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Study on Iraqi Bauxite Ceramic Reinforced Aluminum Metal Matrix Composite Synthesized by Stir Casting

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ABSTRACT

For the past decades researchers are showing immense interest to investigate the natural advantage of preparation of composites from minerals such as bauxite particles, and proved their effectiveness as cost effective reinforcing agents in fabrication of high performance composites. This study, is a new attempt in using the Iraqi natural bauxite powder with different proportions (2, 4 and 6 wt%) in preparation of aluminum metal matrix composites (AMMCs) using stir casting and Mg additives. In experimental work, the bauxite stones were crashed and milled, then the powder was fired at 1400 °C. The powders were characterized using particle size, XRD and XRF analysis. The AMMCs casts were machined, polished, preheated, and their properties were characterized using hardness measurements, microstructural observations, and calculation of their Young's modulus, Poisson's ratio and fracture toughness. Also, their fracture toughness were evaluated by means of crack mouth opening displacement (CMOD) measurements from extensometer recordings. The results proved the successful production of AMMCs with improved fracture toughness, hardness and elastic modulus properties using Mg and Iraqi fired bauxite added at 2 and 4 wt% by stir casting. Moreover, results from CMOD measurements showed the effect of addition bauxite particles at 2 and 4 wt% in increasing "maximum load at failure" and "critical CMOD at critical load" of the matrix materials to about " 25 and 44%" , and " 32 and 47%", respectively. Also, at these ratios, the calculated fracture toughness of the matrix materials by means of K_{IC}, and young modulus showed improvement at about "22 and 69%", and "8 and 12%", respectively. Addition of bauxite at 6% could not give the required improvement in the fracture toughness despite its effects in recording the highest improvements in hardness (57%) and elastic modulus (22%) due to the brittle behavior of AMMCs at this ratio.

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NOMENCLATURE

COD	Crack Opening Displacement (mm)	ν	Poisson's Ratio
AMMCs	Aluminum Metal Matrix Composites	*E*	Young' Modulus (GPa)
XRD	X-ray Diffraction	PSA	Particle Size Analysis
XRF	X-ray Fluorescence	Al	Aluminum
Mg	Magnesium	CT	Compact Tension
HB	Brinell Hardness (MPa)	SEM	Scanning Electron Microscope
KIC	Fracture Toughness (GPa.m$^{1/2}$)	CMOD	Crack Mouth Opening Displacement (mm)

1. INTRODUCTION

For the past decades ceramic-reinforced aluminum metal matrix composites AMMCs materials have proved their dominance in many applications such as field of automobile and marine due to their superior properties such as high strength-to-weight ratio, corrosion resistance and superior tribological properties [1-3].

Also, particles reinforced aluminum metal matrix composites (AMMCs) have received increasingly importance in advanced applications in comparison to fiber reinforced composites due to their superior

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properties such as low cost and relatively isotropic properties [4].

The selection of suitable matrix and reinforcement materials are being the main challenge in the fabrication of AMMCs [1]. Currently, researchers are showing immense interest to strengthening of AMMCs with ceramic materials such as silicon carbide, boron carbide and zirconium oxide [3, 5]. Many studies have investigated the natural advantage of preparation of composites from minerals such as bauxite particles, and proved their effectiveness as cost effective reinforcing agents in fabrication of high performance composites [6, 7].

Iraqi bauxite, is a heterogeneous material found naturally in the form of large blocks in the western desert and in Al-Anbar in Iraq as the main sources for alumina and aluminum production. It consists of aluminum hydroxide minerals, and mixtures of aluminosilicate, iron oxide, silica, titania, and other impurities [8-11].

In view of aforementioned issues, the present work is mainly concentrated on the development of the new trends in use of Iraqi natural bauxite particles in preparation of AMMCs by stir casting process, and study the effect of these particles on the mechanical properties (fracture toughness by means of crack mouth opening displacement, CMOD measurements from extensometer recordings, hardness and Young's modulus).

Stir casting has proved its superiority by means of technical and economical consideration in manufacturing of AMMCs due to its advantages of flexibility, and applicability to large quantity production, and large size components [2].

2. EXPERIMENTAL PROCEDURES

2. 1. Preparation and Charaterization of Starting Materials

2. 1. 1. Bauxite Particles Iraqi bauxite rocks were manually kibbled using mortar to get the quasi finished powder. Then the powder was washed, dried and milled for 8 hours by using ball mill at speed 350 rpm. Then, the powder was fired at 1400 °C to avoid moisture and some impurities. XRD was used to characterize the Iraqi bauxite ceramic powder. The particle size distribution of bauxite powder was determined using particle size analysis (PSA) process. Chemical Composition of the oxides contents and other components in fired and unfired bauxite powder were determined using X-ray Fluorescence, XRF.

