A Review of Mechanical and Microstructural Properties of Aluminum Matrix Composites Produced Using the Powder Metallurgy Technique

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Submission date:- 22/2/2021	Acceptance date:- 6/4/2021	Publication date:- 2/5/2021

Abstract:

The powder metallurgical process has the distinctive advantage of near net shape manufacturing, getting rid of finished machining processes and hence material wastage. Mechanical alloys mix part of metal powder into a powder metallurgical route to create alloys very similar to historically developed alloys. Mechanical alloys are the sound alloying process. Metal powders are mixed to create a consistent delivery before compaction with the aid of ball mill. The composites of the hybrid metal matrix have two separate secondary phases founded in the primary phase, that demonstrate an intriguing behavior and are worth studying in the field of composite science. In this study, various previous studies on mechanical alloy of aluminum with different components and metals are reviewed and their findings are illustrated, in contrast with conventional alloys.

Key Words: Powder Metallurgy, Composites, Aluminum, Mechanical Prosperities.

1. Introduction:

The powder metallurgy technique is a technique of fine powdered components, pressing the powder into its desired shape within a mold followed by the powder heating in a controlled atmosphere, which is designated as sintering to make it easier to form the final element by forming the fastening particles of the powder. The powder metallurgy process; therefore, typically comprises four basic phases: (1) manufacturing the powder, (2) blending powders, (3) compacting powders by using a die, and (4) sintering. The powder metallurgy technique is a method of finely powdered components which press the powder into its desired shape in an atmosphere regulated by the powder fire, designated to make the final element easier to form by forming powder fixing particles. There are four basic steps involved in the powder metallurgy process [1]. Powder metallurgy is the use, and produce, of metal powder. The use of metal powders (especially powders with a high surface-to-volume ratio) as catalysts or in various chemical and metallurgical reactions is of great benefit for the use of metal powders. This review focuses on the use of powder metallurgy in order to produce Ni-base super alloy's powders used in functional engineering components [2].

Powder technologies are suitable to be used because the option of processing allows the preferential assignment of phases for the adaptation of the application portion. The ability of the pressing and the sintering processes to reproduce parts is done to shape volumes suitable for the construction of engineers. The ability to create complicated forms to final form and scale is primarily prized. The three key explanations for the use of PM are individuality, captive and economic applications [3]. For certain requirements that demanded high portion volumes with high precision, the cost is the key factor [4, 5].

PM sections have a strong surface finish and can be heat treated to improve strength and wear resistance. The PM process compromises partial reproducibility and is suitable for the processing of medium to large quantities. Controlled micro-porosity can be used for self-lubrication or filtration, while dimensional precision is preserved, it does not usually compete with that of machined parts [6].The traditional component of PM is porous, and attention must be paid to this while finishing procedures are carried out. Metal powders originate in a range of sizes and forms. Their shape, scale, and size distribution shall be determined by the manner in which they were produced.

The sintering process shows that the heat of the packed powder has reached a particular temperature that is lower than the melting temperature of the source powder. The sintering method allows the bonding mechanism between the various powder particles and increases the strength of the last piece. In order to avoid oxidation, the heating technique must be used in a controlled, inert or decaying environment or in vacuum for the actual serious parts. Until sintering, the compacted powder is brittle and has a very small green strength [7]. Bonding between the powder particles takes place in three techniques: (1) the melting of minor components in the powder particles, (2) the diffusion and (3) the furnace atmosphere are three perilous factors regulating the sintering process [8].

During the reaction, the heat expands out from the compressed materials due to the higher thermal conductivity of the gas vs. vacuum. This decreases the optimal temperature produced during the reaction, which slows down the phase of densification. Moreover, owing to the speed of the reaction, there is not enough time for ambient and ingested vapors to be released into the pores. As a result, the gas is tricked into pores and the densification stops. The heating rate has an effect on the transient liquid process. Prior to reaction launch, but with deliberate heating speeds, solid-state diffusion and intermediate compound formation take place. This retards the aggregation of liquid and the results of low sintered densities. The small temperatures and the sintering atmosphere of argon thus create a small sintering density [9].

