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Studying the Effect of Adding Sea Nodules Powders on Flexural Strength and Hardness of Unsaturated Polyester Resin

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Abstract

This research had studied the effect of Sea Nodules powder filler with different particle size (<53, <75, <106 µm) and volume fraction of (3, 6, 9, 12) % on some mechanical properties of unsaturated polyester resin.

Bending results had revealed a decrease with the increase of volume fractions, and decrease of particle size. While modulus of elasticity increased with increasing volume fraction and decreasing of particle size.

Hardness and bending strength results had show an incremental increase with volume fraction increase and a decrease with particle size decreasing also the maximum shear stress was increased.

Keywords: Sea nodules, hardness and bending strength Flexural, Unsaturated Polyester Resin.

دراسة تأثير أضافة دقائق من عقيدات البحر على مقاومة الانحناء والصلادة للبولي استر غير المشبع

الخلاصة

تم في هذا البحث دراسة تاثير أضافة مسحوق من عقيدات البحر (Sea Nodules) وباحجام دقائقية مختلفة (<53, <75, <106) مايكرون وبكسور حجمية (3, 6, 9, 12) %على بعض الخواص الميكانيكية لراتنج البولي أستر غير المشبع.

أظهرت النتائج بان الانحناء يقل مع زيادة الكسر الحجمي ويقل ايضاً مع نقصان حجم الدقائق. أما معامل المرونة فقد لوحظ بأنه يزداد مع زيادة الكسر الحجمي .

وعند أجراء اختبارات مقاومة الانحناء والصلادة فأن النتائج اظهرت بأن كل من مقاومة الانحناء (F.S) وأقصى أجهاد القص (τ max) والصلادة تزداد مع زيادة الكسر الحجمي وتقل مع زيادة حجم الدقائق.

1- Introduction

The quick technical and industrial development in the world, drive researchers to find a multiuse material having a high engineering and technical characteristics according to the age demands . Researchers found the difference in material properties by studying properties of engineering. Materials (metals, ceramics, polymers) which represented by hardness, toughness, strength, electrical, thermal conductivity and flexural strength. Polymers for example, characterized by light weight, oxidation resistance, transparency, ability to form complex shape, unability to withstand high temperatures (more than 400^{o}C) and high resistance [1,2].

According to this, polymers may be appropriate to use in a certain field and not appropriate to another field, since

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there are a lot of modern industries and technology that need materials have a combination of unusual properties (high impact, light weight and resistance to various environmental condition) which should be economic and suitable for industrial purposes and engineering application.

All of which had led to find out what is termed composite materials [2].

Polymer matrix composite materials are considered as a modern materials in most of engineering and technical applications. The most important demands in the use of these materials are good toughness, high performance, resistance to applied internal and external stresses and its resistance to environmental conditions: temperature, pressure ….etc. The most important required characteristics of these materials are: must be very strong, highly rigid and have low strength to weight ratio. In addition, having better fatigue resistance than traditional engineering metals and high rigidity and toughness [3].

Consequently, It can be found a lot of properties in composite materials which are needed for engineering applications and that cannot be found in ceramic or metallic alloys or polymeric materials[4].

In 1977, Lerchenthal and Brenman studied the reinforcement of epoxy and unsaturated polyester resin with (20-85) % of in organic materials like kaolin and talc as fillers. Flexural strength was calculated for different volume fraction and different size of particles. Results showed the decrease in flexural strength of epoxy due to weak bonding between composite materials phases while polyester showed better results [5].

In 1978, Young and Beaumont studied some mechanical properties of composite materials by adding a silica powders with different volume fractions varied from (up to 52%) to epoxy resin, They found that both Young's modulus that measured by compression test were increased with increasing in volume fraction of silica particles [6].

In 2002, Kereem studied the mechanical properties of nickel particles reinforced epoxy, using particles with different particle size and volume fraction and he found that Young's modulus and yield stress values has been raised with the increasing in volume fraction of particles [7].

Sea nodules are considered as the main resource of metallic material such as: Manganese, Nickel, Cobalt, Zinc and Copper. This nodules found in the bottom of Indian Ocean in the depth of more than five kilometers. Sea nodules also known as manganese nodules because they contain high content of manganese. Sea nodules known to be the main future resource of metals and their researches drive an advanced exhaustion area depending on its metallic resource manganese is the main content in sea nodules while copper, nickel and cobalt are finely dispersed in the oxide base that depend on economic value [8].