2. 1. 2. Matrix Material Al wires (99.7% purity) were used in this study in casting of matrix material. The Al wires were cut into Ø 3mm and (10-15) mm pieces, cleaned and washed, then dried in order to be ready for preparation of AMMCs samples by stir casting. Table 1 shows the results of X-ray for the chemical composition of the Al wire used as matrix material. Mg powder was used as additives in AMMCs.

2. 2. Preparation of AMMCs by Stir Casting

2. 2. 1. Stir Casting Process Table 2 shows the ratios of matrix, reinforcement, and Mg additives used in preparation of AMMCs specimens in the present study.

For fabrication of AMMC composites through stir casting route**,** Al wires were accommodate into the graphite crucible in an electrical furnace type (20122 MILANO). The temperature of furnace was raised slowly above liquidus temperature to melt the Al wires, and it then was maintained at 700°C. Mg additives (Ø 56.05) covered with foil were added to the melt to improve the wettability between matrix and reinforcement; then, the slag was removed. The weighted reinforcements of bauxite were covered with aluminum foil and pressed carefully in order to realize particles from air, then preheated at 300°C for 15 minutes to avoid any moisture contains. The temperature was slowly reduced to below the liquidus temperature of the matrix material. The semisolid molten was mixed for 7 minutes with stirrer blade rotated at a speed of 870 rpm, in order to obtain uniform ceramic particles distribution; thereby, improve wetting and permeability of the reinforcements in the liquid matrix. After that, the temperature was raised slowly again above liquidus temperature (850°C) to increase fluidity of molten metal. Finally, the melt was poured into a preheated casting mould. After casting, the casts were processed to prepare the specimens for tests. Figure 1 shows the flowchart of the experimental approach.

2. 2. 2. Casts Machining and Treating In this process, samples for the compact tension test were prepared according to the American Standard E399 [12], the casts were machined to the final dimensions of

TABLE 1. Chemical composition of the Al wires

%Al	%Si	%Fe	%Cu	%Mn	%Mg
0.70	0.06	0.12	0.01	0.01	0.02
%Zn	%Ti	%B	%V	%Cr	%Others
0.03	0.01	0.005	0.01	0.01	0.015

TABLE 2. Chemical Composition of AMMCs Specimens

Sample code	(Wt%) Al	(wt%) Mg	(wt%) Bauxite
S0	98	2	----
S1	96	2	2
S2	94	2	4
S3	92	2	6

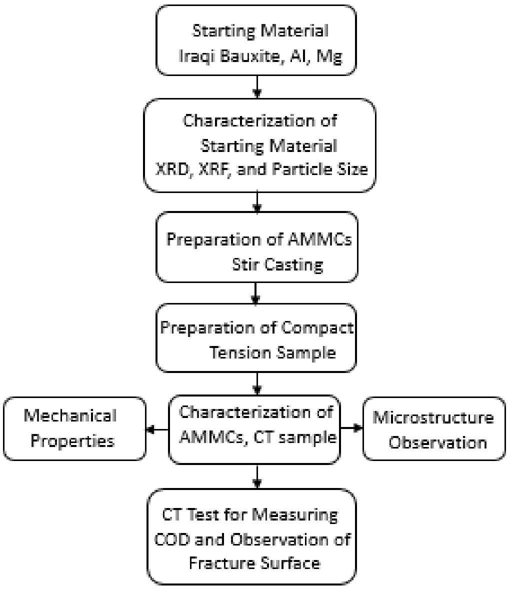

Figure 1. Flowchart of experimental procedures

(36.3×37.8×15.3 mm^3). The casts were first pre-machined using facing milling machine to get the final dimensions. After milling process, the samples were ground using (YMP-2Machine) with (180-2000 grit) SiC grinding papers, and polished. Then, the notches (10mm length) and pre-crack (2mm length) in the samples were made using Wire Electrode Discharge Machining (WEDM) CNC machine. The Ø=7.65 mm two holes were made using drilling machine type (WDM Z5050) as shown in Figure 2. After that, the casts were subjected to heat treatment at 350 °C for 2 hours for stress reliving.

