Optimization of Milling Process Parameters for Machining of Aluminium-Tib2 Metal Matrix Composite

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Abstract-- **This study reports on optimization of milling process by the effects of machining parameters applying Taguchi method in order to improve the quality of manufactured goods and engineering development of designs. In the optimization of milling process parameters for machining of Aluminium-Tib2 composite, an attempt has been made to solve the co-related multiple criteria of optimization of milling process. The target was to search an optimal process environment, capable of producing desired parameters of milling. In this study, the three process parameters i.e. cutting speed, Feed, Depth of cut along with four different compositions has been taken. The Material removal rate and Surface roughness has been optimized in this work. The overall composite principal component has been optimized by using Taguchi method. Signal to noise ratio has been found for different compositions that we have made in order to find the optimal levels of process parameters.**

Keywords------ **Optimization, Taguchi method, Cutting speed, Feed, Depth of cut, Material removal rate, Surface finish**

I. INTRODUCTION

Aluminum 7075 (Al 7075) is chosen as the matrix material. Since, it is low cost and has better properties like good thermal conductivity, high shear strength, abrasion resistance, high temperature operation, non-flammability, minimal attack by fuels and solvents and the ability to be formed and treated on conventional equipment. It possesses excellent casting properties and reasonable strength. This alloy is best suited for mass production of lightweight metal castings. Titanium di-Boride (TiB2) is a hard-ceramic material with more hardness, good thermal conductivity, resistance to corrosion and better oxidation stability. It is a hard material with high strength and high wear resistance at elevated temperatures. The high density combined with the high elastic modulus and high compressive strength, have led to its use in armor components. It is unaffected by most chemical reagents, and has excellent stability and wettability in liquid metals such as zinc and aluminum. This, along with its high electric conductivity, has led to its use in Hall- Herold cells for aluminum production. It is also used as crucibles for molten metals. Milling is the process of machining smooth, curved, or uneven surfaces by feeding the work piece against a rotating cutter containing a number of cutting edges. Milling machine is one of the important machining processes. In this operation, work piece is fed against a rotating cylindrical tool. The rotating apparatus consists of many cutting edges (multipoint cutting tool). Normally axis of rotation of feed is given to work piece. Milling operation is illustrious from other machining operations on the basis of orientation between the tool axis and the feed track; however, in other processes like drilling, turning, etc. the tool is feeding direction parallel to axis of rotation. The milling machine consists basically of a motor driven spindle, which supports and revolves milling cutter, and an interchanging adjustable worktable, which mounts and feeds work piece. Milling is normally used to produce parts that are not axially symmetric and have many features, such as hovels, slots, pockets, and even three-dimensional surface curves. Parts that are fabricated completely through milling often include components that are used in partial quantities, maybe for prototypes such as custom designed clasps or brackets. Due to high tolerances and surface finishes that milling can deal, it is ideal for adding precision features to a part whose basic shape has already been formed. Various types of milling processes are end milling, peripheral milling and face milling. Among different types of milling procedures, end milling is one of most vital and common metal cutting operations used for machining parts because of its capability to remove materials at faster rate with a reasonably good surface quality. The end mill has helical cutting edges passed over onto the cylindrical cutter surface. End mills with smooth ends are used to produce pockets, closed or end key slots etc. End milling operation produces flat upright surfaces, flat horizontal surfaces and other flat surfaces making an angle from table surface using milling cutter named as end mill. This operation is preferably carried out on vertical milling mechanism.

II. EXPERIMENTATION

The process parameters selected for milling of Al/Tib2 composite are shown in table1. The process parameters are Cutting speed, Feed and Depth of cut. There are five levels are taken for each process parameter.

TABLE 1
PROCESS PARAMETERS

Process Parameters	Level 1	Level 2	Level 3	Level 4
Cutting speed (rpm)	500	710	1000	1400
Feed (mm/rev)	20	40	63	80
Depth of cut (mm)	0.2	0.4	0.6	0.8

The Al/TiB2 metal matrix composites, by varying percentage of Tib2 powder from 3% to 12%, were fabricated by using stir casting method. The fabricated Al/TiB_2 composite specimens before machining are shown in fig. 1. Carbide inserts are replaceable and usually indexable bits of cemented carbide used in machining steels, cast iron, high temperature alloys, and nonferrous materials. Carbide inserts allow faster machining and leave better finishes on metal parts. The insert has to withstand extreme heat and force so it's made of some of the hardest material in the world. The carbide insert end milling tool used for machining of Al/TiB2 metal matrix composite is shown in the fig. 2.

Fig 1 Al/TiB2 composite specimens before machining

Fig 2 Carbide insert tool

Design of Experiments (DOE) for selected input parameters are designed using Taguchi L16 orthogonal standard array. For this purpose, Minitab 16 Software is used.

TABLE 2

EXPERIMENTS BASED ON L16 ORTHOGONAL ARRAY

S.No	TiB2 (%)	Cutting speed (rpm)	Feed (mm/min)	Depth of Cut (mm)
1	0	500	20	0.2
2	0	710	40	0.4
3	0	1000	63	0.6
4	0	1400	80	0.8
5	3	500	40	0.6
6	3	710	20	0.8
7	3	1000	80	0.2
8	3	1400	63	0.4
9	6	500	63	0.8
10	6	710	80	0.6
11	6	1000	20	0.4
12	6	1400	40	0.2
13	9	500	80	0.4
14	9	710	63	0.2
15	9	1000	40	0.8
16	9	1400	20	0.6

The complete machining process is carried out on Automated Vertical milling machine which is shown in the fig 3. After performing end milling operation on various specimens of Al/TiB_2 composition with different input parameters, we have obtained totally L16 orthogonal arrays. The specimens after machining have been shown in the fig 4.

Fig 3 Automated vertical milling machine

Fig 4 Al-TiB_2 composite specimens after machining

For every single pass on each specimen, the amount of material removed by the end milling cutter has been calculated by using the weighing machine which has the precision of 0.05 gm. The weighing machine used in the experimentation is shown in the fig: 5. Thus we have calculated the material removal rate. Once the MRR was calculated, the results were noted down for the further experimental process by using taguchi technique and all the specimen were carried out to calculate the surface roughness using taly surf. The talysurf used in the experimentation process uses diamond probe as the indenter and has the maximum range of calculating roughness value is 40 microns. The talysurf used in the experimentation is shown in the fig: 6

Fig 5 weighing machine

Fig 6 Surface roughness tester (Talysurf)

III RESULTS AND DISCUSSIONS

In this study, the Taguchi technique was used to obtain ideal machining parameters in themilling of Aluminum TiB_2 composite. As a result of the Taguchi experimental iterations, the factors improving the Surface Roughness and Material Removal Rate has been obtained. The experimented results have been tabulated in the following table.

TABLE 3

EXPERIMENTAL RESULTS

S. No	TiB2 %	cutting speed(rpm)	Feed (mm/min)	Depth of Cut(mm)	MRR(g)	Surface Roughness(µm)
1	0	500	2	0.2	1.143	2.0393
2	0	710	4	0.4	1.484	1.659
3	0	1000	6	0.6	2.376	1.812
4	0	1400	8	0.8	0.918	1.4323
5	3	500	4	0.6	1.472	1.557
6	3	710	2	0.8	2.149	1.873
7	3	1000	8	0.2	0.188	1.9273
8	3	1400	6	0.4	1.19	1.562
9	6	500	6	0.8	1.564	2.377
10	6	710	8	0.6	1.192	2.123
11	6	1000	2	0.4	0.817	1.8103
12	6	1400	4	0.2	1.821	1.57
13	9	500	8	0.4	2.428	2.4918
14	9	710	6	0.2	0.152	2.1396
15	9	1000	4	0.8	1.64	1.978
16	9	1400	2	0.6	0.638	2.235

After design of experiment, 16 experiments are carried out in automated vertical Face milling machine. After each experiment, Material Removal Rate has been calculated. A quality characteristic for Material removal rate is “larger is the better”.

Effect of Material Removal Rate:

Response Table for Signal to Noise Ratios (Larger is better) is shown in Table 4.

TABLE 4

RESPONSE TABLE FOR SIGNALTO NOISE RATIOS

Level	TiB2	Cutting Speed	Feed	DOC
1	2.8408	4.0272	0.5366	-6.1282
2	-0.7508	-1.191	4.0725	2.7223
3	2.2152	-1.1146	-0.8626	2.1243
4	-2.0662	0.5176	-1.5074	3.5208
Delta	4.9071	5.2182	5.5799	9.649
Rank	4	3	2	1

The effect of Material Removal Rate for different percentages of compositions at various parameters are plotted on a graph using taguchi technique has been shown in the fig 7.

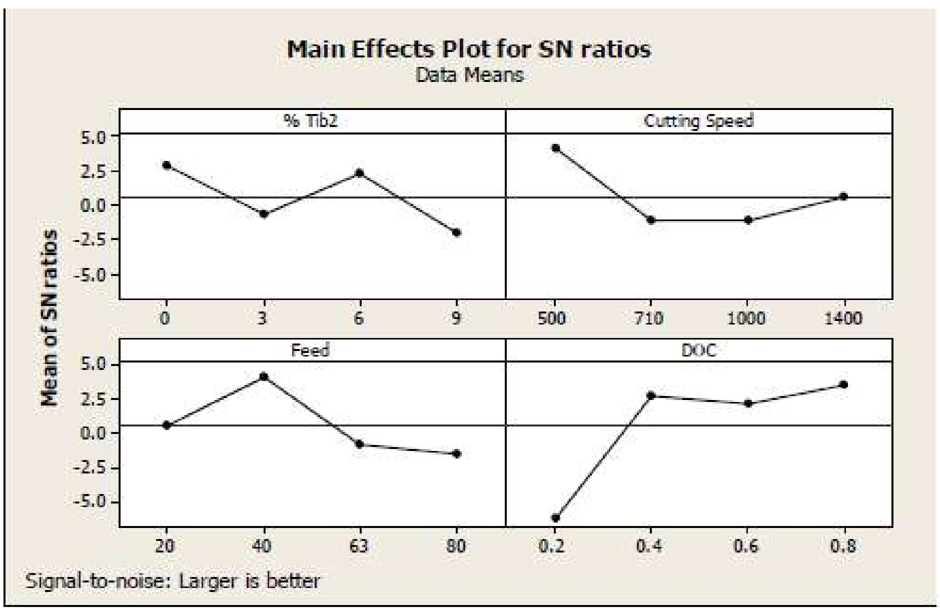

Fig 7 Main effects plot for SN ratios (Material Removal Rate)

From the above plotted graph for obtained values of material removal rate using taguchi technique, we found that in order to get better material removal rate, the optimal parameters are at 6%composition of Ti-B_2 Cutting speed – 500rpm, feed rate – 40mm/min and depth of cut – 0.8mm.

Effect of Surface Roughness:

Response Table for Signal to Noise Ratios (Smaller is better) has been shown in table 5.

TABLE 5

RESPONSE TABLE FOR SIGNALTO NOISE RATIOS

Level	TiB2	Cutting Speed	Feed	DOC
1	-4.717	-6.371	-5.945	-5.602
2	-4.717	-5.748	-4.521	-5.338
3	-5.783	-5.485	-5.79	-5.633
4	-6.86	-4.474	-5.821	-5.504
Delta	2.144	1.897	1.423	0.295
Rank	1	2	3	4

The effect of Surface roughness for different percentage of compositions at various parameters is plotted on a graph using taguchi technique has been shown in the fig 8.

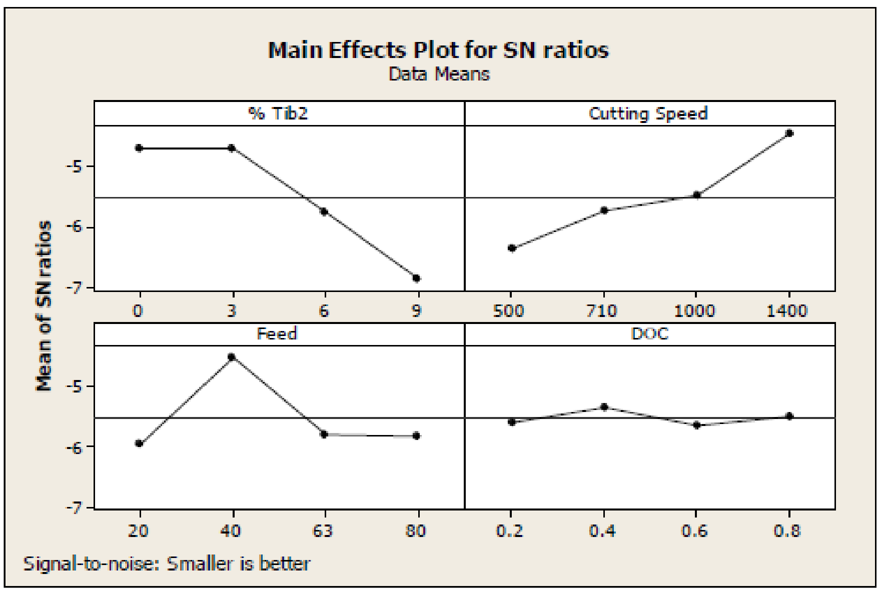

Fig 8 Main effects plot for SN ratios (Surface Roughness)

From the above plotted graphs for the obtained values of Surface roughness using taguchi technique, we found that in order to get better surface finish, the optimal parameters are at 3%composition of Ti-B_2 , spindle speed – 1400rpm, feed rate – 40mm/min and depth of cut – 0.4mm.

IV CONCLUSIONS

After conducting the experiments and analyzing the experimental results, the following conclusions are made.

- Taguchi method has been successfully employed for optimizing the process parameters of Milling of Al TiB2 composite.
- It is observed that Depth of cut has major influence on the Material Removal Rate (MRR).
- The optimum process parameters for MRR are at TiB2: 6%, cutting speed: 500rpm, Feed:40 mm/min and depth of cut: 0.8 mm.
- It is observed that Cutting Speed has major influence on the Surface Roughness.

- The optimum process parameters for Surface Roughness are at TiB_2: 3%, cutting speed :1400rpm, Feed:40mm/min and depth of cut: 0.4 mm.

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REFERENCES

[1] J.A. Ghani, I.A. Choudhury, H.H. Hassan, *"Application of Taguchi method in the optimization of end milling parameters"* , Journal of Materials Processing Technology 145 (2004) 84–92.

