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Experimental Investigation on Al 7075, TiB2, TiC, Metal Matrix Composites to find Power Consumption and MRR while Machining

Pullareddy.M[1], Shabeera Sheik[2], Sk Md Imran[3], Kavitha. K[4], Chanikya.K[5], Lavanya.G[6], Jayasree.K[7], Shahanaaz [8], Anitha.C[9], Manmohan.S[10]

[1,5]Department of Mechanical Engineering, Gates Institute of Technology, Gooty, Ananthapuramu, Andhra Pradesh, India
[2,4,6,8,9]Department of Electrical& Electronics Engineering, Gates Institute of Technology, Gooty, Ananthapuramu, Andhra Pradesh, India
[3,7]Department of Electronics Engineering, Gates Institute of Technology, Gooty, Ananthapuramu, Andhra Pradesh, India
[1,0]Department of Mechanical Engineering, Samskruthi College of Engineering and Sciences , Ghatkesar, Hyderabad, Telanga State, India

ABSTRACT

Composite material is a combination of two or more materials having compositional variations and depicting properties distinctively different from those of the individual materials of the composite. A composite mixture having more than one fiber is known as hybrid composite During the past decade, considerable research effort has been directed towards the development of in situ Metal Matrices hybrid Composites (MMCs), Using this approach, MMCs with a wide range of matrix materials (including aluminum 7075 grade, Titanium carbide, Titanium boride), and second-phase particles (including borides, carbides, nitrides, oxides and their mixtures have been produced In the present work, the elemental TiC, TIB2 powders are mixed with aluminum molten metal to produce the AL-7075, TiC, TIB2 MMC. The proposed investigation is to deal with development of aluminum based composite through casting route of Metal Removal Rate, Power Consumption while doing the Turning Operation on a Horizontal Lathe Machine.

Keywords: Aluminum 7075, TiC (Titanium Carbide) and TiB2 (Titanium diboride), MMCs (Metal Matrix Composites)

I. INTRODUCTION

Composites have superior mechanical properties and yet are light weight. The reinforcing fibers are usually glass, graphite, Boron, etc. New developments concern metal-matrix and ceramic-matrix composites and honey comb structure. Honey comb structure consists of a core of honey comb or other corrugated shapes bonded to two thin outer skins. Ceramic-matrix cutting tools are being developed, made of silicon carbide-reinforced alumina, with greatly improved tool life.

Surface composite layer has hardness and wear resistance about 1.75 and 10times those of as received aluminum matrix alloy. For manufacturing of composite material by stir casting knowledge of its operating parameter are very essential. As there is various process parameters if they properly controlled can lead to the improved characteristic in composite material.

A. Stirring Speed

Stirring speed is the important process parameter as stirring is necessary to help in promoting wetability i.e. bonding between matrix & reinforcement. Stirring speed will directly control the flow pattern of the molten metal. Parallel flow will not promote good reinforcement mixing with the matrix. Hence flow pattern should be controlled turbulence flow. Pattern of flow from inward to outward direction is best. In our project we kept speed from 250-650 rpm. As solidifying rate is faster it will increase the percentage of wetability.

B. Stirring Temperature

It is an important process parameter. It is related to the melting temperature of matrix i.e. Aluminum. Aluminum generally melts at 660◦C. The processing temperature is mainly influence the viscosity of Al matrix. The change of viscosity influences the particle distribution in the matrix. The viscosity of liquid decreased when increasing processing temperature with increasing holding time stirring time. It also accelerates the chemical reaction b/w matrix and reinforcement. In our project in order to promote good wetability we had kept operating temperature at 620°C which keeps Al (7075) in semisolid state.

C. Reinforcement Preheat Temperature

Reinforcement was preheated at a specified 500◦C temperature 30 min in order to remove moisture or any other gases present within reinforcement. The preheating of also promotes the wetability of reinforcement with matrix.

D. Addition of TiC and TiB2

Addition of Magnesium enhances the wetability. However increase the content above 1wt. % increases viscosity of slurry and hence uniform particle distribution will be difficult.

E. Stirring Time:-

Stirring promotes uniform distribution of the particles in the liquid and to create perfect interface bond b/w reinforcement and matrix. The stirring time between matrix and reinforcement is considered as important factor in the processing of composite. For uniform distribution of reinforcement in matrix in metal flow pattern should from outward to inward.