2. 2. 3. Compact Tension Test The compact tension test was achieved on a universal testing machine type (WAW-200). Figure 3 shows the setup loading parts and the arrangement of the samples, extensometer, and other components of the system in the compact tension test. The samples were fixed between the lower and upper jaws of the machine with the aid of clamping tool. The electronic extensometer(YYU-10/50-111276 Japan) was fixed on the samples for recording its extension

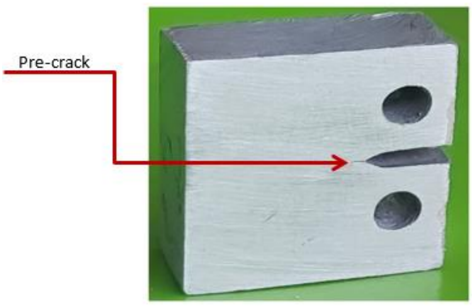

Figure 2. Compact tension of AMMCs Sample

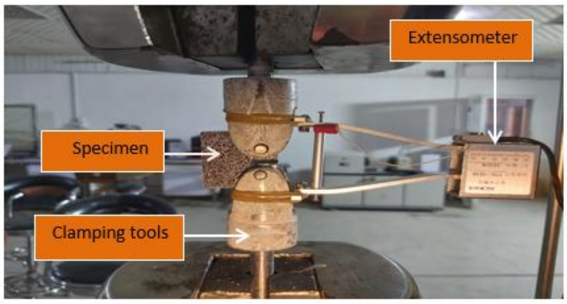

Figure 3. Compact tension sample arrangement during uniaxial tensile test

during the test, it was fixed to be in front to the crack mouth. The results obtained from the system after loading with range (0.1KN) were (load, time, and crack mouth opening displacement (CMOD)). CMOD is a term for measurement of the crack opening displacement (COD) near the crack mouth. COD concept is widely used in fracture toughness evaluation because of it is superficially simple, plausible, and readily visualized in its ideal aspect.

2. 3. Characterization of AMMCs

2. 3. 1. Calculation of Mechanical Properties

The ultrasonic device (CSI type CCT-4) was used for calculation of Young's modulus and Poisson's ratio of AMMCs samples by using equations 1 and 2 [12].

$$\nu = \frac{1-2\left[\frac{C_s}{C_l}\right]^2}{2-2\left[\frac{C_s}{C_l}\right]^2} \quad (1)$$

$$E = 2\,\rho C_s^2(1+\nu) \quad (2)$$

where:

C_L is speed of sound of longitudinal, C_s is speed of sound of shear, ρ is density of the specimen, and E is Young's modulus and ν is Poisson's ratio.

The Brinell hardness of the AMMCs specimens was achieved using the hardness tester type (WILSON HARDNESS UH-250). An average of three measurements was adopted in recording of hardness results.

The fracture toughness of compact tension specimen was measured according to ASTM E 399 using Equation (3).

$$K_{IC} = \left(\frac{P}{BW}\right)^{1/2} \times f\left(\frac{a}{w}\right) \quad (3)$$

where:

$$f\left(\frac{a}{w}\right) = \frac{[(2+a/w)(0.886+4.64(a/w)-13.32(a/w)2+14.72(a/w)3-5.6(a/w)4)]}{(1-a/w)^{3/2}}$$

where:

K_{IC}= Fracture Toughness (MPa.m$^{1/2}$), P= Maximum force (kN), B= width of the specimen (m), W= height of specimen (m), a= crack length (m).

2. 3. 2. Microstructural Characterization The SEM images were used to observe the microstructure of the AMMCs specimens and the crack region using Scanning Electron Microscope model (FIE, TESCAN MIRA3). The SEM was used to observe the distribution of bauxite within the microstructure of the AMMCs specimens.

3. RESULTS AND DISCUSSION

3. 1. XRF Table 3 shows the results of XRF analysis of unfired bauxite powder and fired bauxite powder heated at (1400 °C) with soaking time of (3h). The result showed that the percentages of alumina increased after firing bauxite which used as reinforcement phase with decreasing of most impurities. The major oxides found in Iraqi bauxite were alumina, silica, titania, iron oxide which confirmed using XRF. Iraqi bauxite was used to strengthen the AMMCs due to presence these oxides which have good properties for example stiffness and hardness.

3. 2. XRD Bauxite powders were examined before and after the firing. Figure 4 and Table 3 show that the bauxite rocks consist mainly of Kaolinite, Quartz, Anatase, Boehmite, Calcite, and Gibbsite. Figure 5 shows the XRD patterns of bauxite after firing and the major peak at 25.75° is alumina phase due to the bauxite has the highest percentage of alumina and silica. While changed as the proportion of alumina increased which represented by the highest peaks. Also, peaks of some components reduced or almost disappeared after firing, and through the combustion process, a higher percentage of alumina was obtained, which could be further utilized for the reinforcement of the composite material.

