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A SEMI-SOLID FABRICATION TECHNIQUE OF Al 7075 METAL MATRIX COMPOSITES ENHANCED WITH ALUMINA

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ABSTRACT

Metal matrix composites (AMC) are in demand due to their desirable properties, including superior strength, cost-effectiveness, slow crack propagation, and high-temperature resistance. This work focuses on developing high-strength particulate-reinforced aluminum matrix composites via semi solid state route. The objective of this work is to fabricate Al 7075-Al2O3 composites with 4 , 8 and 10 wt. % of Al2O3 using the semi-solid stir casting technique. Aluminum alloy 7075 was heated above its melting point, followed by controlled cooling to the semi-solid state at 550ºC. Al_2O_3 particles then heated and mixed with Aluminum alloy at 350 RPM. The study investigates the effect of the manufacturing procedure on the microstructure and mechanical properties of as-cast Al 7075 matrix composites. Results include microstructure, porosity, and distribution of Al_2O_3 particles in Al 7075 alloy samples using optical microscopy (OM), scanning electron microscopy (SEM), energy dispersive x-ray (spectroscopy) (EDX), and x-ray diffraction (XRD). Hardness and tensile strength are reported, showing high evenness of reinforcement distribution and uniform mechanical strength. The highest ultimate tensile strength (231.5 MPa) and the maximum hardness value (187.5 HV), is achieved at 10% Alumina reinforcement; demonstrating the effectiveness of the devised manufacturing method.

KEYWORDS: Aluminum matrix composites (AMCs), Stir casting, semi-solid, Reinforcing particles, Microstructure, mechanical properties.

تقنية التصنيع شبه الصلبة للمواد المتراكبة المعدنية المعززة بالالومينا

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الملخص

هناك طلب على المواد المتراكبة المعدنية (AMC) نظرًا لخصائصها المرغوبة، مثل القوة الفائقة والفعالية من حيث التكلفة وانتشار الشقوق البطيء ومقاومة درجات الحرارة المرتفعة. يهدف العمل الحالي إلى تطوير مركبات مصفوفة من الألومنيوم المقوى من خلال الصب التقليبى فى الحالة شبه الصلبة . يركز البحث الحالي فى تقنية تصنيع لمركبات $Al\ 7075\text{-}Al_2O_3$ بنسب وزنية مختلفة (10%، 8%، و4). %) باستخدام تقنية الصب شبه الصلبة، بغرض تحسين قابلية البلل والتساوي في توزيع جزيئات التسليح. تتضمن العملية تسخين سبيكة Al 7075 فوق نقطة انصهارها، يليها تبريد متحكم به إلى الحالة شبه الصلبة عند 550 درجة مئوية. بعد ذلك، يتم إدخال جزيئات Al_2O_3 المسخنة مسبقًا إلى السبيكة ويتم خلطها بمعدل 350دورة في الدقيقة (RPM). تبحث الدراسة تأثير إجراءات التصنيع على البنية المجهرية والخواص الميكانيكية لمركبات المصفوفة Al 7075. تشمل نتائج البنية المجهرية والمسامية وتوزيع جزيئات Al_2O_3 في عينات سبائك Al 7075 باستخدام المجهر الضوئي (OM) المجهز بمحللات الصور الكمية، والمجهر الإلكتروني الماسح (SEM)، والتحليل الطيفي المشتت للطاقة (EDX)، وحيود الأشعة السينية (XRD). . بالإضافة إلى ذلك، يتم قياس صلابة وقوة الشد للعينات. طريقة التصنيع هذه تحقق توازنًا عاليًا في توزيع التسليح، وقوة ميكانيكية موحدة. يتم الحصول على أعلى قوة شد نهائية وأقصى قيمة للصلادة عند تقوية 10% من الألومينا.

الكلمات المفتاحية: مركبات مصفوفة الالومنيوم,تقليب المسبوك,شبه الصلبة,تعزيز الجسيمات,التركيب المجهري,الخصائص الميكانيكية

1. INTRODUCTION

A composite material represents a union of two or more distinct substances, with their interface being discernible.[1] Composites have gained prominence in the contemporary world due to their impressive strength-to-weight ratio, reduced mass, and cost-effectiveness. In modern applications, composite materials are most effectively employed to attain an equilibrium of properties tailored to specific purposes.[2] The majority of composites consist of a mere two components the first is the matrix, enveloping and uniting fragments of the second material, known as the reinforcement. The foremost advantage of modern composite materials is their dual quality of being lightweight and robust.[3] Composites possess the versatility of being readily tailored because many of them can be shaped into various forms. Aluminum, due to its economic cost and diminished weight, is often the preferred choice for a matrix material in composite production. Notably, Al 7075 alloy, characterized by heightened toughness, finds extensive use in the aerospace and automotive sectors.[4, 5] Composite materials excel in meeting design specifications by offering a combination of reduced weight and enhanced strength compared to traditional materials. They have applications in aerospace, automotive, trucking, and mass transportation, all of which impact fuel consumption. Products crafted from composites require less energy for transportation or shipping compared to conventional materials.[6] [7]While composites hold value as weight-saving materials, the prevailing focus lies in optimizing their cost-effectiveness. In pursuit of this goal, the composite industry now employs various manufacturing techniques. When fabricating sporting equipment, it is crucial to consider material characteristics such as strength, deformability under tensile stress, modulus (damping), and cost.. [8], [9], [10]. Al-Salihi et. al. were used stir casting to fabricate aluminum alloy Al 7075 matrix composites with 0-5 wt. % Al_2O_3 particulates reinforcement. They studied the mechanical properties and wear resistance. The addition of Al_2O_3 significantly improved mechanical properties, with a 14.3% increase in ultimate tensile strength and a 34.3% increase in yield tensile strength at 5 wt% Al_2O_3. Hardness also increased by 26.3%.[11]. The study suggested by Jacob et. al. aims to create high-strength aluminum metal matrix composites using the stir casting method, with a focus on Al 7075 alloy. They find that by adding 10% of Al_2O_3 the ultimate tensile strength, microhardness and thermal conductivity are increased from the unfilled Aluminum base matrix. They recorded that ultimate tensile strength and micro hardness were 69.52 N/mm2 and 148.09 VHN respectively. [12][13]. Gangaraj and Manjunath focused on enhancing the performance of Aluminum Metal Matrix Composite (AMC) materials by using a specific 3:2 ratio of SiC and Al_2O_3 reinforcement. This resulted in improved physical and mechanical properties, with a key finding being that a 15% particulate reinforcement of 9 % SiC and 6% Al_2O_3 produced optimal mechanical characteristics. This work has implications for the development of AMC for automotive engine components.[14][15]. Amir et al. examined Al/SiC composites using A356 aluminum alloy matrix with stir and compo-casting techniques. Compo-casting displayed better SiC distribution and lower porosity. Higher SiC content improved mechanical properties, and compo-casting enhanced wear resistance with larger particles, while stir casting achieved better wear resistance with smaller SiC particles.[16]. According to Mishra et al., aluminum hybrid composites, featuring properties like strength, lightweight, corrosion resistance, and thermal conductivity, meet modern engineering requirements. They are widely used in aerospace, marine, minerals processing, and other industries. The study focuses on Al 7075 alloy and employs the stir casting method for composite fabrication.[17][18] [19] Abdul Razak et. al. focused on creating Aluminum Matrix Composites (AMC) using coconut shell particles as reinforcement and Aluminum 6061 as the matrix material through stir casting. Varying percentages of coconut shell filler were used, and mechanical tests were performed. Higher reinforcement percentages resulted in increased tensile strength and hardness in the AMC, indicating the success of the method.[20][21]. Agrawal et al. explored the cold forging of Aluminum metal matrix composites with Silicon Carbide (SiC) particle reinforcements. The study examines two preform shapes, disc and rectangular, using theoretical and experimental methods. It aims to provide insights into deformation characteristics during the forging of metal matrix composites.[22][23]. Moussa et. al. modified A356 aluminum-silicon alloy with yttrium oxide (Y_2O_3) additions. The optimal Y_2O_3 content was 1.5 wt%, which improved eutectic Si particles and ductility by over 20% compared to unmodified specimens. This enhancement was associated with a shift from cleavage to a more ductile fracture mode.[12][13]. Kandil studied magnesium alloy (AZ91) composites with varying SiC content made through stir casting. These composites showed improved mechanical properties, including hardness and strength. However, higher SiC content reduced strain to failure. Strong SiC-matrix bonding was observed in fracture surface analysis.[26]