F. Stir Casting

In a stir casting process, the reinforcing phases are distributed into molten matrix by mechanical stirring. Stir casting of metal matrix composites was initiated in 1968, when S. Ray introduced alumina particles into an Aluminum melt by stirring molten aluminum alloys containing the ceramic powders. Mechanical stirring in the furnace is a key element of this process.

The resultant molten alloy, with ceramic particles, can then be used for die casting, permanent mold casting, or sand casting. Stir casting is suitable for manufacturing composites with up to 30% volume fractions of reinforcement.

The cast composites are sometimes further extruded to reduce porosity, refine the microstructure, and homogenize the distribution of the reinforcement. A major concern associated with the stir casting process is the segregation of reinforcing particles which is caused by the surfacing or settling of the reinforcement particles during the melting and casting processes. The final distribution of the particles in the solid depends on material properties and process parameters such as the wetting condition of the particles with the melt, strength of mixing, relative density, and rate of solidification .The distribution of the particles in the molten matrix depends on the geometry of the mechanical stirrer, stirring parameters, placement of the mechanical stirrer in the melt, melting temperature, and the characteristics of the particles added.

An interesting recent development in stir casting is a two-step mixing process. In this process, the matrix material is heated to above its liquids temperature so that the metal is totally melted. The melt is then cooled down to a temperature between the liquids and solidus points and kept in a semi-solid state. At this stage, the preheated particles are added and mixed. The slurry is again heated to a fully liquid state and mixed thoroughly. This two-step mixing process has been used in the fabrication of aluminum.

Among all the well-established metal matrix composite fabrication methods, stir casting is the most economical. For that reason, stir casting is currently the most popular commercial method of producing aluminum based composites.

II. METHODS AND MATERIAL

1. Machining

Machining is the process of removing the excess material from the work piece using cutting tool. Surface finish obtained in machining process depends upon so many factors like work material, tool material, tool geometry, machining conditions, cutting fluids used and feed rate etc. with the increasing trend in the use of light-weight functional material in emerging industrial applications, understanding the fabrication of Aluminum 7075grade, Titanium carbide, titanium diboride (ABC) composite is becoming needful.

The material is brought to a specified geometry by removing excess material to leave a finished part that meets specifications. Optimum selection of cutting conditions importantly contribute to the increase of productivity and the reduction of cost, therefore outmost attention is paid to this problem in this contribution. In the present research Al 7075, TiB2, TiC composites were fabricated by stir casting with different particular weight fraction (2.5%, 5%, 7.5%), it is planned to study the effect of process parameters on MRR and cutting force by using $\mathbf{L_9}$ orthogonal array and also power consumption rate by using UPF WATTMETER. The composites were characterized by hardness and tensile tests. A neural network model was developed to ensure simple, fast and efficient model to predict response values for turning parameters.

A. Turning

Turning is one of the most basic machining processes. The part is rotated while a single point cutting tool is moved parallel to the axis of rotation. Turning can be done on the external surface of the part as well as internally(boring). The starting material is generally a work piece generated by other processes such as casting, forging, extrusion or drawing. Turning can be done manually, in a traditional form of lathe.

Figure 1. Machining

Experiments were done by varying one parameter and keeping other two fixed so maximum value of each parameter was obtained. Taguchi orthogonal array is designed with three levels of turning parameters with the help of lathe. Investigated a single characteristic response optimization model based on Taguchi technique was developed to optimize process parameters, such as speed, feed, depth of cut, and nose radius of single point cutting tool. Taguchi's $\mathbf{L_9}$ orthogonal array is selected for experimental planning. The experimental results analysis showed that the combination of higher levels of cutting speed, depth of cut and lower levels of feed is the essential to achieve simultaneous maximization of material removal rate.