TABLE 3. XRF results of unfired and fired bauxite

Bauxite Compound	Unfired Bauxite	Fired Bauxite
%Al_2O_3	54.70	68.39
%SiO_2	21.31	25.23
%Fe_2O_3	1.48	1.94
%CaO	0.05	0.07
%MgO	< 0.02	< 0.02
%TiO_2	2.59	3.36
%SO_3	0.04	0.02
%Cl	0.02	< 0.02
%P_2O_5	0.02	0.02
%K_2O	< 0.02	< 0.02
%Na_2O	< 0.02	< 0.02
%L.O.I	0.78	0.93

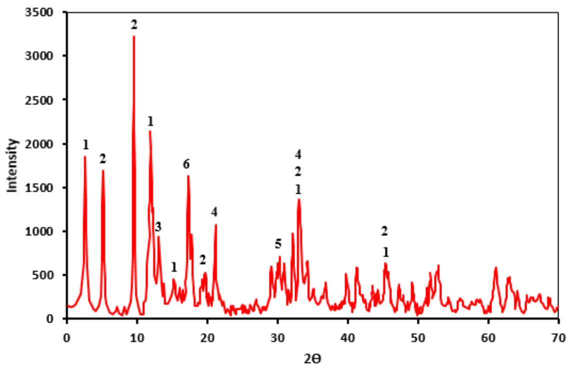

Figure 4. XRD patterns of unfired bauxite

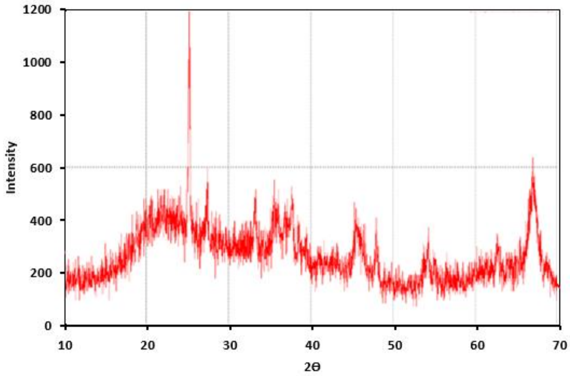

Figure 5. XRD patterns of fired bauxite

Furthermore, the high mullite phase amount observed in fired bauxite can make it more suitable for the fabrication of composite materials with improved properties and uniform distribution of reinforcements [13].

3. 3. Particle Size Analysis The average particle size of fired bauxite powders distribution was (0.979µm) as shown in Figures 6. The small particular size provides the particles of distribution more uniformity during the casting process and hence good results for the properties of composite material due to increase in the surface area of fired bauxite powders. At any rate, the distribution of the particle size is effected by milling time and the presence of the agglomeration [14]. Also, a small particle

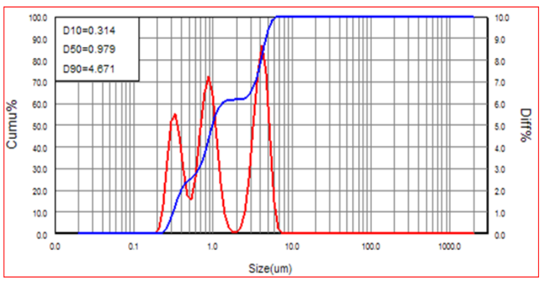

Figure 6. Particle size distribution of fired bauxite powder

size of the reinforcements will provide them a fair homogenous distribution in the matrix which can lead to microstructural advantage [1]. Anyhow, compared to nano-sized particles, micro particles can have a more positive influence on the relative density of AMMCs and their properties due to higher wettability and clustering problems of nano-sized particles [15].

3. 4. Microstructural Observation The microstructure of the different specimens are shown in Figure 7 using SEM**.** A fair homogenous distribution of bauxite particles was observed in the matrix alloy which leads to more microstructural advantage. The SEM images proved that continuous stirring is essential in the fabrication of bauxite reinforced AMMCs composites due to the tendency of particles to form agglomeration or clusters sites at higher reinforcement content [1, 16]. It can also observed that the composites are free from any type of defect in casting.

It is clearly shown that the use of stir during casting of composite induced an acceptable distribution of the reinforcing particles which may improve its mechanical properties. Anyhow, the precise presence of every elements of Al matrix and reinforcement would be confirmed from the EDX analysis [1]. In spite of an acceptable distribution of the particles, there were little agglomerations of the particles in the matrices. This may be reflected on the properties of the specimen's .The proper choice of the parameters for stir casting (stirring speed, time, blade's design, stirring temperatures) played a vital role in the uniform distribution of the bauxite particles in Al matrix. The interface characteristics between matrix metals and reinforcements and microstructure are strongly affected the properties of composites. The microstructural observations shown in Figure 7 were clearly characterized by relatively non-homogeneous distribution of bauxite particles in Al matrix and clustering. Probably, during composites processing the variation of contact time between the molten Al and reinforcement, resulted in poor wetting behavior of particles in the molten and high surface tension, thereby could lead to such distribution. The high bauxite addition in samples S4, resulted in microstructure characterized by more non- homogenization of reinforcement particles in comparison to other AMMCs samples. Generally, the microstructure of all samples were characterized by porosities, because that the bauxite particles introduced air in the melt entrapped between the particles when they added in the melt. Therefore higher porosity can attributed to increase in bauxite particles addition.