2. Literature Review

2. 1. Aluminum-Based Alloys Powders:

Mohammad Umair et. al. [10] reveal that the aluminum boron carbide composite is a primary high strength, low-weight composite class and is widely used in the defense and aerospace industries. The employment of boron carbide is restricted to a certain extent, owing to its exceptional expense and fragility at great concentrations. The core aim of this analysis is to improve aluminum composite strength by adding elements (such as boron carbide and manganese) to a greater degree using powdered metallurgy to achieve improved mechanical functions. The pure aluminum has a limited tensile strength and is less ductile, so that the distortion at low temperatures is easy. The alloy is improved and its casting capacity and mechanical performance increases with less addition of boron and manganese. In order to manufacture composites with superior mechanical properties the powder metallurgy process is used. This composites can replace aluminum wire, and practices in the aerospace, automotive and military applications can be made. In order to manufacture cylindrical form samples, optimum weight ratios of aluminum, manganese and boron are combined in different proportions. These samples are prepared to test their strength, by mixing the powders at 2%, 4% and 6%.

M. Rojas, et. al. [11] has revealed that the sawing machine is the most familiar method used before processing to break down metals. The amount of waste aluminum is substantial (chips). These chips are semi permanent and thin, so that they are not ideal for melting. The goal of this paper, therefore, is to research the recyclability of aluminum chips left by the use and the features of both sintered and Al powder using sawing techniques by powder metallurgy. The grinding process was carried out at varying grinding periods at a rotational speed of 55 rpm. The method of compaction was performed using a pressure of 800 MPa. Argon sintered the cylindrical samples at a temperature of 1 hour at 620°C. Results illustrate that aluminum chips are ideal for processing during the whole phases of powder metallurgy.

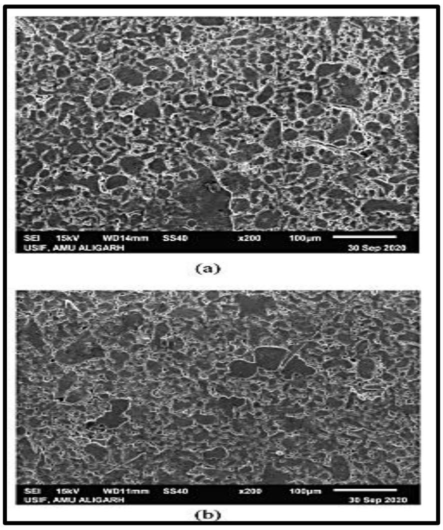

Figure 1: (a) SEM of Al and B4C at 2% composition , (b) SEM of Al, B4C and Mn at 2% composition.

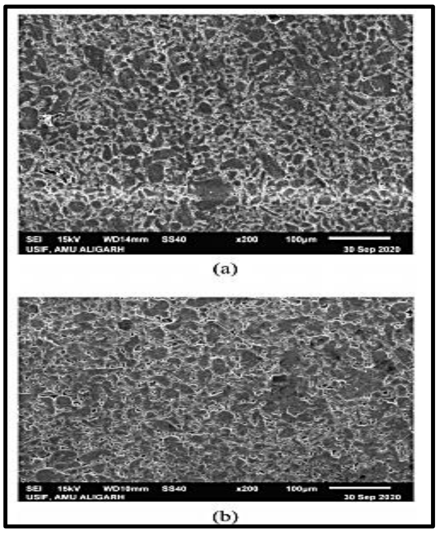

Figure 2: (a) SEM of Al and B4C at 4% composition , (b) SEM of Al, B4C and Mn at 4% composition.

Norul Amierah, et. al [12] have studied a tribo-mechanical outstanding efficiency which was considered to be conducive for achievement of superior mechanical and wear properties in a single material for self-lubricating composites based on hybrid metal (MCCs), reinforced with (Al+Gr+Al2O3) particles. Three hybrid MMC-based formulations, their mechanical and wear properties and the purity of Al+Gr and Al were investigated by using the powder metallurgy method. Different mechanical properties (for example microhardness, tensile and flexurity) were evaluated and tested for sample microstructure. A pin-on-disc tribo-meter was used to test the wear efficiency of hybrid MGCs. The findings revealed that combined wear and mechanical features of the hybrid MMC was substantially enhanced by the combined effect of Al2O3 and graphite reinforcing particles. Both mechanical properties have been improved and the friction and wear rate has been significantly reduced. Furthermore, 10% Al2O3 and 3% Gr (Al+3% Gr+10% Al2O3) reinforcement formulations create a smooth tripod, thus the wear resistance to wear to the highest degree compared with other compositions of the hybrid MMCs.

