	Al6061 0% SiC	Al6061 5% SiC	Al6061 15% SiC
Hardness (HRB)	54	64	78

Table-7 Rockwell Hardness of MMCs

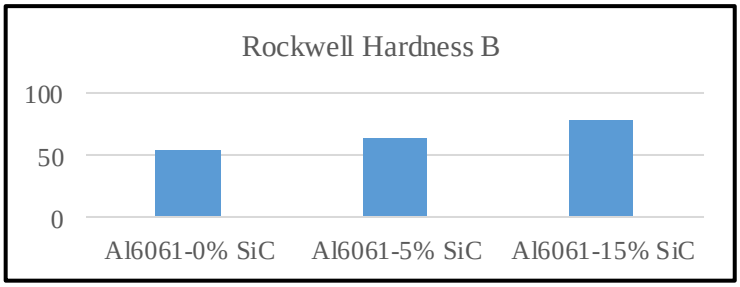

Chart-3 Hardness Comparison of MMCs

3.5 Tensile test

The tensile test was carried out an accordance with the gauge diameter of the test specimen was 10 mm and the gauge length of the test specimen was 50 mm. Tensile properties of the Al-6061 and composite materials were measured. During the tests the load and %elongation data were also measured by software. It is observed that the ultimate tensile strength and yield tensile strength increased with an increase in SiC volume percentage. Figure shows variation of ultimate strength and yield strength with increase in percentage of SiC particles.

	Al6061 0% SiC	Al6061 5% SiC	Al6061 15% SiC
Yield strength (MPa)	209	249	278
Ultimate strength (MPa)	269	304	354

Table-8 Yield strength of MMCs

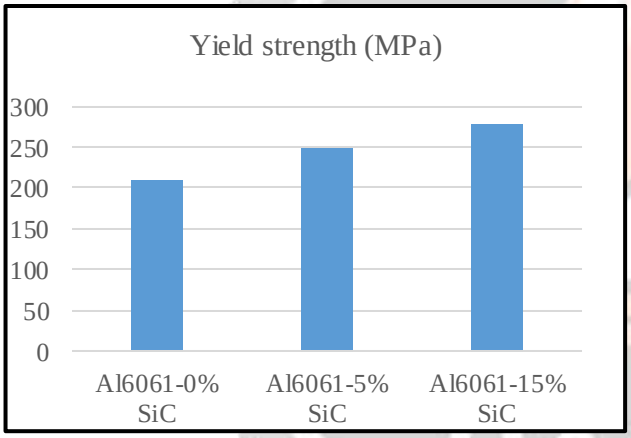

Chart-4 Yield strength Comparison of MMCs

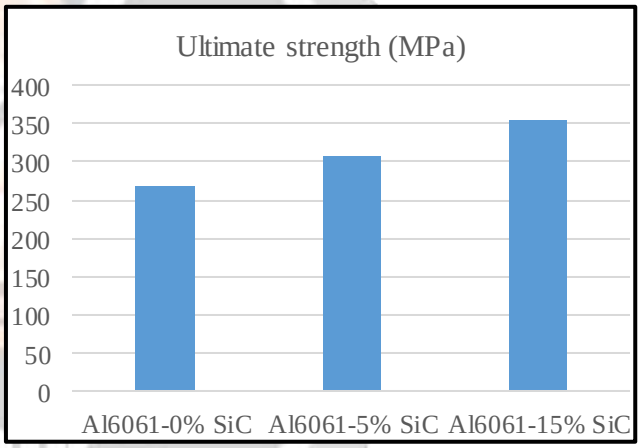

Chart-5 Ultimate strength Comparison of MMCs

3.6 Elongation %

This experimental studies were carried out with tensile strength testing with % elongation of Al-6061 and metal matrix composite of 5% SiC and 15% SiC reinforcement with Aluminum alloy 6061 matrix material. It is observed that Elongation % decreased with increase silicon carbide weight percentage. Following figure shows the variation of elongation with increase in percentage of SiC.