[2] Hasan Oktemm, Tunacay Erzurumlu, Mustafa Col, *"A study of the Taguchi optimization method for surface roughness in finish milling of mold surfaces"* , Int J Adv Manuf Technol (2006) 28: 694–700

[3] Anil Choubey, Vedansh Chaturvedi, Jyoti Vimal, *"The Implementation Of Taguchi Methodology For Optimization Of End Milling Process Parameter Of ALLUMINUM"*, International Journal of Engineering Science and Technology, ISSN : 0975-5462, Vol-2, (2007)

[4] Ahmet Murat Pinar, *"Optimization of Process Parameters with Minimum Surface Roughness in the Pocket Machining of AA5083 Aluminum Alloy via Taguchi Method"*, Arabian Journal for Science and Engineering March 2013, Volume 38, Issue 3, pp 705-714

[5] Azlan Mohd Zain , Habibollah Haron , Safian Sharif, *" Application of GA to optimize cutting conditions for minimizing surface roughness in end milling machining process"* , Expert Systems With Applications; 37, 6; 4650-4659; Expert Systems With Applications, Elsevier Science B.V., Amsterdam.; 2010.

[6] Avinash A. Thakre, *"Optimization of Milling Parameters for Minimizing Surface Roughness Using Taguchi's Approach"*, International Journal of Emerging Technology and Advanced Engineering, Volume 3, Issue 6, June 2013, pp. 226-230.

[7] Sourabh KuamrSoni ,Dr. S.K. Moulick *"Optimization of Milling Process Parameter for Surface Roughness of Inconel 718 By Using Taguchi Method"*, IJSRD International Journal for Scientific Research & Development| Vol. 2,Issue 11, 2015|ISSN 2321-0613.

[8] Mihir Thakorbhai Patel, *"Optimization of Milling Process Parameters"* - A Review- International Journal of Advanced Research in Engineering and Applied Sciences, Vol. 4, No. 9, September 2015.

[9] C. C. Tsao, Grey–*"Taguchi method to optimize the milling parameters of aluminum alloy",* International Journal on Adv.

[10] S. Moshat, Saurav Datta and P. K. Patel, 2010, *"Optimization of CNC end milling process parameters using PCAbased Taguchi method"*, International Journal of Engineering, Science and Technology, 2:16-29

[11] Surasit Rawangwong, Jaknarin Chatthong, R. Burapa and W. Boonchouytan, 2012, *"An investigation of optimum cutting conditions in face milling Al 7075 T6 using design of experiment"* International Conference on Applied Operational Research, Proceedings, Lecture Notes in Management Science, 4:88-94.

FABRICATION AND CHARACTERIZATION OF AL/TIB2 METAL MATRIX COMPOSITES USING STIR CASTING PROCESS

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Abstract: **In this study, the aluminum 7075 alloy was taken as matrix material and the titanium di-boride was taken as reinforcing material. The metal matrix composite has been fabricated by Stir casting method by reinforcing titanium di-boride powder with the aluminium alloy and the mechanical properties of the composites have been observed. Titanium di-boride powder of 325 mesh size has been added in an aluminum alloy matrix and the samples have been fabricated using the stir casting technique with the ratio of 3, 6, 9 and 12 by weight %. The fabricated specimens were subjected to tests such as tensile strength, impact strength and hardness and then the values are validated with the base alloy in order to evaluate the mechanical properties of the metal matrix composite.**

Key wards **- Metal matrix composites, Stir casting, tensile strength, Impact strength and Hardness.**

I. INTRODUCTION

Composite material is consists of two or more chemically and physically dissimilar elements arranged properly and it has unique properties respect to different constituent parts. In general, composites consist of matrix and reinforcements, which are primarily added to enhance the matrix strength. The material, which is used as matrix, should bind firmly the reinforcing phase in position. The matrix for the composite material must be chosen cautiously in relation with its properties and the reinforcement behavior. As it is principal constituent in MMCs, the matrix alloy should be selected only after giving cautious concern to its chemical compatibility with reinforcements. Researchers have proposed a lot of matrix materials depending on their properties. Aluminum, titanium and magnesium are widely used among these available materials. Thus, aluminum based MMCs offer potential in the area where, advanced structural applications, good wear resistance at elevated temperature, and enhanced mechanical properties are significant.

The material used as reinforcement, enhances the stiffness and strength of the composite but, reduces the density of MMCs. To attain better properties, the selection of reinforcement is much important and also it depends on the type, size of particle reinforcement, processing technique and its chemical compatibility while adding to metal matrix. Reinforcements are characterized based on their shape, dimension, property, weight and volume fraction and uniform dispersion in the matrix. Although better enhancement is obtained in properties, with the introduction of fiber reinforcements, the prepared materials are not isotropic. But, the particle reinforced or more number of reinforcements is added to the matrix, it becomes a hybrid composite. In addition, the existing fabrication techniques including hot forging, hot rolling, hot extrusion and machining can be used for fabrication followed by the finishing of the composite materials. It is proven that the effective reinforcement materials are the ceramic particles for aluminum and aluminium alloy, which enhance the mechanical property. Typically, these ceramics are carbides, oxides and nitrides in nature. The general ceramic elements used are Silicon Carbide (Sic), Aluminum Oxide ($A1_2O_3$), Titanium Di boride (TiB_2), Boron Carbide (B_4C), thorium and graphite.

II. EXPERIMENTATION

Aluminium 7075 (Al7075) is chosen as the matrix material since, it is low cost and has better properties like good thermal conductivity, high shear strength, abrasion resistance, high-Temperature operation, non flammability, minimal attack by fuels and solvents, and the ability to be formed and treated on conventional equipment. It possesses excellent casting properties and reasonable strength. This alloy is best suited for mass production of lightweight metal castings.

Titanium di-Boride (TiB_2) is a hard ceramic material with more hardness, good thermal conductivity, resistance to corrosion and better oxidation stability. It is a hard material with high strength and high wear resistance at elevated temperatures. The high density, combined with the high elastic modulus and high compressive strength, have lead to its use in armour components. It is unaffected by most chemical reagents, and has excellent stability and wettability in liquid metals such as zinc and aluminum. This, along with its high electric conductivity, has led to its use in Hall-Héroult cells for aluminum production. It is also used as crucibles for molten metals. The Aluminium 7075 rods are shown in the Fig. 1 and Titanium di-boride powder is shown in the Fig 2.

Fig.1 Aluminium 7075 rod

Fig.2 Titanium di-boride powder

Stir Casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring. Stir Casting is the simplest and the most cost effective method of liquid state fabrication. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologies. In this process particles are often tend to form agglomerates, which can be only dissolved by intense stirring. However, here gas access into the melt must be absolutely avoided, since this could lead to unwanted porosities or reactions. Careful attention must be paid to the dispersion of the reinforcement components, so that the reactivity of the components used is coordinated with the temperature of the melt and the duration of stirring, since reactions with the melt can lead to the dissolution of the reinforcement components. Because of the lower surface to volume ratio of spherical particles, reactivity is usually less critical with stirred particle reinforcement than with fibers. Stir casting setup consist of digital control muffle furnace and a stirrer made of graphite connected to electric motor with speed range of 22-840 rpm. Tib2 particles were artificially oxidized in air at 1000◦c and improve their wettability with molten aluminium. This treatment helps the incorporation of the particles while reducing undesired interfacial reactions. Batches of the matrix alloy were melted in a clay-bonded graphite crucible of 1.5 kg capacity using a small muffle furnace. The temperature of the alloy was first raised to about 800 °C and then stirred at 540 rpm using an impeller fabricated from graphite and driven by a variable ac motor. The stir casting setup is shown in the Fig. 3, and Graphite stirrer is shown in the Fig. 4.

Fig.3. Stir Casting Setup

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Fig .4. Graphite stirrer

The temperature of the furnace was gradually lowered until the melt reached a temperature in the liquid solid range while stirring was continued. Then the stirrer was positioned just below the surface of the slurry and the oxidized particles were added uniformly at a rate of 20 g/min over a time period of approximately 3–5 min and speed is lowered to 260 rpm. At the end of charging the slurry was allowed to mix in the semisolid state isothermally for another 15 min while the stirrer was positioned near the bottom of the crucible. Preheating of particulate is necessary to avoid moisture from the particulate otherwise there is chance of agglomeration of particulate due moisture and gases. Along this Tib2 particles are heated at 1000ºC to form a oxide layer on the Tib2 particles which make it chemically more stable and by the oxide layer formation wettability will increase so particles will effectively embedded in aluminium matrix and less number of porosities in casting. After oxide layer formation preheating of particulate is done on temperature of 400° C.

The synthesis of composite is done by stir casting route. The parameters which are important in this work are stirrer design, preheating temperature for particulate and stirring speed. These parameters are discussed below. Stirrer Design very important parameter for stir casting process. It is essentially requires for vortex formation for the uniformly dispersion of particles. There is different type of stirrer some 90º form the shaft and some are bent at 45º. There is a no uniform dispersion of particle.

In stir casting process stirring is very important parameter for consideration. In the process stirring speed was 240 rpm which was effectively producing vortex without any spattering. Stirring speed is decided by fluidity of metal speed, dispersion of particulates are not proper because of in effective vortex.

Tensile Test

The basic idea of a tensile test is to place a sample of a material between two fixtures called "grips" which clamp the material. The material has known dimensions, like length and cross-sectional area. We then begin to apply weight to the material gripped at one end while the other end is fixed. We keep increasing the weight (often called the load or force) while at the same time measuring the change in length of the sample. The universal testing machine (UTM) is shown in the Fig. 5.

Fig .5. Universal testing machine

A material is gripped at both ends by an apparatus, which slowly pulls lengthwise on the piece until it fractures. The pulling force is called a load, which is plotted against the material length change, or displacement. The load is converted to a stress value and the displacement is converted to a strain value. Measure the dimensions of the sample with a pen mark then mark the gauge length reference points. The gauge length should be marked within the parallel section portion of the sample. Measure original width and thickness of the sample at least four times along the reduced section (gauge length) of the specimen. Find cross-sectional area and average areas. Let the instron testing machine be switched on and stabilized at least 30 mins. Fix the specimen into the testing machine with appropriate grips. Select the cross-head speed. Select appropriate scales for the 'strip chart recorder'. Start applying the load sample get fractured, note down the total extension from the chart. Immediately after fracture there will be a large elastic recovery, measure final gauge length after fracture by carefully. Measure cross sectional dimensions of the specimen after fracture. The tensile testing specimens before testing are shown in the Fig.6 and the tensile testing specimens after testing are shown in the Fig. 7.

Fig. 6 Tensile specimens before testing

Fig. 7 Tensile specimens after testing

Impact test

Impact test is undoubtedly the most commonly used test that is done to characterize the ductile to brittle transition behavior in materials. The impact test is done by placing a square shaped Vnotched specimen in the machine. Generally, the Charpy specimen has a square crosssection of dimensions 10mm × 10mm and contains a 450 V notch of 2 mm deep with root radius of 0.25 mm. A heavy pendulum released from a known height strikes the sample on its downward swing and fractures it. After the test bar is broken, the pendulum rebounds to a height that decreases as the energy absorbed in fracture increases. By knowing the mass of the pendulum and the difference between its initial and final heights, the energy absorbed by the fracture can be measured. In impact testing machine will be used here has the indenter facility to indicate energy in foot pound force absorbed by the fracture. The impact testing machine is shown in the Fig. 8 and the specimen placement for impact test is shown in the Fig. 9.

Fig. 8 Impact testing machine

The thickness of the specimen and the dimensions of the un notched length measured. The pendulum was raised to the left until it indicates the maximum energy range on the upper indicator unit. The specimen was placed horizontally across supports with the notch away from the pendulum. The pendulum was released. The indicated value from the indicator unit was recorded. The brake was applied until the pendulum has returned to its stable hanging vertical position. The specimen was removed from the testing area and observes the failure surface. The Specimens before Impact Test are shown in Fig. 9, and the specimens after Impact Test are shown in the Fig. 10.

Fig. 9 Specimens Before Impact Test

Fig. 10 Specimens After Impact Test..

Hardness:

The Rockwell hardness test method consists of indenting the test material with a diamond cone or hardened steel ball indenter. The indenter is forced into the test material under a preliminary minor load F0 usually 10 kgf. When equilibrium has been reached, an indicating device, which follows the movements of the indenter and so responds to changes in depth of penetration of the indenter, is set to a datum position. Removal of the additional major load allows a partial recovery, so reducing the depth of penetration. The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number. The Rockwell hardness testing machine is shown in Fig 11, and the hardness Testing Specimens are shown in the Fig 12.

Fig. 11. Rockwell testing machine

Fig 12 Hardness Testing Specimens.

Polish the surface of the specimens that have been provided. Fit the specimen is in the sample holder. After fitting the sample, perform the Rockwell hardness of composite specimens.. Measure the dimensions (diameter in case of brinell) of the dimensions produce by brinell and Rockwell techniques. Take mean of the five readings in each of the five cases.

III. RESULTS AND DISCUSSIONS

The tensile strength, impact strength and Hardness of the 5 composite specimens with various Tib2 % are shown in the below table.

The tensile strength of the test specimens increases up to 6% by weight of TiB2 particles as more and more grains starts to appear and the tensile strength decreases upon further addition of TiB2 particles. The test results were given in table 4 and the graph has been shown in figure.

Table 1: Test results for tensile test, impact strength and hardness.

Specimen No (% TiB2)	Tensile Strength (Mpa)	Impact Strength (J/mm²)	Hardness (HRB)
1 (0%)	172.404	0.281	40.6
2 (3%)	165.035	0.318	42.4
3 (6%)	167.685	0.263	43.6
4 (9%)	157.401	0.247	46
5 (12%)	117.79	0.229	47.2

The impact strength of specimen 2 is 0.318 J/mm² and is higher than other specimens. After 6% increase in the TiB2 particles, it results in increase in the hardness of the material, which leads to the reduction in the impact strength.

From the tests, it has been revealed that the hardness increases up to 12% of particles.

IV. CONCLUSION

The Al7075 alloy with different combinations of TiB2 powder were fabricated using stir casting method. The mechanical and physical properties of the composites were analyzed and the following conclusions were made.

1. Al- TiB2 composites were made using stir casting method, successfully.
2. The tensile strength of the test specimens increases up to 6% by weight of TiB2 particles. Maximum tensile strength observed at specimen 3 with Tib2 6% is 167.035 Mpa.
3. The impact strength of specimen 2 is higher than other specimens due to the presence of moderate quantity of TiB2 particles in the composite.
4. From the hardness tests, it has been observed that maximum hardness is 47.2 HRB at specimen 5 with 12% and the hardness is increased with increase of Tib2%.

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REFERENCES:

[1] Kalaiselvan K, Muruganand N and Siva Parameswaran, Production and characterization of AA6061–B4C stir cast composite, *Materials and Design*, **2** (2011), 4004–4009.

[2] Fei Chen, Zongning Chenb, Feng Mao, Tongmin Wang and Zhiqiang Cao,TiB2 reinforced aluminum based in situ composites fabricated by stir casting, *Materials Science and Engineering: A*, **625** (2015), 357-368.

