ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, Vol 9(43), DOI: 10.17485/ijst/2016/v9i43/100410, November 2016 ISSN (Online) : 0974-5645

Analysis of Microstructural, Corrosion and Mechanical Properties of Aluminium Titanium Diboride Particles (Al-TiB2) Reinforced Metal Matrix Composites (MMCs)

M . M. Siva[1*], R. Rajesh[1], S. Pugazhendhi[2], M. Sivapragash[3] and R. R. Neelarajan[4]

[1]Mechanical Engineering Department, Noorul Islam University, Kumaracoil - 629180, Tamil Nadu, India; mmsivasan@gmail.com, rajesh1576@yahoo.co.in

[2]Manufacturing Engineering Department, Annamalai University, Annamalainagar - 608002, Tamil Nadu, India; pugazhs12@gmail.com

[3]MG College of Engineering, Thiruvanathapuram - 695027, Kerala, India; mspragash15@gmail.com

[4]Aeronautical Engineering Department, Noorul Islam University, Kumaracoil - 629180, Tamil Nadu, India; neelarajan2012@gmail.com

Abstract

Objectives: Our aim of this project is to use aluminum titanium diboride metal matrix composites in aeronautical and marine field by reducing its weight and improve the hardness and corrosion behavior. For this aluminum titanium diboride compound are made by stir casting method. **Methods/Statistical Analysis:** Aluminum 2011 material is fabricated by stir casting method with added titanium diboride on various weight percentage compositions. The hardness and corrosion are developed with the raise in weight percentage of titanium diboride particles. The properties of reinforced metal matrix composites iron, copper, zinc, lead, silicon, bismuth and aluminim are the chemical composition of Al2011. The analysis of microstructure, corrosion and mechanical properties of aluminum titanium diboride metal matrix composites with specific attention on the before after as cast and extrusion behavior of the composites. **Findings:** Tensile test for the alloy and composite samples are done using Instron UTM. The tensile stress of the composites improves significantly with the TiB2 content. Micrograph of the heat treated composite samples taken at different locations from outer surface of the casting. Hardness tests are done using the Vickers hardness testing machine. The firmness characters of the precipitation conducted specimens are more than that of the as-cast samples. Meanwhile after the secondary process as per the observation the tensile stress of the extruded composites reveal 135M Pa improvement of 5% opposing the as cast samples. After raising the metal matrix composites to 10% was plastically deranged shows the value 171M Pa. The SEM of the extruded samples shows enlarged grains of aluminum solid solution with inter-metallic particles at the grain boundaries to restrict the deformation. This result improves the extrusion process well in grain enlightening and uniform particle distribution compared to as cast condition of samples. Compare to as cast samples the plastic deformation process gives the extruded samples with higher strength 47 to 60 BHN. **Application/Improvements:** Now a day's Al-2011 is the top most non-ferrous metal used in sector multiple industrial applications like aerospace, marine, automotive, rail, building, packaging, energy distribution, sports and leisure, mechanical industries and engineering, etc. The nature of Al-2011 with TiB2 are lightness, corrosion resistance, suitability for surface treatments, the diversity of the alloys and intermediates, ease of use, recycling, electrical and thermal conductivity, etc

Keywords: As Cast, Composition of TiB2, Extrusion, Hardness, Immersion, Microstructure, Stir Casting Method

1. Introduction

Now a days the composite materials form a good chemical composition of the engineered materials in the market.

The composite materials to be a light weight material compared the other materials. The cost of improving the composite in the manufacturing technology alone is not sufficient for engineering. The Al2011 metal matrix

* Author for correspondence

composites is lighter than other metals like iron, copper, zinc, lead, silicon and bismuth.

Two chemical and physical distinct phases of MMCs and other composites. It provides the properties which is not obtainable by the individual phases. The company sides' Aluminum Matrix Composites (AMCs) plays important material such as aeronautical, automobiles and marine field. The properties of MMCs are high strength and increased corrosion resistance by the various percentage of TiB_2. Aluminum 2011 and titanium diboride materials are used for the fabrication. The preparation of metal matrix composites fabricated is by stir casting process.

Stir compound does not produce bad composition in the metal matrix reinforcement. Stir fabricated composites which is low in cost by easy for fabrication. The salts like potassium hexafluro titanate (K_2TiF_6) and potassium tetrafluro borate (KBF_4) mixed with aluminum 2011 prepared by stir casting method are the properties used to improve MMCs[1].

