

# Processing and Evaluation of Microstructure & Physical Properties of Al7075 Reinforced with Cermets by Stir Casting Route

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**Abstract:** The combination of two or more materials with dissimilar characteristics leads to the formation of Metal matrix composites (MMC). Among MMCs large interest is being given to improve aluminium based MMCs and to develop high temperature ceramics. The present paper discusses the processing and physical properties of Al7075 reinforced with (WC-Co) cermet particulates prepared by stir casting route. An average particle size of 10µm WC-Co particulates produced by planetary ball milling process is used as reinforcement in Al7075 matrix. Microstructure evaluation of the prepared composite is carried out using SEM/EDX. Physical properties of the matrix and prepared composite are evaluated.

**Keywords:** Cermet, composite, ceramics, ball milling

## 1. Introduction

The conventional metals, alloys, ceramics and polymeric materials which are used in general engineering applications are exhibiting a less impressions in their properties in concern with the modern technology required materials which are able to exhibit an unusual contribution of properties. To achieve the modern materials to give a combinations in the betterment of properties development of the composite materials come into the existence. Replacement for the conventional materials can be made by Metal matrix composites implementation in various applications like machine tools, connecting rod, aerofoil structures and in the field of defense. For engineering applications MMC plays a major role and aluminium is an excellent material in the non ferrous family because of its excellent properties like low density, high strength to weight ratio, high thermal and electrical conductivity and fluidity [1]. In the view of all types of MMCs aluminium matrix composites plays a major role in automobile and aerospace industries because of their good electrical and thermal conductivity, high strength and stiffness, low coefficient of thermal expansion and good wear resistance. Utilization of ceramic particles in the aluminium matrix composites are the recent field of research. The attractive combination of ceramic materials in particulate form into a metal matrix composite will result in the increment of mechanical properties which is highly difficult to extract from the monolithic materials [2]. The processing methods used in the present technology requires the knowledge about the various processing techniques and selection of proper processing methodologies for the specific materials



based on the behavior of particulate MMCs is a view of their wider commercial application along with the mass production. Due to the easy availability of particulates and economic techniques adopted for producing the particulate reinforced MMCs there is an increase in the interest for the same [3]. Cermets like WC-Co (Tungsten carbide and Cobalt) have been widely used and studied because of their good corrosion resistance and unique combination of high hardness and toughness, which results from the mixture of brittle (hard) and ductile (soft) phases. Out of many carbide materials Tungsten carbide is a well known ceramic material which is abundantly used because of its high hardness and wear resistance. Being a metallic phase the addition of cobalt which improves the toughness of the composite so that brittle fracture appearance can be reduced [4]. Researches taking place in the present day shows a less work has been conducted on the combination of both ceramic and metallic phase elements in aluminium matrix material for the preparation of the composites which may exhibit low wear resistance, corrosion resistance and high temperature applications.

## 2. Experimental details

In the current work, Al7075 alloy is used as a matrix. An atomic absorption spectroscopic analyzed composition of Al7075 is tabulated in Table 1. Cermet mixtures of Tungsten Carbide (WC) and Cobalt (Co) particulate with a mean size of 10  $\mu\text{m}$  which are prepared using ball milling are used as reinforcing materials.