2- Experimental Part

A polymer matrix of unsaturated polyester resin that reinforced by sea nodules extracted from Indian Ocean a dopted for fabricating specimens.

Unsaturated polyester matrix was prepared from unsaturated polyester resin and 2% of methyl – ethyl keton peroxide as a hardener with 0.5% of cobalt Octeate as an activator. Reinforcing material (sea nodules) was milled and the resulting powder was sieved to the required particle size.

Unsaturated polyester resin has good mechanical properties, bonding with other materials, thermal and electrical insulation, good surface after setting and dimension stability, table (1) gives some properties of unsaturated polyester resin [9].

The Chemical composition of sea nodules used in this research is done by using atomic absorption in national metallurgy laboratory/ India. The data is given in table (2).

Open mold method used to prepare Particulate composite material with a particle size of (<53, <75, <106 μm) and a volume fraction of (3, 6, 9, 12)% for each particle size by using rule of mixture.

The flexural strength specimens was prepared according to (ASTM D-790) with the dimension of (4.8*13*191)mm and (span to depth) ratio of 1:32. Hardness specimens were tested with (shore D) method used for polymer material according to (ASTM D- 2240).

Young's modulus (E_{bend}), flexural strength and maximum shear stress (τ_{max}) were obtained mathematically from equations (1,2,3)respectively [11,12, 13].

$$E_{bend} = \frac{F\ell^3}{I\delta 48} \quad ....(1)$$

$$F.S = \frac{3P\ell}{2bd^2} \quad ....(2)$$

$$\tau_{max} = \frac{3P}{4bd} \quad ....(3)$$

Where:
F: Applied force (N).
ℓ : Support span (mm).
δ : Deformation in specimen due to the applied load (mm).
I : Moment of inertia of specimens cross section (mm^4).
P : Applied load (N).
b : Specimens width (mm).
d : Specimens thickness (mm).

Hardness test was done by (shore D) method.

3- Results and Discussion

Flexural strength test undergoes to identify stress rate which allows the micro cracks to interact with the particles, where the specimen is subjected to tension and compression force at the same time, knowing that the flexural strength is mostly affected by the bonding strength between matrix and reinforcing material [12].

It can be seen from figures (1,2,3), the effect of applied load on deflection rate for various volume fractions and particle sizes, The decrease in particle size and increase in volume fraction results in decrease in the deflection when the Specimen is subjected to a certain load.

Pure Unsaturated polyester Specimens reveals deflection of (3.8mm) at a load of (13N), while for sea nodules reinforced polyester, the increase in volume fraction lead to the decrease in particle size and lead to the decrease in the deflection. The minimum deflection was found at a (12%) volume fraction for all particle size. Table (3) shows the deflection values at different particle size.

The decrease in deflection due to bending my be due to the high adhesive forces between the matrix and the reinforcing material where the force is higher at finer particle size due to an increase in the contact surface area between matrix and reinforcing material which results in a strong interface.

Adding sea nodules particles to the matrix will lead to an increase in the bending of elastic modulus (E_{band}) shown in figure (4).

Bending elastic modulus for pure reference unsaturated polyester reached to (1995 MPa.) compared to maximum value of (5000 MPa.) when particles at size of (<53 µm) and volume fraction of (12%) was added and as shown in figure (5), and the reason of this is whether the increase of volume fraction or decrease in particle size that leads to decrease in the deflection (δ) which leads to increase in bending elastic modulus according to equation (1) due to the increasing of surface contact area between reinforcement and matrix .

Result of flexural strength of unsaturated polyester was calculated before and after the addition of filler had revealed as shown in figure (6) that flexural strength had increased with the increasing in volume fraction and the decreasing of the particle size. Flexural strength of pure reference unsaturated polyester was (150 MPa.) then an increasing had observed with increasing in volume fraction till it reached to its maximum value of (507 MPa.) by the addition of sea nodules at a volume fraction of (12%) as shown in figure (7), and that consider with our suggestion in that bonding strength between unsaturated polyester and reinforcing material is high. The reason for such important may due to the mechanisms of increasing in strength in particulate composite material by increasing in fracture surface area which results from unregular path of crack due to particles which act as an obstade in front of crack propagation and the need for higher energy for crack growth, other reason might be the plastic deformation around the particles that results from the particles in higher locations than the matrix which results in a localized yielding and cause crack growth retarding and closed the crack tip because the matrix is less in hardness than the particles[13].