[3] Valibeygloo N, Azari Khosroshahi R and Taherzadeh Mousavian R,Micro structural and mechanical properties of Al-4.5wt% Cu reinforced with alumina nano particles by stir casting method, *International Journal of Minerals, Metallurgy, and Materials*, 20 (10) (2013), 978-985.

[4] Hamid Reza Ezatpour, Seyed Abolkarim Sajjadi, Mohsen HaddadSabzevara and Yizhong Huang, Investigation of microstructure and mechanical properties of Al6061-nanocomposite fabricated by stir casting, *Materials and Design*, **55** (2014), 921-928.

[5] Sahraeinejad S, Izadi H, Haghshenas M, Gerlich A.P, Fabrication of metal matrix composites by friction stir processing with different Particles and processing parameters, *Materials Science and Engineering :A*, **626** (2015), 505-513.

[6] Nassim Samer, Jérôme And rieux, Bruno Gardiola, Nikhil Karnatak,Olivier Martin, Hiroki Kurita, Laurent Chaffron, Sophie Gourdet, SabineLay, Olivier Dezellus, Microstructure and mechanical properties of an Al–TiC metal matrix composite obtained by reactive synthesis, *Composites Part A: Applied Science and Manufacturing*, **72 (**2015), 50-57.

[7] Sajjadi S.A, Ezatpour H.R, Beygi H, Microstructure and mechanical properties of Al–Al2O3 micro and nano composites fabricated by stir

casting, *Materials Science and Engineering: A*, **528** (29–30)(2011), 8765-8771

[8] Bijay Kumar Show, Dipak Kumar Mondal, Koushik Biswas and Joydeep Maity, Development of a novel 6351 Al–(Al4SiC4+SiC) hybrid composite with enhanced mechanical properties, *Materials Science and Engineering :A*, **579** (2013), 136-149.

[9] Arun Premnath A, Alwarsamy T, Rajmohan T and Prabhu R, The influence of alumina on mechanical and tribological characteristics of graphite particle reinforced hybrid Al-MMC, *Journal of Mechanical Science and Technology*, **28** (11) (2014), 4737-4744.

[10] Auradi V, Rajesh G.L. and Kori S.A., Preparation and evaluation of mechanical properties of 6061Al–B4Cp composites produced via two-stagemelt stirring, *Materials and Manufacturing Processes*, **29** (2) (2014), 194-200.

[11] Riaz Ahamed A, Paravasu Asokan, Sivanandam Aravindan and PrakashM.K, Drilling of hybrid Al-5%SiCp-5%B4Cp metal matrix composites,*International Journal of Advanced Manufacturing Technology*, **49** (9-12)(2010), 871-877.

[12] Saba Khoramkhorshid, Morteza Alizadeh, Amir Hossein Taghvaei, SergioScudino, Microstructure and mechanical properties of Albasedmetal matrix composites reinforced with Al84Gd6Ni7Co3 glassy particles produced by accumulative roll bonding, *Materials & Design*, **90**(2016), 137-144.

[13] Beigi Khosroshahi N, Taherzadeh Mousavian R, Azari Khosroshahi R,Brabazon D, Mechanical properties of rolled A356based composites reinforced by Cu-coated bimodal ceramic particles, *Materials and Design*, **83** (2015), 678-688.

Technical report submitted to UGC on

Experimental Investigations to improve Machining Characteristics during High speed Milling of Al/TIb2 Particulate Metal-Matrix Composites

UGC Minor Research Project sanction **No.F MRP-6935/16 (SERO/UGC)-dated 02-08-2017**

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SUMMARY

In recent years, aluminum alloy based metal matrix composites (MMC) are gaining importance in several aerospace and automobile applications. Aluminum has been used as matrix material owing to its excellent mechanical properties coupled with good formability. Addition of TiB_2 as reinforcement in aluminium system improves mechanical properties of the composite. In the present investigation, Al7075-TiB_2 composite was prepared by stir casting method.

In this project work, the aluminum 7075 has been fabricated by Stir casting method by reinforcing with titanium di-boride powder and the mechanical properties of the aluminum metal matrix composites have been observed. Titanium di-boride powders of 325 mesh size has been added in an aluminum alloy matrix and the samples have been fabricated using the stir casting technique with the ratio of 3, 6, 9 and 12 by weight %. The fabricated specimens were subjected to tests such as tensile strength, impact strength and hardness and then the values are validated with the base alloy in order to evaluate the mechanical properties of the metal matrix composite. It has been observed from the results that the tensile strength and impact strength increases with the increase in weight % of titanium di-boride powder until 6% and upon further increase in the titanium di-boride powder, the value drops.The hardness of the samples has been increased with the increase of weight % of titanium di-boride powder.

The Project reports on optimization of milling process by the effects of machining parameters applying Taguchi method in order to improve the quality of manufactured goods, and engineering development of designs for studying variation. In the optimization of milling process parameters for machining of aluminium-tib_2 composite attempt has been made to solve the co-related multiple criteria of optimization of milling process. The target was to search an optimal process environment, capable of producing desired parameters of milling.

Keywords: Metal matrix composites, Stir casting, tensile strength, Impact strength, Hardness, Milling, optimization, taguchi method.

CONTENTS

CHAPTER - 1

INTRODUCTION

1. INTRODUCTION

1.1 MATERIALS

A material is a substance (mostly a solid, however other condensed phases also included) that is proposed to be used for different applications. More number of materials is available in the world and they can be found in all the places starts from buildings to spacecrafts. Generally, materials can be divided into two categories and they are crystalline and non-crystalline. The examples are metals, polymers and ceramics. Advanced and new materials that are being developed include nano materials, semiconductors, biomaterials etc. The materials are divided based on their era as follows; Stone Age followed by Bronze Age, Iron Age and at last Steel Age. Formerly it originates from the manufacturing of ceramics and its recognized derivative metallurgy. The oldest form of applied science and engineering is may be termed as material science. It was happened in the late 19^{th} century and hence the importance of understanding the behavior of materials evolved. When, scientist Gibbs proved that there is a relation between the physical properties of the material to the thermodynamic properties related to atomic structure. The product of the space race is the main elements of modern materials science i.e. the understanding and engineering Current material science developed straightforwardly from metallurgy. Major changes of silica, metallic alloys and carbon materials used in the manufacture of space vehicles make possible the exploration of space. The field has become wider to include every class of materials, including magnetic materials, biological materials, ceramics, semiconductors, polymers, medical implant materials and nano materials.

1.1.1 CLASSIFICATION OF MATERIALS

Materials are divided into groups, in order that brain can handle its complexity to identify the material. It can also be classified according to their structure, applications and properties. Based on the atoms bound together, the materials are classified as metals, semiconductor, ceramics and polymers. Recently, advanced and composite materials are also developing, since; they found demand in various applications.

Composites: Composites are made of dissimilar materials to achieve its intended properties (example: concrete, fiberglass, wood).

Advanced Materials: The materials used in "High-Tech" industrial applications are usually planned for higher performance but in general its cost is high. Examples for advanced materials are magnetic alloys used for computer disks and titanium alloys used in supersonic airplanes and some special ceramics, etc.

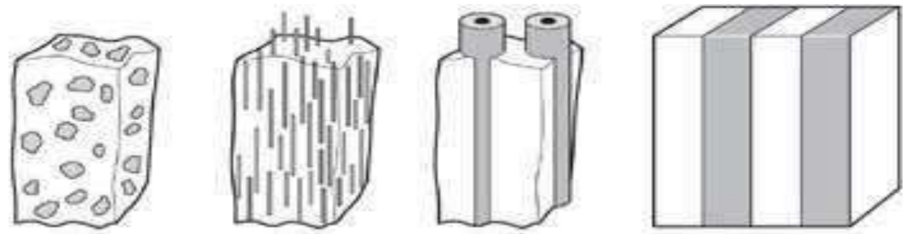
1.2COMPOSITE MATERIALS;

Composite material is consists of two or more chemically and physically dissimilar elements arranged properly and it has unique properties respect to different constituent parts. In general, composites consist of matrix and reinforcements, which are primarily added to enhance the matrix strength. The material, which is used as matrix, should bind firmly the reinforcing phase in position. The most common man made composites can be divided into three groups: i) Polymer Matrix Composites (PMCs), ii) Metal Matrix Composites (MMCs), and iii) Ceramic Matrix Composites (CMCs). In particular, the MMCs play important roles in the engineering and advance manufacturing fields with response to extraordinary demands raised by modern technology. The developments in the area of aerospace, advancing activities in aircrafts field and automotive industry emerges such a demand. Further, MMCs have low specific gravity comparatively, which formulate their superior properties particularly in modulus and strength, to many conventional engineering materials. As a result of this thorough study about the basic behaviour of materials and better understanding of their property, now it is possible to design a new composite material with enhanced mechanical and physical properties. The advanced material consists of composites gives better performance. The continuous demands raised by the developing technology have led to make use of composite materials in various structural and industrial applications and also in diversified field.

1.3 METAL MATRIX COMPOSITES

1.3.1 CHARACTERISTICS OF MMCs

The composite material is said to be a MMC, if the matrix is metal or an alloy. The problems related with the conventional materials are less load carrying capability a perform poor at high temperature applications. To avoid this shortcoming, MMCs are developed. The different forms of reinforcements that are added to the matrices are shown in Figure 1.1.



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

Fig 1.1 Various form of reinforcements (a) Particle, (b) Short fiber,

(c) Continuous fiber, and (d) Laminate

Among the various forms, the particulate reinforced MMCs are widely used due to the uniform dispersion of hard ceramic particles embedded within the matrix. In general, these materials exhibit good mechanical properties, and have the abilities to withstand high velocity impacts, and high toughness. This contribution is much appealing to several engineering fields such as bicycle frames, cylinder block liners, automotive pistons, vehicle drive shafts, etc. But, the drawback of these materials is their low ductility, which is caused by the formation of voids created by the ceramic reinforcements.

1.3.2 FABRICATION METHODS

Fabrication of MMCs is the primary processing route of its production. The fabrication methods are broadly divided into three categories such as liquid state fabrication, solid state fabrication and vapor state fabrication.

1.3.2.1 LIQUID STATE FABRICATION

MMCs fabricated in liquid state find wider application, due to its intrinsic worth of low cost for getting liquid metals compared to metal powder. The probability for fabricating a different complex profile using liquid metals with substantial ease by implementing developed or conventional methods which are in practice in the casting technology. The researchers reported that the techniques used for fabricating MMCs in liquid state are squeeze casting, compo casting, infiltration, spraying, in-situ fabrication, dispersion and stir casting.

1.3.2.2 SOLID STATE FABRICATION

Solid state fabrication of MMCs is generally used to obtain a good mechanical property. This process is implemented to get fine grain control in composite microstructure and the dispersion of reinforcements. In particular, the discontinuous reinforced MMCs are produced by this route to attain improved mechanical behaviour.

1.3.2.3 VAPOR STATE FABRICATION

In this kind of MMC fabrication technique, the matrix material is deposited from the vapor phase to different reinforcement. It is understood thatless or no mechanical disturbance are there in interfacial area and improved adhesion is achieved between matrix and reinforcements.

1.3.3 ADVANTAGES & DISADVANTAGES OF MMCS

MMCs having following merits compared to monolithic metals:

a. Higher stiffness-to-density ratio and strength-to-density ratio
b. Improved wear resistance
c. Higher temperature capability with fire resistance
d. No moisture absorption and no out gassing
e. Higher thermal and electrical conductivity

MMCs having following demerits compared to monolithic metals:

a. High cost
b. Low ductility which is caused by the formation of voids
c. Relatively immature technology

1.4 SELECTION PROCEDURE

1.4.1 Matrix material

The matrix for the composite material must be chosen cautiously in relation with its properties and the reinforcement behavior. As it is principal constituent in MMCs, the matrix alloy should be selected only after givingcautious concern to its chemical compatibility with reinforcements. Researchers have proposed a lot of matrix materials depending on their properties. Aluminum, titanium and magnesium are widely used among these available materials. Beryllium is lightest structural materials available and having greater tensile modulus compared to steel. It is understood that Beryllium is brittle and it is not suitable for the use of general applications. Though, Mg is light, it is more reactive in nature with oxygen. Al is one of the most excellent choices available for matrix, due to its better mechanical property, with high corrosion resistance, high toughness and also low density.In addition, Al is also not expensive compared to other light elements. Thus, aluminum based MMCs offer potential in the area where, advanced structural applications, good wear resistance at elevated temperature, and enhanced mechanical properties are significant.

1.4.2 REINFORCEMENTS

The material used as reinforcement, enhances the stiffness and strength of the composite but, reduces the density of MMCs. To attain better properties, the selection of reinforcement is much important and also it depends on the type, size of particle reinforcement, processing technique and its chemical compatibility while adding to metal matrix. Reinforcements are characterized based on their shape, dimension, property, weight and volume fraction and uniform dispersion in the matrix. Although better enhancement is obtained in properties, with the introduction of fiber reinforcements, the prepared materials are not isotropic. But, the particle reinforced or more number of reinforcements is added to the matrix, it becomes a hybrid composite. In addition, the existing fabrication techniques including hot forging, hot rolling, hot extrusion and machining can be used for fabrication followed by the finishing of the composite materials.

It is proven that the effective reinforcement materials are the ceramic particles for aluminum and aluminium alloy, which enhance the mechanical property. Typically, these ceramics are carbides, oxides and nitrides in nature.

The general ceramic elements used are Silicon Carbide (SiC), Aluminum Oxide ($A1_2O_3$), Titanium Diboride (TiB_2), Boron Carbide (B_4C), thorium and graphite.

1.4.3 MILLING OPERATION

Milling is the process of machining smooth, curved, or uneven surfaces by feeding the work piece against a rotating cutter containing a number of cutting edges. Milling machine is one of the important machining processes. In this operation, work piece is fed against a rotating cylindrical tool. The rotating apparatus consists of many cutting edges (multipoint cutting tool). Normally axis of rotation of feed is given to work piece. Milling operation is illustrious from other machining operations on the basis of orientation between the tool axis and the feed track; however, in other processes like drilling, turning, etc. the tool is feeding direction parallel to axis of rotation.The milling machine consists basically of a motor driven spindle, which supports and revolves milling cutter, and an interchanging adjustable worktable, which mounts and feeds work piece. Milling is normally used to produce parts that are not axially symmetric and have many features, such as hovels, slots, pockets, and even three-dimensional surface curves. Parts that are fabricated completely through milling often include components that are used in partial quantities, maybe for prototypes such as custom designed clasps or brackets. Due to high tolerances and surface finishes that milling can deal, it is ideal for adding precision features to a part whose basic shape has already been formed. Various types of milling processes are end milling, peripheral milling and face milling.