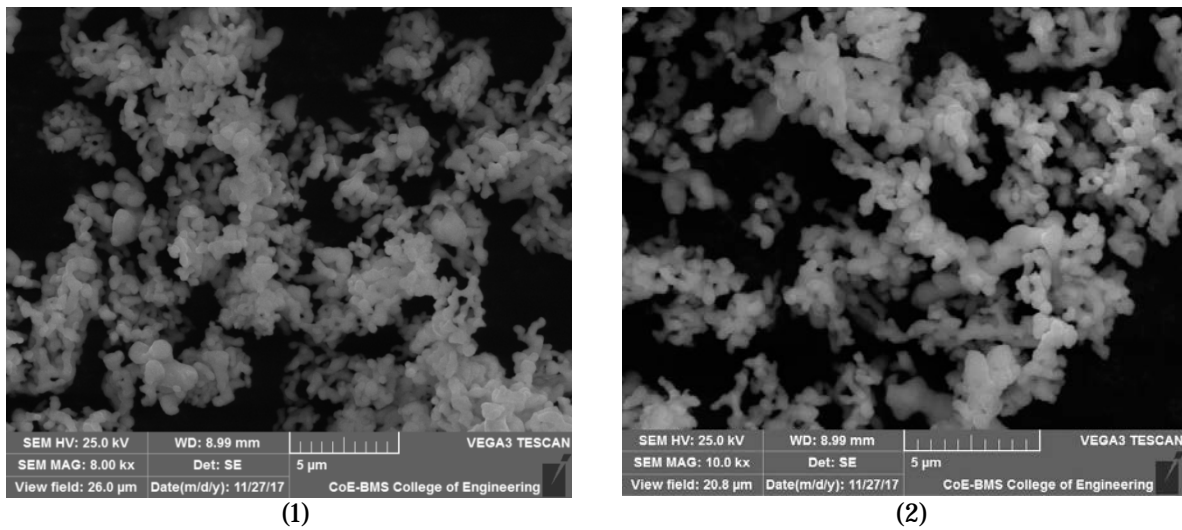
**Table 1.** Composition of Al7075 matrix

Alloys	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
%	0.4	0.5	1.6	0.3	2.5	0.15	5.5	0.2	Balance

### 2.1 Cermet preparation

Planetary Ball milling process is chosen for the preparation of the cermet because of efficient and simple method to prepare the cermet with sub-micron or micro structured powder form, which can be used as a particulate reinforcement in the preparation of the composites [5]. The rotational effect generated in the ball mill equipment produces a strong mechanical energy which results in formation of extremely fine powder [6-7]. A fairly distribution of hard phases in ductile metallic matrices is due to counteract breaking and cold welding process during milling, breaking of particle's is mainly caused by shear load transferred by grinding balls colliding under a low angle, while cold welding is dominate for perpendicular impact of grinding balls and the crystallite size decreases with proceeding milling time [8-9].

A batch of WC and Co powders is added to the container and the process of milling is carried out for 6 hr with a speed of 300rpm of rotational speed. Further, the addition of iron particles can happen during the milling process which leads to the contamination of the cermet powder. To prevent the iron contamination Alumina medias are used instead of steel medias. The homogeneous distribution of hard phases in ductile metallic matrices takes place due to counteract breaking and cold welding process. The WC-Co cermet after ball milling has an average particle size of 10  $\mu\text{m}$  analyzed via sieve analysis and SEM images of the same are presented in Figure 1-2. The prepared cermets were used as reinforcement for the preparation of composite.



**Figure 1-2.** SEM microphotographs of WC- Co cermets powder produced by planetary ball milling at different magnifications.

## 2.2 Preparation of Al7075 & WC-Co Cermet Composites

Composites containing Al7075 matrix with 9wt% of WC-Co Cermet reinforcement were prepared using stir casting technique at temperature of 750°C. A batch of 400 grams of Al7075 matrix is melted in a graphite clay crucible using resistance furnace. When liquid matrix reaches 750°C the presence of adsorbed gaseous content from the molten aluminium is been removed with the addition of solid hexachloroethane ( $C_2Cl_6$ ) which acts as a degassing agent. To generate vortex in the liquid matrix, stirring is carried out using zirconia coated steel rod with a spindle speed of 300 rpm for 10 min. Preheated WC-Co cermet in an amount equivalent to 9 wt% is then introduced into the liquid matrix. After introduction of the reinforcement, again stirring is carried out for a period of 60 sec to ensure the clear and fair distribution of the reinforcement. Into a preheated permanent die (125 mm×Φ15 mm) the liquid metal of composite is poured at 750°C.