Adhesive between matrix and reinforcing material has a large effect in giving the maximum shear stress specimen that load to increase shear stress of particle reinforced polyester to a higher amount than that of polyester specimen alone as shown in figure (8), which the Sea nodules particulate composite material had a maximum shear stress of (8.1MPa.) at volume fraction of (12%) and particle size of (53 µm) as shown in figure (9) compared to the shear stress of unsaturated polyester which is (2.4 MPa.).

The reinforcement of unsaturated polyester with sea nodules particles have a great role in obtaining a higher hardness, A (shore D) type hardness test was used for specimen of polyester before and after reinforcing with particles Figure (10) shown the effect of particles volume fraction on hardness, It can be seen that the hardness of unsaturated polyester increases with increasing the fillers particles size and with the increasing of volume fraction. Adding the filler particles will raise the materials hardness due to the increasing in material resistance against the plastic deformation. Results had revealed that the hardness of unsaturated polyester alone was (78.5 shore D) compared to the maximum value (86 shore D) when particles at volume fraction of (12%) and particle size of (53 µm) have been added as shown in figure (11), the reason of the increase in hardness is that sea nodules contains an elements harder than the matrix like Cobalt, Nickel, Cupper, and Manganese that lead to an increase in hardness of the prepared composite material system.

4- Conclusions

The effect of adding sea nodules particles on some mechanical properties of unsaturated polyester was studied, results shows that the best hardness value was (86 shore D) elastic modulus (5000 MPa.), flexural strength (507 MPa.), and maximum Flexural stress (8.1 MPa.) at volume fraction of (12%) and particle size (53 µm), while the bending phenomena was decreased with increasing in volume fraction also with the decrease in particle size which had a value of (1.55mm) at (12%) volume fraction and (<53 µm) of particle size.

6- References

[1] لميس علي خلف " **دراسة الخصائص الميكانيكية والفيزيائية لمتراكبات البولي استر المدعم بالياف الزجاج والنايلون** " رسالة ماجستير، الجامعة التكنولوجية،2006.

حسين جبار حسين، "**دراسة تاثير بعض خواصد[2] الايبوكسي المدعم بمواد طبيعية وصناعية**"، رسالة ماجستير، الجامعة التكنولوجية، 2005.

[3] Mare Nature Meyers & Krishan Kumar Chawla ,"**Mechanical Behavior of Material**", Prentice-Hall Inc.1999.

[4] Mikell, P. Groover, " **Fundamentals of Modem Manufactory** ", Prentice-Hall Inc.1996.

[5] CH. H. Lerchenthal & M. Brenman, Ports ,'' **Inorganic Particle Reinforced Thermosetting Resins**'', Journal of Composite, Vol.8, No.1, (1977).

[6]R. J. Young & P. W. R. Beaumont, " **Failure of Brittle Polymers by Slow Crack Growth – Part 3 : Effect of Composition Upon the Fracture of Silica Particle - Filled Epoxy Resin Composite** ", Journal of Material Science, Vol.12, No.4, (1978).

[7] H. A. Kereem,'' **Study the Influence of Adding Nickel Powder to a Thermosetting Epoxy Resin on the Mechanical Properties**'',M. Sc. Thesis, University of Technology, Baghdad, (2002).

[8]Witold A. Charewicz, Zho Chaoyin, Tomasz Chmielewski, " **The Leaching Behavior of Ocean Polymetallic Nodules in Chloride Solutions**", Physicochemical Problems of Mineral Processing,Vol.35(2001).

[9] W.D.Callister,JR**.," Materials Science and Engineering An Introduction"** 6th ed., John Wiely and Sons,Inc., New York, (2003).

[10] B. R. Sanders & T. L. Weintraub, **" Matel Hand Book Mechanical Testing "** ,Vol.8 , 9th ed. ,USA, (1985).

[11] N. G. Mccrum, C. P. Buckley & C. B. Bucknall **"Principles of Polymer Engineering"**, 2nd ed., John Wiley & Sons, New York, (1997).

[12] L. Holliday, **"Composite Material"**, Elsevier Publishing, London, (1966).

[13]G. C. Shin, & L. J. Ebert, "**Composite**" , Vol.17, No.4 (1986).

25- Clarke M.T., Lee A., "Arora levels of metal ions after small – and large – diameter metal – on – metal hip arthoplasty", J. Bone Joint Surg., Vol. 85(6), pp.913-920, 2003.

Table (1): some properties of unsaturated polyester resin [9].