While researchers have made commendable strides in the exploration of incorporating ceramic materials into different alloys, whether in a fully melted, semi-solid, or solid state, the poor wettability between ceramic and alloy remains a significant hurdle. Therefore, this study specifically focuses on enhancing the wettability between alumina and Al 7075 via semi-solid approach (compo casting technique) to obtain best mechanical properties of Al 7075/Al_2O_3 composites. This technique is known for its impact on the microstructure and mechanical properties, particularly concerning the dispersion of reinforcing particles. The introduction of alumina in semi solid state is predicted to contribute to favorable mechanical properties, rendering the alloy noteworthy across diverse industrial applications.

2. EXPERIMENTAL

2.1 MATERIALS

A commercially aluminum alloy 7075 with a chemical compositions shown in **table 1**, was used to be reinforced by alumina. The enhancing the mechanical properties of this base alloy involved the incorporation of carefully selected quantities of Al_2O_3 particles, with 4 wt.%, 8 wt.%, and 10 wt.%. These distinct proportions of play a pivotal role in fine-tuning the material's characteristics, imparting specific attributes such as enhanced mechanical performance, improved wear resistance, and advanced thermal properties.

Table 1. chemical composition of aluminum alloy 7075

Cr	Ti	Mn	Zn	Si	Cu	Fe	Mg	Other	Al
0.18	0.07	0.17	5.35	0.42	1.2	0.62	2.3	0.15	Bal.

The selected reinforcement ceramic material is Alumina particles. As seen in **Fig. 1(a)**, the Al_2O_3 particles utilized in this investigation had a nearly spherical shape. Also, **Fig. 1(b)** indicates high purity alumina. This size specification is of paramount importance, as it affects the dispersion and interaction of the particles within the matrix, thereby influencing the overall material properties. The average size of Al_2O_3 employed in this experiment is 0.6 ± 0.07 micrometers (μm), as shown in **Fig. 2**, which was determined by using size distribution by intensity test in a suspended solution.

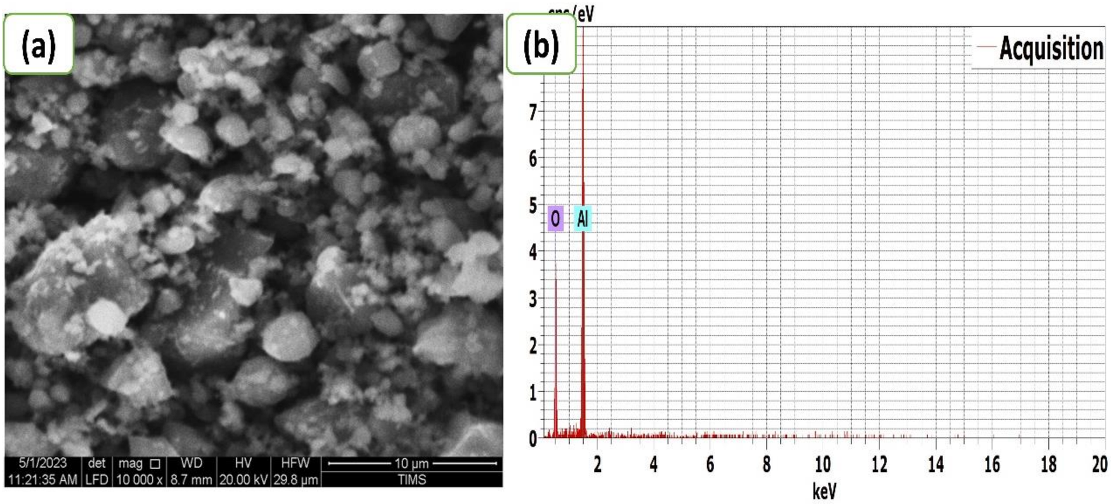
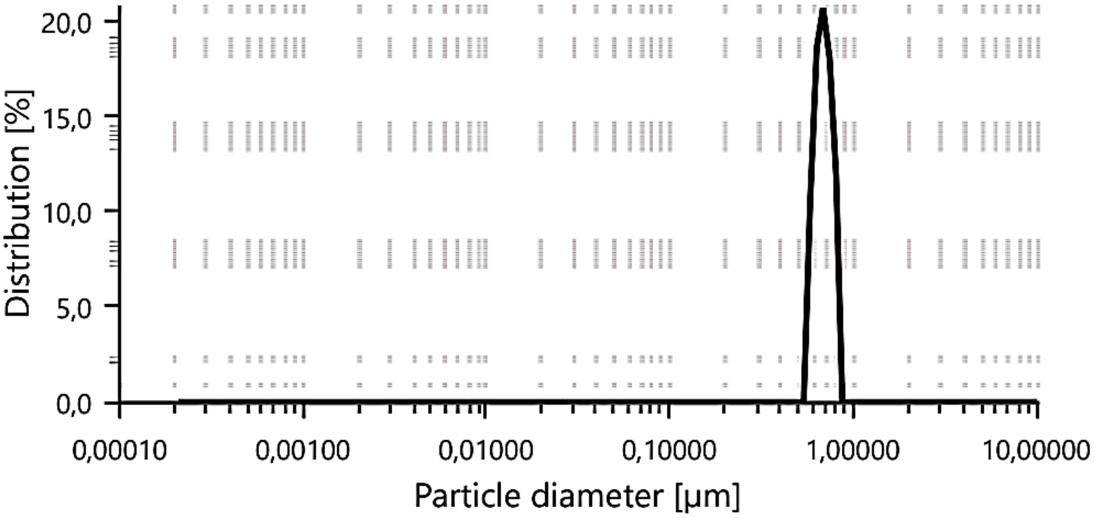