Hence, a detailed review being fabrication about aluminum composites built-up the microstructure, hardness, elongation, stress and corrosion measured.

2. The Procedure for Experiment

2.1 The Chemical Composition of Material

The 2011-aluminum is mostly used a cast alloy for different field. It has good castability, corrosion and pressure tightness and machining and welding characteristics. The chemical and mechanical properties of Al2011 MMCs are given in Table 1.

Table 1. The chemical composition of Al2011

Alloy	Cu	Si	Pb	Fe	Zn	Bi	Others	AL
	%	%	%	%	%	%	%	%
AL2011	5.5	0.4	0.4	0.7	0.1	0.4	0.15	Remaining

2.2 Stir Casting

The stir cast assembles with pre-heater, electric-powered furnace and stirrer etc. The three stage electrical resistance variety is 10 KWs capacity in which furnace is used. The furnace as well as pre-heater temperature is 1000˚C and 900˚C. The melting point of the Al-2011 is 700˚C-800˚C.

After the caster set-up, metal melted in an induction furnace was moved to a resistance holding furnace where it was stabilized at a temperature 20°C above the liquids temperature. The melt was then poured into the stir caster furnace which had been preheated to 570°C to 595°C for Al 2011 weight % TiB_2. The different percentage of casting composition for TiB_2 and Al-2011 MMCs is given in Table 2.

Table 2. Various casting composition for Al2011 MMCs

S.No	TiB_2 for wt%	AL2011 for wt%
1	2.82 kg for 5%	613.5 gm for 5%
2	5.64 kg for 10%	1227 gm for 10%

Up to 600–700 rpm the stirrer is rotated. The stirring of the melt is poured into the preheated die ten minutes later. The required casts are acquired after solidification[2],

Figure 1 shows the schematic diagram of stir casting process investigation the various composites of aluminum and titanium diboride brace of many research groups to fabricated uses this technique.

Figure 1. Stir casting furnace.

The cut off temperature was fixed at 900^0C. The melt temperature was maintained at ≈870^0C. The current rating was maintained at 20 Amps and voltage at 110 V.

After mixing of salts was started, the melt temperature was maintained between 865-870^0C. Within 15 minutes all the salts were completely dropped into the melt and for an additional 15 minutes the stirring was continued. After 30 minutes of stirring in total the melt which was at ≈865^0C was poured into permanent molds. One of the ingot casting weighted 1.03 kg and then other ingot casting weighted 2.13 kg. The TiB_2 is added 5% and 10%

by weight with base or raw material Al2011 grade. In this process the number of heating elements used is 6 in series.

3. Result and Discussion

3.1 Microstructural Characteristics of Al2011 Particle Reinforced MMCs produced by Various Combinations

The electronic console and the electron column are the two main components which are used to make SEM instrument. The filament current, accelerating voltage, focus, magnification, brightness and contrast are adjusted by the control knobs and switches. The instrument rather than control knobs and switched found on older style scanning electron microscopes are controlled by the GUI or software. CRTs located on the electronic console are viewed usually by the image produced by the SEM. The computer monitor is used to see the image instead with FEI. The images captured are saved in digital format and printed directly[3.]

The cast specimen is polished and etched as per the standard metallographic procedure. When the as cast after and before heat treated aluminum with titanium diboride samples analyzed by scanning electron microscope was shown in Figures with average size of less than 50 microns. The Figures 2, 3, 4 and 5 shows that the fabricated microstructures are Al2011 metal matrix reinforced with different wt% of TiB_2 composites. The cast microstructure of Al2011 metal matrix composites is presented in Figures 2, 3, 4 and 5. The super cooling of composite during solidification reveals the formation of aluminum network structure. Mostly the microstructure of TiB_2 is shown in Figure 2, which consists of mainly Al and primary titanium diboride surrounded uniformly by sharp edges titanium needles.

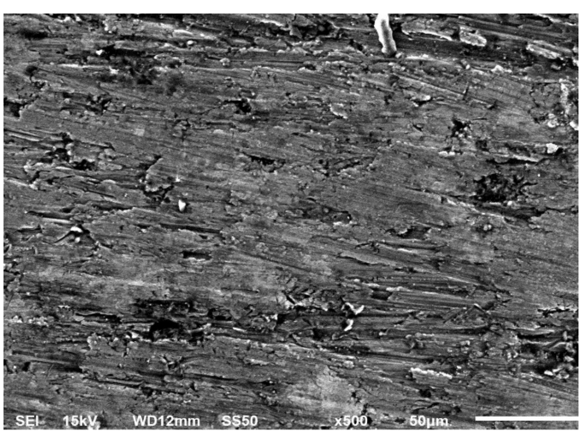

Figure 2. 5% As cast before heat treatment.

