Effect of tool material on machinability of TiCp reinforced Al-1100 composite

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Abstract. In present days MMC’s are widely used in most of the industries, like automobiles, aerospace, minerals and marine industries, because of its high specific strength to weight ratio. There are many types of reinforcements are available, selection of reinforcement is depends on availability, cost and desired reinforcement properties. In our study Al-1100 is selected as a primary material and Titanium carbide particle (TiCp) of 44µm size as reinforcement and synthesized by manual stir casting method, by varying the reinforcement percentage. K2TiF6 salt was used as wetting agent in order to improve the wetting behaviour of the reinforcement and same was observed in optical micrographs. Further, prepared composite materials are subjected to machinability studies by using lathe tool dynamometer in order to evaluate the cutting force, surface roughness with respect to reinforcement percentage and tool material. From the results, it is observed that the hardness and surface roughness of a specimen increases with the increasing of reinforcement percentage and Hardness of the tool material respectively.

Keywords: Metal matrix composite (MMC), Stir casting, Hardness, Machinability, K2TiF6, PCD, Carbide (WC), Weight percentage (wt%).

1. Introduction

Naturally available materials are not meeting our requirements, because of this reason preparation of composites came into picture, it exhibits an excellent property, like good specific strength, stiffness, hardness, low thermal expansion [6]. This is possible only by combining two or more metals of completely different physical and chemical properties [1]. Today’s industries like automobile, aerospace and mainly structural industries are mainly concentrating on this type of materials [3]. In MMC production selection of material plays a vital role. Most of the researcher selecting aluminium and its alloys as a base metal, because it has good castability and formability property [5]. And reinforcement particles are selected on the basis of cost, availability and also on particle hardness. In composites Matrix material gives support and envelops completely to the shuffled reinforcement particles [6], this shuffling is done by manual stirring, because it is economically best. This stirring avoid the agglomeration and bottom settling of particles [4]. The main challenge of stir casting is to distribute reinforcement particles in a matrix material uniformly [6], for this purpose some modifications are made during casting like adding some reagents to melt (Degasing tablet-C2Cl6and wetting agents-K2TiF6). These specimens are
subjected in optical microscope for the conformation of uniform distribution of reinforcement particulates in matrix material [7]. Hardness test is carried out on these specimens, for analysing how reinforcement wt% affects the hardness value. The reinforcement particulates increases the hardness and reduces the wear rate with the reduction of weight [1]. The specimens are set to machining (Turning) test. Machining is a process of removal of material with desired shape and size at low cost. The major problem of particulate type MMC material is that, it is difficult to machine due to harder TiC particulates and particulates have good wear property [2]. The machining effects are studied by keeping 3 parameters as constant with varying one parameter. From machinability test optimum cutting conditions are to be defined [1]. Based on this study, how the work material responds to the cutting Parameters like speed, feed and Depth of cut. Surface roughness plays a vital role in the machining process, effective machining means to produce good surface finish with low tool wear.

2. Experimental Procedure

2.1 Specimen preparation.
Here TiC particulates are reinforced with Al-1100 in the rate of 4wt% and 8wt% by manual stir casting method shown in figure 1(a). During casting process the Al-1100 of required wt% is placed in the crucible and place inside the furnace for melting up to 800°C. When the required temperature attains, the degassing tablet C₂Cl₆ was mixed for the removal of entrapped gasses. Using Zirconium coated steel rod the melt was mixed thoroughly at a speed of 200 rpm upto 4-6 min. parallely TiCₚ and K₂TiF₆ salt mixture is prepared. The K₂TiF₆ salt acts as a wetting agent [3]. When the temperature of melt reaches to 750 °C, well mixed mixture is added in 2 stage and stirred thoroughly upto 2-3 min, to avoid the jumbling and get a good particle distribution in melt. This melt is poured to the preheated metallic mould, in Figure 1 shown that stirring, melt pouring and cast specimens. Particle distribution is analysed and studied using OLYMPUS Optical microscope.

![Figure 1: Specimen preparation. (a) Stirring, (b) Melt pouring, (c) Cast Specimens.](image)

2.2 Machinability.
Machinability is a term showing how the work material reacts to the cutting process. The specimens are machined using self-centred 3jaw medium duty lath machine (BANKA Lathe, LTH 20, 3KW, 4HP) using High speed steel (HSS), Carbide (WC) and Polycrystalline diamond (PCD) tools at different cutting conditions. In this work cutting force and surface properties are analysed in dry machining.
(Turning process) of pure aluminium reinforced TiC$_p$. Turning is done using 3 tool material as mentioned above. For interrelation study between characteristics like cutting force, surface roughness and tool tip temperature. The parameters like speed, feed and depth of cut are altered to 3 levels, for the analysis of effect of these parameters during machining of composite using lathe tool dynamometer. Figure 2 shows the equipment used for testing and measuring of surface finish.