Fig. 1: a) SEM photograph and b) EDX of alumina particles



Results

Hydrodynamic diameter	19,153 µm	**Mean intensity**	225,7 kcounts/s
Polydispersity index	27,8 %	**Absolute intensity**	177590,6 kcounts/s
Diffusion coefficient	0,0 µm²/s	**Intercept g1²**	0,7722
Transmittance	46,7 %	**Baseline**	0,997

Particle size distribution peaks (intensity)

Peak name	**Size [µm]**	**Area [%]**	**Standard deviation [µm]**
Peak 1	0,6949	100,00	0,07051
Peak 2	-	-	-
Peak 3	-	-	-

Fig. 2. Alumina particles size distribution by intensity

2.2 FABRICATION SETUP AND PROCEDURE

The process commences with Al 7075 Alloy (400 gm), being melted in a crucible, gradually heated in a heat resistance furnace until it reaches 750°C and maintaining this temperature for one hour. **Fig. 3** shows the experimental setup of the fabrication technique. Additionally, hexachloroethane powder (Scum powder) is introduced to the molten Aluminum to effectively remove slag. The melted Aluminum is then deliberately cooled below the liquid state to maintain a semi-solid slurry. Pursuing to enhancing the wettability, Aluminum oxide particles are preheated at 500°C for three hours. Automatic stirring is facilitated through a radial stirrer powered by an electric DC motor, running for a duration of approximately 3 to 4 minutes at a stirring rate of 350 revolutions per minute (R.P.M). During this stage, the preheated aluminum oxide particles are manually incorporated into the vortex. Throughout the final mixing stages, temperature control is meticulously held within the range of 550 ± 10°C. After the process concludes, the molten composite undergoes a temperature increase to 750 ± 10°C after the stirring process. Following that, we pour the molten composite into a mold measuring 200 mm x 100 mm x 8 mm, which has been preheated to 350 ± 10°C, shaping the specimen as desired. This approach remains consistent for specimens with different compositions, encompassing 4%, 8%, and 10% of aluminum oxide.

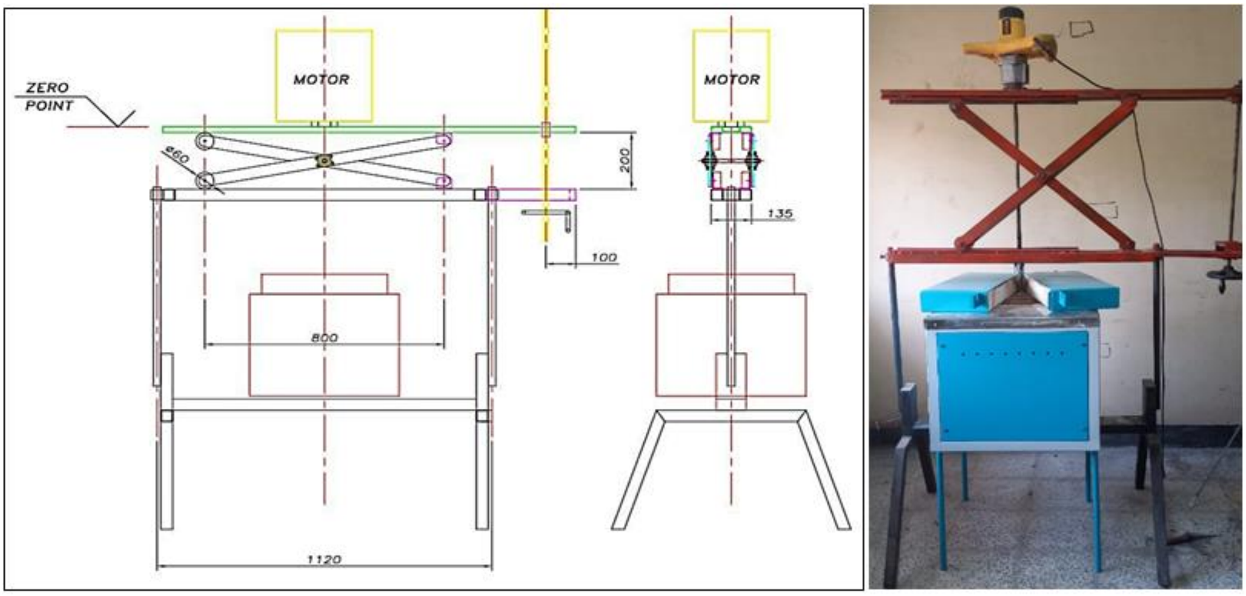


Fig. 3. Design drawing a) Stir casting machine b) Machine setup

2.3 CHARACTERIZATIONS

For metallographic analysis, representative samples were meticulously sectioned. Optical microscopy (OM) with a REICHERT model AUSTRIA Nr.69125 from USA was employed to examine the microstructure and phase distribution of the Al_2O_3 particles within the ingot composites. Additionally, selected samples underwent scanning electron microscope (SEM) analysis using a QUANTA FEG 250 model from the USA, operating at 20.00 kV with an LFD detector, housed at the Desert Research Center (DRC) in Cairo, Egypt. These samples were etched using a specific solution consisting of 1.5 vol.% concentrated HF, 2.5 vol.% concentrated NHO_3, and vol.% HCl in 95 vol.% distilled water to unveil their microstructure. An energy-dispersive spectrometer (EDX & Mapping) from the same SEM model was employed. X-ray diffraction (XRD) was conducted on the as the as cast base matrix and the fabricated Al 7075-(4%,8%,10%) Al_2O_3 composites using an Axs-D8 Advance model from Bruker, scanning diffraction angles (2θ) between 20° and 100° with a step size of 0.02° per second. XRD analysis took place at the central metallurgical research and development Institute (CMRDI) in Cairo, Egypt.

2.4 TENSILE TEST

The specimens of tensile test was prepared in accordance with ASTM standard [25] as shown in **Fig. 4**. The tensile characteristics of the composite materials and the unreinforced alloy were evaluated. The solidified base matrix and composites was represented in this test with fife specimens to obtain high level of test results accuracy. The assessment involved conducting tensile tests on flat specimens measuring 25 mm in gauge length, 10 mm in width, and 6 mm in thickness, adhering to the specifications outlined in the ASTM E8-13a standard. Universal a testing machine (This testing took place at the central metallurgical research and development Institute (CMRDI) in Cairo, Egypt.), the tests were performed at an applied strain rate of 0.20 mm/min.