B. Turning Operation

The work piece rotates in the lathe, with a certain spindle speed (N), at a certain number of revolutions per minute. In relation to the diameter of the work piece, at the point it is being machined, this will give rise to a cutting speed, or surface speed (Vc) in m/min. the cutting speed is only constant for as long as the spindle speed and or part diameter remains the same. The Experimental investigation conducted to the turn Aluminum 7075, TiC (Titanium Carbide) and TiB2 (Titanium diboride), MMCs (Metal Matrix Composites by employing Taguchi technique to determine the optimal levels process parameters. In case of MRR response, depth of cut is dominant one followed by feed. The optimal combination of process parameters parameter is obtained at 150m/min cutting speed 0.25mm/rev, 0.5mm depth of cut and 0.4mm nose radius. The study deals with optimization of multiple power consumption parameters in search of an optimal parametric combination cable of producing desired surface quality of the hybrid turned product.

Figure 2. Turning Operation on Lathe

Taguchi method has been found fruitful for evaluating the optimum parameter setting and solving such a multi objective optimization problem. The said approach can be recommended for continuous quality improvement and off-line quality control of a process/product. Taguchi method for find a specific range and combinations of turning parameters like cutting speed, feed rate and depth of cut to achieve optimal values of response variables like cutting force, power consumption, material removal rate in turning of aluminum hybrid material. It is a scientifically disciplined mechanism for evaluating and implementing improvement in products, process, materials, equipments and facilities.

Figure 3. Turning operation on lathe

2. Machining Parameters

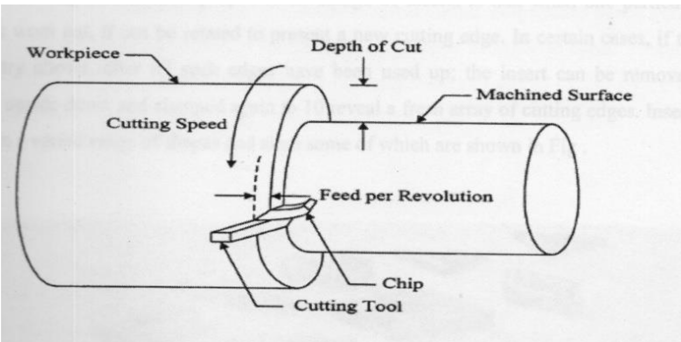


Figure 4. Machining Parameters

A. Cutting Speed:

Cutting speed may be defined as the rate at which the uncut surface of the work piece passes the cutting tool. It is often referred to as surface speed and is ordinarily expressed in m/min, though ft/min is also used as an acceptable unit. Cutting speed can be obtained from the spindle speed.

The spindle speed is the speed at which the spindle, and hence, the work piece, rotats. It is given in terms of number of revolutions of the work piece per minute i.e. RPM. If the spindle speed, is N(RPM), the cutting speed Vc (m/min) is given as

$$Vc = \frac{\pi DN}{1000} \qquad (1)$$

Where, D=Diameter of the work piece in mm

B. Feed

Feed is the distance moved by the tool Tip along its path of travel for every revolution of the work piece. It is denoted as 'f' and is expressed in mm/rev. It is also expressed in terms of the spindle speed in mm/min as

$$Fm = fN \qquad (2)$$

Where, f=Feed in mm/rev
N=Spindle speed in rpm

C. Depth of Cut

Depth of cut is defined as the distance from the newly machined surface to the work piece measure from the work piece surface before rotations= of the work piece. The diameter after machining is reduced by twice of the depth of the uncut surface. In other words, it is the thickness of material being removed from the work piece. It can also be defined as the depth of penetration of the tool into cut as this thickness is removed from both sides owing to the rotation of the work.

$$d = \frac{(D1-D2)}{2} \qquad (3)$$

Where,
D1= Initial diameter of job
D2=Final diameter of job

D. Cutting Tool:

The geometry and nomenclature of cutting tools, even single-point cutting tools, are surprisingly complicated subjects. It is difficult, for example, to determine the appropriate planes in which the various angles of a single-point cutting tool should be measured; it is especially difficult to determine the slope of the tool face. The simplest cutting operation is one in which a straight-edged tool moves with a constant velocity in the direction perpendicular to the cutting edge of the tool. the application of a single-point cutting tool in a turning operation. It helps to correlate the terminology used in orthogonal and oblique non-free cutting.