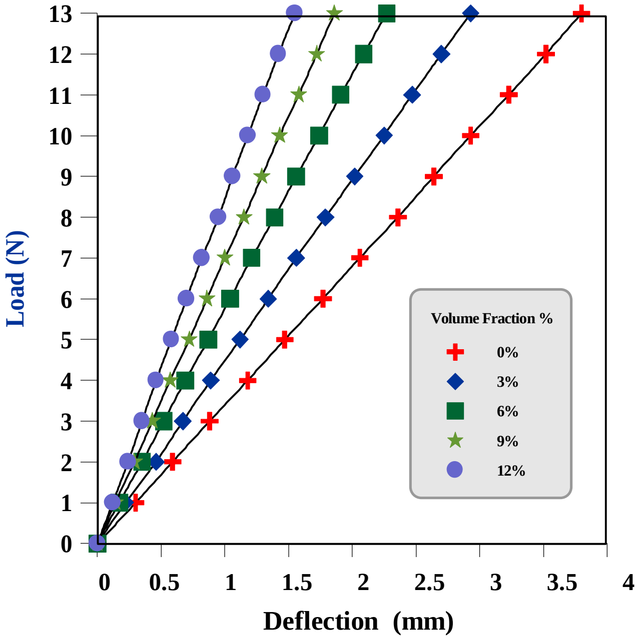
Young's modulus (E) (GPa.)	Tensile strength (MPa.)	Thermal conductivity (W/m. °C)	Density (kg/m^3)
2.06–4.41	70.3 -103	0.17	1200

Table (2): Chemical composition of sea nodules.

Metal	g/L
Cu	1.800
Ni	2.000
Co	0.206
Zn	0.087
Mn	22.51

Table (3): the deflection values at different particle size at volume fraction (12%).

Particle size (μ m)	53	75	106
Deflection (mm)	1.55	1.75	1.92



Figure(1): shown the effect of load on deflection for varying volume fraction with a particle size of (53 μm).

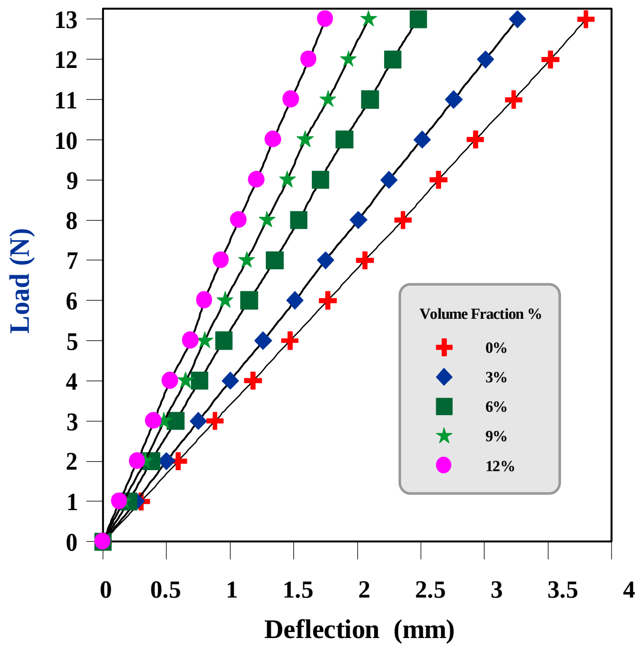


Figure (2): shown the effect of load on deflection for varying volume fraction with a particle size of (75 μm).

