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Fabrication of Al-TiB_2 Metal Matrix Composites for Evaluation of Surface Characterization and Machinability

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Abstract

The present study discusses about the fabrication of Al MMC with TiB_2 as 2% reinforcement with 400 mesh particle size by novel vacuum stir casting method. A series of experiments performed to know morphology and surface topography of developed MMC. Micro structural observation along with the SEM and XRD testing has been carried out to investigate the distribution of TiB_2 particle reinforced in Al2014 matrix. EDAX report has been generated of a standard specimen to know the weight percent of all the materials that were developed during the casting process. Machinability test has been carried out on medium duty lathe with coated carbide insert by using Taguchi L9 orthogonal array to know the surface roughness values with a selection of different cutting parameters as cutting speed, feed rate and cutting depth respectively for three different levels. The optimal cutting conditions were found using the Signal-to-Noise (S/N) ratio of surface roughness parameters (Ra, Rz) and material removal rate according to "the-smaller-the-better" and "larger-the-better" criteria respectively. Taguchi response analysis is used to optimize the parameters influencing the objectives. To get good surface finish high cutting speed and lower feed rates has been found as optimal parameters of developed Al-TiB_2 MMC.

Keywords: Aerospace Application, MMC, Taguchi Analysis, Tib_2 Particle, Vacuum Stir Casting

1. Introduction

Development of Metal Matrix Composite (MMC) always attracts researchers towards it due to the significant changes observed in thermal, mechanical, material and machining properties of matrix material by the addition of certain particulate reinforcement. Al 2014 T6 has its wide applications in the fabrication of airplane wing parts, jet engine turbine blades and other complex part of the airplane which led to the modernization of this lightweight and hard material. The present paper discusses about the fabrication of aluminium based MMC with 2 wt% TiB_2 reinforcement. The particle size of reinforcement is 400meshes. TiB_2 serves a large number of advantages over the other ceramic reinforcement particulate. In aluminium alloys contains magnesium and Al_2O_3 reinforcement react to form the Al_2MgO_4 while the thermodynamic stability of TiB_2 at high temperature in liquid aluminium helps to improve properties[1,2]. Clustering of TiB_2 particles by casting route is quite popular. Research on forces on TiB_2 after clustering[3] and mechanical properties with the XMT micro tomography validation[4] has been done. Powder metallurgy method is also used to study the thermal behaviour[4] along with the dry sliding wear behaviour of the same by at varying reinforcement percentage[5]. Fabrication of MMC with TiB_2 reinforcement also achieved by mixing KBF_4, K_2TiF_6, and Na_3AlF_6[6,7]. A novel method of stir casting is

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used to make composites with less porosity. An extensive micro structural observation at various magnification levels has been done along with FESEM image analysis to understand the surface topography of the material. XRD analysis also performed to characterize the atomic structure of composites and to relocate distribution of TiB_2 reinforcement which has been followed by the EDX report to get the validity of TiB_2 presence in the MMC along with the alien particles which were formed during casting. Taguchi method with L9 orthogonal array has been implemented to know the machining parameters like surface roughness and material removal rate at 3 different levels of cutting speed, feed rate, and cutting depth.

2. Experimental Details

2.1 Selection of Matrix and Reinforcement

Al alloy is available in the vast range of 2xxx, 3xxx, 6xxx, 7xxx series. Al 2014 T6 can also be employed for forged products viz, located in the heat affected area. 1.25 Kg of Aluminium is taken in the round bar form with a diameter of 25 mm to make the casting process. In present study Al 2014 T6 which is solution heat treated and artificially aged has been opted as matrix material due to its specific application in helicopter rotor blade and extruded members of supersonic aircraft.

In present study TiB_2 has been selected as reinforcement material. TiB_2 belongs to the group of metallic hard materials. In addition to its hardness it is distinguished by an extremely high electrical conductivity, thermal stability and inertness. These properties make the TiB_2 most prominent reinforcement so far as aerospace applications are concerned. Only 2% of TiB_2 by weight is added to make casting to get optimum properties with moderate increase in cost and weight as both are high. The chemical composition of matrix and reinforcement is given in Table1.