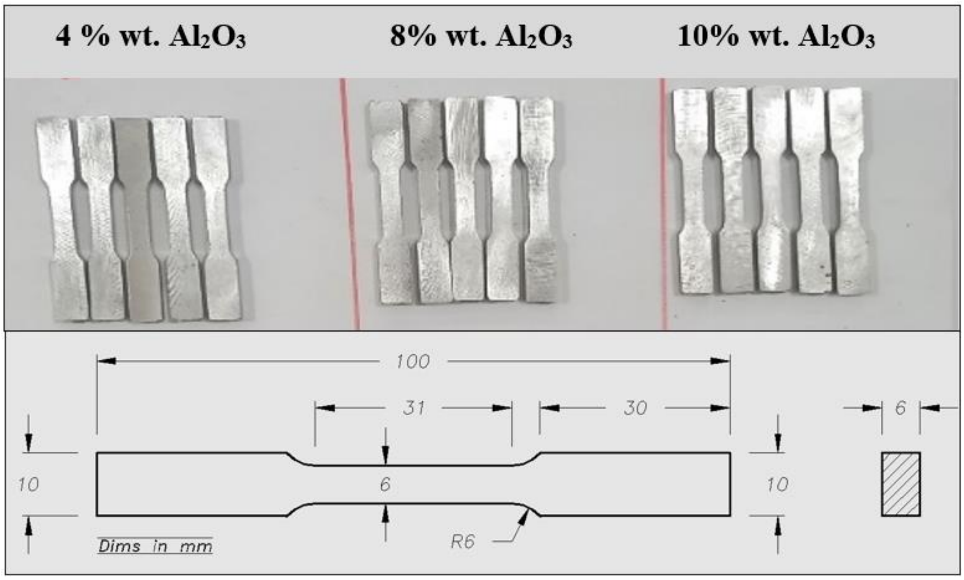


Fig. 4 specimens of tensile test

2.3MACRO HARDNESS

The assessment of hardness is contingent upon the depth of penetration experienced under a uniform external load. In the exploration of Al 7075, various compositions were tested for hardness, incorporating 0%, 4%, 8%, and 10% by weight of Al_2O_3 particles. These tests were conducted utilizing a Vickers Hardness Tester, employing a pre-load of 10 Kg via the Leco device sourced from the USA, test took place at the central metallurgical research and development Institute (CMRDI) in Cairo, Egypt. Initially, the material demonstrated heightened hardness.

3. RESULTS AND DISCUSSIONS

3.1 MICROSTRUCTURE

The properties and behavior of a wide range of metal alloys and composites are intricately linked to several critical factors, including the orientation of their constituents, the size of the grain structures, and the distribution of secondary phases within the matrix. Notably, in the realm of aluminum alloys, the introduction of Al_2O_3 serves as a prominent strategy to enhance mechanical properties by capitalizing on the principles of solid solution strengthening. Within the context of this research or discussion, the visual representations of typical microstructures in **Fig. 5** emerge as pivotal in understanding the inherent intricacies of as-cast composites. One aspect of paramount importance is the manner in which reinforcing particles are distributed within the matrix. This distribution, though seemingly subtle, carries profound implications. Achieving a uniform and consistent dispersion of these reinforcing elements within the matrix presents a formidable challenge, yet its success is inextricably linked to the ultimate properties and overall quality of the composite material. Non-uniform distributions established in the initial stages of processing have a propensity to persist through to the final product. This persistence manifests in the form of streaks or clusters of infiltrated reinforcement, often accompanied by undesirable porosity. These structural irregularities, in turn, have a pronounced detrimental effect on the composite's ductility, strength, and toughness, thereby underscoring the significance of achieving a homogeneous reinforcement distribution. The distribution of particles is an outcome of the solidification process itself. In the study's context, AMC have been fabricated with various weight fractions of Al_2O_3, specifically 4 wt.%, 8 wt.%, and 10 wt.% as shown in **Fig. 5 (b,c,d)**. These fractions have been meticulously selected to ensure effective wetting and strong bonding between the Al_2O_3 particles and the matrix. A closer examination of the Al_2O_3 distribution within the matrix, as depicted in **Fig. 5 (b,c,d),** reveals intriguing microscopic irregularities. It becomes evident that the Al_2O_3 particles are less uniformly distributed; instead, they tend to cluster in specific regions, and there is a subtle presence of micro-porosity. This microscopic complexity adds a layer of nuance to the overall understanding of the composite material's composition and structure.

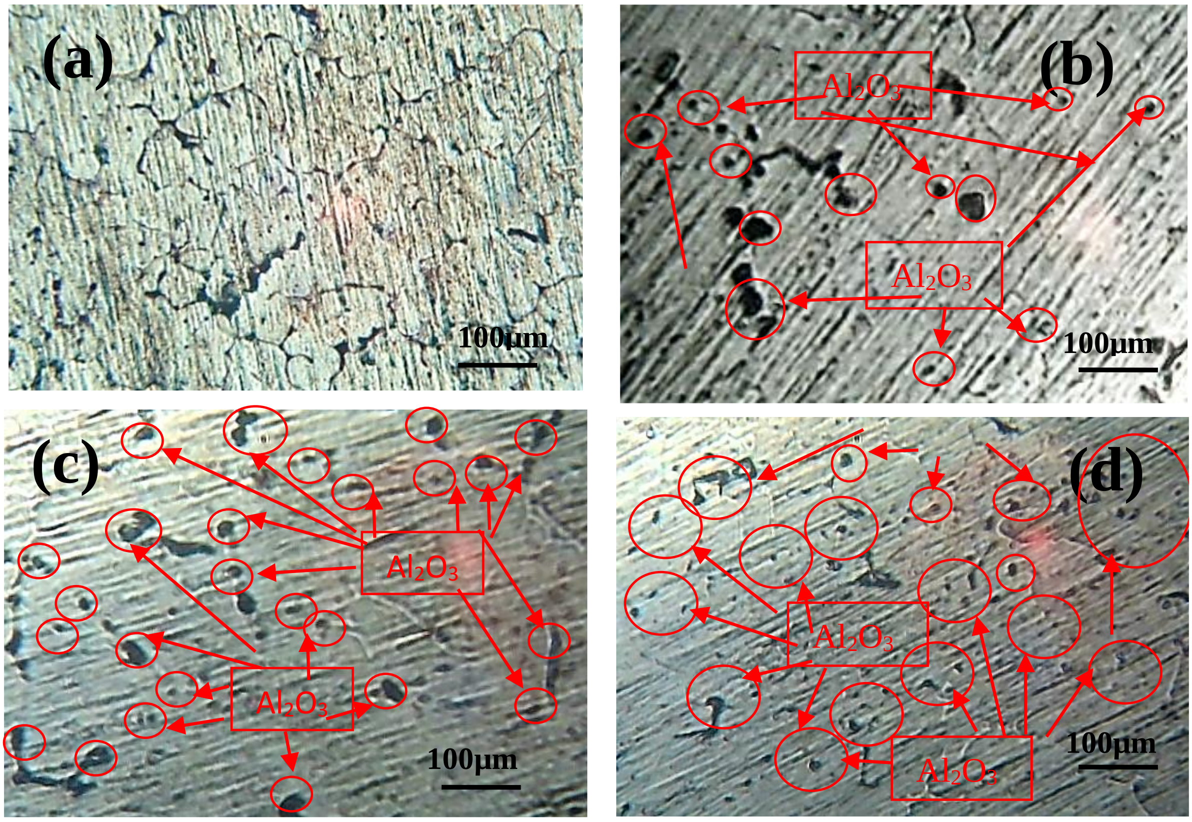


Fig. 5 Optical micrographs of **a)** the as cast microstructure of Al 7075 **b)** Al7075 reinforced with 4 wt. %, **c)** Al7075 reinforced with 8wt. %, and **d)** Al7075 reinforced with 10 wt. %,

3.2 X-RAY DIFFRACTION

The X-ray diffraction (XRD) analysis has provided us with invaluable insights into the structural composition of both the base alloy and the composite material. In the case of the base alloy, the XRD results reveal that it primarily comprises α-Al solid solution, which is the fundamental aluminum matrix, and interspersed intermetallic precipitates of Al Zn. This combination of elements and phases is in line with the typical composition of such alloys and underscores the importance of understanding the underlying crystallographic structure in materials science. However, when we turn our attention to the composite material, the XRD analysis presents a fascinating contrast. While it retains the same composition as the base alloy, consisting of α-Al solid solution and Al Zn intermetallic precipitates, it also introduces a distinctive addition in the form of Al_2O_3 particles. This unique element is clearly depicted in the XRD patterns, as exemplified in **Fig. 6**. This introduction of Al_2O_3 particles represents a deliberate modification of the material's structure and properties, aimed at enhancing its mechanical and functional attributes. It's through these detailed XRD analyses that we gain a profound understanding of the crystalline nature of the base alloy and the incorporation of Al_2O_3 particles within the composite, paving the way for comprehensive materials engineering and development.