Among different types of milling procedures, end milling is one of most vital and common metal cutting operations used for machining parts because of its capability to remove materials at faster rate with a reasonably good surface quality.The end mill has helical cutting edges passed over onto the cylindrical cutter surface. End mills with smooth ends are used to produce pockets, closed or end key slotsetc. End milling operation produces flat upright surfaces,flat horizontal surfaces and other flat surfaces making an angle from table surface using milling cutter named as end mill.This operation is preferably carried out on vertical milling mechanism.

1.4.4. WORKING PRINCIPLE

The workpiece is holding on the worktable of the machine. The table movement controls the feed of workpiece against the rotating cutter. The cutter is mounted on a spindle or Arbor and revolves at high speed. Except for rotation the cutter has no other motion. As the workpiece advances, the cutter teeth remove the metal from the surface of workpiece and the desired shape is produced.

Milling is the machining process of using rotary cutters to remove material from a work piece advancing (or feeding) in a direction at an angle with the axis of the tool. It covers a wide variety of different operations and machines, on scales from small individual parts to large, heavy-duty gang milling operations. It is one of the most commonly used processes in industry and machine shops today for machining parts to precise sizes and shapes.

1.4.5. MILLING PARAMETERS

1.4.5.1. CUTTING SPEED

It is the distance travelled by a point on the cutting edge of the milling cutter to remove metal in time duration of one minute. It is expressed in meters per minute.

$$\text{Cutting Speed} = \frac{\pi DN}{1000} \quad \text{meter / minute}$$

Where: D = The diameter of the milling cutter in mm

N = Spindle speed in rpm

The cutting speed depends upon the material to be machined, the cutter material, depth of cut, feed, type of operation and the coolant used.

1.4.5.2 FEED

The feed in amilling machine is defined as the distance the workpiece advances under the cutter. Feed can be expressed in three different methods:

Feed per tooth: It is the distance the work advances in the time between engagements by the two successive It is expressed in mm per tooth.

Feed per cutter revolution: It is the distance the work advances in the time when the cutter turns through one complete It is expressed in mm per revolution of the cutter.

It is the distance the work advances in one It is expressed in mm per minute. The feed in a milling machine depends on the material to be machined, cutter material, depth of cut, cutting speed, type of operation and the rigidity of the machine.

1.4.5.3 DEPTH OF CUT

In the milling process, the „depth of cut (d) is defined as the thickness of the layer of material of material removed in one pass of the work piece under the cutter. A depth of cut from 3 mm to 8 mm is common for roughing cuts and is less than 1.5 mm for finishing cuts.

1.4.5.4 MATERIAL REMOVAL RATE (MRR)

Material removal rate (MRR) is the volume of material removed in unit time. For milling MRR is g MRR = B* d* f, mm3 /min Where, B= width of cut, D= depth of cut F= rate of feed

1.4.5.5 SURFACE ROUGHNESS

Roughness average is the most commonly used parameter for expressing the measurements of surface contour. The value represents the arithmetic average of the height of the roughness irregularities above the mean line along the sampling length L. The value Ra is normally measured in the micro inches or in microns in the metric system.

The roughness parameter, Rq, represents the root mean square (RMS) of the peak heights and is more sensitive to the occurrence of occasional high and low points. The RMS is the geometric average height of roughness irregularities over the sampling length, L. The RMS is normally expressed in micro inches or microns.

Although both Ra is universally accepted as a means of expressing surface roughness, this parameter can often be misleading. It is possible that two surfaces having widely different profiles could have the same Ra, but perform quiet differently.

Roughness is produced by the action of the cutting tool or machining process usually resulting in process marks. Function of a component – sliding, sealing, rotating, etc. It dictates what amount of roughness is necessary for correct performance. Cosmetic appearance or secondary operations such as painting and plating can also be important in choosing specification.

Cutting tool geometry along with machine tool settings such as feed rate, depth of cut and speed influence roughness as follows:

- Amplitude: vertical distance between peaks and valleys.
- Spacing : Horizontal distance between peaks and valleys.
- Slope : Sharpness of individual peaks and valleys roughness is a controllable, deliberate element of component design and is always superimposed on the waviness element.

CHAPTER - 2

LITERATURE REVIEW

2. LITERATURE REVIEW

A thorough literature survey is done in order to understand the basics and importance of the research work held related to the proposed work. Based on the literature survey, the research gap and the objectives are identified. The literature review presented here is based on the MMC.

MMCs are produced by joining two or more materials which are dissimilar in chemical and physical behaviour. Nowadays, this material is having better attention, due to their strength, less density and high stiffness. These materials have high demand in the field of structural engineering, aerospace and automotive industries. The recent research work in this composite has been moved towards aluminum based metal matrix composites, because of its wider applications such as automotive pistons, vehicle shafts, bicycle frames, etc.

Kalaiselvan et al. have studied the production and characterization of boron carbide reinforced aluminum alloy based composite. The MMCs are fabricated by various techniques namely, squeeze casting, stir casting, and spray deposition, pressure infiltration, liquid infiltration and powder metallurgy. Among all the manufacturing process, conventional stir casting is an attractive fabrication method, as it is relatively cheap and provides wide selection of materials.

Fei Chen et al. have fabricated aluminum based in situ composites reinforced with TiB_2 particulate with better particle distribution in the matrix. The processing parameters such as stirring duration, stirring intensity and stirring start time are optimized according to the microstructure and mechanical properties.

Valibeygloo et al. have fabricated the Al-4.5wt. % Cu alloy reinforced with varying volume fractions of alumina nano particles through the stir casting process and observed a uniform dispersion of reinforcements in the matrix. An outstanding improvement in compression strength and hardness is observed.

Hamid Reza Ezatpour et al. have investigated the influence of adding nano alumina particles to Al 6061 alloy produced by stir casting process with an objective to improve the mechanical properties of the composites and reported that the nano composites present a fine grain microstructure with high porosity. Vinoth Babu and Moorthy have fabricated Al7075/TiB2 composite through stir cast and reported that the stir casting is the simplest and most commercially used technique for casting MMCs. The crucial thing is to create improved wettability between the reinforcement particles and the aluminum alloy. Mahendra and Radhakrishna have investigated thecharacterization of stir cast Al—Cu—(fly ash + TiB2) hybrid metal matrix composites and found that the mechanical properties of the prepared composite are improved.

Sahraeinejad et al. have examined the effect of Al_2O_3, TiB2 , SiC, and B_4C particle sizes from 130 nm to 4.3 µm on Al 7075 matrix, and with different process parameters to obtain a uniform distribution of particles within the stir zone. They reported that Nano-scale particles seem to be more effective to increase hardness by increasing the particle fraction in the produced composites. Harichandrana and Selvakumar have studied the influence of nano and micro level B_4C particles on the mechanical properties of aluminium metal matrix composites. The fabricated composites are characterized by using scanning electron microscopy and an X-ray diffractometer. The study also reports that the impact energy and ductility of the nano B_4C reinforced composites are better than the micro particle reinforced composites.

Nassim Samer et al.investigated the microstructure and mechanical properties of an Al composite reinforced with nano sized TiC particles. The mechanical property of this composite behavesuncommon with regard to previous micrometer sized Al–TiC composites. The composite consists of high amount of reinforcement are having Young's modulus of ∼110 GPa, tensile strength of about 500 MPa and a maximum elongation about 6%.

Sajjadi et al. have studied the outcome of inclusion of reinforcements on the micro structural and mechanical properties of A356/Al_2O_3 composites. The micro structural analysis shows the uniform distribution and low porosity in composite specimen and the mechanical results reveal that the inclusion of alumina in the matrix has led to increase the hardness, compression strength, the yield strength and ultimate tensile strength.

Bijay Kumar Show et al. fabricated a novel 6351 Al – (Al $_4SiC_4$+SiC) hybrid composite and understood that the composite had a marginal improvement in hardness, strength and ductility with respect to cast 6351 Al. Ali Mazahery and Mohsen Ostad Shabani have investigated the mechanical properties of B_4C reinforced A356 composite and found that the hardness, tensile strength and porosity are greater than the Al alloy and also increase with an increase in the B_4C content.

Arun Premnath et al. studied the mechanical properties of Al_2O_3 reinforced at different weight fractions (5, 10 and 15%) in aluminum based composites. They found that the density and the hardness were increased with the increase in Al_2O_3 content. Mohanty et al. 0 prepared the composite with aluminum 1100 alloy and B_4C particle (25 wt. %) and concluded that the decrease in the electrical conductivity and density from 2.52% to 1.8% and from 48% to 11%, noted, respectively.

Auradi et al. fabricated Al alloy based composites with the reinforcement content of 5 and 7 weight percentage B_4C powder. The experimental results proved the enhancement in the properties such as hardness, tensile strength and compression strength of the materials.

Riaz Ahamed et al. have done the investigation on Al-SiC-B_4C metal matrix composite and found an increase in the hardness, elongation, tensile strength and yield strength of the composite compared to the pure alloy. Aykut Canakci et al. have fabricated AA2024–B $_4$C composite by stir casting process with varying volume fraction of 3, 5, 7 and 10 % and with sizes 29 and 71 µm. They have concluded that the raise in volume percentage, increases hardness of the composite, although the strength of the material is decreased with an addition of the particle volume percentage.

Saba Khoramkhorshid et al. have done an experimental analysis on the mechanical properties of Al composite reinforced with $Al_{84}Gd_6Ni_7Co_3$ powders and concluded that the presence of particles significantly enhances the mechanical properties compared to pure Al.

Beigi Khosroshahi et al. have investigated the mechanical properties of rolled Aluminium composites reinforced with Cu-coated bimodal ceramic particles. The experimental results reveal that the mechanical properties of the fabricated composites, which contain a bimodal ceramic reinforcement of fine SiC and coarse Al_2O_3 particles, have the highest strength and hardness.

CHAPTER – 3

MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1 Raw materials:

Raw materials used in this experimental work are :

1. ALUMINIUM 7075
2. TITANIUM DI- BORIDE

3.1.1 Aluminium 7075 :

Aluminium 7075 (Al7075) is chosen as the matrixmaterial since, it is low cost and has better properties likegood thermal conductivity, high shear strength, abrasionresistance, high-Temperature operation, non flammability,minimal attack by fuels and solvents, and the ability to beformed and treated on conventional equipment. It possessesexcellent casting properties and reasonable strength. This alloyis best suited for mass production of lightweight metalcastings.

Fig.3.1 Aluminium 7075 rod

Composition of Al7075 alloy (%):

Al	Si	Iron	Cu	Mn	Mg	Cr	Zn	Ti	Others
87.12 - 91.4	Max 0.4	Max 0.5	1.2 to 2.0	Max 0.3	2.1 to 2.9	0.18 to 0.28	5.1 to 6.1	Max 0.20	Max 0.15

Table 3.1 Composition of Al7075 alloy

Aluminium 7075 properties :

- 7075 aluminium alloy is an aluminium alloy , with zinc as the primary alloying element. It is strong, with a strength comparable to many steels, and has good fatigue strength and average machinability.
- It has lower resistance to corrosion than many other aluminium alloys, but has significantly better corrosion resistance than the 2000 alloys.
- Its relatively high cost limits its use.
- 7075 aluminium alloy's composition roughly includes 5.6–6.1% zinc, 2.1–2.5% magnesium, 1.2–1.6% copper, and less than a half percent of silicon, iron, manganese, titanium, chromium, and other metals.
- Aluminium 7075 has a density of 2.810 g/cm³ (0.1015 lb/in³)
- Un-heat-treated 7075 (7075-0 temper) has maximum tensile strength no more than 280 MPa (40,000 psi), and maximum yield strength no more than 140 MPa (21,000 psi).
- The material has an elongation (stretch before ultimate failure) of 9–10%. As is the case for all 7075 aluminum alloys, 7075-0 is highly corrosion-resistant combined with generally acceptable strength profile.
- Aluminium 7075 has a specific gravity is 2.7
- It's Melting point is 660°C
- It's Boiling point is 2467°C

3.1.2 Titanium di-boride:

Titanium di-Boride (TiB_2) is a hard ceramic material with more hardness, good thermal conductivity, resistance to corrosion and better oxidation stability.It is a hard material with high strength and high wear resistance at elevated temperatures. The high density, combined with the high elastic modulus and high compressive strength, have lead ot its use in armour components.

It is unaffected by most chemical reagents, and has excellent stability and wettability in liquid metals such as zinc and aluminum. This, along with its high electric conductivity, has led to its use in Hall- Héroult cells for aluminum production. It is also used as crucibles for molten metals.

fig.3.2 Titanium di-boride powder

TiB2 Properties:

- DENSITY -4.52 g/cm^3
- MELTING POINT - 2850 – 2900 °C
- THERMAL EXPANSION - 8.1 × 106°C
- THERMAL CONDUCTIVITY - 60 – 120 W/m-K
- ELECTRIC RESISTIVITY - 10- 30 micro-ohm-cm
- FLEXURAL STRENGTH - 350 – 500 MPa
- MODULUS OF ELASTICITY - 550 GPa
- KNOOP HARDNESS - 3000 Kg/mm^2

Applications:

Due to its high hardness, extreme melting point and chemical inertness, TiB_2 is a candidate for a number of applications.

1) Ballistic Armour:

The combination of high hardness and moderate strength make it attractive for ballistic armour, but its relatively high density and difficulty in forming shaped components make it less attractive for this purpose than some other ceramics.

2) Aluminium Smelting

The chemical inertness and good electrical conductivity of TiB_2 have led to its use as cathodes in Hall-Heroult cells for primary aluminium smelting. It also finds use as crucibles for handling molten metals and as metal evaporation boats.

3) Other Applications

High hardness, moderate strength and good wear resistance make titanium diboride a candidate for use in seals, wear parts and, in composites with other materials and cutting tools. In combination with other primarily oxide ceramics, TiB_2 is used to constitute composite materials in which the presence of the material serves to increase strength and fracture toughness of the matrix.

3.2. OPTIMIZATION

Optimization using Taguchi method is a powerful tool for the design of high-quality systems. It provides simple, efficient and systematic approach to optimize designs for performance, quality and cost. Taguchi method is used where the quality is improved at the design stage instead of controlling it at the manufacturing stage. A customer usually considers several correlated quality characteristics of a product. Metal cutting is widely used manufacturing process in the industries. The metal cutting studies focus on features of tools and machine parameters which affects the process and output quality characteristics.

High speed machining technologies and use of modern machine tools enables the improvement of surface roughness by accurate displacement of tool and good surface finish of the machined surface. The desired cutting parameters are determined based on experience or by hand book. Cutting parameters are reflected on surface roughness, surface texture and dimensional deviation turned product.the correct selection of cutting parameters such as feed rate, depth of cut, cutting speed etc. generates optimum conditions during machining and becomes the main exigency of manufacturing industry. The philosophy of Taguchi is broadly applicable. He proposed that engineering optimization of a process or product should be carried out in a three-step approach, i.e., system design, parameter design, and tolerance design. Chart of Taguchi Method In system design, the engineer applies scientific and engineering knowledge to produce a basic functional prototype design, this design including the product design stage and the process design stage. In the product design stage, the selection of materials, components, tentative product parameter values, etc., are involved. In process design stage, the analysis of processing sequences, the selections of production equipment, tentative process parameter values, etc., are involved. Since system design is an initial functional design, it may be far from optimum in terms of quality and cost.