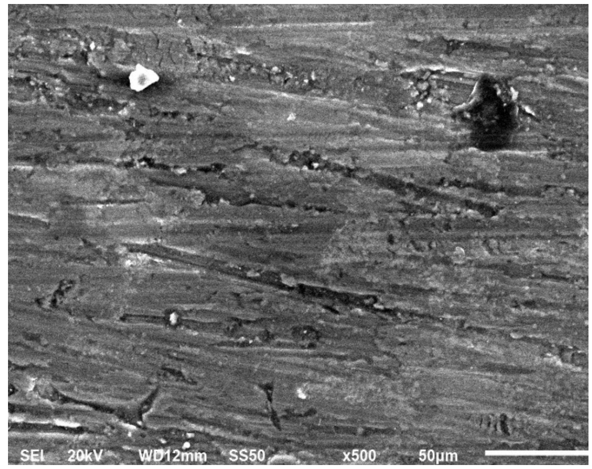

Figure 3. 5% As cast after heat treatment.

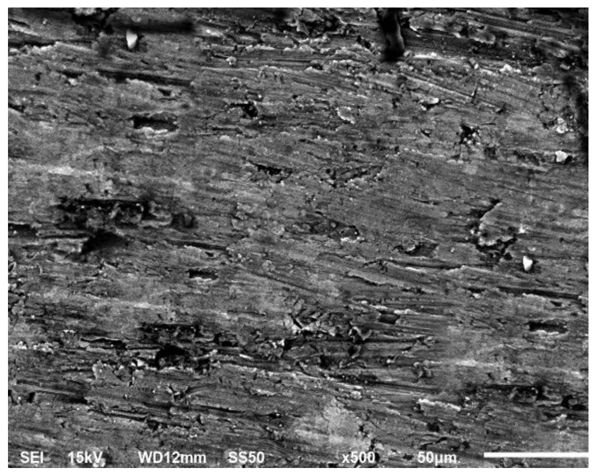

Figure 4. 10% As cast before heat treatment.

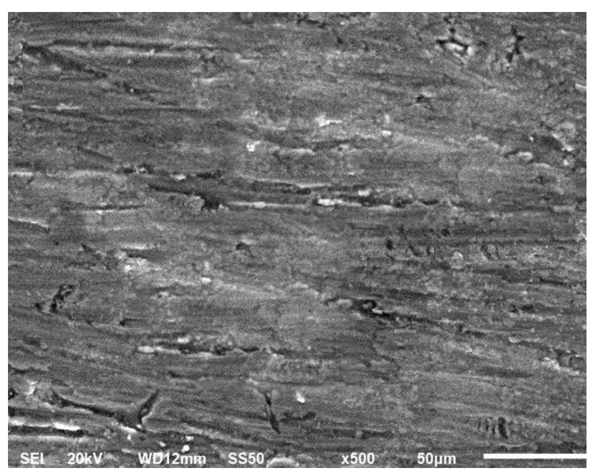

Figure 5. 10% As cast after heat treatment.

Microstructure of the composites presented in Figure 2. The distributions of TiB_2 in the Al2011 metal matrix composites are uniformly exposed. And there is no appearance of porosity and cracks in the castings. The distributions of reinforcements in the respective matrix are uniformly observed in Figures 6, 7, 8 and 9. The extrusion samples in comparison to the as cast samples are found to be finer than the size of particles in Figure 6. Base metals average grain size is 67.4 lm and the grain size of FS1 sample is 9.6 1m and FS2 samples is 12 lm. The dynamic recrystallization during FSP is decrease in grain size. The increase in temperature of FS2 compared to FS1 compared to small increase in grain size. The SEM images shown in Figures 7 and 9 are for before and after extrusion process samples. The solidified grains were up takes from the unmelted region are seen in extrusion samples.

The particle matrix interface and confirmation by analysis are the observation of splitting up of Cu, Si, Bi, Fe and Zn. The presence of the aluminum and salts containing 5% and 10% wt. The size of the pro-eutectic Al2011 became fine due to increase in the percentage of $TiB_{2.}$ The distribution of aluminum matrix composites uniformly exhibits the cast composite 5, 10wt. % TiB_2 particles of zooming size 10–50 μm also. Alumina particles reinforced composite are find by the microstructures of Al with TiB_2 -5 and 10 wt. % fabricated by stir casting method[4].