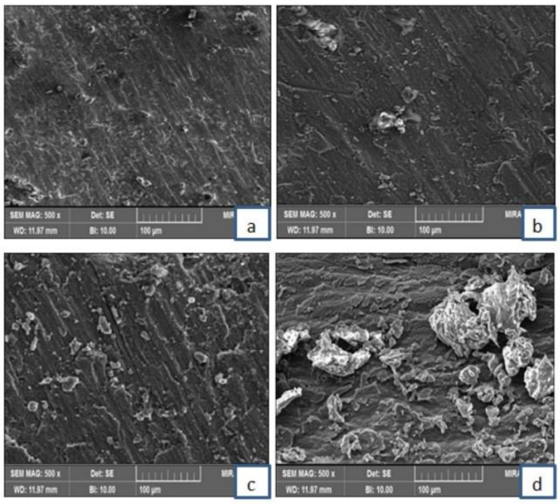

Figure 7. Microstructure observation of AMMACs specimens: (a) S0, (b) S1, (c) S2, and (d) S3 using SEM

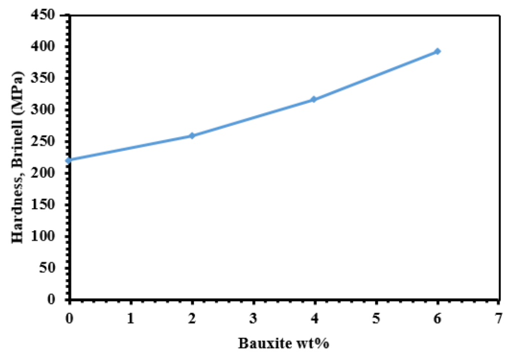

Figure 8. Effect of the bauxite on the hardness of AMMCs Specimens

3. 5. Results of Mechanical Properties

3. 5. 1. Hardness Results The results from Brinell hardness test are presented in the Figure 8. Each value was considered as an average of three reading. The micro-hardness of AMMCs increased with an increasing of reinforcement. Addition of bauxite particles in to Al melt provided supplementary substrate for the solidification to activate there by decreasing the grain size and increasing the nucleation rate. High hardness of bauxite particles could act as barriers to dislocation motion or the matrix motion. Also, the hardness of the AMMC composites enhanced with an increase in weight percentage of bauxite reinforcements due to the resistance provided to the indentation by hard bauxite particles. The increment percentage of Brinell hardness were 17.6, 35.3 and 56.8% for the S1, S2, and S3, respectively comparing with unreinforced specimens (S0). The results are in agreement with other works [17]. Furthermore, the microstructure of composite is strongly affected by stirring time and stirring speed which can cause the change in structure and hardness results of fabricated AMMCs. Also, the particle agglomerate is more when operated with less stirring time and at low stirring speed. However, increase in speed and stirring time can give better particles distribution [16].

3. 5. 2. Results of Fracture Toughness, Young's Modulus and Poisson's Ratio (K_{IC}, E, and ν) The results of fracture toughness, ultrasonic method for determination of (E, ν) are shown in Table 4. The clear increasing of fracture toughness, Young's modules and Poisson's ratio can be related to effect of sinterability of MgO which hinder the grain growth and enhanced the densification of the sample while at 6% the fracture toughness was decreased due to the brittle behavior of AMMCs at this percent [18-20].

3. 6. Time and Load Relationship From the results recorded using the extensometer device, the values of the load projected with time and the deformations of the material along the fracture area were obtained. The relationship between time and load is shown in Figure 9. It showed load increasing with time and reached a critical value as the maximum value of the projected load. After this value the load decreased, thereby indicating the occurrence of the crack and failure of the material. In general, this maximum load increased from 4.74 kN for sample S0 to 5.9 kN and 6.8 kN after increasing bauxite particles to 2and 4 wt%, respectively. Again, the reinforcement using bauxite particles proved its effects in improvement of fracture toughness of the composite materials. Anyhow, sample S3 expressed brittle behavior, which resulted in decreasing of maximum load to 5 kN.

