

An Experimental Study of Tri-Biological Behaviour on Aluminium/Diamond Composite Using Powder Methodology

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ABSTRACT: Al based materials including Al-Nanodiamonds and Al-Al₂O₃ processed by explosive compaction are considered in this paper. Improvements of composite properties were obtained by the introduction of diamond and ceramic Nanoparticles (10 wt% of each) into the mixture of aluminium Nanopowder. Various schemes and conditions, including a theoretical calculation of the explosion process, were suggested and discussed. Physical and mechanical properties of composites reinforced with Nanoparticles are determined and discussed with special consideration paid to process conditions. The results show an increase in the hardness, compressive strength and elastic modulus of the composites after explosive compaction with the introduction of Nanoparticles into the powder mixture. Improvement of mechanical properties of composites compared to pure aluminium is determined by dispersion strengthening, small material grain size and internal compressive stresses caused by dynamic shock-wave compaction processing.

KEYWORDS: Aluminium, Nanoparticles, Explosive compaction, Composite, Mechanical properties, Diamond powder.

I. INTRODUCTION

In the recent years, cast aluminium alloys are widely used in automobile and other engineering applications as cylinder blocks, piston, piston ring, brake disc and drum, due to light weight, corrosion resistance, high thermal conductivity, fatigue strength and workability. However the applications of aluminium alloys are limited due to poor wear and seizure resistance at room and elevated temperatures. The demand for light weight, inexpensive and energy efficient Aluminium Metal Matrix Composites (AMCs) has been increasing with multifunctional properties for automobiles, aircraft and other applications. The AMCs is an attractive material due to its low density, high hardness, strength, stiffness, good corrosion resistance and high thermal conductivity. Recent studies have used micro-sized particles to improve the mechanical properties of AMCs. However, the poor ductility and reduced fracture toughness have limited the application of micro-sized ceramic particle-reinforced AMCs (Dongshuai Zhou et al. 2014). The use of Nano-sized particles to improve the mechanical properties of the AMCs is attractive because it improves ductility, high temperature creep resistance, fatigue life, wear resistance and fracture toughness. The Nano particle content increases the mechanical and wears resistance of the aluminium metal matrix Nanocomposites (AMNCs). The fabrication of AMNCs by ultrasonic cavitation-based solidification processing is attractive due to better matrixparticle bonding,

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easier control of matrix structure, simplicity, inexpensive processing, flexibility, applicability to bulk production and complex shape.

II. MATERIAL AND METHOD

METAL MATRIX COMPOSITES

A metal matrix composite is a composite material consisting of two or more where tailored properties are achieved by systematic combination of different constituents. One is a metal and the other material can be different metal or other materials such as a ceramic and organic compound. Metal matrix composites reinforced with ceramic particulate offer significant advantages over pure metals and alloys. The metal matrix composites offer several advantages when compared with conventional material. A few such advantages include the combination of high strength, high elastic modulus, high toughness and impact resistance, thermal stability and thermal shock resistance, high surface durability, high hardness, high thermal and electrical conductivity, improved wear resistance, minimum exposure to the potential problem of moisture absorption resulting in environmental degradation, and improved fabricability with conventional metal working equipment.

