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Effect of deformation on properties of Al/Al-alloy ZrB_2 powder metallurgy composite

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ABSTRACT

Plastic deformation plays a key role on powder metallurgy(PM) made components in order to enhance properties as per required applications. In the present study, Effect of deformation is studied on Al, Al-2ZrB_2, Al-4Cu, Al-4Cu-0.5 Mg, Al-4Cu-2ZrB_2 and Al-4Cu-0.5 Mg-2ZrB_2 made through PM. All the composites are homogenous grounded for exact compositions and cold compacted in a tool steel die triaxilly. The compacted green compacts are then pressureless sintered at 550 °C for 1 h followed by annealing. The whole sintering process was carried out in continuous argon flow inert atmosphere in order to avoid oxidation during sintering. The sintered composites are cold and hot deformed upto failure. The stress used and strain calculated was correlated to the relative density to evaluate densification behavior. The deformed samples were tested for hardness and correlated to the deformation data. Hardness of deformed composite increased with progressing deformation. The deformed composites are subjected to potentiodynamic polarization study in 3.5% aqueous NaCl solution to determine the corrosion rate which was analyzed with deformation data. Corrosion rate decreased with extent of deformation.

1. Introduction

The evolution of composite and hybrid materials during past decades gave the scope for improvement in the efficiency of materialistic properties. The properties like high strength, toughness and weight reduction over conventional monolithic alloys and metals are of great significance. The energy efficiency and other characteristics of metal matrix composites (MMC) are the reason for wide range of applications in automobile and structural industries [1]. The lightweight monolithic aluminium and aluminium alloys do not cater to the present days high performing requirements. Thus need to alter the existing conventional materials for enhancement of properties to suit for the intended use. The requirement for improving properties created scope in reinforcing the metals and alloys. The commonly used ceramic particles like Al_2O_3, Si_3N_4, B_4C, TiC, SiC, $TiB_2$and ZrB_2improved both physical and mechanical properties based on the inherent properties of the ceramic particle used as reinforcement in the matrix [1,2]. The increasing production and use in commercial applications of different types of MMCs created a need to attain knowledge regarding the processing and mechanical behavior of MMCs [3]. Densification and associated changes during the processing of MMCs play significant role on the performance of the components produced by PM route.

Densification in 4032 Al alloy preform is done by hot rolling with parallel spray deposition [4]. A variation in the strain is observed from surface to the inner layers of preform during rolling process. The effect of flake thickness of Al powder particles and the amount of Alumina on the ductility and the grain structure of the composites were analyzed [5]. Hot deformability of aluminum–copper–magnesium P/M alloy, P/M 2324, was studied in comparison to its wrought counterpart AA2024. The presence of secondary phase in P/M 2324 was (Al_2Cu) whereas the S phase (Al_2MgCu) was pronounced in the wrought system accounts for the ductile property [6]. The effect of size of the reinforcements and the initial densities on the workability and instantaneous strain behavior is studied. The amount and size of pores have a significant effect on the workability of preform under compression testing [7]. The effect of initial relative density and aspect ratio on the strain hardening behavior of the aluminium–3.5% alumina composite preforms was studied. The relationship between strain-hardening exponent n and strength coefficient K was reported [8]. Workability studies of Al–Al_2O_3 composite was reported and the stress

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formability index increased with increase in initial relative density and lower with the aspect ratio [9].

Deformation characteristics and fracture mechanism of sintered copper powder strips were studied during the cold forging. Comparative studies have been done between theoretical and experimental results were analyzed to explain the deformation characteristics and the fracturing mechanism of sintered copper powder strips during cold upsetting [10]. Powder preform forging was performed on Fe–0.8%C–1.0%Si–0.4%Cu steel performs during cold upsetting and densification behavior is studied. During the process of deformation enhancing of densification, the strength and strain is also induced. Work hardening behavior was not homogeneously enhanced with respect to strain and densification [11]. Alloying addition of 1% graphite to Fe powder has a great effect on deformation and densification behavior which have a significant effect on corrosion rate reduction of sintered powder preforms. Full densification is not attained by cold upsetting irrespective of sintering temperature [12]. Densification increased with the decrease in the aspect ratio with increased frictional conditions. Fracture strain which depends on diameter and height strain increased significantly when decrease in friction conditions [13]. Effect of aspect ratio and carbon content on the deformation behavior of steel powder preforms is reported. Formability behavior was correlated with the microstructures of the preforms [14].