Jiangshan Zhangab, et. al. [13] showed that, for the properties and microstructures of particulate reinforced metal matrix composites, the dispersion of ceramic nanoparticles is important. In this analysis, SiC-graphene nano-sheets and SiC-graphite have, using the powder metallurgy process, been mixed with aluminum matrix composites. The microstructural evolution and the dispersion of the reinforcements of the composites were described by means of X-Ray Diffraction, SEM, Raman spectroscopy, and TEM. The findings indicate that thin GNSs improved the aluminum particle deformation, and flaws during the ball milling process were founded in carbonate phases. Al4C3 needles were produced and observed for bridging aluminum grain during a hot pressing process. GNSs were distributed more evenly within the composite compared with graphite, which decreased grain growth. As a result, the SiC-GNSs have been applied to the nanostructure composite (57.7 nm).

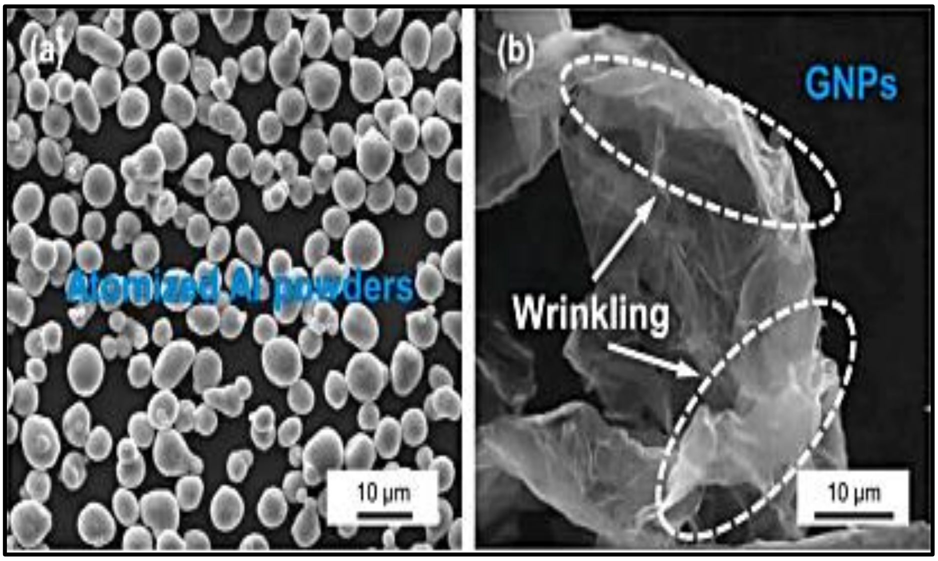

Figure 3: Morphology of Original Powders, (a) Atomized Al Powder, (b) GNPs.

G. A. W. Sweeta et. al. [14] have studied a commercial-relevant process for aluminum powder metallurgy (APM) used to manufacture Metal-Matrix Composites from a 2,000 series aluminum alloy. Cylindrical preforms comprising 0-5 volts are used to analyze mechanical properties and the development of the microstructure. At the values of (0.1–1.0 s^{-2}), the samples were deformed to a 0.15–1.55 mm/mm maximum pressure. TEM observations on forged goods found that the Al–AlN interfaces had no flaws and were of good quality. Near-full (>99.5% theoretical) densities were detected at 1.40 mm/mm. Unlike a sample that was non-deformed, forged MMC's showed tensile ductility up to five times. There have also been rises in fatigue power of up to 98 MPa (57 %). Densification and residual oxide interruption and an increased dispersion of the AlN process resulted in mechanical benefits.

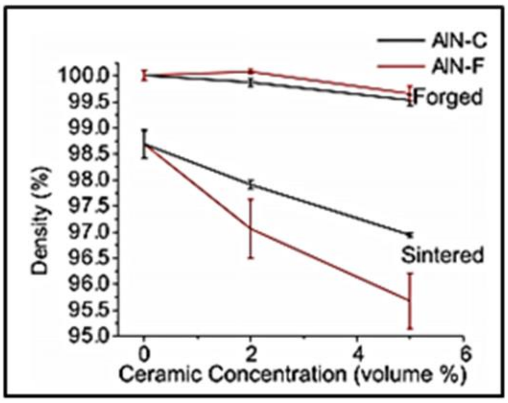

Fig (4) :comparison of sintered and forged densities for MMC system that utilized different types and concentration of AIN particulate .ALL samples hot upset forged to a true strain of 1.40 mm/mm