FABRICATION OF ALUMINIUM METAL MATRIX NANOCOMPOSITES

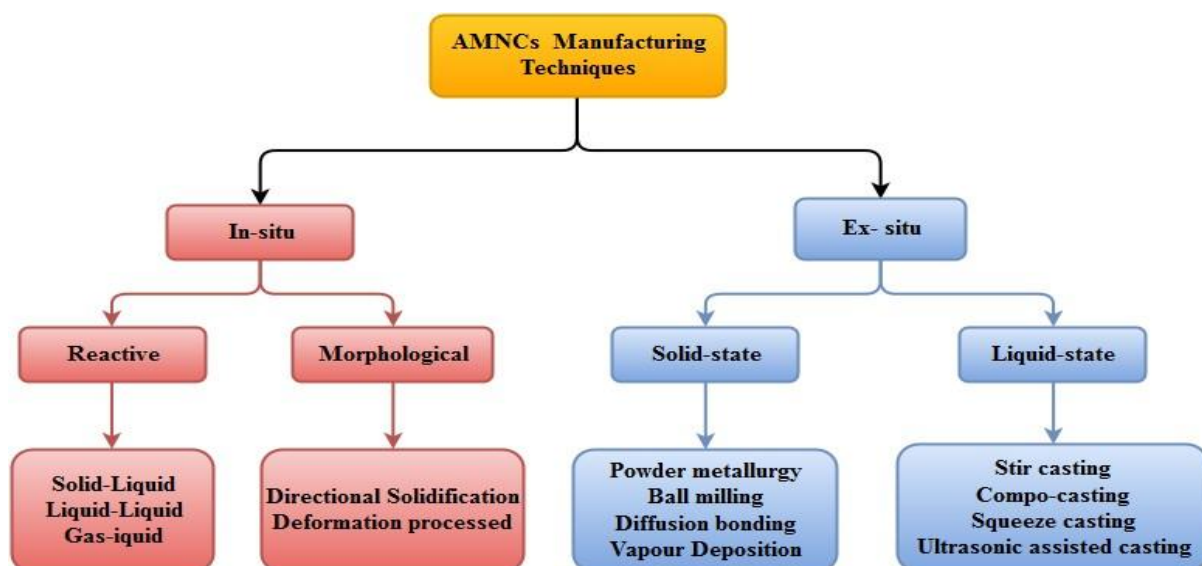


Fig1: Classification of AMNC

POWDER METALLURGY

Powder metallurgy is the process of blending fine matrix and reinforcement powders followed by pressing into a desired shape and then heating the compressed material in a controlled atmosphere to bond the material. The

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powder metallurgy process generally consists of four basic steps: (1) powder manufacture, (2) powder mixing and blending, (3) compacting, (4) sintering. A schematic of a typical powder metallurgy process is shown in Figure 1.3. Recent developments have made it possible to use rapid manufacturing techniques which use the Nano powders for the Nanocomposite products.

The advantages of the powder metallurgy process are flexibility, near-net shape products, production of complex shapes to very close dimensional tolerances, with minimum scrap loss and fewer secondary machining operations. Physical and mechanical properties of Nanocomposite can be tailored through close control of starting materials and process parameters. Particular properties of the Nanocomposites can be improved through secondary processing operations such as hot or cold extrusion. The advantages of this processing method include the capability of incorporating a relatively high volume fraction of Nanoparticles and fabrication of Nanocomposites with matrix alloy. However, this method requires alloy powders that are generally more expensive than bulk material, and involves complicated processes during the fabrication of Nanocomposites. The powder metallurgy may not be an ideal processing technique for mass production of MMNCs.

BALL MILLING

Ball milling is a grinding method that grinds Nanotubes into extremely fine powders. During the ball milling process, the collision between the tiny rigid balls in a concealed container will generate localized high pressure. Usually, ceramic, flint pebbles and stainless steel are used. In order to further improve the quality of dispersion and introduce functional groups onto the Nanotube surface, selected chemicals can be included in the container during the process. The factors that affect the quality of dispersion include the milling time, rotational speed, size of balls and balls/ Nanotube amount ratio. Under certain processing conditions, the particles can be ground to as small as 100 nm. This process has been employed to transform carbon Nanotubes into smaller Nanoparticles, to generate highly curved or closed shell carbon Nanostructures from graphite, to enhance the saturation of lithium composition in SWCNTs, to modify the morphologies of cup-stacked carbon Nanotubes and to generate different carbon Nanoparticles from graphitic carbon for hydrogenstorage application. Even though ball milling is easy to operate and suitable for powder polymers or monomers, process-induced damage on the Nanotubes can occur.