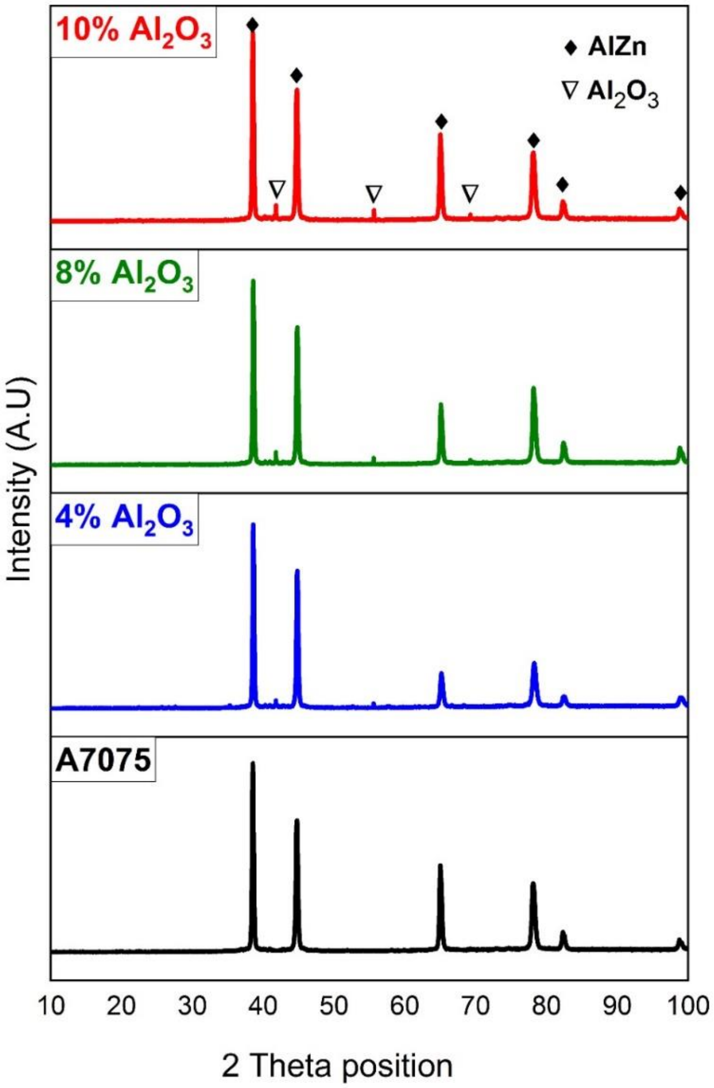
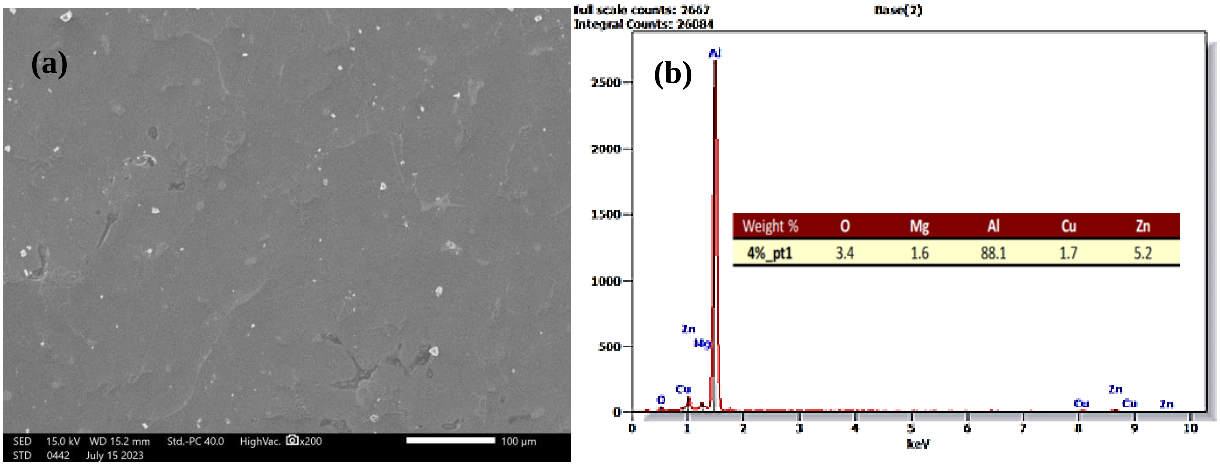


Fig. 6 XRD patterns of Al 7075/Al_2O_3 composite of (0%, 0.4 wt %,8wt %,10 wt %)