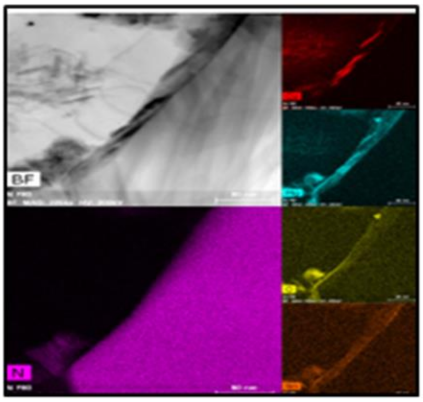

Fig (5) :TEM analysis of an exemplary Al-AIN interface including a S TEM bright field image and EDS maps for the key elements of interest .the material was MMC 2C hot upset forged to a true strain of 1.40 at rat 0.1 s^{-1}

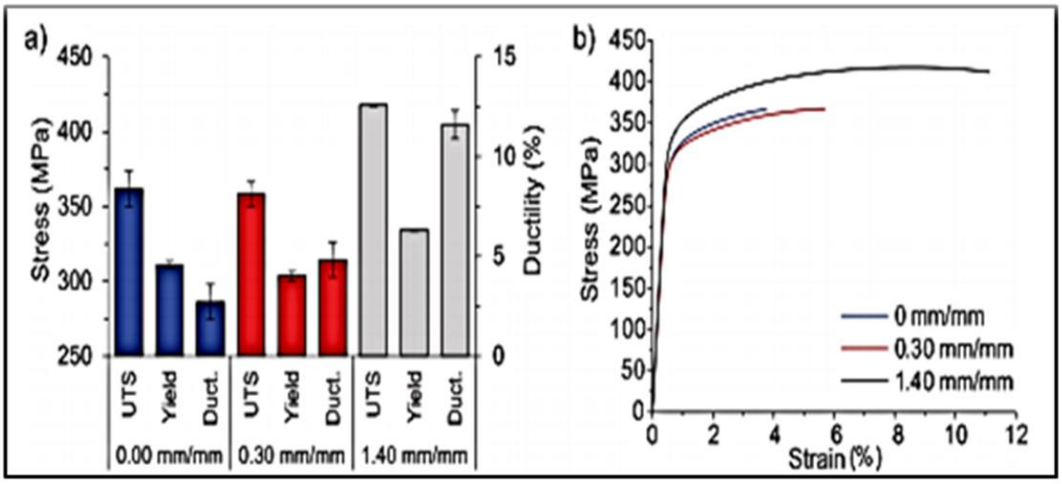

Fig (6) : (a) Summanzed tensile properties and (b) stress –stain curves of MMC2C when forged to different levels of trues strain all samples heat treated to the T6 state .data for 0.00 mm/mm

H. Yu, et. al. [15] have made a graphene study to strengthen the metal matrix due to its good mechanical properties combined with excellent electrical and thermal properties. The powder metallurgy is made from pure Al strengthened composites with 0.5 wt. % graphene nanoplatelets (GNPs). The mechanical and physical properties of the microstructure effects are routinely studied. Since mechanical stirring, GNPs have been thoroughly flattened. The findings of Raman GNP spectroscopy indicate that the composite powder preparation defect is being fixed. The findings of the scan electron microscope after hot extrusion revealed that GNPs were evenly distributed in Al matrix. Aluminum carbide was also approved at the GNP/Al interface by means of a high-resolution transmission electron microscopy. The tensile yield strength, hardness and composite fracture are 73 HV and 248 MPa. The average thermal conductivity and electrical conductivity of the composite is calculated in 201 W −1 K-1 and in 56% IACS. The elimination concentrations in the similar process are 2.4% and 6.7% compared to pure alcohol. The negligible depletion of physical properties then contributed to thrilling strength gains in return.

Kanhu Charan, et. al. [16] reveal that the composites based on powder metallurgy are commonly used to produce parts in many areas, for example aerospace, automobile, and electronics because of physical and mechanical features enhanced. The cylindrical hybrids' physical or mechanical properties were investigated in the present work. Four composite alloy samples were consisting of aluminum powder combined with silicone carbide at 2 and 7 volts and alumina at 3 and 8 volts. For the calculation of compression strength cool compression tests have been performed. An increase in al/SiC volume reduces compressive strength, density and hardness. A Voce equation distinguishes the voltage of flow from composites compressed in cold. The proposed PM pipeline for the processing of aluminum matrix composites has dramatically improved physical and mechanical properties in comparison to those for commercial aluminum.