Figure 5. Metal Removing

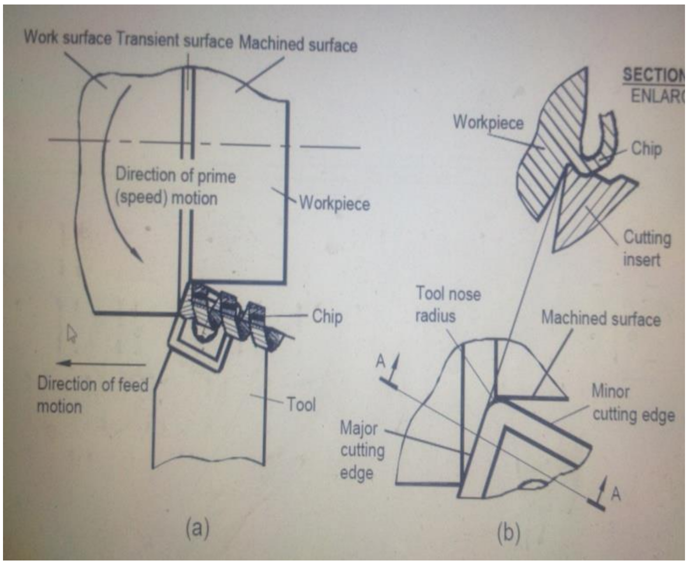


Figure 6. Single Point Cutting Tool

This section aims to introduce the basic definitions of the terms and notions involved in tool geometry considerations. Proper definitions and illustrations of these items are important for comprehension of the basic and advanced concept of the tool geometry. This is particularly true because a wide diversity of terms used in the books, texts, research papers, tool companies catalogs, trade materials, and even standards (National and International) combined with the so-called "machine shop terminology" makes it difficult to understand even the basic concepts of the tool geometry.

3. Electrodynamometer Wattmeter

Figure 7. Attachment of Electrodynamometer to lathe machine

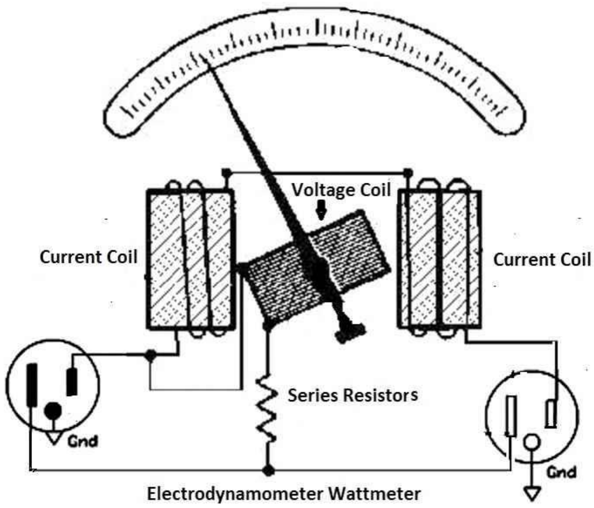


Figure 8. Working of electrodynamometer

An electrodynamometer wattmeter consists of two fixed coils, FA and FB and a moving coil M as shown in figure. The fixed coils are connected in series with the load and hence carry the load current. These fixed coils form the current coil of the wattmeter. The moving coil is connected across the load and hence carries a current proportional to the voltage across the load. A highly non-inductive resistance R is put in series with the moving coil to limit the current to a small value. The moving coil forms the potential coil of the wattmeter if an ordinary electrodynamometer wattmeter is used for measurement of power low power factor circuits, (PF<0.5), then the measurements would be difficult and inaccuratesince:

- The deflecting torque exerted on the moving system will be very small and
- Errors are introduced due to pressure coil inductance.

III. RESULTS AND DISCUSSION

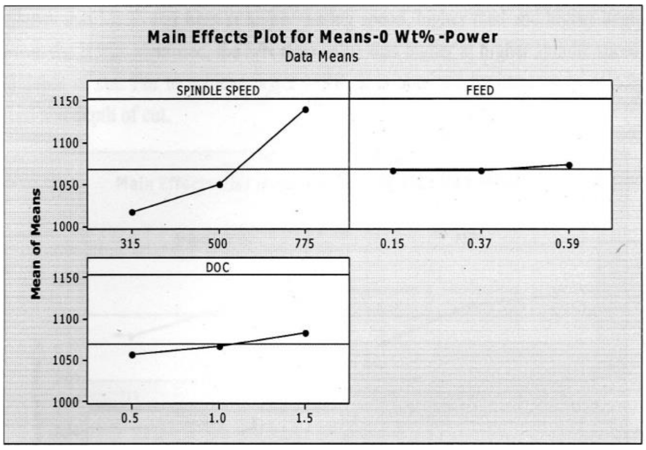
1. Experiment

The investigation was performed by using Minitab16 software.

