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Proceeding Paper

Optimization of Process Parameters of Aluminium 7075/TiCnp MMC Fabricated Using Powder Metallurgy Route †

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Abstract: Aluminum metal matrix composites (AMMCs) havewidespread application due to their exceptional properties. This study reinforced aluminum alloy 7075 with nano-titanium carbide across varying weight percentages using powder metallurgy. Optimization by TAGUCHI and ANOVA techniques which was carried out consideringthe following key parameters: sintering temperature (250–400 °C), sintering time (30–120 min), compacting pressure (300–450 MPa), and TiCnp content. Microhardness, evaluated with a Vickers tester and an L16 orthogonal array, led to optimal conditions: 15 wt.% TiCnp, 120 min sintering, 450 MPa pressure, and 400 °C temperature. Confirmation tests validated the resulting enhanced microhardness.

Keywords: powder metallurgy; AA7075; TiCnp; Taguchi; ANOVA

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1. Introduction

Metal matrix composites (MMCs) havebroad applications [1,2]. Aluminum is the preferred matrix material [3]. Prior research used nitride, boride, oxide, and carbide reinforcements [4,5] like SiC, ZrO_2, B4C, TiB_2, AlN, TiC, TiN, and Al_2O_3 [6]. Smaller particles boost composite strength [7,8], reducing porosity and enhancing bonding strength with nano-sized reinforcements [9]. Multiple production methods like powder metallurgy and stir casting have been employed [10,11], with a preference for powder metallurgy [12]. Titanium carbide, due to its superior wear resistance, corrosion resistance, and mechanical properties, is commonly used [13]. AA7075 MMCs outperform AA7075 matrix materials [14]. Al-Mg-Si-based AMCs with MoS2 reinforcement (1.5–4.0 wt.%) prepared using powder metallurgy exhibit uniform MoS2 distribution via SEM testing [15]. Process parameters play a pivotal role in compressive strength and microhardness [16]. Sintering at 750 °C with 0.1 wt.% graphene yields the best electrical and mechanical characteristics [17]. Varying mixing technique, sintering temperature, and oxygen content modifies Ti-O alloys' shape, dispersion, and solid solution microstructure [18]. No study has analyzed Al7075/TiC composites regarding microhardness fabrication and optimization. Our research employs powder metallurgy to create Al7075 with TiC at different wt.% (0–15 wt.% in 5 wt.% increments), optimizing process parameters through the Taguchi technique and ANOVA.

2. Materials and Methods

2.1. Materials

Aluminum alloy 7075 exhibits poor wear resistance and mechanical properties, prompting a need for enhancements in certain applications. Table 1 lists its elemental composition. AA7075 finds extensive use in producing aircraft components, shafts, gears, worm gears, etc. TiC boasts superior mechanical, corrosion, and tribological attributes, with an average particle size of 100 nm. A particle size analyzer assessed the particle sizes of AA7075 and TiC powder particles [19]. For specific Al7075 and TiC particle details, refer toTable 2.

Table 1. Chemical composition of Al7075.

Elements	Cr	Si	Mg	Zn	Cu	Ti	Fe	Mn	Al
wt.%	0.21	0.07	2.3	5.7	1.4	0.06	0.23	0.05	Bal.

Table 2. Details for AA7075 and titanium carbide powder particles.

Property	Tensile Strength	Melting Point	Density	Modulus of Elasticity (GPa)
Al7075	259 MPa	570 °C	2.81 g/cm^3	187
TiC	335 MPa	3150 °C	4.94 g/cm^3	412

2.2. Composite Fabrication

Al7075 matrix and TiC reinforcement were used in various weight percentage (wt.%) combinations to produce composites through powder metallurgy. An electronic weighing system measured materials, followed by ball milling and compacting at 500 KN using a zinc-coated die wall. Sintering occurred at different temperatures and times in a muffle furnace, with 12 h cooling. Optimization factors were sintering temp (300–450 °C), time (30–120 min), pressure (300–450 MPa), and TiC wt.% (0–15). Microhardness was the response parameter. Al7075/TiCnp composites were created using L16 OA design based on L9 OA design inputs, with composites measuring 24 mm in diameter and 12 mm in length.

2.3. Testing of Al7075Fortified Nanocomposites

Microhardness tests were performed on the Al7075/TiC composites to determine microhardness. The microhardness test was carried out in accordance with ASTM E384 [20]. Wire-cut EDM was used to cut the required ASTM size for hardness testing from the produced composite. For cutting the composites to the requisite ASTM size, wire-cut EDM was used. Wire-cut EDM is employed to cut particles without causing dislocation. The Vickers hardness FMV-1 model was used for hardness testing. Toughness was determined by conducting three trials and calculating the average value. All manufactured composites underwent a hardness test using the L16 OA.