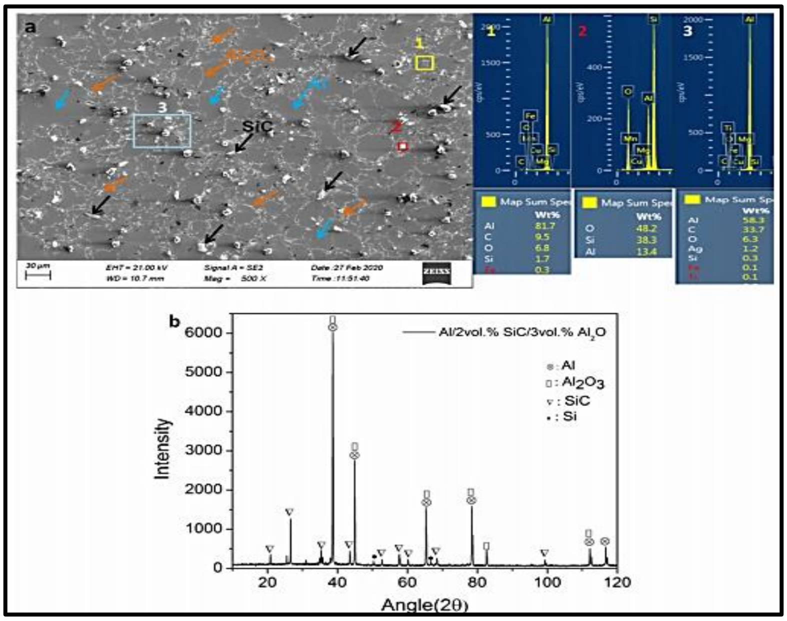

Fig 7 (a) SEM image and elemental mapping for AlAL/2vol% sic/3 vol% Al_2o_3, hybrid composite and (b) XRD of Al/2 vol% sic/3 vol% Al_2o_3, hybrid composite

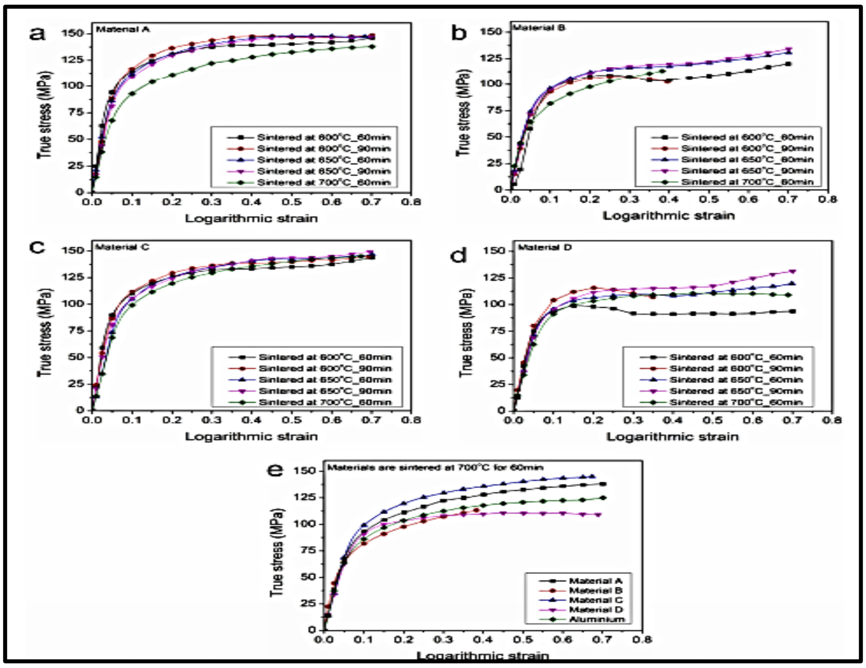

Fig (8) : flow curves of AL/SiC/Al2O3 composites , (a) Material A , (b) Material B, Material C ,(D) Material D and(e) comparison of flow curves of different composite with pure Al .

Pankaj Kumar, et. al. [17] state the preparation, with powder metallurgy and sintering, of functionally graded metal materials (FGMs). Fine powder (pure 99.9 percent, 200 meshes) and copper powder produce the AL-CU FGMs (purity 99.9 %, 300 mesh). The proposed structure of the classified substance consists of a multilayered composite sheet of various Cu compositions. Optical microscopy (OM), SEM pictures and morphological features have been taken for each sample to verify the material being produced. The results show that FGM's micro-structural hypotheses are successful.