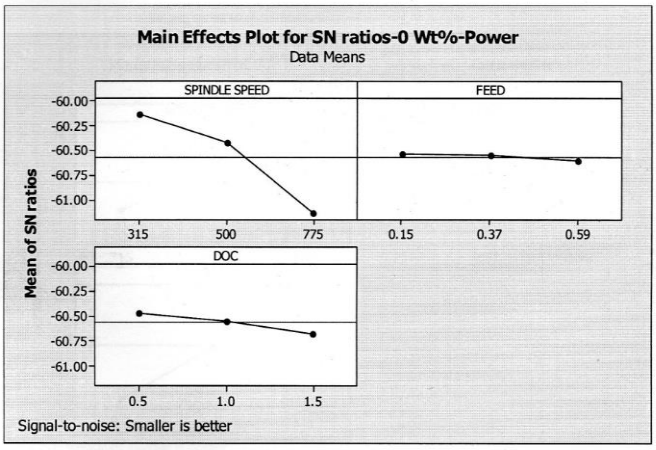
Table 1. Experimental results for Al 7075

Specimen No	Rotational Speed(RPM)	Feed (mm/rev)	Depth of cut (mm)	Power (Watts)	MRR (mm^3/min)
1	315	0.13	0.5	1000	2036
2	315	0.34	1.00	1020	4231
3	315	0.55	1.50	1030	6589
4	500	0.13	1.00	1040	3894
5	500	0.34	1.50	1050	7234
6	500	0.55	0.50	1060	4092
7	775	0.13	1.50	1070	6324
8	775	0.34	0.50	1080	4257
9	775	0.55	1.00	1090	6018

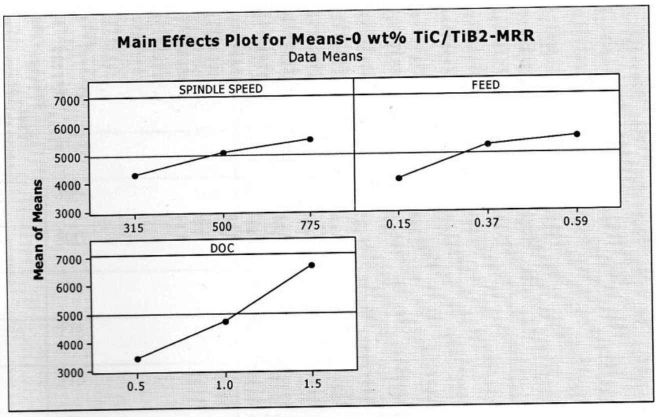
Al 7075-Power



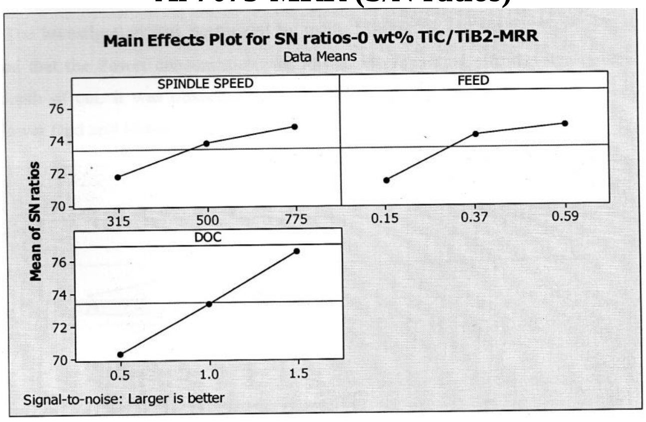
Al 7075-Power(S/N ratios)



Al 7075-MRR



Al 7075-MRR (S/N ratios)