Table 1. Chemical composition of matrix and reinforcement material

Composition (Wt %)	Al	Cu	Fe	Mg	Mn	Si	Ti	B	C	B_2O_3	O
Al 2014	90.4	3.9	0.7	0.2	0.4	0.5	0.2	-	-		-
TiB_2	-	-	0.3	-	-	-	66	29	2	2.5	2.5

2.2 Fabrication Procedure

In this experiment Al 2014 is used as the matrix material with the 2% TiB_2 as reinforcement. For fabricating this composition matrix material is weighed carefully to 1.25 Kg and melted in the furnace up to 750°C. 25 grams of TiB2 as per the reinforcement percentage is then added. Wetting agent magnesium with similar weight percentage as that of reinforcement (2%) is added to the molten metal and stirred properly to get the uniform distribution. Magnesium (Mg) is added as a wetting agent for attainment of strong bonding between the matrix and reinforcement along with the removal of impurities. A graphite rod is used as a stirrer. After addition of Mg dross are found out on the upper layer of molten metal which was removed out before allowing it to solidify in preheat permanent mould (250˚C). A molten mix is then poured into the vacuum die of diameter 50 mm and is allowed to solidify at atmospheric conditions for 90 minutes.

3. Surface Characterization

After fabrication of discontinuous reinforced matrix, to investigate the distribution of reinforcement in a matrix, micro structural observation has been performed. Quality of specimen prepared can be checked by studying the microstructure of the specimen. Scanning electron microscope connected to the computer imaging system is used to analyze the surface topography of the specimen.

XRD analysis was also carried out for metallographies study. Skin turned work piece was used to investigate microstructure. A specimen of 30 mm diameter and 5mm thickness crowned with Bakelite was initially polished using emery paper of grit size 200, 400, 600, 800, and 1000. Later the specimen was polished using disc polishing machine. Keller's reagent was applied on specimen to reveal the clear microstructure. Microstructure taken by optical microscope of developed composite was observed at 100X and 200X magnifications. From Figure 1 it is revealed that reinforcement is uniformly distributed on dendrites.

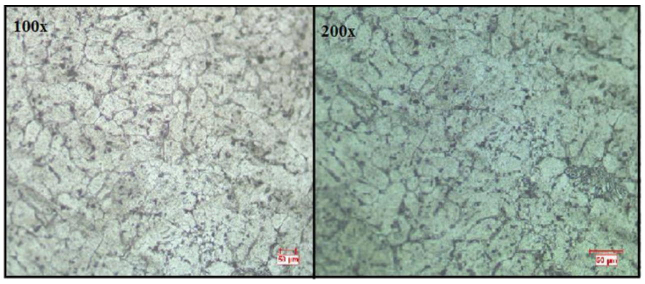

Figure 1. Microstructure of composite at 100X and 200X

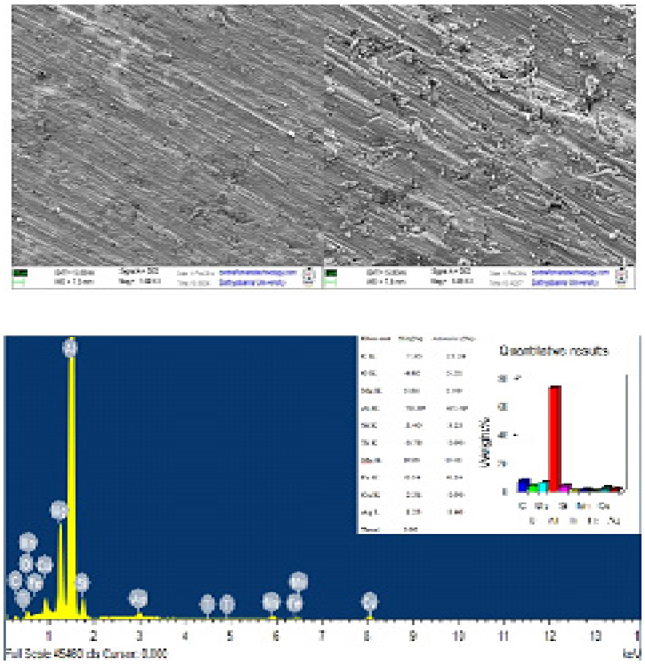

Figure 2. SEM Image and EDAX graph.

To know more about the surface topography of the MMC composition non destructive surface analytical techniques such as SEM & EDAX has been performed. A standard polished specimen of 10 mm diameter and 5 mm length is prepared. From EDAX graph (Figure 2) various foreign materials as Fe K, Ce K are found out. Reduction in the percentage of TiB_2 can be confirmed from the EDAX results. The XRD result of developed composite has been shown in Figure 3.