TABLE 4. Results of fracture toughness, Young's modulus, and Poisson's ratio

Sample	KIC (MPa.m$^{1/2}$)	E (GPa)	N
S0	19	69	0.33
S1	23	74	0.33
S2	32	77	0.22
S3	16	84	0.31

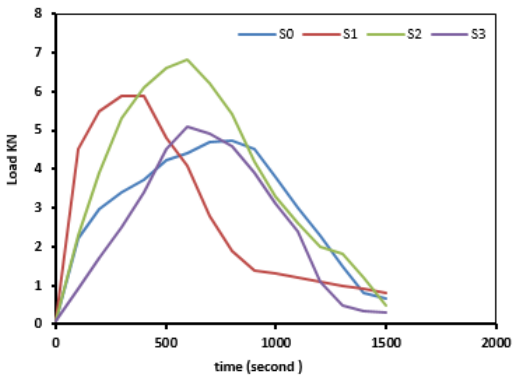

Figure 9. Load versus time of AMMCs specimens

3. 7. COD and Time Relationship CMOD results at mouth notch were recorded using the clip gauge that fixed on the mouth of notch region, as described in Figure 3. Figure 10 shows the results of time versus CMOD from extensometer recordings. It can be observed, that the area of CMOD decreased with increasing the bauxite particles from 2 to 4 wt%, denoting the strengthening influences in the AMMCs samples. Anyhow, S3 samples (6%wt) could not give the required results because of their behavior similar to those of brittle material.

3. 8. COD and Load Relationship The relationship between CMOD with applied load are shown in Figure 11. Generally, the curves can be divided into three stages. The first stage showed a sudden increase or a linear increase in the load to a certain limit with CMOD, denoting the materials resistance to the applied load. The second stage represented the critical stage in the behavior, where there was a continuous increasing in the load to critical point of maximum load and critical CMOD. Furthermore, the reinforcement with bauxite particles proved its effects in improving the fracture toughness properties by means of small critical CMOD at high critical load. Also, the critical CMOD values were 5.4, 3.7 and 2.9 mm for sample S0, S1 and

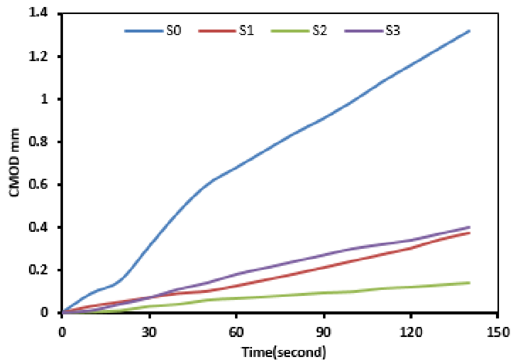

Figure 10. Results of time versus CMOD from extensometer recordings

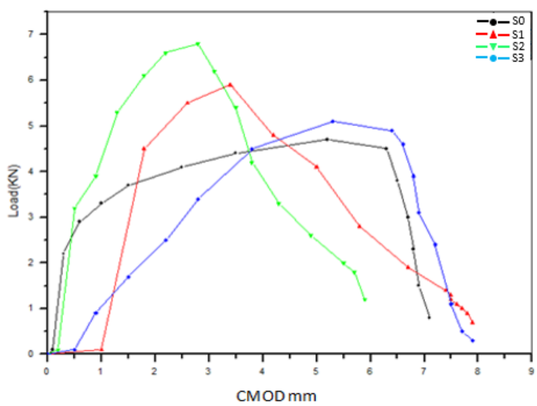

Figure 11. Results of Load versus CMOD

S2, respectively. Again, the brittle behavior of S3 sample recorded values of CMOD and load better than those of samples S0, but not better than those of samples S1 and S2. The three stage represented the failure stage, where the load decreased with increasing of CMOD to the failure point. It can be also divided to three parts. The first part, the relationship is linear until reach the peak load (maximum load). The second part start when move away from peak load where the crack opening displacement (CMOD) increase with decreasing the load. The final part represent the tail of curve shows the crack opening displacement (CMOD) increase while the load gradually decreased. The critical (CMOD) are 5.4, 3.7 and 2.9 mm of S0, S1 and S2, respectively. The critical (CMOD) of S1 and S2 is less than of S0 that result from addition of bauxite that enhancing the mechanical properties of sample. While the critical CMOD of S3 increased due to the brittle behavior produced from addition (6wt %) of bauxite.

3. 9. Fracture Results Figures 12 to 15 show the SEM images for the crack regions for different samples. In general, the images could prove the role of reinforcement with bauxite particles in improving the fracture toughness of $AMMC_S$ by means of cracks propagation and their behavior in the composite materials.

Figure 12 shows the fracture nature of a metal-based alloy. It can be clearly observed that the magnesium granules located around the fracture area, and due to the high ductility of aluminum, high deformation can be observed in the fracture region.

For samples S1, Figure 13 shows less fracture progresses with less deformations than those of samples S0. Also, the bauxite particles presented in the way of fracture progress, could cause obstruction of the fracture progress, and thereby, increasing the fracture toughness**.**

For samples S2, Figure 14 shows a clear ablution in the bauxite granules that are more presented in the fracture area and thus hinder the progress of the fracture. This increases in the time period of failure resulting from changing in the fracture trajectory due to the accumulation of the bauxite particles. The bauxite percentages of 2 and 4% in both samples S1 and S2, respectively leads to enhance the fracture toughness of AMMCs due to stain localization ahead of crack tip (i.e. large plastic zone ahead of fractured particle).