The objective of the parameter design is to optimize the settings of the process parameter values for improving performance characteristics and to identify the product parameter values under the optimal process parameter values Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only. A loss function is then defined to calculate the deviation between the experimental value and the desired value. Taguchi recommends the use of the loss function to measure the performance characteristic deviating from the desired value. The value of the loss function is further transformed into a signal-to-noise (S/N) ratio. There are three categories of the performance characteristic in the analysis of the S/N ratio, that is, the lower-the-better, larger is better and nominal is better. The S/N ratio for each level of process parameters is computed based on the S/N analysis. Regardless of the category of the performance characteristic, the larger S/N ratio corresponds to the better performance characteristic. Therefore, the optimal level of the process parameters is the level with the highest S/N ratio ρ Furthermore, a statistical analysis of variance (ANOVA) is performed to see which process parameters are statistically significant. With the S/N and ANOVA analyses, the optimal combination of the process parameters can be predicted. Finally, a confirmation experiment is conducted to verify the optimal process parameters obtained from the parameter design.

In this project, the cutting parameter design by the Taguchi method is adopted to obtain optimal machining performance in Milling. Where y is the average of observed data,is the variance of y, n is the number of observations and y is the observed data. Notice that these S/N ratios are expressed on a decibel scale. We would use S/NT if the objective is to reduce variability around a specific target, S/NL if the system is optimized when the response is as large as possible, and S/NS if the system is optimized when the response is as small as possible. Factor levels that maximize the appropriate S/N ratio are optimal. The goal of this research was to produce minimum surface roughness (Ra) in a milling operation. Smaller Ra values represent better or improved surface roughness. Therefore, a smaller-the-better quality characteristic will be implemented and introduced in this study.

3.2.1. TAGUCHI METHOD

Taguchi Method is evolved via Dr. Genichi Taguchi, a Japanese first-class management representative. The method explores the idea of quadratic exceptional loss function and uses a statistical degree of overall performance referred to as Signal to Noise (S/N) ratio. The S/N ratio takes both the imply and the variability into account. The S/N ratio is the ratio of the imply (Signal) to the usual deviation (Noise). The ratio depends at the high-quality characteristics of the product/technique to be optimized.

The general S/N ratios normally used are as follows: - Nominal is Best (NB), Lower the Better (LB) and Higher the Better (HB). In this assignment the experiments are designed with the assist of taguchi L9 orthogonal array.The software program used for DOE (Design of test) is Minitab18. The mission incorporates many procedures that are described one after the other within the methodology respectively.

- Taguchi defines Quality Level of a product because the Total Loss incurred through society because of failure of a product to carry out as preferred whilst it deviates from the added goal performance ranges.
- This consists of prices associated with poor performance, running fees (which adjustments as a product a long time) and any added fees due to dangerous side results of the product in use.
- Taguchi Methods Help corporations to perform the Quality Fix.
- Quality problems are due to Noises in the product or technique system
- Noise is any unwanted effect that will increase variability
- Conduct vast Problem Analyses
- Employ Inter-disciplinary Teams FER3
- Perform Designed Experimental Analyses
- Evaluate Experiments the usage of ANOVA and Signal-to noise strategies Defining the Taguchi Approach
- Factors Cause Functional Variation
- They Fall into Three "Classes"

1. Outer Noise – Environmental Conditions
2. Inner Noise – Lifetime Deterioration
3. Between Product Noise – Piece to Piece Variation

3.2.2. REGRESSION ANALYSIS

Regression analysis is carried out to ensure a least squared fitting to error surface in Minitab 16 environment. Regression analysis has been performed to find out the relationship between input factors and output factors. During regression analysis it is assumed that the factors and the response are linearly related to each other. In common, the units of process parameters differ from each other. Even, if some of the factors have the same units, not all of these factors are tested over the same range. The general first order model is proposed to predict the surface roughness over the experimental region can be expressed as equation 3. $Y (SR) = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5$ ----------- Where Y is the response (surface roughness) and X1, X2, X3, X4, X5 are the coded factors respectively. βs are regression coefficients. The results indicate that the estimated linear model by the regression procedure is significant at the α–level of confidence (0.05). Rsquared (R2) amount is calculated to check the goodness of the fit. R2 is a measure of the amount of reduction in the variability of response obtained by using the regressor variables in the model. As R2 always increases, as we add terms to the model, some model builders prefer to use an adjusted R2 statistic. In general, the R2 adj statistic will not always increase as variables are added to the model. In fact, if unnecessary terms are added, the value of R2 adj will often decrease. When R2 and R2 adj differ dramatically, there is a good chance that no significant terms have been included in the model.

CHAPTER – 4

EXPERIMENTATION

4. EXPERIMENTATION

4.1 Fabrication details:

4.1.1 Stir casting:

Stir Casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring . Stir Casting is the simplest and the most cost effective method of liquid state fabrication. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologies. In this process particles are often tend to form agglomerates, which can be only dissolved by intense stirring . However, here gas access into the melt must be absolutely avoided, since this could lead to unwanted porosities or reactions. Careful attention must be paid to the dispersion of the reinforcement components, so that the reactivity of the components used is coordinated with the temperature of the melt and the duration of stirring, since reactions with the melt can lead to the dissolution of the reinforcement components. Because of the lower surface to volume ratio of spherical particles, reactivity is usually less critical with stirred particle reinforcement than with fibers.

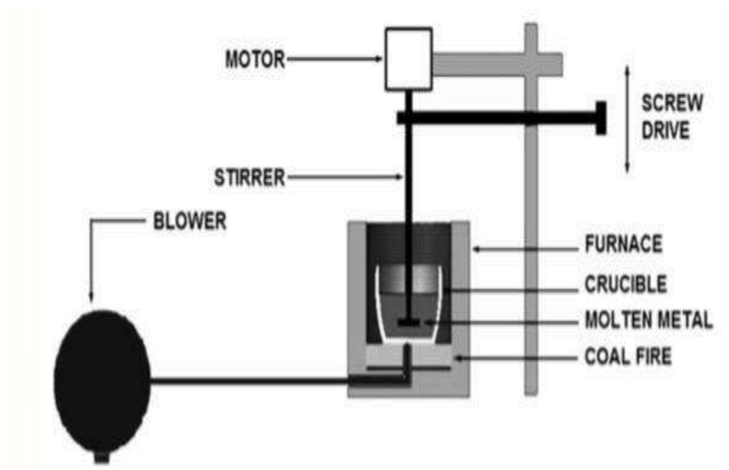


Fig.no. 4.1 schematic diagram of stir casting equipment

Stir Casting is characterized by the following features:

i. Content of dispersed phase is limited (usually not more than 30% by volume).

ii. Distribution of dispersed phase throughout the matrix is not perfectly homogeneous:

1. There are local clouds (clusters) of the dispersed particles (fibers) 2. There may be gravity segregation of the dispersed phase due to a difference in the densities of the dispersed and matrix phase.

iii. The technology is relatively simple and low cost.

Distribution of dispersed phase may be improved if the matrix is in semi-solid condition. The method using stirring metal composite materials in semi-solid state is called Rheocasting. High viscosity of the semi-solid matrix material enables better mixing of the dispersed phase.

4.1.2 Furnace:

Stir casting setup consist of digital control muffle furnace and a stirrer made of graphite connected to electric motor with speed range of 22-840 rpm. SiC particles were artificially oxidized in air at 1000 ◦C for 150 min to form a layer of SiO2 on them and improve their wettability with molten aluminium. This treatment helps the incorporation of the particles while reducing undesired interfacial reactions. Batches of the matrix alloy were melted in a clay-bonded graphite crucible of 1.5 kg capacity using a small muffle furnace. The temperature of the alloy was first raised to about 800 °C and then stirred at 540 rpm using an impeller fabricated from graphite and driven by a variable ac motor.

Fig.4.2. Stir Casting Setup

4.1.3 Graphite stirrer :

The temperature of the furnace was gradually lowered until the melt reached a temperature in the liquid solid range while stirring was continued. Then the stirrer was positioned just below the surface of the slurry and the oxidized particles were added uniformly at a rate of 20 g/min over a time period of approximately 3–5 min and speed is lowered to 260 rpm. At the end of charging the slurry was allowed to mix in the semisolid state isothermally for another 15 min while the stirrer was positioned near the bottom of the crucible.

Fig.4.3 Graphite stirrer.

4.1.4 Particle Preheating Temperature:

Preheating of particulate is necessary to avoid moisture from the particulate otherwise there is chance of agglomeration of particulate due moisture and gases. Along this SiC particles are heated at 1000ºC to form a oxide layer on the SiC particles which make it chemically more stable and by the oxide layer formation wettability will increase so particles will effectively embedded in aluminium matrix and less number of porosities in casting. After oxide layer formation preheating of particulate is done on temperature of 400° C.

4.1.5 Synthesis of composite :

The synthesis of composite is done by stir casting route. The parameters which are important in this work are stirrer design, preheating temperature for particulate and stirring speed. These parameters are discussed below. Stirrer Design very important parameter for stir casting process. It is essentially requires for vortex formation for the uniformly dispersion of particles. There is different type of stirrer some 90º form the shaft and some are bent at 45º. There is a no uniform dispersion of particle.

Stirring speed:

In stir casting process stirring is very important parameter for consideration. In the process stirring speed was 240 rpm which was effectively producing vortex without any spattering. Stirring speed is decided by fluidity of metal speed, dispersion of particulates are not proper because of in effective vortex.

4.2 Testing of Composites:

4.2.1. Tensile Test

The basic idea of a tensile test is to place a sample of a material between two fixtures called "grips" which clamp the material. The material has known dimensions, like length and cross-sectional area. We then begin to apply weight to the material gripped at one end while the other end is fixed. We keep increasing the weight (often called the load or force) while at the same time measuring the change in length of the sample.

Fig.4.4 Universal testing machine

Procedure:

A material is gripped at both ends by an apparatus, which slowly pulls lengthwise on the piece until it fractures. The pulling force is called a load, which is plotted against the material length change, or displacement. The load is converted to a stress value and the displacement is converted to a strain value.

Measure the dimensions of the sample. With a pen mark then mark the gauge length reference points.The gauge length should be marked within the parallel section portion of the sample.Measure original width and thickness of the sample at least four times along the reduced section (gauge length) of the specimen. Find cross-sectional area and average area.Let the Instron testing machine be switched on and stabilized for at least 30 mins. Fix the specimen into the testing machine with appropriate grips.Select the cross-head speed. Select appropriate scales for the “strip chart recorder”.Start applying the load.sample get fractured, note down the total extension from the chart. Immediately after fracture there will be a large elastic recovery.Measure final gauge length after fracture by carefully.Measure cross sectional dimensions of the specimen after fracture.

Fig 4.5 Tensile specimens before testing

Fig.4.6 Tensile specimens after testing

4.2.2 Impact Strength :

Impact test is undoubtedly the most commonly used test that is done to characterize the ductile to brittle transition behavior in materials. The impact test is done by placing a square shaped Vnotched specimen in the machine. Generally, the Charpy specimen has a square crosssection of dimensions 10mm × 10mm and contains a 450 V notch of 2 mm deep with root radius of 0.25 mm. A heavy pendulum released from a known height strikes the sample on its downward swing and fractures it. After the test bar is broken, the pendulum rebounds to a height that decreases as the energy absorbed in fracture increases. By knowing the mass of the pendulum and the difference between its initial and final heights, the energy absorbed by the fracture can be measured. In impact testing machine will be used here has the indentor facility to indicate energy in foot pound (ft.Lb) force absorbed by the fracture.

Fig.4.7 Impact testing machine (Charpy test)

Fig.4.8 Specimen placement for impact test

Principles of Measurement:

In an impact test a specially prepared notched specimen is fractured by a single blow from a pendulum striker and energy required being a measure of resistance to impact. The impact test involves a pendulum (Figure 2) swinging down from a specified heighth0 to hit the specimen and fracture it. The height h to which the pendulum rises after striking and breaking the specimen is a measurement of the energy used in the breaking. if no energy were used, the pendulum would swing to the same height h0 it started from, i.e.the potential energy mgh0 at the top of the pendulum swing before and after the collision would be the same. The greater the energy used in the breaking, the greater the 'loss' of energy and so the lower the height to which the pendulum rises. If the pendulum swings up to a height h after breaking the specimen, then the energy used to break it is

$E = mgh_o - mgh$ *[Nm or J]*

This energy value called impact toughness or impact value.

Procedure:

The thickness of the specimen and the dimensions of the un notched length measured. The pendulum was raised to the left until it indicates the maximum energy range on the upper indicator unit. The specimen was placed horizontally across supports with the notch away from the pendulum. The pendulum was released. The indicated value from the indicator unit was recorded. The brake was applied until the pendulum has returned to its stable hanging vertical position. The specimen was removed from the testing area and observes the failure surface.

Fig. 4.9 Specimens Before Impact Test.

Fig. 4.10 Specimens After Impact Test.