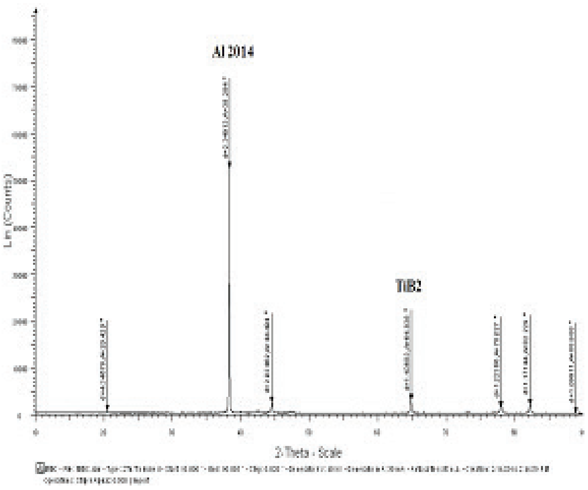

Figure 3. XRD image.

Presence of Al matrix and TiB_2 reinforcement in prepared specimen of composite is confirmed. Main peaks are of Al matrix and TiB_2 particle which indicates the uniform distribution of reinforcement in the matrix. Some other impurities can also be traced due to other small peaks.
Strong bonding between Aluminium and TiB_2 can be found out from the SEM image analysis and it can be validated from the peaks observed in XRD image.

Table 2. Process parameters with 3 levels for L9 array

Process Parameters	Units	Level 1	Level 2	Level 3
Cutting Speed (A)	m/min	80	100	120
Feed rate (B)	mm/rev	0.1	0.21	0.29
Depth of cut (C)	mm	0.3	0.6	0.9

4. Machinability Study

Machinability test has been carried out to know optimal cutting parameters. To carry out experimental trials, L9 design matrix is opted with three levels of process parameters, as given in Table 2, with the use of TN 8135 grade CVD coated carbide inserts for the fabricated Al 2014/TiB_2 composite.
From the literature, it is observed that the influence of cutting speed and feed rate is more significant when compared to cutting depth. The experiments are planned using the Taguchi's orthogonal array. To obtain optimal performance, the-smaller-the-better quality characteristic of surface roughness and the larger the better characteristic for material removal rate has been considered.

Table 3. Experimental results after machining

Trials	Cutting Speed (m/min.)	Feed Rate (mm)	Depth of Cut (mm)	MRR (mm^3/sec)	Ra (μm)	Rz (μm)
1.	80	0.103	0.3	59.577	2.2389	13.9107
2.	80	0.206	0.6	94.740	2.8599	15.3137
3.	80	0.296	0.9	341.770	2.6578	16.2366
4.	100	0.103	0.6	69.354	2.2005	13.0590
5.	100	0.206	0.9	356.327	4.5099	21.7618
6.	100	0.296	0.3	127.980	4.5882	21.6521
7.	120	0.103	0.9	220.217	2.6231	14.1392
8.	120	0.206	0.3	239.963	5.5599	28.2416
9.	120	0.296	0.6	249.388	4.4039	22.2879

5. Result and Discussion

Results for S/N (Signal to Noise) ratio values of surface roughness and material removal rate responses are depicted in Table 3. By considering "the-smaller-the-better" approach, Taguchi's S/N ratio method is used to validate the responses of R_a, R_t and R_z. To get best performance index for surface roughness, ranking to the process parameters of L9 array has been given with the help of MINITAB 16 software. The mean S/N ratio for each level of the cutting parameters is summarized and called the S/N response table for surface roughness. In addition the total mean S/N ratio for the nine experiments is also calculated. The greater is the S/N ratio, the smaller is the variance of surface roughness parameters around the desired (the-smaller-the-better) value. Along with the surface roughness value material removal rate (the-larger-the-better). Material Removal Rate (MRR) is calculated practically which is included in the Table 3. The response for mean S/N ratio (Signal To Noise) for surface roughness Ra, Rz and MRR given in Table 4, 5, 6 respectively. Plots for the response of S/N ratio also shown in Figure 4, 5, 6 for the same.