Increasing the bauxite content to 6% in the samples S3 causes an increase in the brittleness of the composite material and hence rapid progression of fracture as shown in Figure 15. The high percentage of bauxite caused to increase the high density of dislocation of the aluminum metal matrix composite which leads to increase the brittle phase at this percentage.

Generally, the results of mechanical properties obtained in the present work can be comparable to those of other works in the literature although they recorded hardness results higher than those of the present study. Furthermore, the study presented in this paper focused on

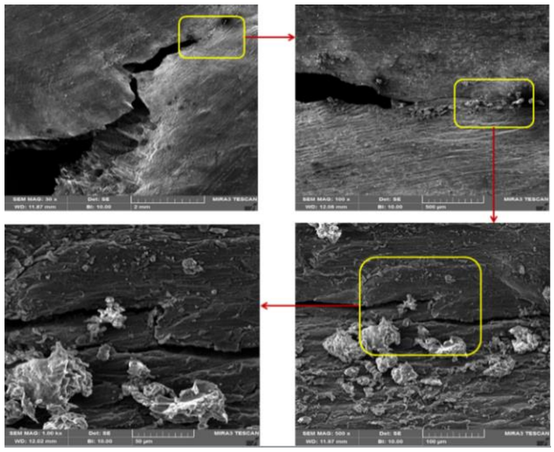

Figure 12. SEM images of samples S0 at different magnifications

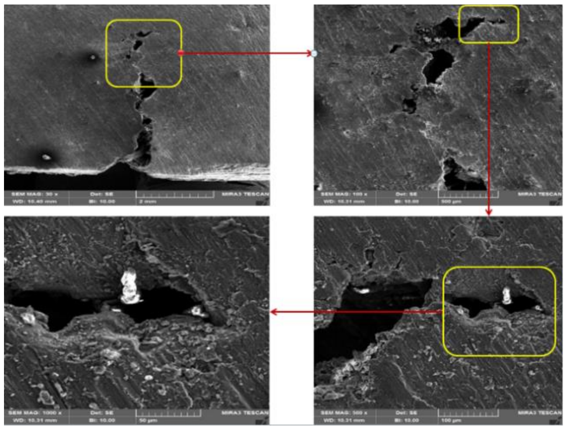

Figure 13. SEM images of samples S1 at different magnifications

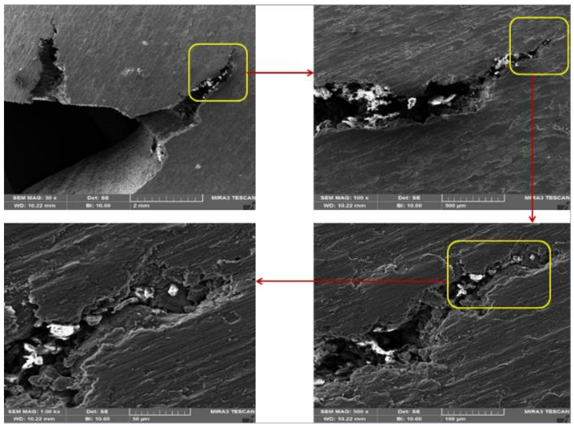

Figure 14. SEM images of samples S2 at different magnifications

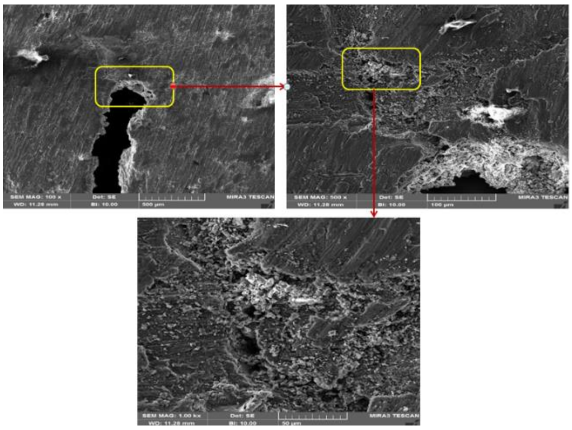

Figure 15. SEM images of samples S3 at different magnifications

development new process in fabrication of AMMCs through relatively green and natural resources of reinforcements, which eliminates using of conventional or industrial reinforcements, hence concerning for the costs saving and human safety. The other works [2, 3, 5, 16] used many types of reinforcement like, Al_2O_3, SiC, TiC, Gr, TiO_2, and B_4C, where these reinforcements have more advantages over its matrix material and still having the cost barrier. Also, other studies in the literature used industrial waste martials like red mud [1,16] , and industrial and agro waste like fly ash, groundnut shell, rice husk ash and bagasse ash [16, 21] in reinforcement of AMMC composites. Anyhow, compared to the present study ,most of works aforementioned above focused on the investigation of mechanical properties (hardness and ultimate tensile strength), tribological properties, and thermal expansion, and they did not investigate the fracture toughness using the methods which adopted in the present study (calculated and measured by means of crack mouth opening displacement CMOD measurements from extensometer recordings) and Young's modulus .The results of present study might promote the future works in reinforcement of metal matrix composites using natural bauxite and study of their accurate fracture mechanics using CMOD measurements and accurate observation of crack initiation, propagation and failure.

4. CONCLUSIONS

The outstanding results concluded from the study are list as follows:

1. Iraqi natural bauxite reinforced AMMCs with improved mechanical properties and fracture toughness can be prepared using stir casting route.