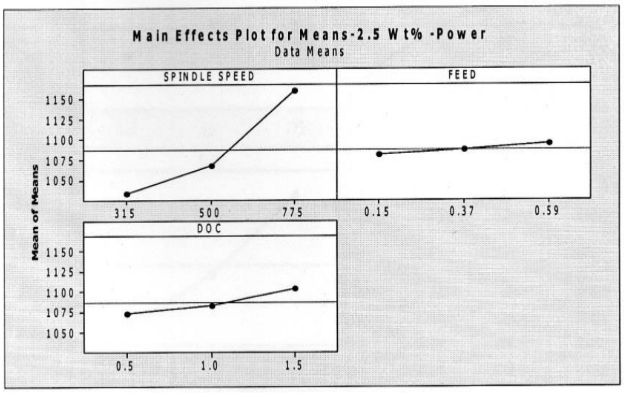


Experimental results for Al 7075 Shows that the MRR was high at higher cutting speed, higher feed and higher depth of cut. From the it was identified, the S/N ratio value was higher at higher spindle speed, feed and depth of cut. For to achieve better MRR, it is obtained by increase in spindle speed, feed and depth of cut.

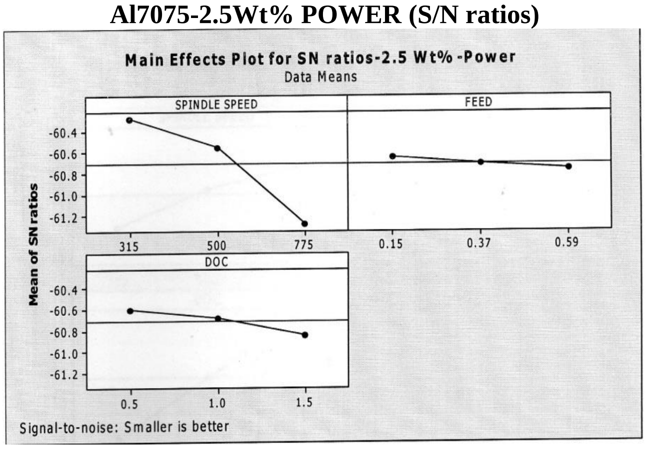
TABLE 2. Experimental Results For Al 7075-2.5Wt% TiB2,TiC

Specimen No	Rotational Speed (RPM)	Feed (mm/rev)	Depth of cut (mm)	Power (Watts)	MRR (mm^3/ min)
1	315	0.13	0.5	1010	1960
2	315	0.34	1.00	1040	4284
3	315	0.55	1.50	1050	6326
4	500	0.13	1.00	1050	3723
5	500	0.34	1.50	1080	7096
6	500	0.55	0.50	1070	3946
7	775	0.13	1.50	1180	6247
8	775	0.34	0.50	1140	4210
9	775	0.55	1.00	1160	5946

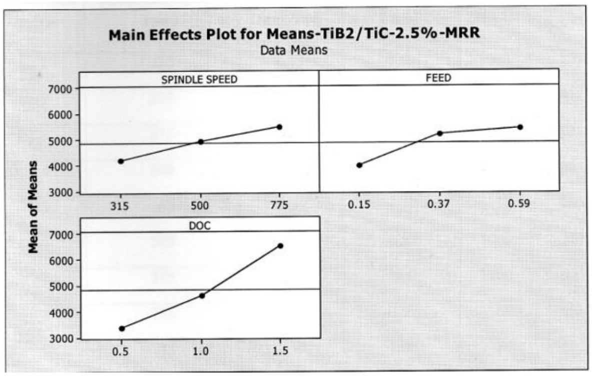
Al7075-2.5Wt% POWER



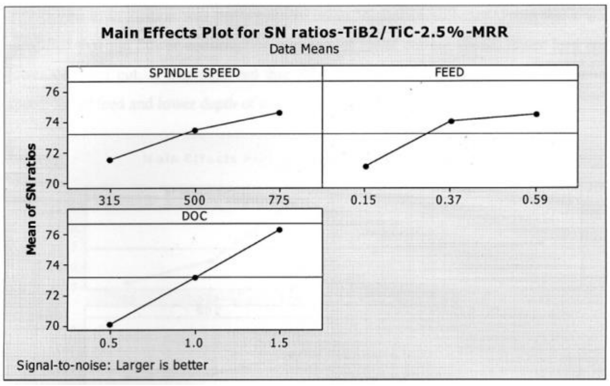
Al7075-2.5Wt% POWER (S/N ratios)



Al7075-2.5Wt% MRR (S/N ratios)