Observation from the optical micrograph of composites eutectic silicon morphology changes after the heat treatment samples is shown in Figures 7 and 9. In the case of aluminum–5, 10% TiB_2 composites load of clay particles was found. After the extrusion process the structure of Al/TiB_2 nets are fine grained.

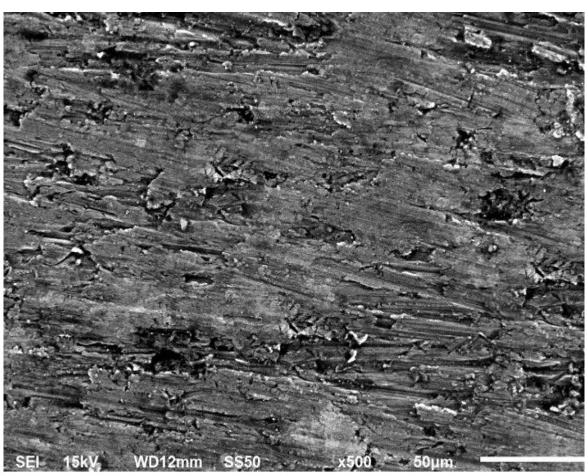

Figure 6. 5% extrusion before heat treatment.

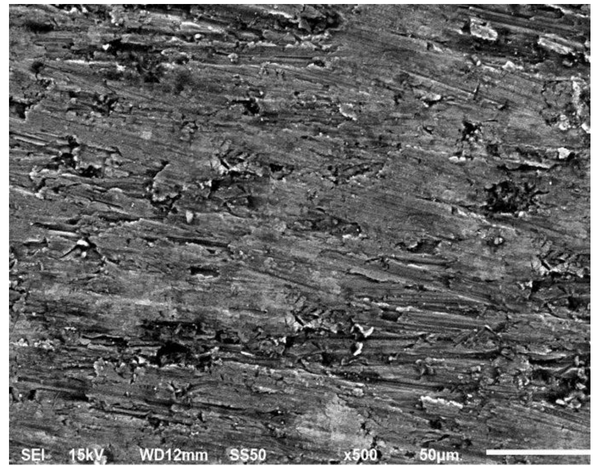

Figure 7. 7. 5% extrusion after heat treatment.

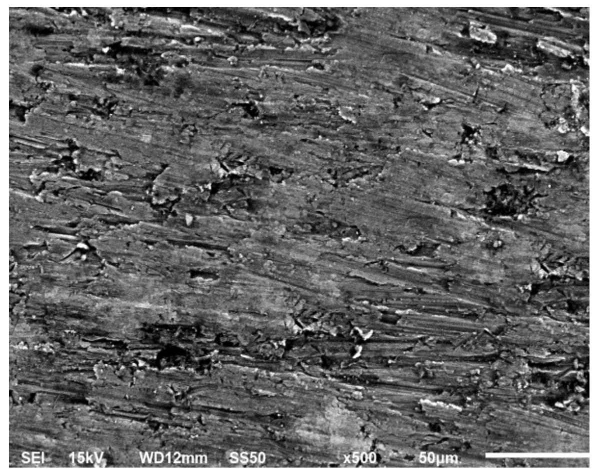

Figure 8. 10% extrusion before heat treatment.

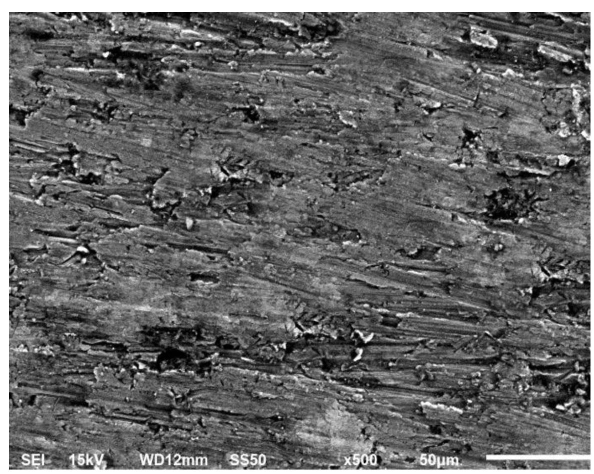

Figure 9. 10% extrusion after heat treatment.