Deformation studies of Fe powder alloy preforms with different carbon contents were studied. With the increase in the carbon content the resistant bainite structure increased correspondingly hardness increased. PM produces the resistant microstructure bainite in Fe-based alloys in required quantity by mechanical alloying process [3]. The instantaneous strain behavior of Fe preforms with different amounts of carbon content was evaluated at room temperature. Densification rate decreased with increase in carbon content but highest density is achieved in preforms with more amount of carbon [15]. The Cu–Al–Ni strips were prepared by hot rolling of pre alloyed powders. The effect of nano-sized alumina on the strips influenced the grain growth during heat treatment. The heat treated strips appeared to have a combination of both fracture strength and fracture strain [16]. The workability studies of Al preforms with different Fe amounts were studied and reported that there is a significant change in workability with the particle size and the amount of Fe in preform [17]. The formability of TiC reinforced steel preforms was studied at elevated temperatures. The shape of the barrel radius of the preform is correlated to the stress ratio parameters and expressions for the same were derived [18]. The effect of C and Mo on the densification of steel preforms was studied during deformation. Various stress ratio and strain parameters were correlated and reported [19]. The effect of the mean stress and the effective stress during the deformation of powder preforms was studied and workability of the same is reported [20]. Corrosion rate of 6061Al alloy composite increased than the base alloy in corrosion media because of the galvanic couple effect. It also increased with the increase in the concentration of corrosion media and the temperature [21]. The corrosion rate of 6063 Al alloy was tested in different media for corrosion properties by conducting potentiodynamic polarization and electro impedance spectroscope studies [22]. Corrosion rate of the composite increased with increase in the reinforcement and decreased with the temperature used during deformation process [23]. Increase in the usage of Al and its composites in wide range of applications created the need for the information regarding the corrosion behavior of the composites. The parameters of alloy composition which have an effect on corrosion behavior are

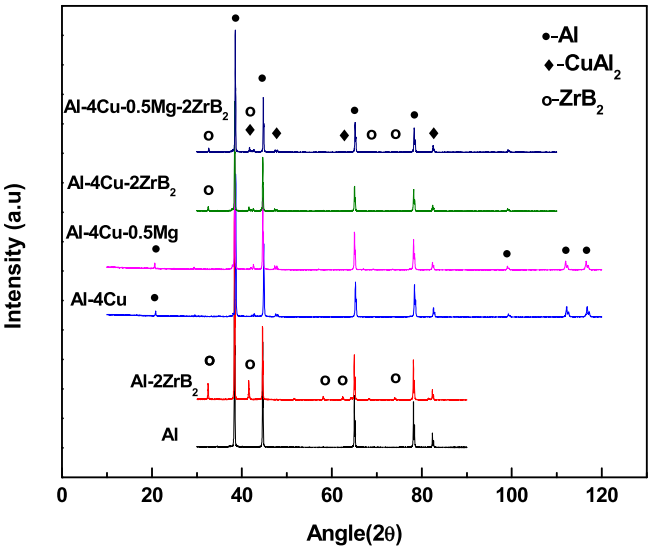

Fig. 1. Phase analysis comparison of all composite compositions.

composition, size, volume fraction, and pretreatment of the reinforcements [24]. The effect of SiC particles on the corrosion behavior of different series of Al alloys were tested. Effect of concentration of NaCl is correlated with the SiC phase in the composites. The effect of presence of oxygen is evaluated by comparing with the corrosion test conducted in inert atmosphere [25].

The family of borides are blessed with inherent properties like high chemical stability, high hardness and good thermo-electric properties. Among the family titanium diboride (TiB_2) and zirconium diboride (ZrB_2) are significant boride ceramics which exhibit superior properties like high melting point, extremely high hardness and wear resistance, low specific gravity, magnetic, electrical properties, with high mechanical properties and chemical inertness at elevated temperatures. The ZrB_2 based materials exhibit great dimensional stability which was of prominent importance in automobile functioning. The ZrB_2 powder can be used in order to manufacture ceramic reinforced composites such as Cu-ZrB_2, Al-ZrB_2 etc.

In the present study Al and Al alloy composite densified preforms are produced by hot and cold deformation. The effect of alloying and addition of ZrB_2 particles on the deformation is to be studied. The effect of deformation on densification behavior is to be evaluated. In view of the Al and Al alloy composites performance requirements in automobile and marine industries it is necessary to evaluate the performance, properties and life of material. Therefore potentio-dynamic polarizations studies are performed on deformed Al and Al alloy composite preforms.

2. Experimental part

2.1. Raw materials

The metal precursors Al(>99% pure and the particle size < 44 μm, Sisco Research Laboratories, India), Cu(>99.9% pure and the particle size < 44 μm, Alfa aesar), Mg(>99.9% pure and the particle size < 40 μm, Alfa aesar) and ultra-hard ceramic ZrB_2ZrB_2 (>99% pure and the particle size < 4 μm, H·C Starck, Germany) are used in the preparation of Al and Al-alloy composites.