Fabrication and Investigation of Al2024-B_4c-Tic Hybrid Metal Matrix Composites using Laser Beam Machining

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Abstract: *The use of unconventional machining technique for Aluminum based Metal Matrix Composites [MMCs] are generated considerable interest in machining. In the aviation industry, in order to obtain a high precision, a good surface finishing and high working speed, the processing of these hard materials is done with the help of the fiber beam laser). The objective is to determine the mechanical properties of the hybrid composite and further investigate its machinability. The aerospace industry uses the laser machining for its machining process like drilling the cooling holes etc. Standard frequency and variation in other parameters such as pulse width, power, and time will occur the impact in the laser beams composites like diameter and roundness of the hole. Especially, the increase in the variation of power and time plays a vital role in the diameter and roundness of the hole.*

Key Words: *Composite, Al alloy, mechanical properties, laser machining, roundness*

1. INTRODUCTION

Many researchers have been carried out experiments on aluminum alloy based MMC. These materials are widely used in the various applications such as space, aircraft fuselage structures, helicopters fuselage structures and IC engines etc. They are widely applied in space structures, aircraft fuselages, rotating components, satellites, helicopters fuselages and IC engines, etc. Al alloy has unique properties due to its light weight ratio, higher ductility, stiffness, controlled thermal expansion point, high heat dissipation capacity, heavy electrical conductivity & cost efficiency. Even though there were many studies on aluminum alloy were reported, there is still a high demand for more new hybrid materials.
The methods of metal matrix composites studies can experience the improvement of properties such as creep, fatigue, thermal properties [1]. The conventional machining in MMC is tougher due to increased tool wear and tool damage which is caused by hard reinforcement, so the

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nonconventional machining is preferred for very good surface quality and easy machining process [2]. There was a possibility for the melting and vaporization to happen while machining the al-cu based materials. This high induced gas pressure will degrades the surface quality of the laser machined material. These features should be reduced by using updated Al aeronautic alloy [3]. The long milled B_4C distribution will remove pores and creep. The strong interface bonding without chemical properties is obtained due to mechanical alloying.

This will help tensile strength and Young's modulus to improve [4]. Stir casting is one of the economical methods to manufacture Al MMC. By using aluminum metal matrix composite method the strength and life of the composite can be increased and also used to increase hardness and micro hardness, tensile and yield strength. In order to fabricate Al based hybrid MMC, stir casting has more advantages than other processes [5]. The procedure to maintain temperature range size and speed of the impeller factors is been considered. Compared to other casting methods stir casting is cost effective and easily controllable [6]. By adding B_4C with aluminum alloy, MMC's metrological and morphological changes have been examined on laser treated surface [7].

To avoid cracks and rough cutting edge, laser cutting is very useful and also it gives smooth cutting edge and good finishing quality [8]. The fabricated AL 2024 composite reinforced with titanium carbide has been examined for the tensile test. The result shows that joints are disturbed in the initial phase. To avoid such type of disturbances laser extensometer is used [9]. By decreasing the particle size of the hybrid composite material like B_4C and at the same time increasing the volume fraction of particle, the composite density has been decreased [10].

From the literature review, it was understood that many researchers have studied the Al alloy based composite but there are limited works reported on hybrid composites. The processing of such composites by machining works for their transformation into a usable form is limited. Very few are addressed on investigating the machinability of Al alloy based materials and no one attempted to evaluate the machinability of Al 2024 based hybrid composite. Hence there is a scope for evaluating its machinability behavior through laser beam machining process.

2. FABRICATION

Al (2024)-TiC-B_4C hybrid MMC is manufactured by using two step stir casting process. The composition of aluminum alloy 2024 is tabulated in Table 1. The TiC, B_4C of 150 μm particle size is added as fillers and the weight ratio of TiC and B_4C are given in the Table 2. Aluminum alloy 2024 is heated to a 650°C to get melted and molten alloy is allowed to cool down at 490°C which results slurry upon mechanical stirring results alloy in liquid stage. Then preheated TiC and B_4C are added in to molten alloy with mechanical stirring at 300rm for ten minutes. The resultant mixture heated up to 650°C for uniform dispersion of fillers and free from defects like blow holes, cavities, cracks. The resultant molten composite mixture is poured into the square shaped mold to solidify. The fabricated composite is subjected to mechanical testing to determine its Tensile strength, Hardness, Impact strength. The stir casting facility used for manufacturing the composite is shown in Figure 1.

Table 1. Chemical composition of Al2024

Elements	Cu	Mg	Mn	Fe	Si	Zn	Cr	Ti	Al
wt. %	4.85	1.31	0.667	0.254	0.11	0.079	0.033	0.008	bal.

Table 2. Weight ratio of fillers

Sample code	Filler	
	B_4C	TiC
5 wt. % Filler	2.5%	2.5%

Figure 1. Experimental setup

3. EXPERIMENTAL PLAN

The machinability of the material is also determined through laser beam machining. The varying process parameters considered are Frequency, Pulse width, laser power, time and the constant pressure of N_2 gas. The responses taken into account for this research work are the diameter, the roundness and circumference of the hole.

Laser Beam Machining [LBM]

The fabricated material is preferred for machining using laser drilling. The optical fiber beam pulse high peak power Nd-YAG laser is planned for laser machining. The model JK 300 fiber delivering a power of 300W is used for the experimental study in AL2024-B4C-TiC component. It is preferred due to the importance of usage of fiber laser in the aerospace industry. Because of its multiple materials processing, it has been used for several decades. This fiber laser is also used in the medical field, aerospace industry and electronics sectors due to high peak power, relatively low average power, low electricity efficiency & inconsistent beam property. The profile beam focuses on the spot that has a top hat distribution. This helps in a large portion of the spot profile below the threshold for vaporization. It provides the single or two long pulses to make a drilled hole with excellent surface quality rather than using multiple short holes. Table 3 shows the details of the parameters considered for this work.