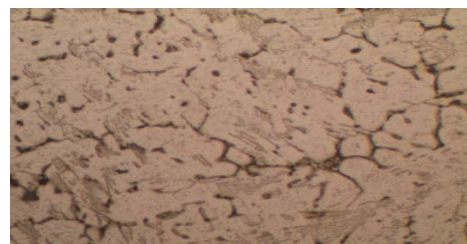
## 3. Results and discussions

### 3.1 Microstructure characterization using SEM/EDAX

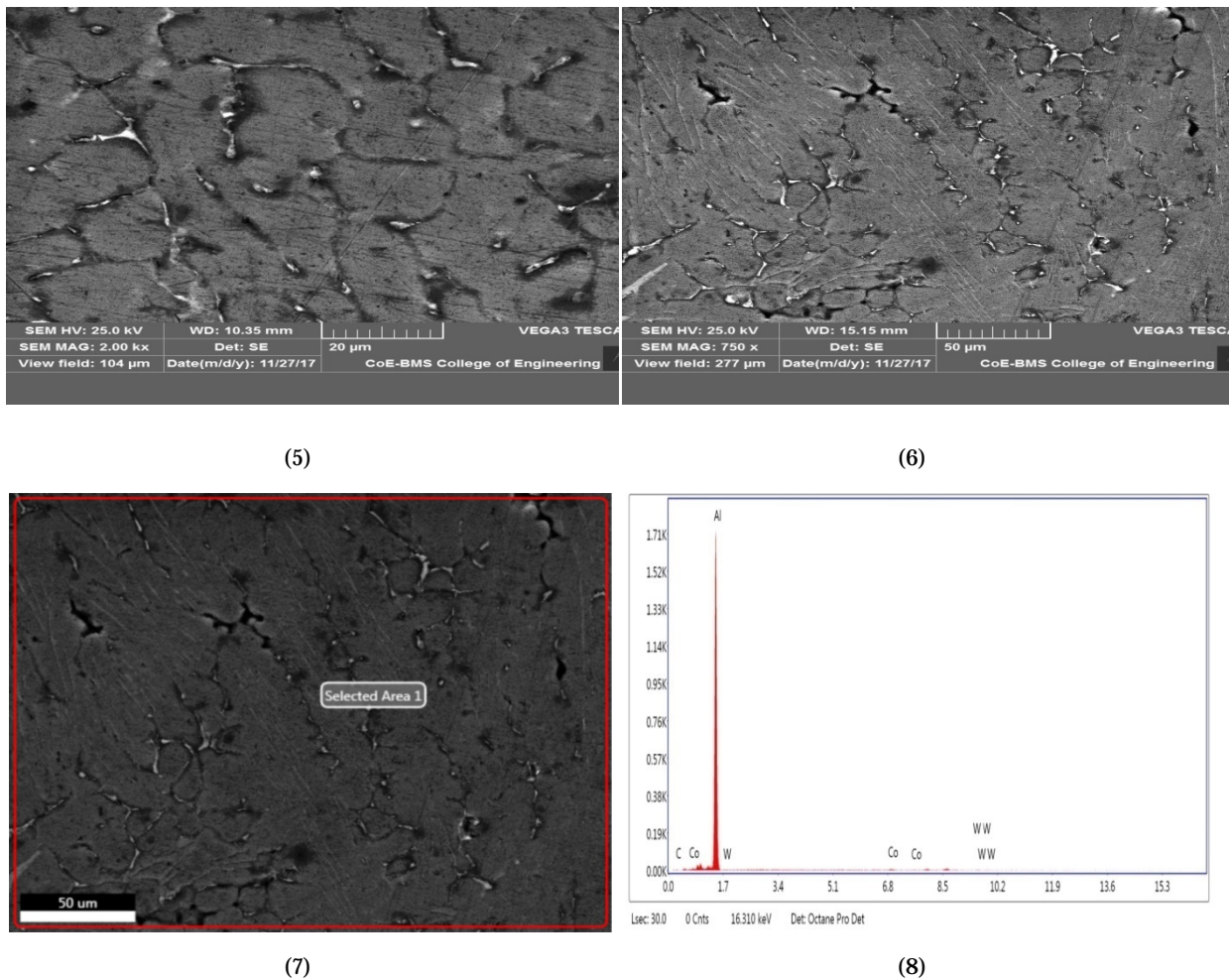
The prepared composites are subjected for the preparation of the test samples in the size of 5×10×5mm were taken from the center portion of the work piece. Optical microscopy and SEM equipped with EDX is employed for determining the presence and distribution of WC-Co cermet particles in Al matrix. Optical microstructure shows the formation of inter dendrite precipitates in a matrix of aluminium solid solution and also intermetallic particles are seen in the matrix. A fairly distribution of reinforcement can be observed in the SEM micrographs shown in Figure 2 (a-d). EDX spectra taken at the centre of the particle shows the presence of Al, WC and Co materials shown in Figure 3-8.