3. Results and Discussion

The microhardness of Al7075/TiCnp composites was evaluated using an L16 OA design.The key factors affecting microhardness include sintering temperature, compacting pressure, TiCnp weight percentage, and sintering time, as illustrated in Figure 1. Nano-titanium carbide enhances microhardness, but this decreases at higher sintering temperatures, while increased compacting pressure raises microhardness, and extended sintering times reduce it. Nano-titanium carbide enhances the bonding between reinforcements and the matrix [20]. Higher sintering temperatures and longer sintering times soften composites, reducing microhardness [20]. ANOVA results confirm the significant effects of nano-titanium carbide, sintering temperature, and time on microhardness (all p-values < 0.05). Optimization yields reliable results with a 99% adjusted R-square value. The best parameter combination for maximum microhardness comprises 15 wt.% TiCnP, 250 °C sintering temperature, 450 MPa compacting pressure, and 30 min of sintering time, which is supported by main effect plots and ANOVA. Contour plots in Figure 2 clarify microhardness relationships, showing that higher wt.%TiC boosts microhardness while increased sintering temperature and time reduce it. The confirmation test was conducted using the best combination ofinput process parameters, and the determined microhardness was found to be 115H.v. The confirmation test was conducted with the best combination of parameters, resulting in a wear loss of 16 mg. Figure 3a,b depict the microstructure and EDAX test results of Al7075/9wt.%TiCnp. The surface of the confirmation test specimen composites was polished using grit sheets ranging from 200 to 400, 600, and 800. The surface of the confirmation test specimen was polished to 1 µm. Figure 3a shows the microstructure of Al7075/9wt.%TiCnp, demonstrating the homogeneous distribution of TiCnp reinforcements in the Al7075 matrix material. Figure 3b shows the presence of elements.

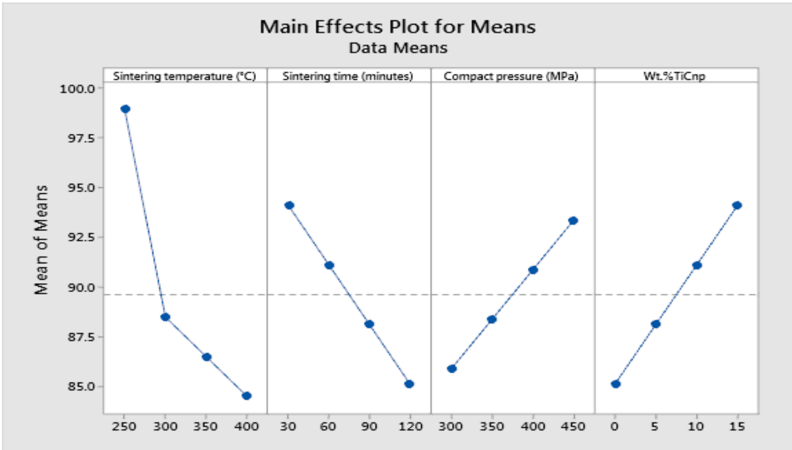

Figure 1. Main effect plot for means of microhardness.

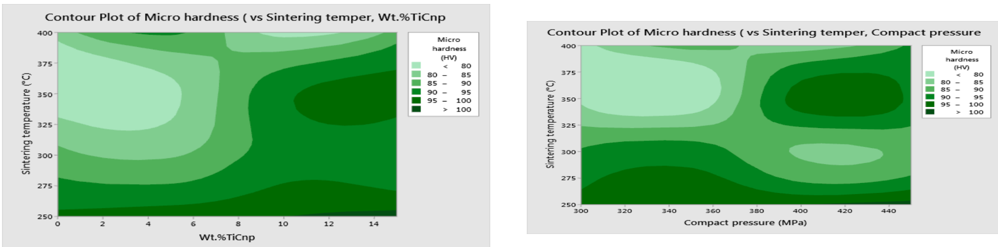

Figure 2. Contour plot for microhardness with input parameters.

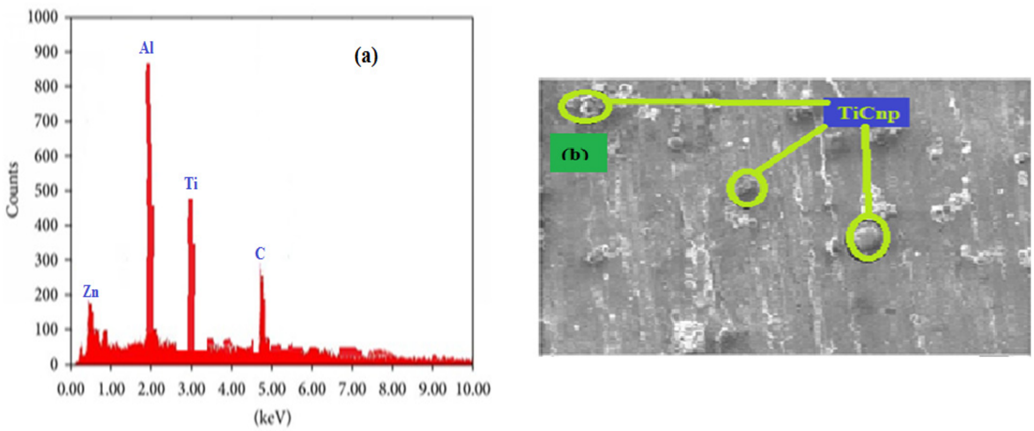

Figure 3. (**a**,**b**) EDAX and SEM of Al7075/15wt.%TiCnp.

4. Conclusions

Using powder metallurgy, aluminum alloy 7075 was strengthened with nano-titanium carbide (TiCnp) in varying weight percentages. Alloy 7075 and TiCnp had particle sizes of 2 µm and 100 nm, respectively. Taguchi and ANOVA methods optimized parameters like TiCnp weight percent, compact pressure, sintering time, and temperature for Al7075/TiCnp composites. Microhardness was the response parameter. The best parameters for maximum microhardness were 15wt.%TiCnP, 250 °C sintering temperature, 450 MPa compact pressure, and 30 min sintering time. In the confirmation test, the microhardness was 115, and SEM confirmed the even TiCnp distribution in Al7075/15% TiCnp.

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