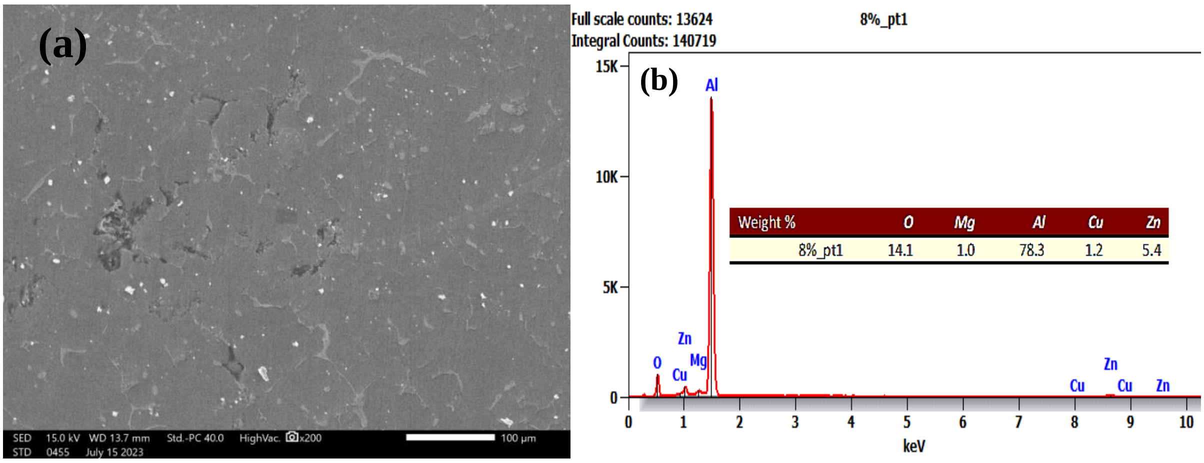
3.3 SEM ANALYSIS

The microstructures of Al 7075 specimens with varying weight percentages of aluminum oxide reinforcement are depicted in **Figs. 7–11**. Specifically, SEM photographs and EDX analyses were conducted on specimens reinforced with Al_2O_3 particles at 4 wt.%, 8 wt.%, and 10 wt.%, illustrated in Figures 7, 8, and 9, respectively. These SEM images were captured at a magnification of 500X, with the base matrix constituents appearing as a gray-colored background and aluminum dioxide as light-colored particles. **Fig 7(a)** exhibits uniformly distributed aluminum oxide (4%) throughout the base matrix. Conversely, in specimens with 8 wt.% and 10 wt.% reinforcement **(Fig. 8(a) and Fig. 9(a)),** a noticeable increase in the presence of aluminum oxide particles is observed. However, it's crucial to note that as the weight composition of aluminum oxide particles increases, the microstructure's uniformity and homogeneity tend to decrease. **Figs. 7 (b), 8 (b), and 9 (b)** offer detailed insights into the material compositions of three distinct specimens. Across all three specimens, aluminum emerges as the predominant material, demonstrating its superiority. Following closely behind is zinc, which is the second most abundant material. In contrast, materials such as magnesium (Mg) and oxygen (O) are present in smaller proportions.



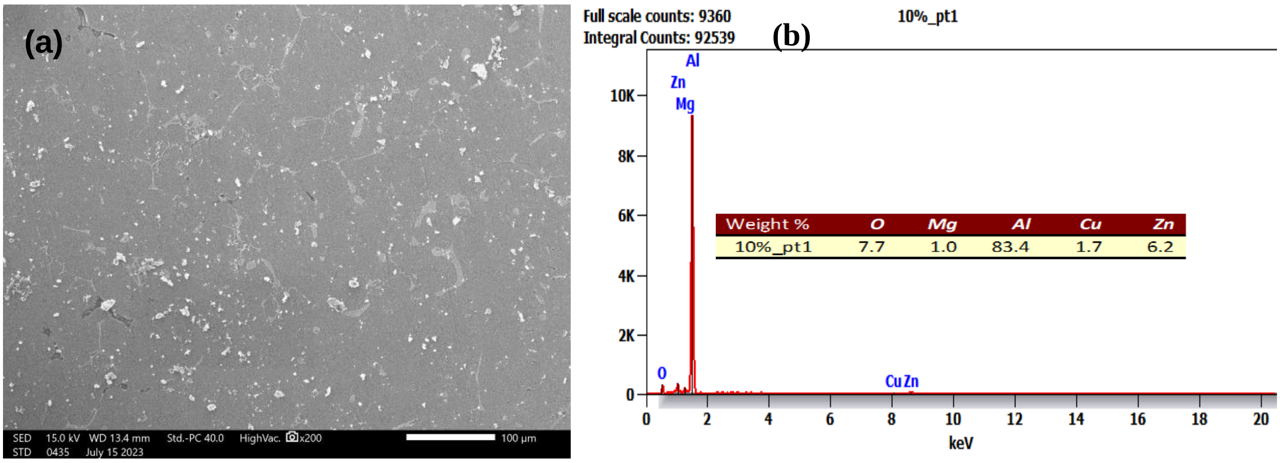
Weight %	O	Mg	Al	Cu	Zn
4%_pt1	3.4	1.6	88.1	1.7	5.2

Fig. 7 SEM micrograph and EDX of Al 7075 reinforced with 4 % Al_2O_3 particles.



Weight %	O	Mg	Al	Cu	Zn
8%_pt1	14.1	1.0	78.3	1.2	5.4

Fig. 8. SEM micrograph and EDX of Al 7075 reinforced with 8 % Al_2O_3 particles.



Weight %	O	Mg	Al	Cu	Zn
10%_pt1	7.7	1.0	83.4	1.7	6.2

Fig. 9. SEM micrograph and EDX of Al 7075 reinforced with 10 % Al_2O_3 particles.

Additionally, **Figs. 10 and 11** present SEM mapping analysis and elemental distribution, confirming the even distribution of constituents within both the base matrix and the reinforcement. This homogeneous distribution is a crucial observation, emphasizing the integrity and consistency of the material composition in these specimens, thereby enhancing the overall performance of the prepared Al 7075/Al_2O_3 composite. In **Fig. 10**, a higher magnification focuses on demonstrating the presence of aluminum oxide particles. An SEM photograph in this region captures both particles and the base matrix, facilitating SEM map scanning as shown in **Fig. 10(b). Fig. 10(b)** reveals the presence of different elements, distinguished by various colors above a green background representing aluminum metal. Elemental distribution for **Fig. 10(b)** is shown in **Fig. 11**, depicting the distribution of magnesium, oxygen, copper, and zinc in yellow, red, blue, and white colors, respectively. Comparing the distribution of oxygen in **Fig. 11** with **Fig. 10(a)**, it is evident that oxygen appears in the same region where aluminum oxide particles are present. Conversely, the distribution of magnesium, copper, and zinc is uniform throughout the entire base matrix. Notably, oxygen appears only in the region where aluminum oxide is present in **Fig. 10(a).** This analysis indicates that oxygen exclusively combines with aluminum, confirming the presence of aluminum oxide particles. These findings align with XRD results, supporting the indication of alumina in the Al 7075 alloy

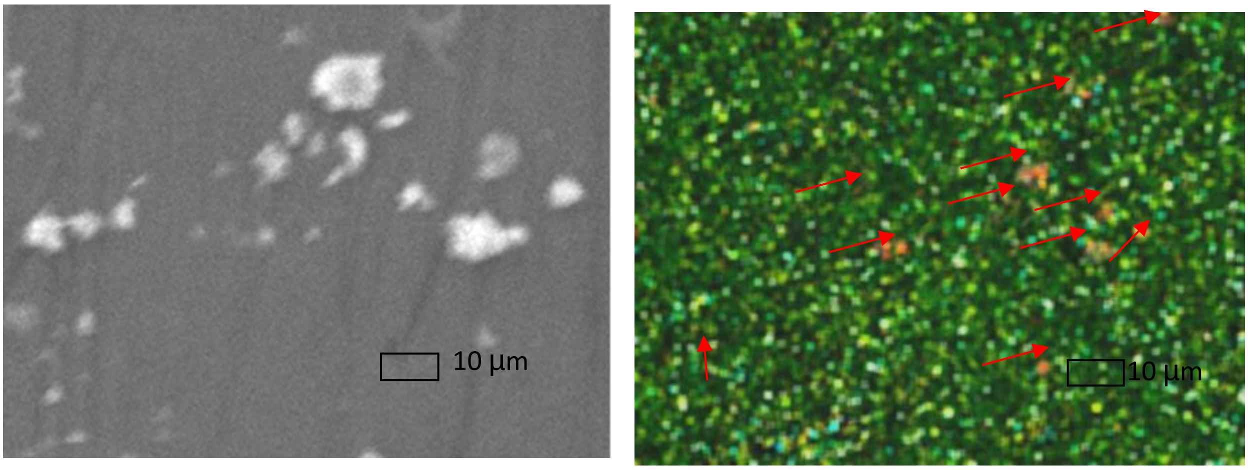


Fig. 10 SEM mapping for the distribution of element (Al 7075) (4%Al_2O_3)