T. Albert et. al. [18] show that the strength-to-weight ratio of aluminum (Al) is commonly used in all industries. This work involves three volume fractionation, a synthesis of mechanically alloyed by powder metallurgy processes to develop the mechanical properties of aluminum carbide (TiC) in metal aluminum metal composites, of 100% – Al – Al & 5% – TiC – 90% – and a synthesis of Al& 10% – TiC. In this work, the three different volume fractions are formulated. Al–TiC preparations are distinguished by EDX and SEM and display a coherent distribution of enhanced particles in metal matrix with a microstructure. In addition, the hardness of the composite has been tested and the results suggest that adding TiC greatly increases the composite hardness.

Norul Amierah et. al. [19] have made an analysis on nanocomposites (MMNCs) metal aluminum-aluminum oxide (Al-Al2O3) with the various volume of reinforcement Al2O3. Three Al-Al2O3 nano-composite forms of 10% were produced using a standard route of pumped metallurgy (PM), 15% and 20% volume fractions of Al2O3 and their mechanical and microstructure features were considered. At 200 kN load and at a temperature of 630°C, the samples were packed. By inserting Al2O3 nanoparticles, the relation between the microstructure and mechanical properties was explored. Optical micrographs showed that nanoparticles with a strong relation between the matrix and reinforcement of Al2O3 are almost equally distributed in the Al matrix. Moreover, with the rising amount of strengthening, the mechanical properties of the reinforcement (including hardness, tensile resistance and compressive power) will increases. However, as Al2O3 nanoparticles increase in the drug, the impact intensity decreases.

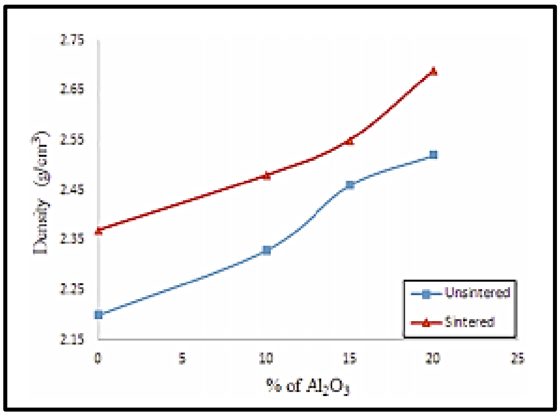

Figure 9: Variation of density of nanocomposites.

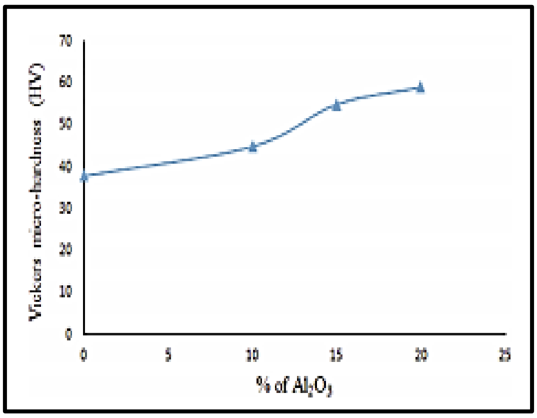

Figure 10: Variation of Hardness of nanocomposites.

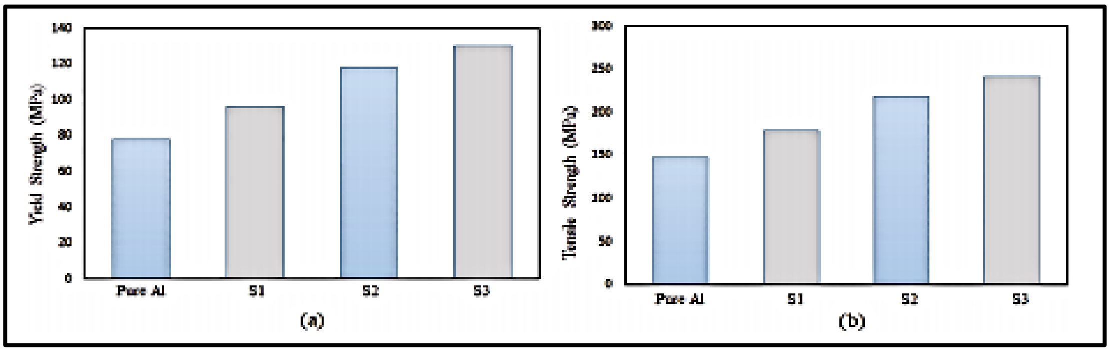

Fig (11) : (a)yield and (b) ultimate strength of the AL-AL_2O_3 nano composite with different volume fraction of reinforcement