Calculations:

1. For Al7075+TiB2(0%):

Length of specimen (L) = $55mm$

Effective cross-section area (A_e) = $45mm^2$

Effective value (V_e) = 45×55

= $2475mm^3$

Observed angle (β) = 153-18 = 135°

Initial angle (α) = 141.47°

Pendulum radius (R) = $0.815m$

Weight of hammer (W) = 21.04×9.81

= $206.4027N$

Rupture energy (U) = WR $(cos\beta - cos\alpha)$

= $(206.4 \times 0.815 \times 0.0757)$

= $12.645\ J$

Modulus of rupture (U_r) = U/V_e

= $12.645/2475$

= $5.109\times 10^{-3} J/mm^3$

Notch impact strength (I) = U/A_e

= $12.645/45$

= $0.281\ J/mm^2$

2. For Al7075+TiB2(3%):

Length of specimen (L) = $55mm$

Effective cross-section area (A_e) = $53mm^2$

Effective value (V_e) = 55×53

= $2915mm^3$

Observed angle (β) = 151-18 = 133°

Initial angle (α) = 141.47°

Pendulum radius (R) = $0.815m$

Weight of hammer (W) = 21.04×9.81

= $206.4027N$

Rupture energy (U) = WR $(cos\beta - cos\alpha)$

= $(206.4 \times 0.815 \times 0.1003)$

= $16.885\ J$

Modulus of rupture (U_r) = U/V_e

= $16.885/2915$

= $5.792\times 10^{-3} J/mm^3$

Notch impact strength (I) = U/A_e

= $16.885/45$

= $0.318\ J/mm^2$

3. For Al7075+TiB2(6%):

Length of specimen (L) = 55 mm

Effective cross-section area (A_e) = 48 mm^2

Effective value (V_e) = 48×55

= 2640mm^3

Observed angle (β) = 153-18 = 135°

Initial angle (α) = 141.47°

Pendulum radius (R) = 0.815m

Weight of hammer (W) = 21.04 × 9.81

= 206.4027N

Rupture energy (U) = WR ($cos\beta - cos\alpha$)

= (206.4 × 0.815 × 0.0757)

= 12.645 J

Modulus of rupture (U_r) = U/V_e

= 12.645/2640

= 4.789× $10^{-3} J/mm^3$

Notch impact strength (I) = U/A_e

= 12.645/48

= 0.263 J/mm^2

4. For Al7075+TiB2(9%):

Length of specimen (L) = 55 mm

Effective cross-section area (A_e) = 51mm^2

Effective value (V_e) = 55×51

= 2805mm^3

Observed angle (β) = 153-18 = 135°

Initial angle (α) = 141.47°

Pendulum radius (R) = 0.815m

Weight of hammer (W) = 21.04 × 9.81

= 206.4027N

Rupture energy (U) = WR $(cos\beta - cos\alpha)$

= $(206.4 \times 0.815 \times 0.0757)$

= 12.645 J

Modulus of rupture (U_r) = U/V_e

= $12.645/2805$

= $4.508 \times 10^{-3} J/mm^3$

Notch impact strength (I) = U/A_e

= $12.645/51$

= $0.2479 J/mm^2$

5. For Al7075+TiB2(12%):

Length of specimen (L) = 55 mm

Effective cross-section area (A_e) = $55 mm^2$

Effective value (V_e) = 55×55

= $3025 mm^3$

Observed angle (β) = 153-18 = 135°

Initial angle (α) = 141.47°

Pendulum radius (R) = 0.815m

Weight of hammer (W) = 21.04×9.81

= 206.4027N

Rupture energy (U) = WR $(cos\beta - cos\alpha)$

= $(206.4 \times 0.815 \times 0.0757)$

= 12.645 J

Modulus of rupture (U_r) = U/V_e

= $12.645/3025$

= $4.180 \times 10^{-3} J/mm^3$

Notch impact strength (I) = U/A_e

= $12.645/55$

= $0.229 J/mm^2$

4.2.3. Hardness :

Rockwell hardness test:

The Rockwell hardness test method consists of indenting the test material with a diamond cone or hardened steel ball indenter. The indenter is forced into the test material under a preliminary minor load F0 usually 10 kgf. When equilibrium has been reached, an indicating device, which follows the movements of the indenter and so responds to changes in depth of penetration of the indenter, is set to a datum position. While the preliminary minor load is still applied an additional major load is applied with resulting increase in penetration (Fig. 1B). When equilibrium has again been reach, the additional major load is removed but the preliminary minor load is still maintained. Removal of the additional major load allows a partial recovery, so reducing the depth of penetration. The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number.

HR = E - e

F0 = preliminary minor load in kgf,

F1 = additional major load in kgf

F = total load in kgf

HR = Rockwell hardness number

e = permanent increase in depth of penetration due to major load

F1 measured in units of 0.002 mm

E = a constant depending on form of indenter: 100 units for diamond indenter, 130 units for steel ball indenter

D = diameter of steel ball.

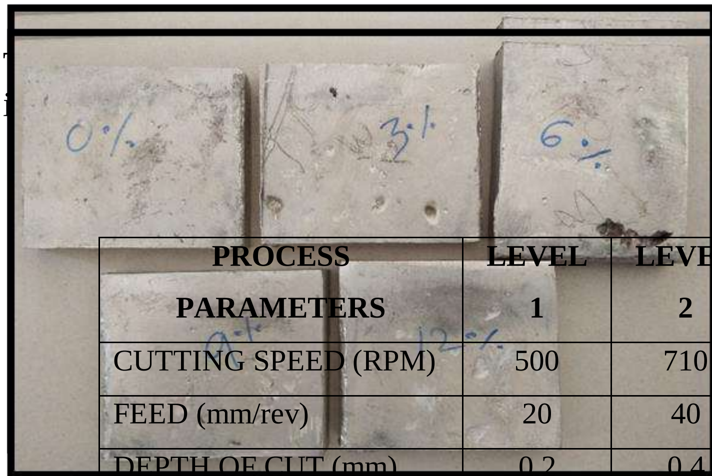
Fig. 4.11. Rockwell Hardness testing machine

Experimental Procedure:

Polish the surface of the specimens that have been provided to you.Fit the specimen is in the sample holder. After fitting the sample, perform the brinell, Rockwell and Rockwell superficial hardness of mild steel, aluminum and brass.Measure the dimensions (diameter in case of brinell) of the dimensions produce by brinell and Rockwell techniques. Take mean of the five readings in each of the five cases.

Fig 4.12 Hardness Testing Specimens.

4.3. INPUT PARAMETERS AND THEIR LEVELS



T ... Tib2 composite are shown i ... ore machining are shown in fig: 3

... ers

PROCESS PARAMETERS	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
CUTTING SPEED (RPM)	500	710	1000	1400
FEED (mm/rev)	20	40	63	80
DEPTH OF CUT (mm)	0.2	0.4	0.6	0.8

Fig 4.13 : Al/TiB_2 composite specimens before machining

Carbide Insert Tool:

Carbide inserts are replaceable and usually indexable bits of cemented **carbide** used in machining steels, cast iron, high temperature alloys, and nonferrous materials. **Carbide inserts** allow faster machining and leave better finishes on metal parts. The **insert** has to withstand extreme heat and force so it's **made** of some of the hardest material in the world.

The carbideinsert end milling tool used for machining is shown in the fig.4

fig 4.14: carbide insert tool

4.4. DESIGN OF EXPERIMENTS (DOE)

For selected input parameters, experiments are designed using Taguchi L16 orthogonal standard array. For this purpose, software Minitab 16 is used.

Table 2: Experiments based on L16 orthogonal array

S.No	TiB2 (%)	cutting speed(rpm)	Feed(mm/min)	Depth of Cut(mm)
1	0	500	20	0.2
2	0	710	40	0.4
3	0	1000	63	0.6
4	0	1400	80	0.8
5	3	500	40	0.6
6	3	710	20	0.8
7	3	1000	80	0.2
8	3	1400	63	0.4
9	6	500	63	0.8
10	6	710	80	0.6
11	6	1000	20	0.4
12	6	1400	40	0.2

13	9	500	80	0.4
14	9	710	63	0.2
15	9	1000	40	0.8
16	9	1400	20	0.6

The complete machining process is carried out on Automated Vertical milling machine which is shown in the fig: 5. After performing end milling operation on various specimens of Al/TiB_2 composition with different input parameters, we have obtained totally L16 orthogonal arrays. The specimens after machining has been shown in the fig: 6

Fig 4.15: Automated vertical milling machine

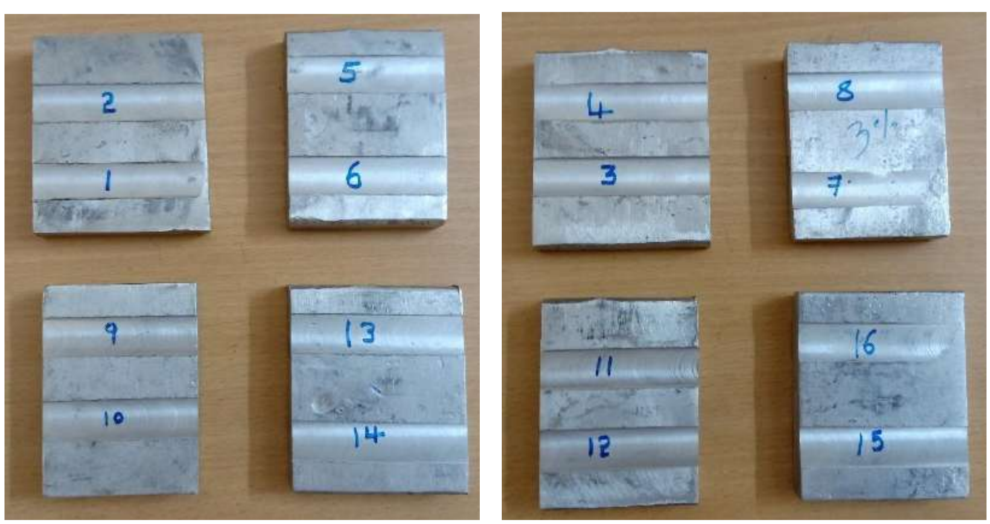


Fig 4.16: specimen of Al TiB_2 composite after machining

For every single pass on each specimen, the amount of material removed by the end milling cutter has been calculated by using the weighing machine which has the precision of 0.05 gm. The weighing machine used in the experimentation is shown in the fig: 7. Thus we have calculated the material removal rate.

Fig 4.17: weighing machine used to calculate MRR

Once the MRR was calculated,the results were noted down for the further experimental process by using taguchi technique and all the specimen were carried out to calculate the surface roughness using taly surf. The talysurf used in the experimentation processuses diamond probe as the indenter and has the maximum range of calculating roughness value is 40 microns. The talysurf used in the experimentation is shown in the fig: 8

Fig 4.18: Measuring of surface roughness using Talysurf

CHAPTER – 5

RESULTS AND DISCUSSIONS

RESULTS AND DISCUSSIONS

5.1 Tensile Test:

The tensile strength of the test specimens increases up to 6% by weight of TiB2 particles asmore and more grains starts to appear and the tensile strength decreases upon further additionof TiB2 particles.

5.1.1 Aluminium 7075 + 0% TiB_2 powder :

In this composition tib2 powder was not used only pure aluminium taken.then values are shown in the table.

Input Data			Output Data		
Specimen Shape	Solid Round		Load At Yield	16.655	kN
SpecimenType	Aluminum		Elongation At Yield	11.480	mm
Specimen Description			Yield Stress	137.915	N/mm2
			Load at Peak	20.820	kN
			Elongation at Peak	17.200	mm
Specimen Diameter	12.4	mm	Tensile Strength	172.404	N/mm2
Initial G.L. For % elong	61.4	mm	Load At Break	0.025	kN
Pre Load Value	0	kN	Elongation At Break	23.660	mm
Max. Load	100	kN	Breaking Strength	0.207	N/mm2
Max. Elongation	150	mm	% Reduction Area	15.48	%
Specimen Cross Section Area	120.763	mm2	% Elongation	9.12	%
Final Sp Diameter	11.4	mm			
Final Gauge Length	67	mm			
Final Area	102.07	mm2			

Table5.1 Input and Output values of Tensile Test Values at 0%

Graph :

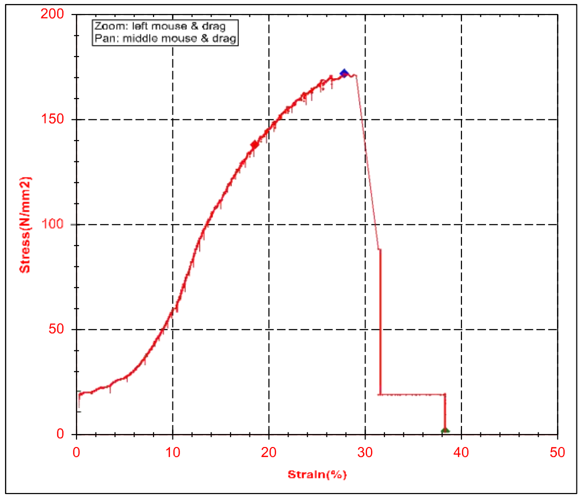


Fig 5.1 Stress-Strain Diagram at Al -0%TiB_2

5.1.2 Aluminium 7075 + 3% TiB_2 powder :

In this composition 3 % of TiB_2 powder was added with the Aluminium 7075.then values are shown in the table.

Specimen Description			Yield Stress	148.589	N/mm2
			Load at Peak	18.665	kN
			Elongation at Peak	15.740	mm
Specimen Diameter	12	mm	Tensile Strength	165.035	N/mm2
Initial G.L. For % elong	61.7	mm	Load At Break	1.605	kN
Pre Load Value	0	kN	Elongation At Break	21.310	mm
Max. Load	100	kN	Breaking Strength	14.191	N/mm2
Max. Elongation	150	mm			
Specimen Cross Section Area	113.097	mm2			

Table 5.2 Input and Output values of Tensile Test Values at 3%

Graph:

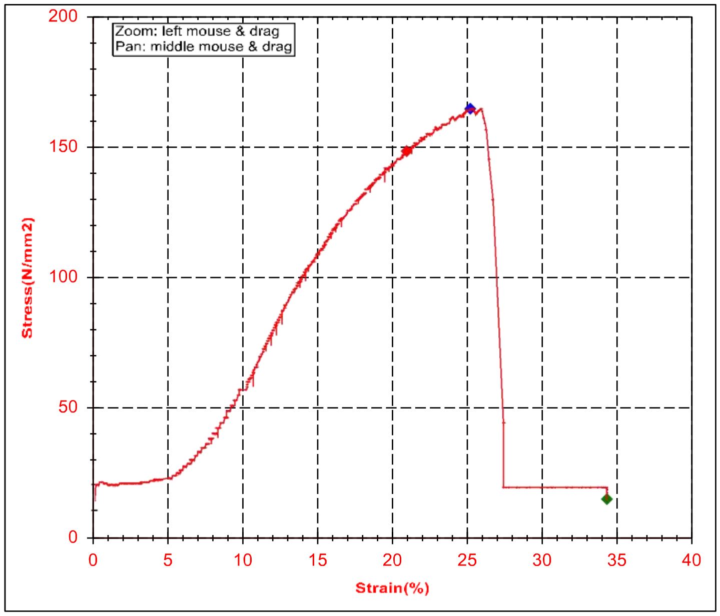


Fig. 5.2 Stress-Strain Diagram at Al -3%TiB_2

5.1.3 Aluminium 7075 + 6% TiB_2 powder :

In this composition 6 % of TiB_2 powder was added with the Aluminium 7075.then values are shown in the table.