Al7075-2.5Wt% MRR (S/N ratios)



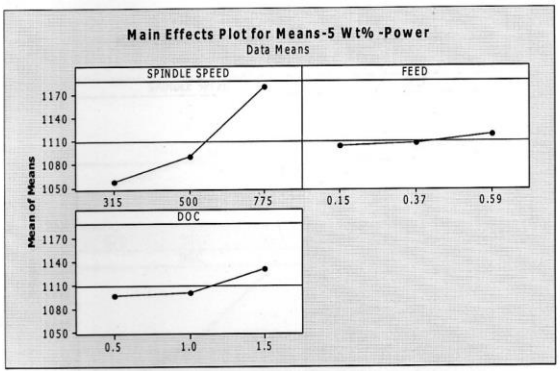
Experimental results for Al7075-2.5Wt% MRR (S/N ratios) Shows that the MRR was high at higher cutting speed, higher feed and higher depth of cut. From the it was identified, the S/N ratio value was higher at higher spindle speed, feed and depth of cut. For to achieve better MRR, it is obtained by increase in spindle speed, feed and depth of cut.

TABLE 3

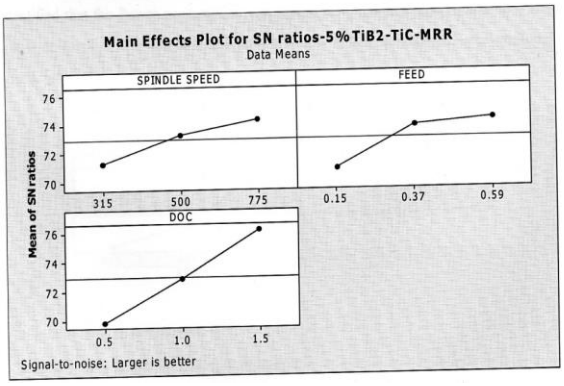
Experimental Results For Al 7075-5Wt% TiB2,TiC

Al 7075-5Wt% TiB2,TiC-POWER

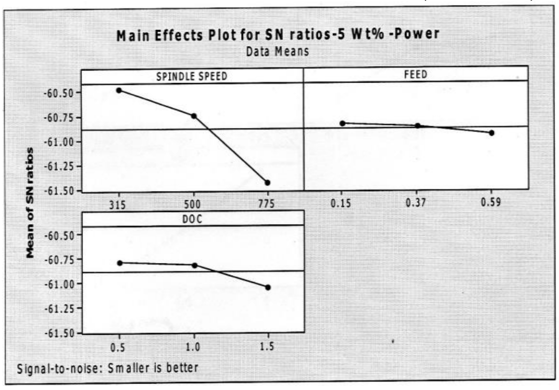
Specimen No	Rotational Speed(RPM)	Feed (mm/rev)	Depth of cut (mm)	Power (Watts)	MRR (mm^3/min)
1	315	0.13	0.5	1040	1910
2	315	0.34	1.00	1050	4123
3	315	0.55	1.50	1080	6287
4	500	0.13	1.00	1070	3645
5	500	0.34	1.50	1110	6953
6	500	0.55	0.50	1090	3816
7	775	0.13	1.50	1200	6064
8	775	0.34	0.50	1160	4087
9	775	0.55	1.00	1180	5623



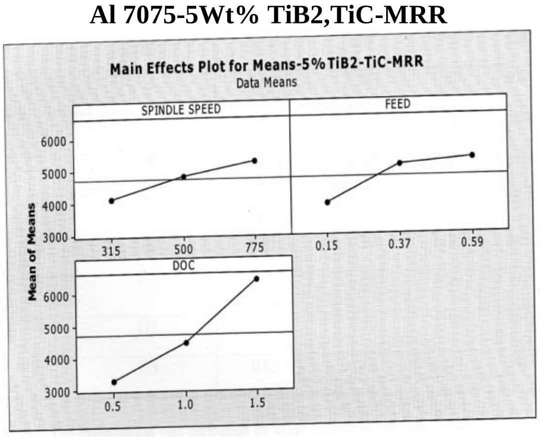
Al 7075-5Wt% TiB2,TiC-MRR(S/N ratio)



Al 7075-5Wt% TiB2,TiC-POWER(S/N ratio)