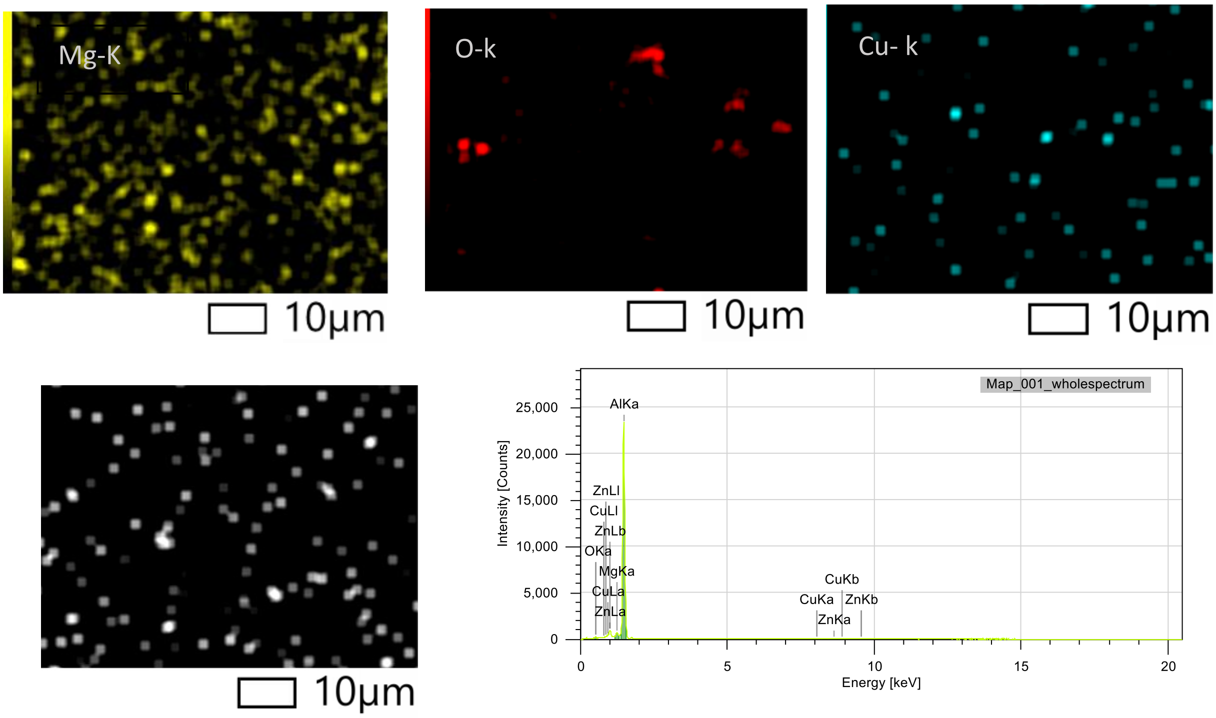


Fig.11 SEM mapping for the distribution of elements (Al 7075) C,(b)(Zn),(c)(O),(d)(Mg)and(e)(Cu) for particle reinforcement 4% Al_2O_3

3.4 TENSILE TEST RESULTS

Tensile tests were conducted to assess the ultimate tensile strength of the base alloy and composites. The experimental testing resulted in stress-strain curves for Al 7075 alloy and Al 7075 composites reinforced with 4 wt. %, 8 wt. %, and 10 wt. % Al_2O_3 particles **Fig. 13**, as outlined in **Fig. 12**. The ultimate tensile strength (UTS) of Al 7075 alloy ; 4 wt. %; 8 wt. % and 10 wt.% are 124.8 ± 3.722, 168.6 ± 5.14, 185.34 ± 5.13 and 231.5 ± 4.37 MPa respectively. Notably, the ultimate tensile strength of the composites exhibited significant improvements, with both parameters increasing as the percentage of Al_2O_3 reinforcement increased. This enhancement in ultimate tensile strength can be attributed to the presence of hard Al_2O_3 particles within the Al 7075 matrix, contributing to increased strength. The increased strength values with higher Al_2O_3 content are associated with lower porosity and a more uniform distribution of Al_2O_3 particles. The introduction of Al_2O_3 particles into the matrix also provides heterogeneous nucleation sites during solidification, resulting in refined grains. Therefore, the improvement in tensile properties is closely linked to grain size. The hard Al_2O_3 particles transfer their strength to the Al 7075 matrix through load distribution from the matrix to the reinforcing particles. Previous studies have explored the mechanical properties of Al 7075 composites reinforced with silicon carbide and Al_2O_3 using the stir-casting method, reporting significant improvements in ultimate tensile strength (15.07% and 46.7%) and yield tensile strength (14.3% and 34.3%) [10]. In current study, as evident from the results presented in Table 2 and utilizing the semi-solid technique, it's observed that adding Al_2O_3 to Al 7075 composites increases the tensile strength by more than 50%. This underscores the significance of this technique in obtaining Al 7075 composites with exceptional ultimate tensile strength. The increase in ultimate tensile strength can be primarily attributed to Al_2O_3 particles acting as barriers to dislocations and the resulting matrix strengthening due to a reduction in Al 7075/Al_2O_3 grain size [11]. Thus, the higher tensile of the composite is attributed to the hindrance of dislocation movement by the Al_2O_3 particles.

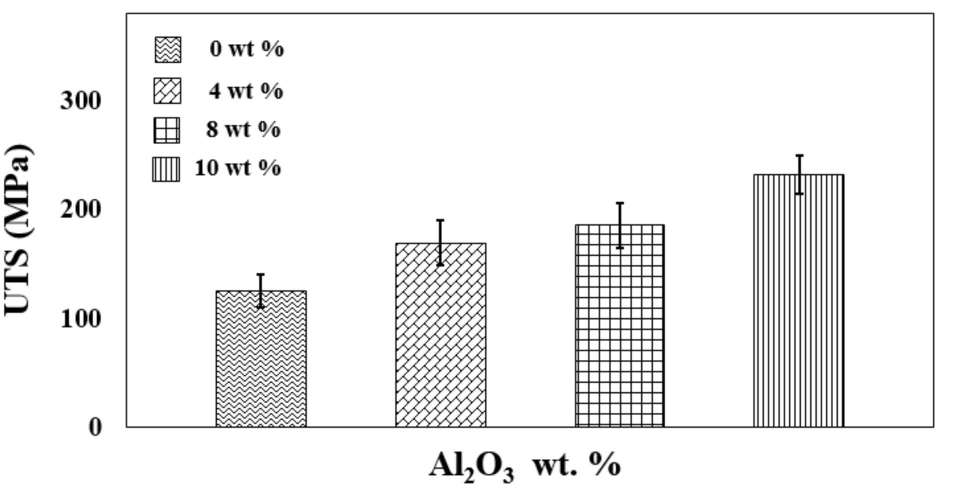


Fig. 12 Ultimate tensile strength (UTS) of Al 7075 with 0;4 , 8 and 10 wt. % of Al_2O_3