Input Data

Specimen Shape	Solid Round	
SpecimenType	Aluminum	
Specimen Description		
Specimen Diameter	11.9	mm
Initial G.L. For % elong	61.2	mm
Pre Load Value	0	kN
Max. Load	100	kN
Max. Elongation	150	mm
Specimen Cross Section Area	111.220	mm2
Final Sp Diameter	10.7	mm
Final Gauge Length	68.5	mm
Final Area	89.92	mm2

Output Data

Load At Yield	16.13	kN
Elongation At Yield	12.100	mm
Yield Stress	145.028	N/mm2
Load at Peak	18.650	kN
Elongation at Peak	15.820	mm
Tensile Strength	167.685	N/mm2
Load At Break	0.905	kN
Elongation At Break	28.610	mm
Breaking Strength	8.137	N/mm2
% Reduction Area	19.15	%
% Elongation	11.93	%

Table 5.3 Input and Output values of Tensile Test Values at 6%

Graph:

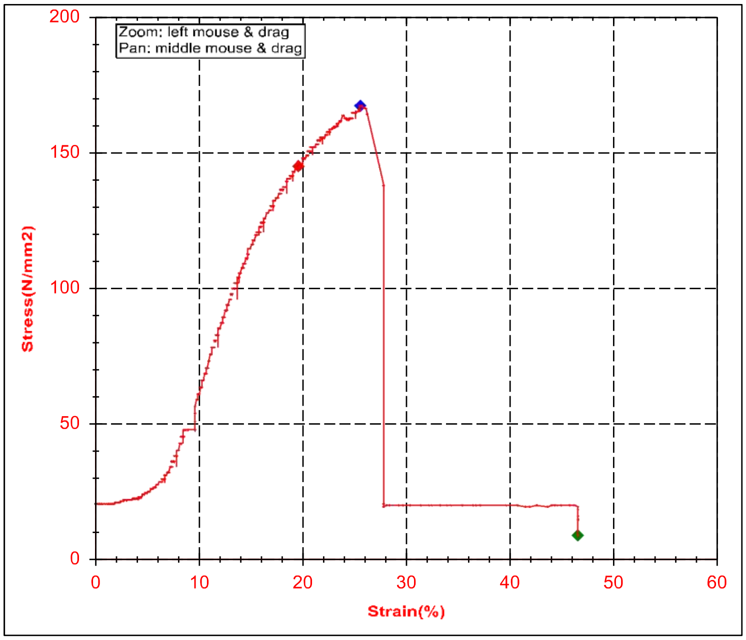


Fig 5.3 Stress-Strain Diagram at Al -6%TiB_2

5.1.4 Aluminium 7075 + 9% TiB_2 powder :

In this composition 9% of TiB_2 powder was added with the Aluminium 7075.then values are shown in the table.

Input Data			Output Data		
Specimen Shape	Solid Round		Load At Yield	8.705	kN
SpecimenType	Alumimum		Elongation At Yield	7.540	mm
Specimen Description			Yield Stress	74.466	N/mm2
			Load at Peak	18.400	kN
Specimen Diameter	12.2	mm	Elongation at Peak	13.320	mm
Initial G.L. For % elong	63.9	mm	Tensile Strength	157.401	N/mm2
Pre Load Value	0	kN	Load At Break	0.055	kN
Max. Load	100	kN	Elongation At Break	17.350	mm
Max. Elongation	150	mm	Breaking Strength	0.470	N/mm2
Specimen Cross Section Area	116.899	mm2	% Reduction Area	9.59	%
Final Sp Diameter	11.6	mm	% Elongation	8.61	%
Final Gauge Length	69.4	mm			
Final Area	105.68	mm2			

Table 5.4 Input and Output values of Tensile Test Values At 9%

Graph:

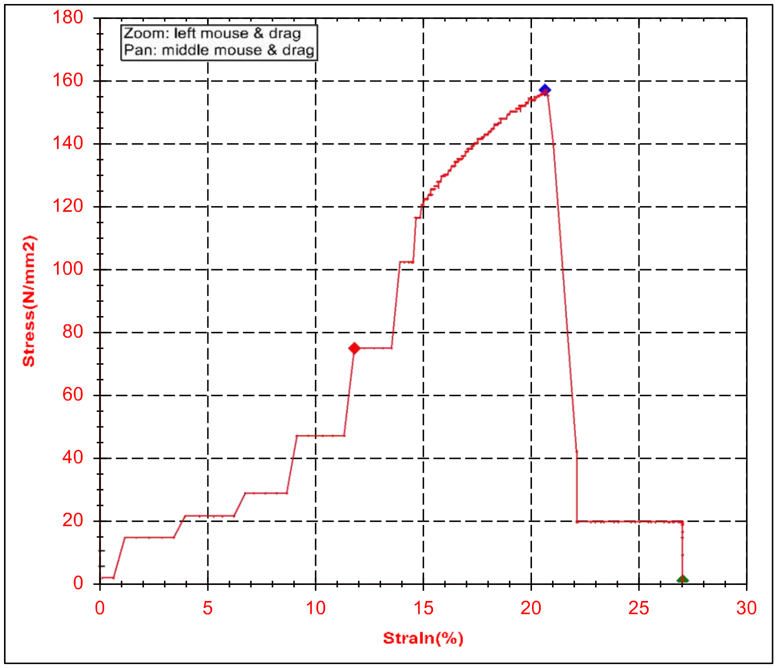


Fig 5.4 Stress-Strain Diagram at Al -9%TiB_2

5.1.5 Aluminium 7075 + 12% TiB_2 powder :

In this composition 12 % of TiB_2 powder was added with the Aluminium 7075.then values are shown in the table.

Input Data			Output Data		
Specimen Shape	Solid Round		Load At Yield	11.55	kN
SpecimenType	Aluminum		Elongation At Yield	7.540	mm
Specimen Description			Yield Stress	94.118	N/mm2
			Load at Peak	14.455	kN
Specimen Diameter	12.5	mm	Elongation at Peak	9.350	mm
Initial G.L. For % elong	62.5	mm	Tensile Strength	117.790	N/mm2
Pre Load Value	0	kN	Load At Break	0.140	kN
Max. Load	100	kN	Elongation At Break	10.110	mm
Max. Elongation	150	mm	Breaking Strength	1.141	N/mm2
Specimen Cross Section Area	122.718	mm2	% Reduction Area	16.83	%
Final Sp Diameter	11.4	mm	% Elongation	0.48	%
Final Gauge Length	62.8	mm			
Final Area	102.07	mm2			

Table 5.5 Input and Output values of Tensile Test Values at 12%

GRAPH:

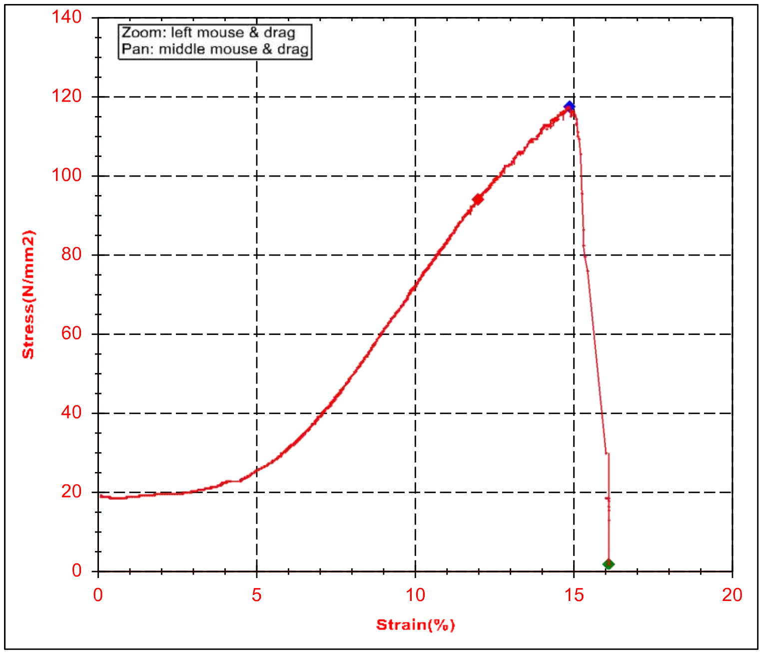


Fig 5.5 Stress-Strain Diagram at Al -12%TiB_2

The tensile strength of the test specimens increases up to 6% by weight of TiB2 particlesasmore and more grains starts to appear and the tensile strength decreases upon further additionof TiB2 particles. The test results were given in table 4 and the graph has been shown in figure.

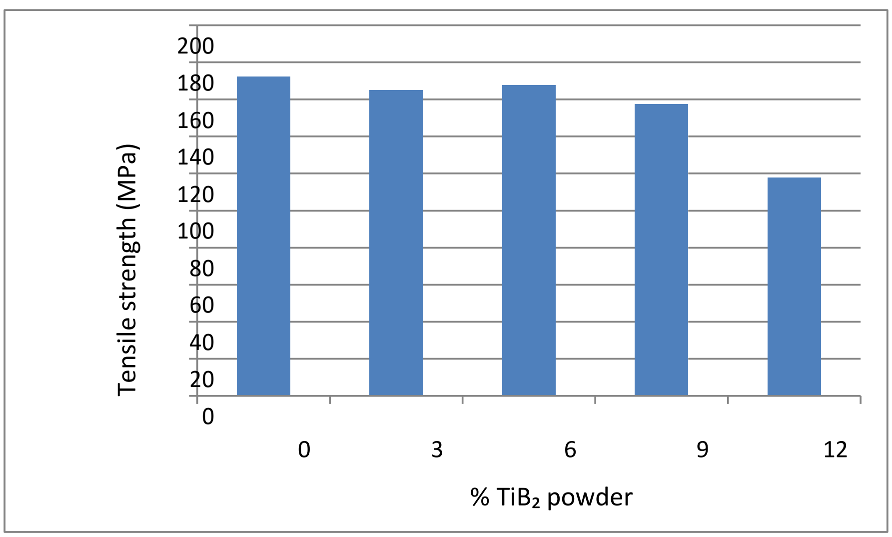


Fig.5.6 Result of tensile test

5.2 Impact strength:

The impact strength of specimen 2 is higher than other specimens due to the presence ofmoderate quantity of TiB2 particles in the composite. After 6% increase in the TiB2 particles,it results in increase in the hardness of the material, which leads to the reduction in the impact strength.

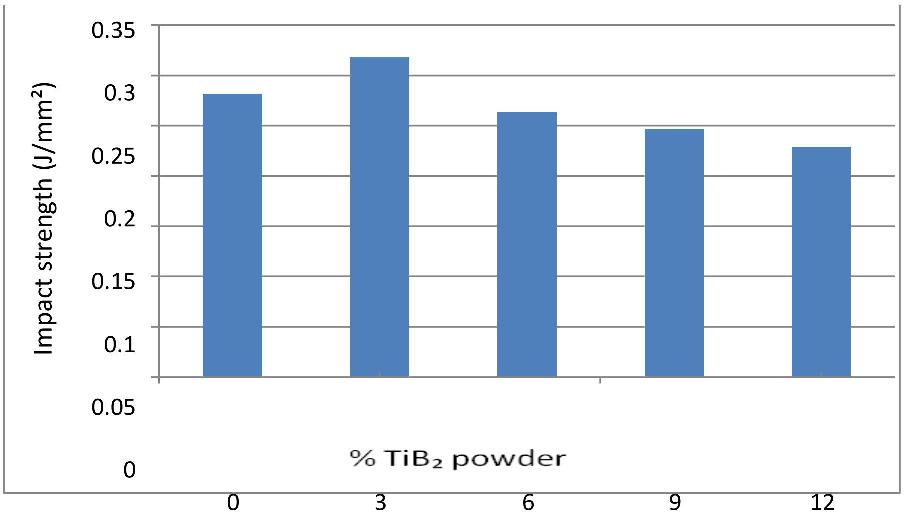


Fig.5.7 Result of impact test

5.3 HARDNESS TEST:

From the tests, it has been revealed that the hardness increases upto 12% of particles.The test results for hardness have been given the graph.

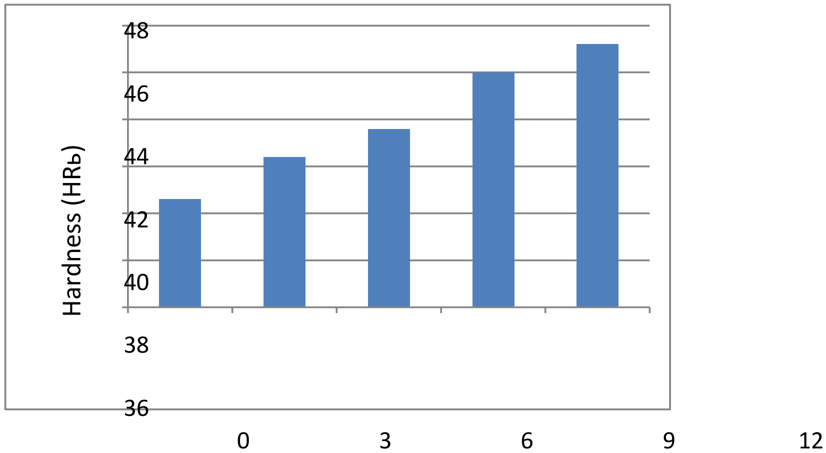


Fig.5.8 Result of Hardness test.

5.4 Results :

COMBINATION (in % TiB2)	TENSILE STRENGTH (MPa)	IMPACT STRENGTH (J/mm²)	HARDNESS (HRb)
Specimen 1 (0%)	172.404	0.281	40.6
Specimen 2 (3%)	165.035	0.318	42.4
Specimen 3 (6%)	167.685	0.263	43.6
Specimen 4 (9%)	157.401	0.247	46
Specimen 5 (12%)	117.79	0.229	47.2

Table 5.6 Test results for tensile test, impact strength and hardness.

In this study, the Taguchi technique was used to obtain ideal machining parameters in the milling of Aluminum TiB_2 composite. As a result of the Taguchi experimental iterations, the factors improving the Surface Roughness and Material Removal Rate has been obtained. The experimented results have been tabulated in the following table.

S. No	TiB_2%	cutting speed(rpm)	Feed(mm/min)	Depth of Cut(mm)	MRR(g)	Surface Roughness(μm)
1	0	500	20	0.2	1.143	2.0393
2	0	710	40	0.4	1.484	1.659
3	0	1000	63	0.6	2.376	1.812
4	0	1400	80	0.8	0.918	1.4323
5	3	500	40	0.6	1.472	1.557
6	3	710	20	0.8	2.149	1.873
7	3	1000	80	0.2	0.188	1.9273
8	3	1400	63	0.4	1.19	1.562
9	6	500	63	0.8	1.564	2.377
10	6	710	80	0.6	1.192	2.123
11	6	1000	20	0.4	0.817	1.8103
12	6	1400	40	0.2	1.821	1.57
13	9	500	80	0.4	2.428	2.4918
14	9	710	63	0.2	0.152	2.1396
15	9	1000	40	0.8	1.64	1.978
16	9	1400	20	0.6	0.638	2.235

After design of experiment, 16 experiments are carried out in Automated vertical Face milling machine. After each experiment, Material Removal Rate has been calculated. A quality characteristic for Material removal rate is “larger is the better”.