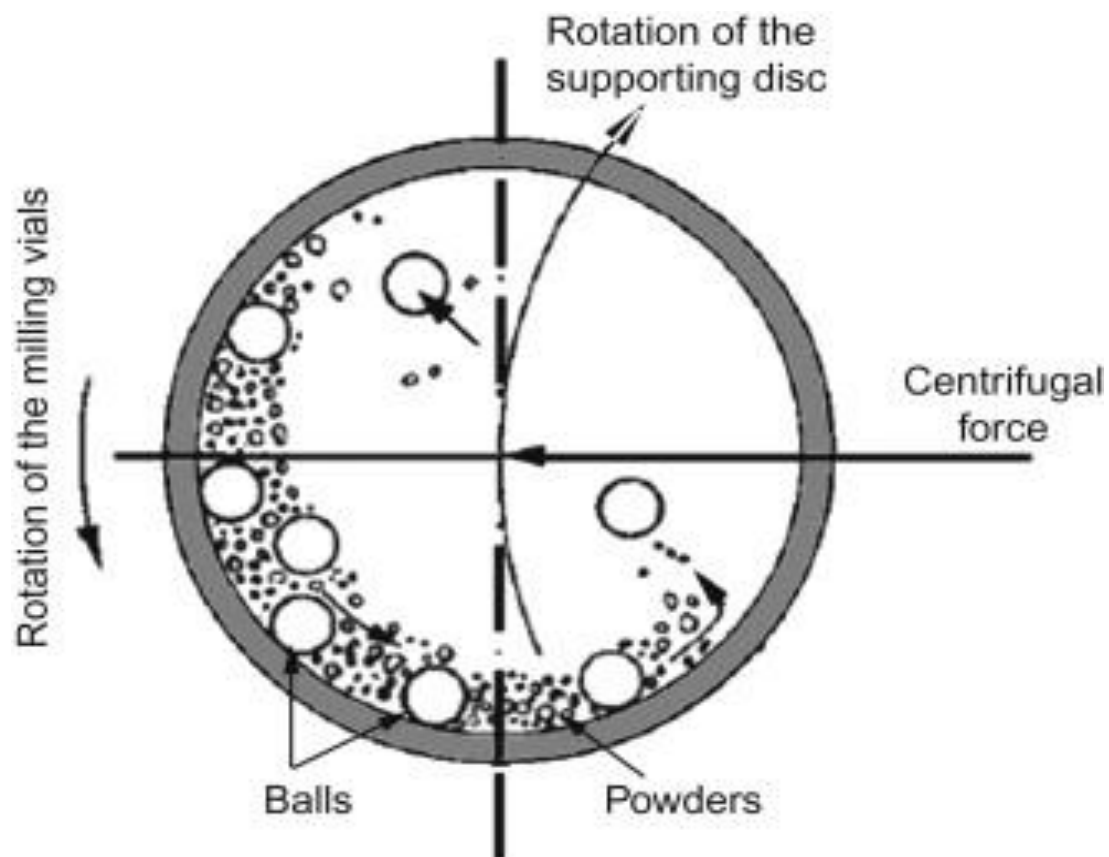


Fig2: Ball Milling

III. MECHANICAL PROPERTIES OF THE ALUMINIUM/DIAMOND METAL MATRIX NANOCOMPOSITES

TENSILE TEST

The tensile strength is a fundamental mechanical property to provide basic design information on the strength of aluminium matrix composite materials and dictate how the material will react to the force applied in tension. Tensile tests are used to find the modulus of elasticity, elastic limit, elongation, proportional limit, tensile strength, and yield point and yield strength. The tensile strength of aluminium matrix composite material depends on selection of the reinforcement particle and an efficient bonding between matrix and reinforcement. Moreover, the reinforcement particle size is one of the important factors to improve the tensile strength, hardness and ductility of the composites.