	Al6061 0% SiC	Al6061 5% SiC	Al6061 15% SiC
Elongation (%)	9.5	8.5	7.4

Table-9 Elongation of MMCs

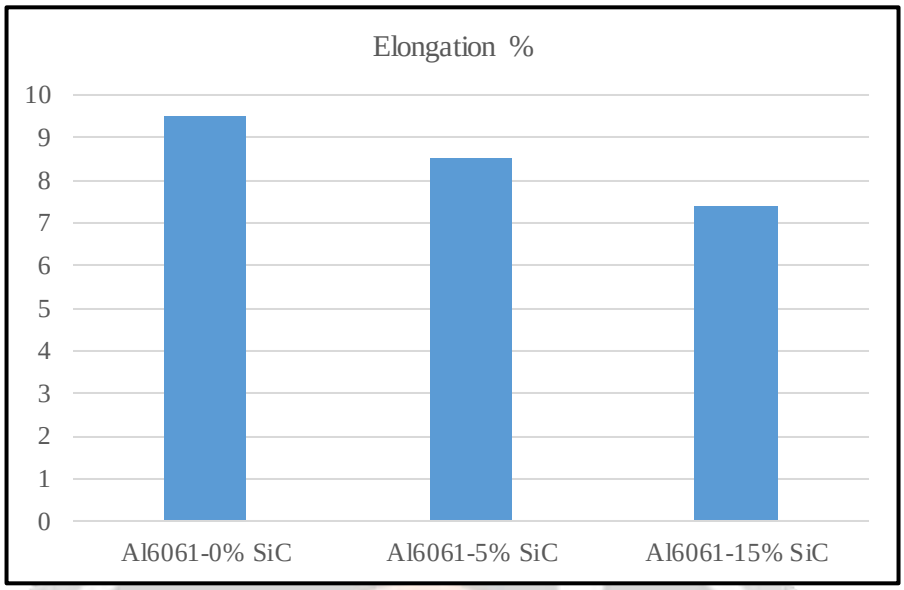

Chart-6 Elongation % Comparison of MMCs

3.7 Corrosion test

The salt spray test is a standardized and popular corrosion test method used to check corrosion resistant of materials. Salt spray testing is an accelerated corrosion test that produces a corrosive attack and the appearance of corrosive product (rust) is evaluated after a pre-determined period of time. Test duration depends on the corrosion resistance of the materials. Salt spray testing is popular because it is relatively inexpensive, quick, well standardized and reasonable repeatable. The apparatus of testing consists of a closed testing cabinet/ chamber where a salt water (5% NaCl) solution is atomized by means of spray nozzle using pressurized air. This produces a corrosive environment of dense of salt water fog also referred to as a mist or spray in chamber, so test samples exposed to this environment are subjected to several corrosive conditions. In this test, the salt solution prepared by dissolving 5% by mass of sodium chloride in 95% of D.M. water. Temperature maintained around 35º C in salt spray chamber for 24 hours test. Results revealed that no rust found in the test specimen.

	Hardness (HRB)	**Yield strength (MPa)**	**Ultimate strength (MPa)**	**Density (g/cm^3)**
SAE 316	95	280	550	7.99
SAE 410	80	310	483	7.74
SAE 416	82	280	510	7.70
Cast iron	95	150	460	7.20
Carbon steel	85	250	420	7.80
Alloy Steel (EN 24)	85	295	570	7.80
Al6061-0% SiC	54	209	269	2.65
Al6061-5% SiC	64	249	304	2.69
Al6061-15% SiC	78	278	354	2.77

Table-10 Properties comparison with different materials

4. CONCLUSION

The Al6061-SiC MMCs with 5% and 15% weight fraction produced by stir casting method and the microstructure, chemical composition, density, yield strength, ultimate strength, elongation % were measured and compared with various materials which are used to making different types of valves. Also were tested corrosion resistance and fatigue strength are tested.

- Hardness, Density, yield strength, ultimate strength are increases with the increase reinforcement particles of silicon carbide.
- The Elongation % is decrease with the increase reinforcement particles of silicon carbide.
- Development of Al-SiC MMCs for making valves is possible by comparing different properties with existing materials which are used to making valves. Valves are manufactured with casting and forging processes and it is possible both processes after developing MMCs for making valves.
- Also this research revealed that MMCs of Aluminum alloy 6061 with SiC powder will be produced corrosion resistant material.

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BIOGRAPHIES

Devendrabhai Rajendrabhai Patel
Post graduate student, M.E. Machine design.
Ipcovala institute of Engg, & Tech, Dharmaj
Gujarat, India.
Mob. No- +91-8140608088
Email id- devendrapatel14@gmail.com
drp_141010709002@gtu.edu.in

Prof. Nilamkumar S. Patel
Head of Mechanical Department
Ipcovala institute of Engg, & Tech, Dharmaj
Gujarat, India.
Mob. No.- +91- 9879605272
Email id- nilam5272@gmail.com