Effect of Material Removal Rate

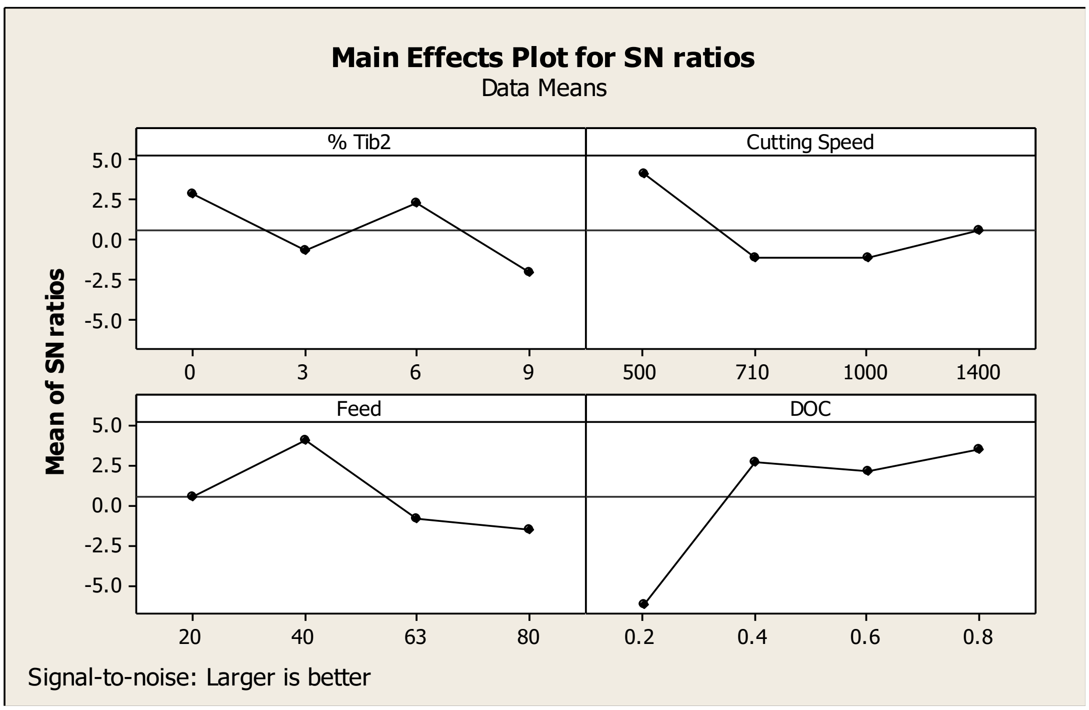
Taguchi Analysis: MRR versus % Tib2, Cutting Speed, Feed, DOC

Response Table for Signal to Noise Ratios (Larger is better) is shown in Table:5.2

Table 5.2: Response Table for Signal to Noise Ratios

Level	TiB2	Cutting Speed	Feed	DOC
1	2.8408	4.0272	0.5366	-6.1282
2	-0.7508	-1.191	4.0725	2.7223
3	2.2152	-1.1146	-0.8626	2.1243
4	-2.0662	0.5176	-1.5074	3.5208
Delta	4.9071	5.2182	5.5799	9.649
Rank	4	3	2	1

The effect of Material Removal Rate for different percentage of compositions at various parameters are plotted on a graph using taguchi technique has been shown in the fig: 9



From the above plotted graphs for obtained values of material removal rate using taguchi technique, we found that inorder to get better material removal rate, the optimal parameters are at 6%composition of Ti-B_2 spindle speed – 500rpm, feed rate – 40mm/min and depth of cut – 0.8mm.

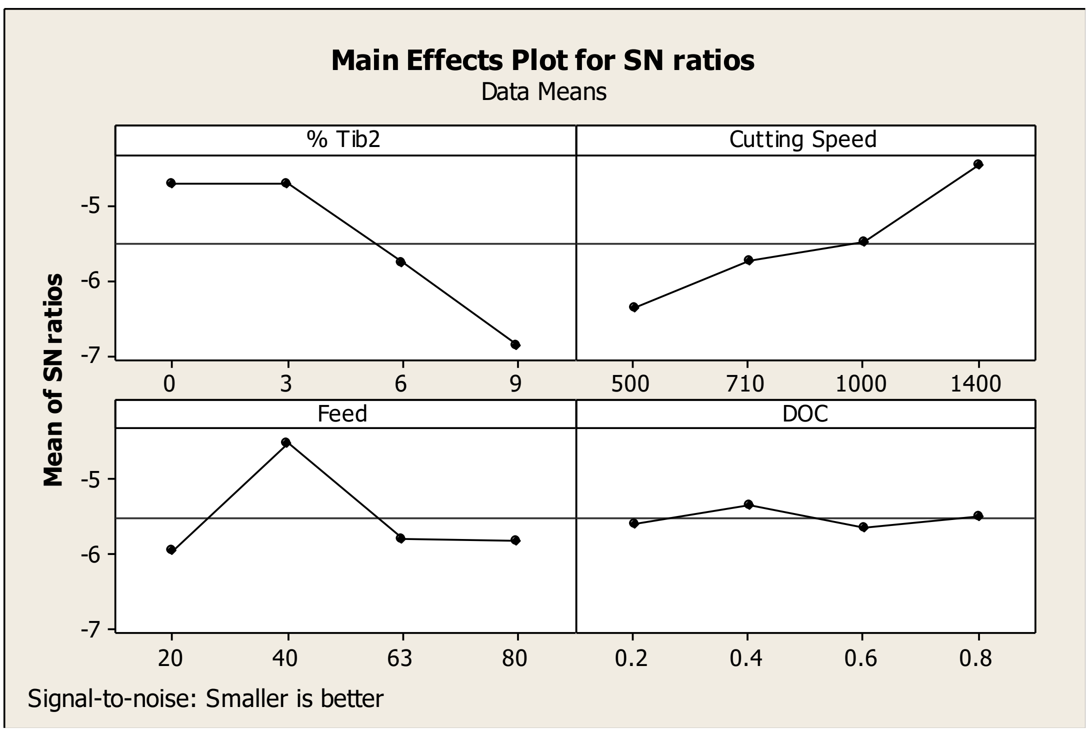
Effect of Surface Roughness

Taguchi Analysis: SR versus % Tib2, Cutting Speed, Feed, DOC

Response Table for Signal to Noise Ratios(Smaller is better) has been shown in table 5.4

Table5.4: Response Table for Signal to Noise Ratios

Level	TiB2	Speed	Feed	DOC
1	-4.717	-6.371	-5.945	-5.602
2	-4.717	-5.748	-4.521	-5.338
3	-5.783	-5.485	-5.79	-5.633
4	-6.86	-4.474	-5.821	-5.504
Delta	2.144	1.897	1.423	0.295
Rank	1	2	3	4



From the above plotted graphs for the obtained values of Surface roughness using taguchi technique, we found that inorder to get better surface finish, the optimal parameters are at 3%composition of $Ti\text{-}B_2$,spindle speed – 1400rpm, feed rate – 40mm/min and depth of cut – 0.4mm.

Regression Analysis

Regression Analysis: MRR versus % Tib2, Cutting Speed, Feed, DOC

The regression equation for MRR:

MRR = 1.38 - 0.0233 % Tib2 - 0.000469 Cutting Speed - 0.00145 Feed + 1.08 DOC

Table: Regression Analysis for MRR

Predictor	Coef	SE Coef	T	P
Constant	1.3839	0.7983	1.73	0.111
%TiB2	-0.02328	0.05332	-0.44	0.671
Cutting Speed	-0.0004691	0.0005296	-0.89	0.395
Feed	-0.001453	0.007868	-0.18	0.857
DOC	1.0825	0.7998	1.35	0.203

From the regression equation for MRR,it is observed that MRR of Al/TiB_2 composite is directly proportional to Depth of Cut and inversely proportional to cutting speed and feed.

Confirmation Experiment for MRR:

Confirmation experiment is conducted with the optimal parameter settings. The predicted value of MRR from the regression equation is 1.95g.The obtained experimental value of MRR is 2.152g.

Regression Analysis: SR versus % Tib2, Cutting Speed, Feed, DOC

The regression equation for Surface Roughness:

SR = 1.97 + 0.0555 % Tib2 - 0.000433 Cutting Speed + 0.00151 Feed + 0.020 DOC

Table:Regression Analysis for Surface Roughness

Predictor	Coef	SE Coef	T	P
Constant	1.9662	0.2467	7.97	0
%TiB2	0.05553	0.01647	3.37	0.006
Cutting Speed	-0.0004334	0.0001636	-2.65	0.023
Feed	0.001509	0.002431	0.62	0.548
DOC	0.02	0.2471	0.08	0.937

From the regression equation for Surface Roughness, it is observed that Surface Roughness of Al/TiB_2 composite is directly proportional to Feed and Depth of Cut and inversely proportional to cutting speed.

Confirmation Experiment for Surface Roughness:

Confirmation experiment is conducted with the optimal parameter settings. The predicted value of Surface Roughness from the regression equation is 1.433µm.The obtained experimental value of Surface Roughness is 1.423µm.

CHAPTER-6

CONCLUSIONS

CONCLUSIONS

The Al7075 alloy with different combinations of TiB2 powder were fabricated using stir casting method. The mechanical and physical properties of the composites were analyzed and the following conclusions were made.

1. Al- TiB2 composites were made using stir casting method, successfully.

2. The tensile strength of the test specimens increases up to 6% by weight of TiB_2 particles and then after the tensile strength was decreased.

3. The impact strength of specimen 2 is higher than other specimens due to the presence of moderate quantity of TiB2 particles in the composite.

4. From the tests, it has been observed that the hardness increases upto 12% of particles.
5. Taguchi method has been successfully employed for optimizing the process parameters of Milling of Al TiB_2 composite.
6. It is observed that Depth of cut has major influence on the MRR.
7. The optimum process parameters for MRR are at TiB_2: 6%, cutting speed :500rpm, Feed:40mm/min and depth of cut: 0.8 mm.
8. It is observed that Cutting Speed has major influence on the Surface Roughness.
9. The optimum process parameters for Surface Roughness are at TiB_2: 3%, cutting speed : 1400rpm, Feed:40mm/min and depth of cut: 0.4 mm.
10. The Regression equations for MRR and Surface roughness are obtained by Regression analysis.
11. Confirmation experiment is conducted with the optimal parameter settings. The predicted value of MRR from the regression equation is 1.95g. The obtained experimental value of MRR is 2.152g.
12. Confirmation experiment is conducted with the optimal parameter settings. The predicted value of Surface Roughness from the regression equation is 1.433µm.The obtained experimental value of Surface Roughness is 1.423 µm.

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REFERENCES

1.Kalaiselvan K, Muruganand N and Siva Parameswaran, Production and characterization of AA6061–B4C stir cast composite, *Materials and Design*, 2 (2011), 4004–4009.

2.Fei Chen, Zongning Chenb, Feng Mao, Tongmin Wang and Zhiqiang Cao,TiB2 reinforced aluminum based in situ composites fabricated by stir casting, *Materials Science and Engineering: A*, 625 (2015), 357-368.

3.Valibeygloo N, Azari Khosroshahi R and Taherzadeh Mousavian R,Micro structural and mechanical properties of Al-4.5wt% Cu reinforced with alumina nano particles by stir casting method, *International Journal of Minerals, Metallurgy, and Materials*, 20 (10) (2013), 978-985.

4.Hamid Reza Ezatpour, Seyed Abolkarim Sajjadi, Mohsen HaddadSabzevara and Yizhong Huang, Investigation of microstructure and mechanical properties of Al6061-nanocomposite fabricated by stir casting, *Materials and Design*, 55 (2014), 921-928.

5.Sahraeinejad S, Izadi H, Haghshenas M, Gerlich A.P, Fabrication of metal matrix composites by friction stir processing with different Particles and processing parameters, *Materials Science and Engineering :A*, 626 (2015), 505-513.

6.Nassim Samer, Jérôme And rieux, Bruno Gardiola, Nikhil Karnatak,Olivier Martin, Hiroki Kurita, Laurent Chaffron, Sophie Gourdet, SabineLay, Olivier Dezellus, Microstructure and mechanical properties of an Al–TiC metal matrix composite obtained by reactive synthesis,*Composites Part A: Applied Science and Manufacturing*, **72 (**2015), 50-57.

7.Sajjadi S.A, Ezatpour H.R, Beygi H, Microstructure and mechanical properties of Al–Al2O3 micro and nano composites fabricated by stir casting, *Materials Science and Engineering: A*, 528 (29–30)(2011), 8765-8771.

8.Bijay Kumar Show, Dipak Kumar Mondal, Koushik Biswas and Joydeep Maity, Development of a novel 6351 Al–(Al4SiC4+SiC) hybrid composite with enhanced mechanical properties, *Materials Science and Engineering :A*, 579 (2013), 136-149.

9.Arun Premnath A, Alwarsamy T, Rajmohan T and Prabhu R, The influence of alumina on mechanical and tribological characteristics of graphite particle reinforced hybrid Al-MMC, *Journal of Mechanical Science and Technology*, 28 (11) (2014), 4737-4744.

10.Auradi V, Rajesh G.L. and Kori S.A., Preparation and evaluation of mechanical properties of 6061Al–B4Cp composites produced via two-stagemelt stirring, *Materials and Manufacturing Processes*, 29 (2) (2014), 194-200.

11.Riaz Ahamed A, Paravasu Asokan, Sivanandam Aravindan and PrakashM.K, Drilling of hybrid Al-5%SiCp-5%B4Cp metal matrix composites,*International Journal of Advanced Manufacturing Technology*, 49 (9-12)(2010), 871-877.

12.Saba Khoramkhorshid, Morteza Alizadeh, Amir Hossein Taghvaei, SergioScudino, Microstructure and mechanical properties of Albasedmetal matrix composites reinforced with Al84Gd6Ni7Co3 glassy particles produced by accumulative roll bonding, *Materials & Design*, 90(2016), 137-144.

13.Beigi Khosroshahi N, Taherzadeh Mousavian R, Azari Khosroshahi R,Brabazon D, Mechanical properties of rolled A356based composites reinforced by Cu-coated bimodal ceramic particles, *Materials and Design*, 83 (2015), 678-688.

14. J.A. Ghani, I.A. Choudhury, H.H. Hassan, *"Application of Taguchi method in the optimization of end milling parameters"*, Journal of Materials Processing Technology 145 (2004) 84–92
15. Hasan Oktemm, Tunacay Erzurumlu, Mustafa Col, *"A study of the Taguchi optimization method for surface roughness in finish milling of mold surfaces"* , Int J Adv Manuf Technol (2006) 28: 694–700
16. Anil Choubey, Vedansh Chaturvedi, Jyoti Vimal, *"The Implementation Of Taguchi Methodology For Optimization Of End Milling Process Parameter Of ALLUMINUM"*, International Journal of Engineering Science and Technology, ISSN : 0975-5462, Vol-2, (2007)