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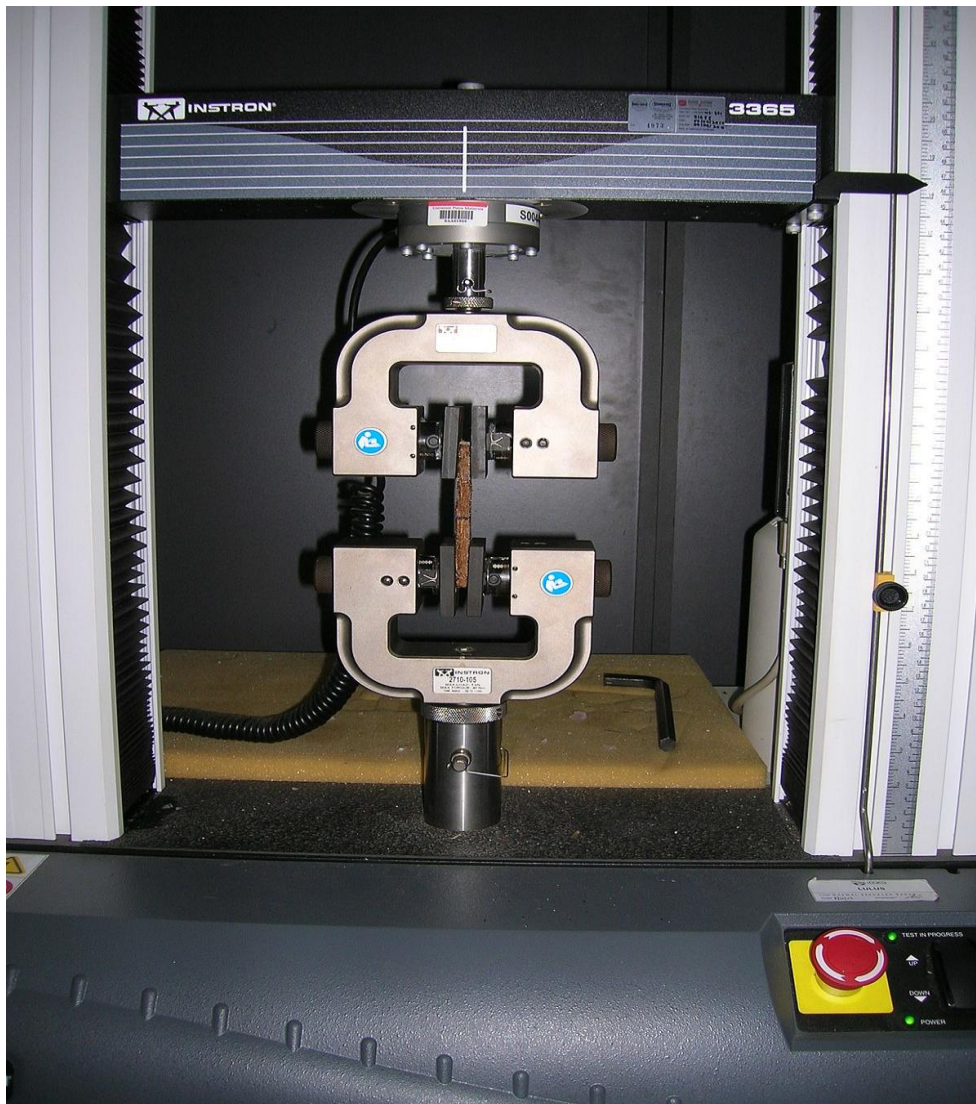


Fig 3: Tensile Test

HARDNESS TEST

Hardness is defined as the resistance of a material to permanent deformation such as indentation, wear, abrasion, scratch. Principally, the importance of hardness testing has to do with the relationship between hardness and other properties of material. For example, both the hardness test and the tensile test measure the resistance of a metal to plastic flow, and results of these tests may closely parallel each other. The hardness test is preferred because it is

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simple, easy, and relatively non-destructive. There are many hardness tests currently in use. The necessity for all these different hardness tests is due to the need for categorizing the great range of hardness from soft rubber to hard ceramics.



Fig4: Hardness Test

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COMPRESSION TEST

Compression testing is one of the most fundamental types of mechanical testing, alongside tensile and flexion tests. Compression tests are used to determine a material's behaviour under applied crushing loads, and are typically conducted by applying compressive pressure to a test specimen (usually of either a cuboid or cylindrical geometry) using platens or specialized fixtures on a universal testing machine. During the test, various properties of the material are calculated and plotted as a stress-strain diagram which is used to determine qualities such as elastic limit, proportional limit, yield point, yield strength, and, for some materials, compressive strength.