3.2 Corrosion Behavior

Corrosion test is done by static immersion test and the values are shown in Table 3. The samples 10 × 10 mm size are made by this method. Before testing the specimen, it is polished by the paper of silicon carbide 500 and 1000 grit size. In next step the specimen is polished again with the diamond glue of 1.5 to 3 micron to get outside reflector. The specimens are rinsed in water and acetone before starting the test and exactly weighed. Uniform dispersion of Al2011-TiB_2 reinforcements to study by optical microscope is used. All percentage specimens were carrying by the corrosion procedure as per ASTM. Hydrochloric Acid (HCL) solution is used as a corrodant. All types of specimens were conducted the exposure time in 72 hours. The corrodant is used to keep the hamper accommodate the consistent samples under a roof of beaker Figure 10.

Adhered scales are removed with smooth brush by clean the samples were kept in acetone for few seconds at the end of the experiment. By dehydrating the samples, they were weighed to determine the amount of weight wasted is shown in Figure 11. After the corrosion test the corroded surfaces of the samples were considered down the SEM[5].

In before and after process, corrosion resistance increases redistribution of secondary process particles. Surface heat treatment is used in redistribution of extrusion process and improves the corrosion resistance.

Figure 10. Test samples in HCL solution.

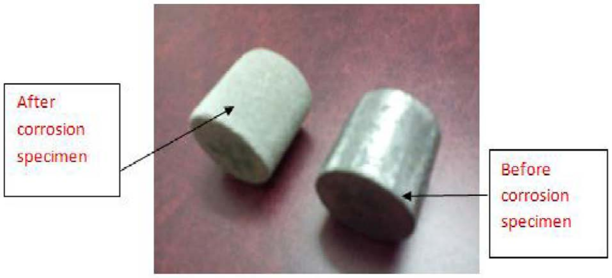

Figure 11. Corrosion test samples.

3.3 Mechanical Properties of Al2011 MMCs are produced by Various Combinations

A square based diamond pyramid indenter has a ground forms a standard 136 degrees between opposite faces are used.

Table 3. The table for immersion test

Process	AL2011+ % of TiB_2	BH = Before Heat treatment AH = After Heat treatment	Sample code	Before weight W_b (grams)	After Weight W_a (grams)	Weight Loss $W = W_b - W_a$ (grams)
Cast	5%	BH	A	0.709	0.586	0.123
		AH	B	0.819	0.697	0.122
	10%	BH	C	0.812	0.632	0.180
		AH	D	0.804	0.702	0.102
Extruded	5%	BH	E	0.814	0.687	0.127
		AH	F	0.823	0.726	0.097
	10%	BH	G	0.730	0.560	0.170
		AH	H	0.704	0.570	0.134

The micro force ranges for ASTM standard (20 g to 1 kg) is E383.

Vickers tests has two versions namely Macro Vickers (load over 1 kg) and Micro Vickers (load less than 1 kg).

The shape of pyramidal diamond indenter that forms a square indent is in Vickers micro ranges.

Vickers hardness test method steps are:

- Diagonals of the indentation produced are approximately seven times larger than the depth of indentation[6].
- The Vickers test is especially suitable for hardness measurements in thin layers and very hard alloys.
- Vickers hardness number is nearly independent of the test loads of the impression remains constant under different test loads above 5 kg. At lower loads it may be load dependent.

3.4 HV = Constant x test force/indent squared diagonal

The hardness test result for various combinations like before and after corrosion of metal matrix composites and reinforcement materials in weight percentage Table 4 and Table 5. The hardness property of Al2011 is increased by addition of TiB_2. The hardness of the composite is augmented from 117 HV to 189 HV[7,8].

A decline in hardness is expected as the markdown of the secondary process particles occurred in both the process. The hardness values of the as cast, extrusion before and after heat treatment samples are different as per percentage of TiB_2. The outer layers of conducted specimens decreased in firmness are observed. There is a change in the microstructure and melting in the samples because of decrease percentage in firmness is top in specimens (5%) related to the specimens (10%)[9].

The low absorption in solid phase which attributes the hardness values to be decreased. The finer grain size decrease the hardness value in FSP samples easily dissolved in the composites. The volume fraction of reinforcement increases due to the increase in strength of the composite. Following section elaborates tensile properties of Al2011-TiB_2 particles reinforced composite. The dispersions of the particles improve the mechanical properties. UT increase 43%, 11% and 10% with the addition of TiB_2 particles[10,11].