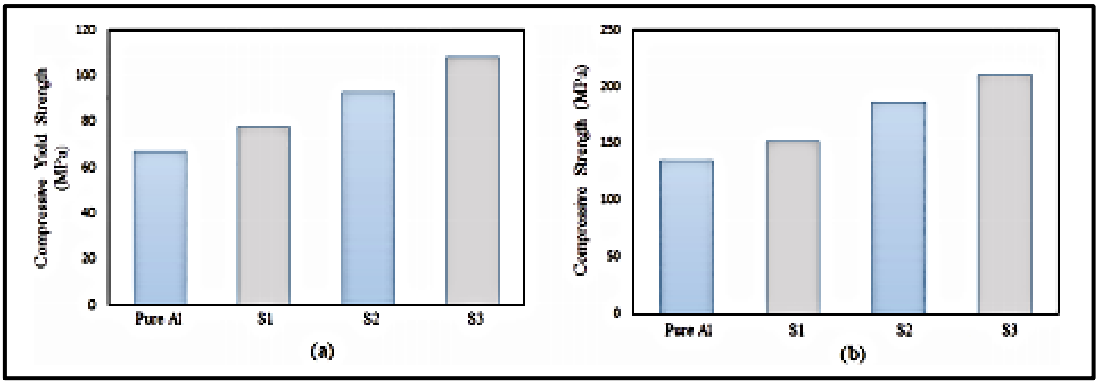

Fig (12) : (a) Compressive Yield and (b) Ultimate compressive strength of the AL-Al2o3 nano composite with different volume fraction of reinforcement

Venkatesh et. al. [20] have produced Aluminium-Kaoline composites by means of powder metallurgy technology. Kaoline is an abundantly available clay material in northern India. This paper sums up the mechanical behavior of the kaolin fortified aluminum matrix. Composite samples are made using a methodology for powder metallurgy, reinforced by 5 wt.%, 10 wt.%, 15 wt.% and 20 wt.%. On the processed composite samples we carried out tensile strength, compression strength, stiffness and hardness measurements. The rigidity of A-Kaoline has been shown to improve from 77 VHN to 187 VHN for aluminum without reinforcement to 20% for reinforcement. The tensile and compression strength of the composition were improved by 0 % to 20 % with the inclusion of strong ceramic particles such as Al_2O_3 & SiO_2 in the kaoline reinforcement phase. About 54.8% improved tensile strength by 20% composed of pure aluminum.

Conflicts of Interest

The author declares that they have no conflicts of interest.

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مراجعه الخواص الميكانيكية والتركيبية للمادة المركبة ذات الاساس اللامنيوم المنتجة بأستخدام تقنية تكنولوجيا المساحيق

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الخلاصة:

تتميز عملية تكنولوجيا المساحيق المعدني بميزة مميزة تتمثل في التصنيع بالشكل القريب، والتخلص من عمليات المعالجة النهائية وبالتالي إهدار المواد. تمزج السبائك الميكانيكية جزءًا من مسحوق المعادن في مسار مسحوق معدني لإنشاء سبائك مشابهة جدًا للسبائك المطورة تاريخيًا. السبائك الميكانيكية هي عملية صناعة السبائك الصوتية. يتم خلط مساحيق المعادن لإنشاء توصيل متسق قبل الضغط بمساعدة مطحنة الكرة. تحتوي مركبات المصفوفة المعدنية الهجينة على مرحلتين ثانويتين منفصلتين تم تأسيسهما في المرحلة الأولية، والتي تُظهر سلوكًا مثيرًا للفضول وتستحق الدراسة في مجال العلوم المركبة. في هذه الدراسة، تمت مراجعة العديد من الدراسات السابقة على سبيكة ميكانيكية من الألومنيوم بمكونات ومعادن مختلفة وتم توضيح نتائجها، على عكس السبائك التقليدية.

الكلمات الدالة: تكنولوجيا المساحيق، المركبات، الألمنيوم، الخواص الميكانيكية.