2. The claimed improvements can be attributed to uniform distribution of bauxite particles in the matrix, their ceramic properties, and their obstructing to the crack initiation.
3. Bauxite addition at 2, and 4 wt% could give improvements in AMMCs hardness at about 17 and 43%, respectively.
4. CMOD measurements showed the effect of addition bauxite particles at 2 and 4% in increasing "maximum load at failure" and "critical CMOD at critical load" of the matrix materials to about " 25 and 44%" , and " 32 and 47%", respectively.
5. The calculated fracture toughness by means of K_{IC}, and young modulus at additions of 2 and 4 wt% showed improvement at about " 22 and 69%" ,and " 8 and 12%", respectively.
6. Addition of bauxite at 6 wt% could not give the required improvement in the fracture toughness despite its effects in recording the highest improvements in hardness (57%) and elastic modulus (22%) due to the brittle behavior of AMMCs at this ratio.

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Persian Abstract

چکیده

طی دهه های گذشته محققان علاقه زیادی به تحقیق در مورد مزیت طبیعی تهیه کامپوزیت ها از مواد معدنی مانند ذرات بوکسیت نشان داده اند و اثربخشی آنها را به عنوان تقویت کننده های مقرون به صرفه در ساخت کامپوزیت های با کارایی بالا ثابت کرده اند. این مطالعه ، تلاش جدیدی در استفاده از پودر بوکسیت طبیعی عراق با نسبت های مختلف (۲ ، ٤ و ٦ درصد وزنی) در تهیه کامپوزیت های ماتریس فلزی آلومینیوم (AMMC) با استفاده از ریخته گری و مواد افزودنی منیزیم است. در کار آزمایشی ، سنگهای بوکسیت خرد شده و آسیاب شدند ، سپس این پودر با دمای ۱٤۰۰ درجه سانتیگراد حرارت دید. پودرها با استفاده از اندازه ذرات ، تجزیه و تحلیل XRD و XRF مشخص شدند. خصوصیات ریخته گری AMMC به ماشینکاری ، جلا ، پیش گرم شده و با استفاده از اندازه گیری های سختی ، مشاهدات ریزساختاری و محاسبه مدول Young ، نسبت پواسون و مقاومت به شکست آنها مشخص شد. همچنین ، ضخامت شکستگی آنها با استفاده از اندازه گیری جابجایی بازشدن دهان (CMOD) از ضبط های extensometer مورد ارزیابی قرار گرفت. نتایج نشان داد که تولید موفقیت آمیز AMMC با مقاومت به سختی شکستگی ، سختی و خاصیت مدول الاستیک با استفاده از Mg و بوکسیت حریق عراقی با ۲ و ٤ درصد وزنی با ریخته گری اضافه شده است. علاوه بر این ، نتایج حاصل از اندازه گیری CMOD ، اثر ذرات بوکسیت اضافی را در ۲ و ٤ درصد وزنی در افزایش "حداکثر بار در شکست" و "CMOD بحرانی در بار بحرانی" مواد ماتریس به حدود "۲۵ و ٤٤٪" ، و "نشان داد. به ترتیب ۳۲ و ٤٧٪ ". همچنین ، در این نسبت ها ، محکم بودن شکستگی مواد ماتریس با استفاده از KIC ، و مدول یانگ به ترتیب در حدود "۲۲ و ٦٩٪" و "۸ و ۱۲٪" بهبود نشان داده است. افزودن بوکسیت با ٦٪ نمی تواند با وجود تأثیرات آن در ثبت بالاترین پیشرفت در سختی (٥٧٪) و مدول الاستیک (۲۲٪) به دلیل رفتار شکننده AMMC ها در این نسبت ، بهبود مورد نیاز را ایجاد نکند.