![Figure 2: Equipment used. (a) Lathe Tool Dynamometer, (b) Surface tester.](image)

3. Results and discussions

3.1 Microstructure.
From optical micrograph images it is evident that 2 stage addition and continuous stirring have considerable effect on particle distribution. In Figure 3 shown that, the uniform distribution of TiC particulates of 4wt% and 8wt% respectively.

![Figure 3: Optical Micrograph image. (a) Base metal, (b) Al+4wt% TiC$_p$, (c) Al+8wt% TiC$_p$.](image)

3.2 Hardness.
The hardness of specimens are evaluated using Rockwell Hardness test machine, of load 980N, 1/16” Ball, Scale ‘B’ and Time 20sec. Due to TiC particulates in Al-1100 composite, the hardness of the material improved by 24%. Hardness measurement means resistance to surface indentation [8]. It shows
that hardness is directly proportional to the wt\% of reinforcement addition shown in Figure 4(a). Indentations are shown in Figure 4(b).

![Image](a)

![Image](b)

**Figure 4:** (a) Hardness v/s wt\% reinforcement, (b) Indentations.

### 3.3 Machinability.

The number of parameters influencing on surface property during machining operation. For example work material composition, geometry of the tool, and machine condition. The effect of tool material on surface roughness (Ra) shown in table 1.

| Cutting speed (RPM) | Feed (mm/rev) | DOC | Surface roughness (Ra) |
|--------------------|---------------|-----|------------------------|
|                    |               |     | 0 wt\% | 4 wt\% | 8 wt\% |
|                    |               |     | HSS    | WC     | PCD    | HSS    | WC     | PCD    |
| 175                | 0.067         | 0.2 | 1.37   | 1.51   | 1.6    | 3.06   | 3.18   | 3.4    | 3.52   | 3.87   | 3.9    |
| 263                | 0.111         | 0.6 | 1.59   | 1.62   | 1.71   | 3.35   | 3.66   | 3.76   | 3.75   | 3.55   | 3.61   |
| 395                | 0.167         | 0.4 | 1.87   | 1.9    | 2.3    | 3.14   | 3.06   | 3.09   | 4.15   | 4.32   | 4.62   |

3.3.1 **Surface roughness** (Ra): From the Table 1, surface roughness depends on the wt\% of reinforcement added, say surface roughness continuously increasing from 0wt\% to 8wt\% shown in Figure 5(b) and also depends on type of tool material used. Ra increasing from HSS, WC and PCD continuously, because harder tool have effective material removal property. By decreasing feed and Depth of cut the Ra can be reduced [4]. PCD gives us a good machining condition. In Figure 5(b) the numbers 1, 2, 3 indicates the machined surface of HSS, Carbide (WC) and PCD respectively.

3.3.2 **Cutting force** (Fy): From the Figure 5(a), the force required to machine the composite depends on, the wt\% of reinforcement added and type of tool material used. Cutting force Fy continuously decreases from PCD to HSS, because cutting force is directly proportional to the Hardness of the tool. When the hardness of the tool increases the reinforcement particle collision to the tip increases i.e., Fy increases, shown in Figure 5(a). Figure 5(b) shows the machined specimens, in this figure 1, 2 and 3 indicates the turned surface of HSS, WC and PCD respectively.
Figure 5: (a) Cutting force v/s Wt% of TiC<sub>p</sub>, (b) Machined specimens.

Figure 6: Tool wear v/s Wt% of TiC<sub>p</sub>

Tool wear is directly depends on both percentage of reinforcement addition and hardness of the tool material shown in Figure 6.

4. Conclusions
In this experimental study, the 2stage addition effectively have effects on particle distribution, this particle distribution finally affects the hardness, and surface property.

- The Al-1100 reinforced TiC<sub>p</sub> composites successfully prepared by liquid metallurgical technique.
- Hardness is directly depends on wt% of reinforcement added. When the percentage of reinforcement increases, hardness of the material also increased by 24%.
- Machining of composite is difficult with increase in wt% reinforcement.
- Surface roughness also depends on hardness of the tool, i.e., surface roughness increases from HSS to PCD because of tool wear.
- Weight% of reinforcement addition have direct impact on Surface Roughness and Cutting forces and also feed rate and Depth of cut.
- With increase in speed we can get good surface finish and force required during cutting also decreases.
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