The percentage elongation, yield and tensile strength of composite is decreased and increased as per the additions of 5%, 10% TiB_2. When 4% of elongation in the as-cast condition which is exhibited by TiB_2 25 wt in percentage. The tensile strength for Al2011-5% TiB_2 and Al2011-10% TiB_2 succeed at 750°C and 900°C. The Al-2011 with TiB_2 combinations growth the hardness, tensile strength and corrosion resistance. It was observed that the hardness of this Al-2011 was better than the larger fraction of TiB_2 particulates will be in corporate in the matrix causing large value of hardness and tensile strength. The 5%, 10% before and after heat treatment as cast, extruded sample values such as yield stress, ultimate tensile stress and elongation are shown in the Table 6. Similarly in the extruded sample excellent values for yield stress, ultimate tensile stress and elongation are tabulated[12,13].

The Al-2011 with TiB_2 mechanical properties such as proof stress, tensile, shear, elongation and hardness Vickers values shown in the Table 7.

Table 4. The table for hardness Vickers test (before corrosion)

Process	AL2011+ % of TiB_2	BH = Before Heat treatment AH = After Heat treatment	Sample code	Value of Micro Hardness (1)	Value of Micro Hardness(2)	Value of Micro Hardness(3)	Average Micro Hardness Value (HV)
Cast	5%	BH	A	65.92	75.7	_	70.81
		AH	B	89.43	85.9	90.68	88.67
	10%	BH	C	90.89	85.59	85.65	87.37
		AH	D	83.31	82.75	_	83.03
Extruded	5%	BH	E	80.89	82.32	_	81.605
		AH	F	81.18	74.79	76.98	77.65
	10%	BH	G	92.07	80.53	81.57	84.72
		AH	H	92.32	85.17	93.01	90.16

Table 5. The table for hardness Vickers test (after corrosion)

Process	AL2011+ % of TiB_2	BH = Before Heat treatment AH = After Heat treatment	Sample code	Value of Micro Hardness (1)	Value of Micro Hardness(2)	Value of Micro Hardness(3)	Average Micro Hardness Value (HV)
Cast	5%	BH	A	117	120	117	118
		AH	B	141	160	154	151
	10%	BH	C	152	147	163	154
		AH	D	173	162	151	162
Extruded	5%	BH	E	134	122	137	131
		AH	F	184	149	189	174
	10%	BH	G	172	169	175	172
		AH	H	188	160	183	177

Table 6. The table for Al2011 mechanical properties

Process	AL2011+ % of TiB_2	BH = Before Heat treatment AH = After Heat treatment	Yield Stress (MPa)	Ultimate Tensile stress (MPa)	Elongation (%)
Cast	5%	BH	55.46	0.182	15.77
		AH	58.66	0.193	15.20
	10%	BH	67.46	0.206	10.80
		AH	69.33	0.193	9.20
Extruded	5%	BH	36.78	0.209	9.25
		AH	38.89	0.182	7.67
	10%	BH	28.33	0.209	9.24
		AH	38.30	0.232	8.05

Table 7. The mechanical properties for Al2011

Alloy	Proof Stress (MPa)	Tensile Strength (MPa)	Shear Strength (MPa)	Elongation (%)	Hardness Vickers (HV)
AL2011	290	395	235	15	115

4. Conclusions

Al2011–TiB_2 composites with various weight percentages of metal matrix composites and its effect such as, SEM analysis, corrosion and hardness were calculated by modified stir cast route.

- The volume fraction of Al2011-TiB_2 are viewed by using the Metallurgical Image Analysis System. The volume of TiB_2 is increased by increasing the wt. % of TiB_2.
- It is found from the corrosion level decreases from 17 mpy to 7 mpy for a period of 72 hours due to presence of aluminum titanium diboride composites.
- Al2011 with TiB_2 which act as a protective layer to improve the corrosion resistance.
- A significant role of the titanium diboride content in aluminum composites are the irritant protective layer of the object. The percentage of TiB_2 addition with Al2011 will increase due to the strength of base material[14].
- By adding 5 and 10 % of TiB_2 the micro hardness values of the MMCs was raised from 117 HV to 189 HV.
- The aim of this project is to improve the hardness of the Al2011 alloy moderates the strength by reinforcement with TiB_2 and the results justify the objective. The current project ordinary Al to Al2011 grade property which reduces manufacturing cost.

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