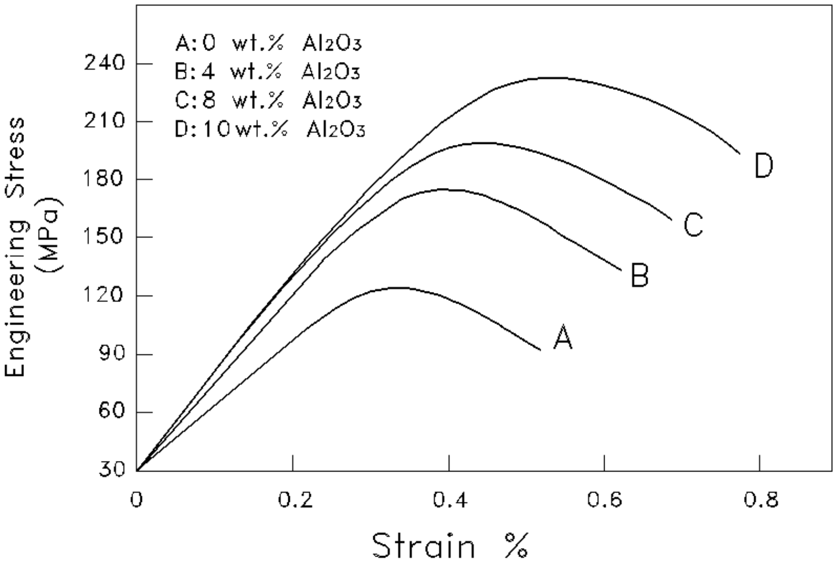


Fig. 13 Engineering stress strain curve of Al 7075 with 0;4 , 8 and 10 wt. % of Al_2O_3

3.5 MACRO HARDNESS

Macro hardness of Al 7075 base material with 0 wt. % , 4 wt. %, 8 wt. %, and 10 wt. % were assessed; **Fig. 14**. Notably, the hardness of the investigated composites surpasses that of the base material in its as-cast state. The average hardness value of the matrix and composites refers to that the hardness increases with increasing the percentage of Al_2O_3 particles up to 10 wt.%. The pinnacle hardness measurement recorded stood at 187.5 ± 5.4 HV, achieved specifically with the 10% by weight reinforcement of Al_2O_3 which is 29.8 % higher than that of the unreinforced base alloy. This increase in hardness within the composites directly correlates with the elevated Al_2O_3 content integrated into the Al 7075-Al_2O_3 composites. This enhanced hardness primarily stems from the inherent high hardness of the Al_2O_3 particles. A distinct enhancement in the hardness of the Al 7075 matrix is evident with the incorporation of Al_2O_3 particles is indicated in **Fig. 14**. The observed improvement in Vickers hardness is linked to the presence of the rigid Al_2O3 material within the relatively softer Al 7075 matrix contributes significantly to the overall hardness of the matrix material. Where, reinforcement particles serve as barriers to dislocation motion preventing their movement and consequently, improving the hardness. Moreover, even distribution of reinforcements throughout the Aluminum Matrix Composite (AMC) [10]. It's evident that hardness increases with a higher concentration of Al_2O_3 particles. The most favorable results were achieved with the cast Al 7075/Al_2O_3 composite, which contained 10 wt% of Al_2O_3 particles. This composite exhibited markedly superior hardness values compared to other composites and the pure matrix material in this study. It's worth noting that the semi-solid technique yielded a more substantial improvement in hardness compared to the other techniques mentioned in previous studies.

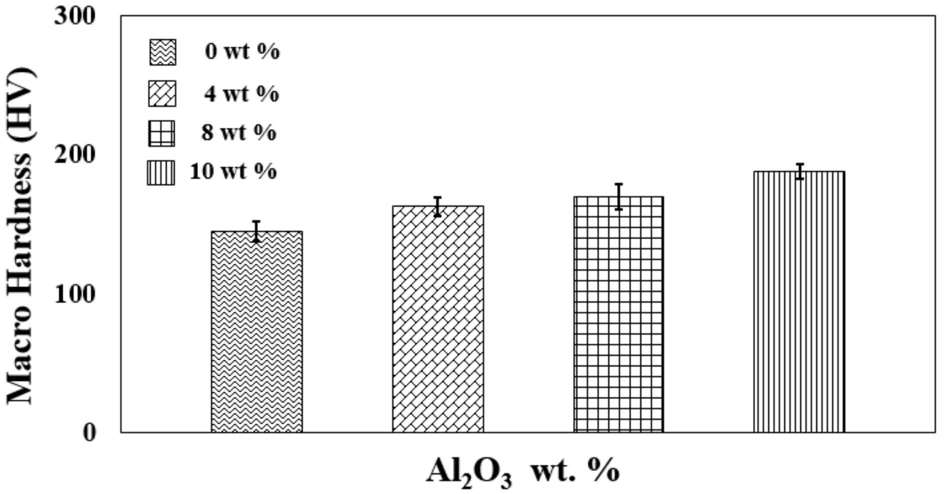


Fig.14 Macro hardness (HV) of Al 7075 with 0; 4 , 8 and 10 wt. % of Al_2O_3

4. CONCLUSIONS

- The primary obstacle encountered in this study pertains to the incorporation of Al_2O_3 particles, a ceramic substance, within the Al 7075 aluminum alloy without resorting to surface treatment involving chemicals. These chemicals are widely acknowledged among researchers in this domain as the primary agents responsible for allowing the intrusion of alumina grains. However, their specific details are often omitted, resulting in the failure of numerous experiments reliant on this research. However, this research paper introduces a breakthrough by utilizing the semi-solid technique. It establishes that adhering to the procedural steps outlined in the research empowers any researcher to successfully introduce alumina into the specified alloy. This method stands as a pivotal achievement within this research domain, offering a pathway for future endeavors to overcome the challenge of integrating ceramic materials into aluminum alloys without chemical surface treatment.
- Upon varying the proportions of aluminum oxide, it's observed that the highest tensile stress and macro hardness peaks at 10 wt% aluminum oxide addition, achieving 231.5 ± 4.37 MPa, 187.5 ± 5.4 HV, whereas the lowest tensile stress occurs at the inclusion of 4 wt% aluminum oxide.

- The comprehensive analysis utilizing SEM images, SEM mapping, and in-depth microstructure evaluations serves as an essential visual aid within the research, depicting a finely tuned distribution of Al_2O_3 particles. This well-illustrated distribution pattern, especially when applied to the alloy produced through the semisolid method, yields a substantial 25% surge in maximum tensile strength compared to research employing different techniques. This pronounced increase in strength finds further validation in the results of the hardness test, underscoring the robust and uniform dispersal of alumina throughout the alloy. Such detailed examinations not only provide visual confirmation but also signify the key role played by an optimally distributed Al_2O_3 in enhancing the mechanical properties of the alloy when produced via the semisolid technique.

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