Table 4. Response Table for S/N Ratio for R_a

Factor	Level 1	Level 2	Level 3	Max-Min	Rank
A	-8.206	-11.056	-12.051	3.845	2
B	-7.409	-12.371	-11.533	4.961	1
C	-11.712	-9.618	-9.98	2.094	3

Total mean of S/N ratios:-10.43

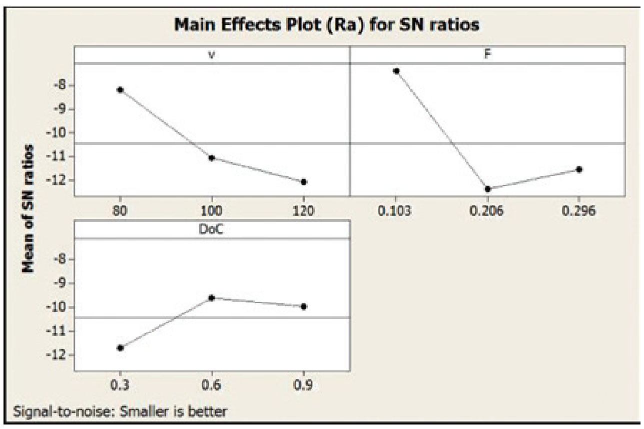

Figure 4. S/N ratio response for R_a.

Table 5. Response Table for S/N ratio for R_z

Factor	Level 1	Level 2	Level 3	Max-Min	Rank
A	-23.59	-25.26	-26.33	2.74	2
B	-22.73	-26.49	-25.96	3.76	1
C	-26.20	-24.33	-24.66	1.87	3

Total mean of S/N ratios:-25.06

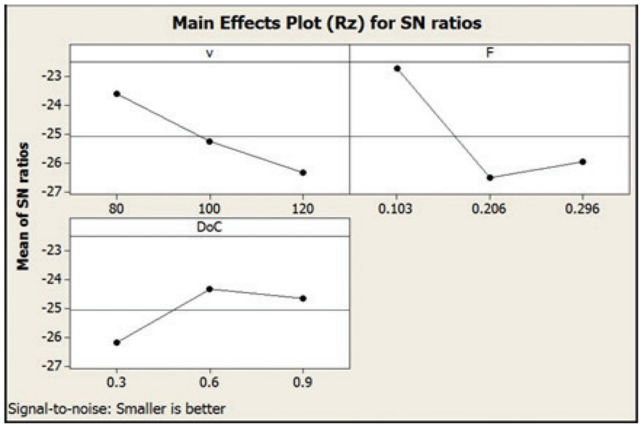

Figure 5. S/N ratio response for R_Z.

Table 6. Response Table for S/N Ratios for MRR

Factor	Level 1	Level 2	Level 3	Max-Min	Rank
A	41.90	43.33	47.47	5.56	3
B	39.73	46.06	46.92	7.19	1
C	41.75	41.43	49.52	8.09	2

Total mean of S/N ratios: 44.23

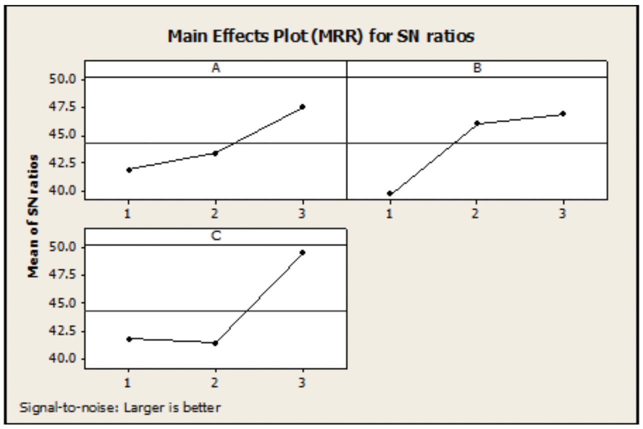

Figure 6. S/N ratio response for MRR.

6. Conclusion

In the present study Al 2014 T6/TiB_2 composite successfully developed from vacuum stir casting to know about surface morphology and assessment for MRR and surface roughness has been done.

1. From the microstructure obtained it is found that the surface is free from scratches and having less porosity. SEM images also reveal the amorphous texture of the composite and no crack formation has been found out.
2. EDAX test clearly confirms existence of foreign particles and reduction in the reinforcement percentage from 2 to 0.78 estimated after fabrication is done.
3. The peaks obtained in XRD image mentions about the strong bonding between matrix material and reinforcement. The sharp peaks also confirms about the crystalline structure of the composite.
4. For MRR the feed rate and cutting speed are most significant factors. The plots obtained for S/N ratio for Ra, Rz & MRR values of surface roughness concludes that Feed rate is most influential parameter for better results. Next to feed rate is cutting Speed and depth of cut.

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