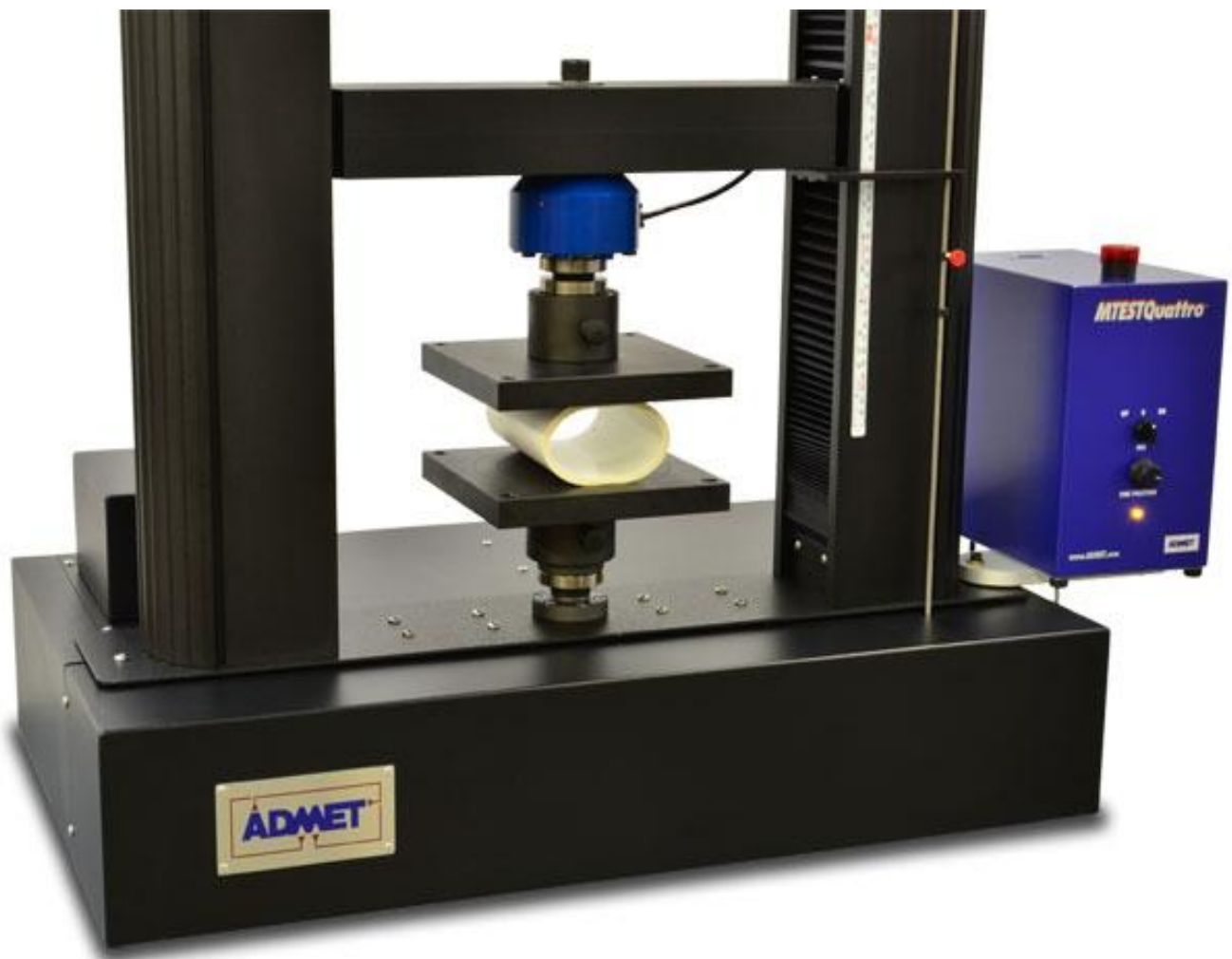


Fig 5: Compression Test

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IV. CONCLUSIONS

The results show that the squeeze casting infiltration process can be used for the fabrication of Al–diamond composites. The samples produced by this technique are free from voids and microcracks indicating good bond majority of the diamond particles remain unaffected by the processing of the composites. From this it follows that regardless of their size, stability of mono crystalline synthetic type IB micron diamonds can principally be achieved in aluminum by using the squeeze casting in filtration process under the conditions described. However, decomposition or transformation of individual diamond particles into amorphous carbon has been observed to happen when using type Ib micron diamond powders. Ongoing investigations will show, whether the formation of amorphous phases and Al₄C₃ can be prevented in squeeze cast Al–diamond composites by using higher quality, non-crushed synthetic cubo-octahedral diamond monocrystals, the final aim being to assess the potential of these materials for thermal management applications.

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