Table 3. Parameters and their levels

S. NO	**Frequency (Hz)**	**Pulse Width (ms)**	**Laser Power (W)**	**Time (Ssec)**	**N_2 Gas (bar)**
1	100	2	175	200	12
2	100	2.5	190	180	12
3	100	3	210	160	12
4	115	2	190	180	12
5	115	2.5	210	160	12
6	115	3	175	200	12
7	125	2	210	160	12

8	125	2.5	175	200	12
9	125	3	190	180	12

4. RESULTS & DISCUSSIONS

Mechanical properties

Hardness testing is conducted under the Brinell hardness test on aluminum hybrid. The increase in the volume fraction of B_4C and TiC particle in the matrix alloy increases the hardness of the composite. Addition of reinforcement particle in the matrix surface area causes a reduction in the grain size and ductile metal content of matrix alloy, which leads to the reduction of ductility, thereby increase the hardness value. The tensile test is conducted to measure the tensile strength of reinforced hybrid AL2024-TiC-B4C composite and the tensile strength is increased due to the addition of 5 wt. % reinforcement.

The increase in the addition of reinforcement particles B_4C and TiC in matrix alloy increases the ultimate and yield strength of the composite. The impact testing is done on the composites. The impact energy of the composites decreases with increased B_4C and TiC weight fraction. The brittle natures of ceramic particle which affect stress concentration area, thereby reduces the impact strength. Table 4 shows the mechanical properties of hybrid composite materials.

Table 4. Mechanical properties of AL2024-B_4C-TiC composite

S. NO	PROPERTIES	VALUES
1	Hardness	89.2 BHN
2	Ultimate strength	222MPa
3	Yield strength	121.6MPa
4	Impact strength	3 Joules

The size of the laser beam used for this study is 0.3mm and the effect of parameters such as frequency pulse width, power and time on the response characteristics are evaluated. At varying process conditions, the holes are drilled, and their characteristics such as the entry diameter, exit diameter and roundness of the hole are measured with accuracy. Table 5 shows the variations in the dimensions of holes at the entry level for different conditions of 5 wt. % reinforced composite. Figure 2 shows the laser drilled holes made on the fabricated composite material.

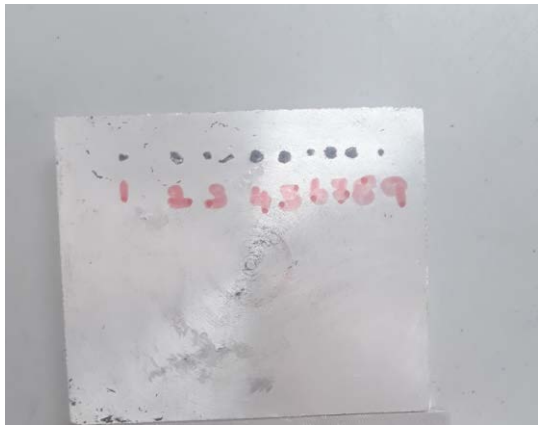

Figure 2. Laser drilled holes

Table 5. Response values for entry holes

Hole no.	Diameter (mm)	Circumference (mm)	Area (mm^2)	Roundness
1	0.285	0.895	0.064	0.018729
2	0.314	0.987	0.078	0.030693
3	0.165	1.039	0.116	0.037082
4	0.384	1.207	0.116	0.037422
5	0.291	0.913	0.066	0.021619
6	0.342	1.074	0.092	0.027910
7	0.348	1.092	0.095	0.019361
8	0.323	1.014	0.082	0.026741
9	0.312	0.979	0.076	0.014853

Table 6 shows the variations in dimensions of holes at exit level for different conditions of 5 wt. % reinforced composite.

Table 6. Response values for exit holes

Hole no.	Diameter (mm)	Circumference (mm)	Area (mm^2)	Roundness
1	0.236	0.741	0.044	0.022230
2	0.215	0.674	0.036	0.053988
3	0.205	0.643	0.033	0.021001
4	0.231	0.726	0.042	0.027719
5	0.242	0.761	0.046	0.023170
6	0.146	0.459	0.017	0.032980
7	0.207	0.650	0.034	0.022859
8	0.185	0.582	0.027	0.016782
9	0.181	0.568	0.026	0.014726

The variation in size of the holes is evaluated under the different parameters such as pulse width, frequency, time, power.

In order to obtain the optimum parameter for the precised hole making under required dimensions, optical measurement is adopted. While increasing the pulse width, power and time leads to the increase in hole's diameter and roundness is noted. Then the frequency is increased to higher level, the variation in the parameter affects the entry hole diameter and roundness and reduce it.

In the exit holes side optical measurement data reveal the ranging of standard frequency and variation in the parameters such as pulse width, power and time. The decrement in the size of the diameter and roundness is observed for the variation in the process parameter. It is understood that the variation of time and power plays a major role in influencing the diameter of the holes.

5. CONCLUSIONS

- The hard reinforced ceramic particles such as TiC, B_4C based hybrid composite are successfully fabricated through two step stir casting process.
- The fabricated hybrid composite, AL2024-TiC-B_4C is having the improved mechanical properties such as hardness, tensile strength, ultimate strength and yield strength.

- The addition of particles into the matrix decreases the impact strength due to the increased ceramic fillers.
- The influence of process parameter is noticed and evaluated for understanding the machinability behavior of the hybrid composite.
- The increment in the variation of power and time plays the vital role in deciding the diameter and roundness of the holes.

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