Al 7075-5Wt% TiB2,TiC-MRR



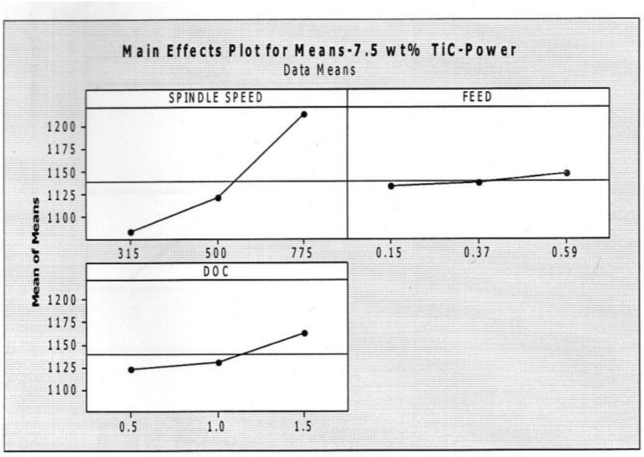
Experimental results for Al 7075-5Wt% TiB2,TiC-POWER(S/N ratio)Shows that the MRR was high at higher cutting speed, higher feed and higher depth of cut. From the it was identified, the S/N ratio value was higher at higher spindle speed, feed and depth of cut. For to achieve better MRR, it is obtained by increase in spindle speed, feed and depth of cut.

TABLE 4

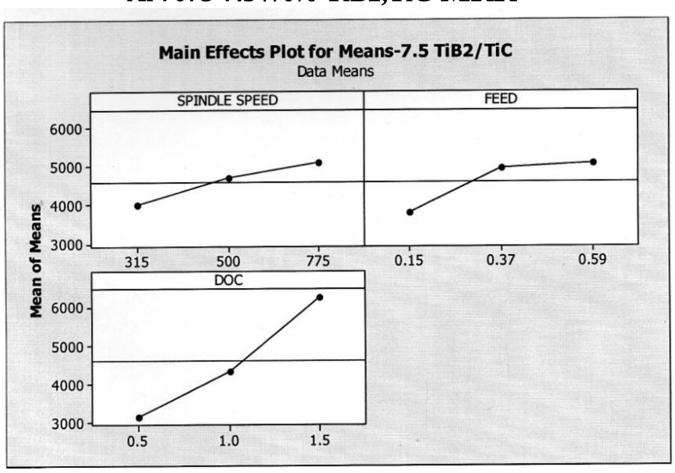
Experimental Results for Al 7075-7.5Wt% TiB2,TiC

Specimen No	Rotational Speed(RPM)	Feed (mm/rev)	Depth of cut (mm)	Power (Watts)	MRR (mm^3/min)
1	315	0.13	0.5	1060	1883
2	315	0.34	1.00	1080	4024
3	315	0.55	1.50	1110	6096
4	500	0.13	1.00	1100	3584
5	500	0.34	1.50	1140	6810
6	500	0.55	0.50	1120	3657
7	775	0.13	1.50	1240	5915
8	775	0.34	0.50	1190	3934
9	775	0.55	1.00	1210	5417

Al 7075-7.5Wt% TiB2,TiC-POWER



Al 7075-7.5Wt% TiB2,TiC MRR



Al 7075-7.5Wt% TiB2,TiC-POWER(S/N ratio)

IV. CONCLUSION

The processing of Stir casting route is done with TiC and TiB2 powders are mixed in various proportions with Al7075 molten metal to produce the Hybrid composite AL7075,TiC, TiB2. For newly developed materials mechanical properties investigated and machining parameters optimized and finally we investigated and optimized cutting parameters speed, feed and Depth of Cut (DOC) for different proportions of TiC, TiB2. From the Taguchi optimization study it was observed that the best parameter combination fro to get higher MRR for turning Al 7075, Al 7075-2.5 wt% TiB2/TiC, Al 7075-5 wt% TiB2/TiC, Al 7075-7.5 wt% TiB2/TiC is A-3,B-3 and C-3 i.e. higher cutting speed, higher feed and higher feed and higher depth of cut.

Hence in the future we can use this Hybrid composite Al 7075,TiC, TiB2 to improve machining parameters, strength and hardness in the industries.

V. ACKNOWLEDGEMENT

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