(3)



(4)



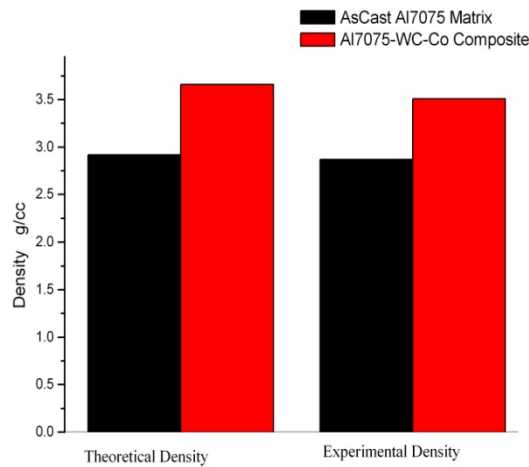
**Figure 3-8.** (3-4) Optical micrographs of Al7075+9% WC-Co composite at 100X and 500X magnifications. (5-6) SEM micrographs of Al7075+9% WC-Co composite at 2.00KX and 700X magnifications. (7-8) EDX spectrum of Al7075+9% WC-Co composite.

### 3.2 Density and Hardness measurements

**Table 2.** Ascast Matrix and Composite specimens Physical Properties

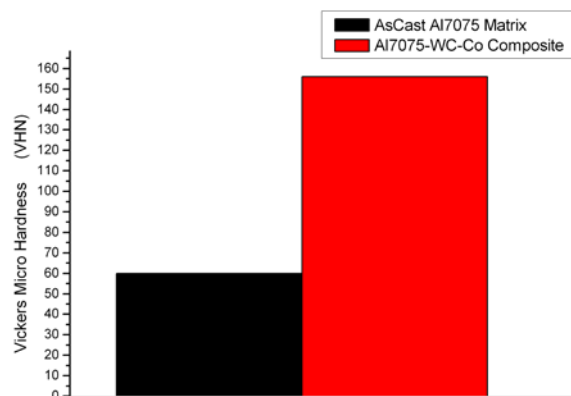
	Ascast matrix Specimen	Composite Specimen
Theoretical Density (g/cc)	2.92	3.66
Experimental Density (g/cc)	2.87	3.51
Porosity (%)	1.71	4.09
Vickers micro hardness (VHN)	60	156

Archimedes principle is used to determine the experimental density of the specimen while rule of mixture is used to evaluate theoretical density. From Table 2 it is clear that measured density of the composite is came in between the base Al7075 matrix and the reinforcement densities. The porosity level of the composite is higher when compared with the base matrix Al7075. The increase in porosity of the composite is due to the entrapment of the gas during the action of stirring, pouring distance and shrinkage during solidification



**Figure 9.** Variation in densities of ascast matrix and composite prepared at 750°C.

The prepared composites as well as matrix were subjected to hardness measurements using Zwick micro hardness tester. Measurements were done at a load of 20N on a polished surface with a settle time of 10sec and an average value of 20 readings was reported. Table 2 shows the comparison between Vickers micro hardness values of matrix and composite. Figure 10 shows the drastic improvement in the hardness of the composite due to the fair distribution of the hard ceramics in the matrix.



**Figure 10.** Vickers micro hardness of matrix before and composite prepared at 750°C

#### 4. Conclusions

- Cermet reinforced aluminium matrix composite was successfully synthesized by conventional stir casting technique.
- Microstructural evaluation using OM, SEM/EDX studies have indicate fair distribution of the cermet reinforcement particles in the matrix system.
- Major improvement in hardness found in the prepared composite.

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