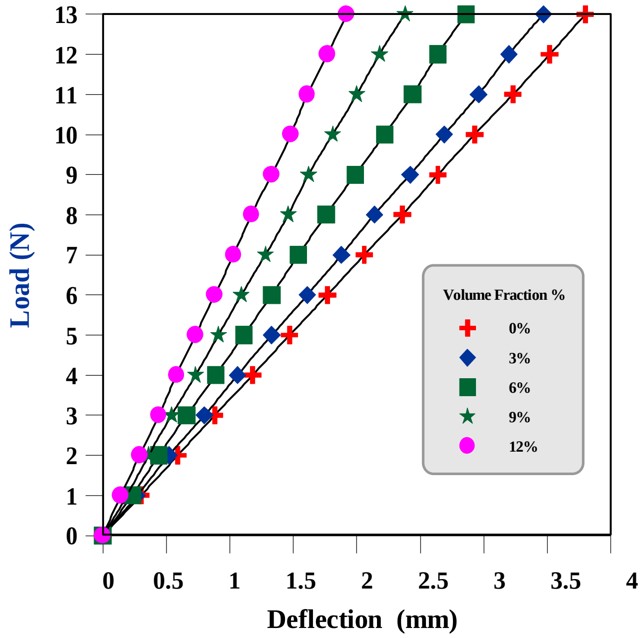
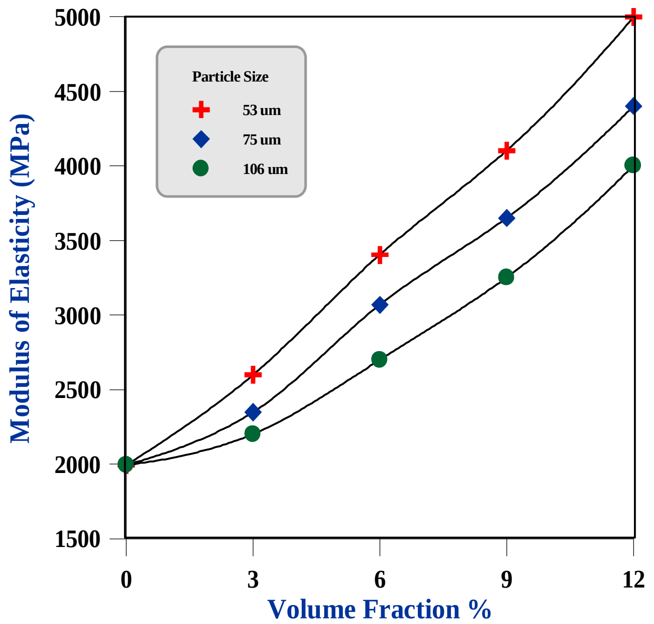


Figure (3): shown the effect of load on deflection for varying volume fraction with a particle size of (106 μm).



Figure(4): shown the effect of volume fraction on young's modulus.

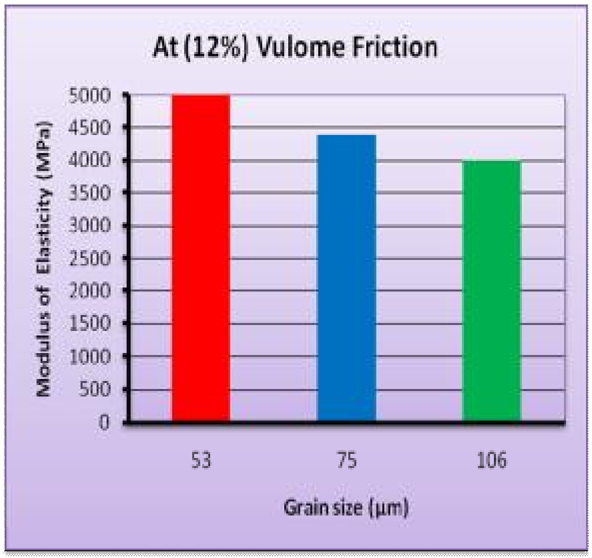


Figure (5): shown the effect of particle size on young's modulus at volume fraction of (12%).

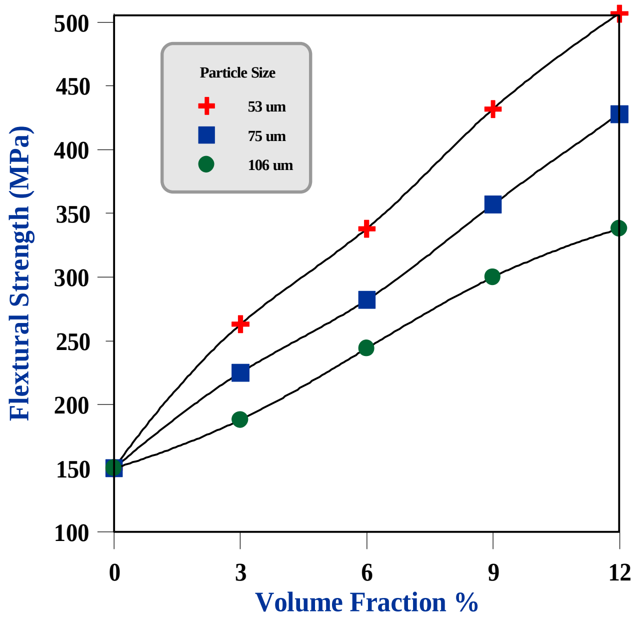


Figure (6): shown the effect of volume fraction on flexural strength.

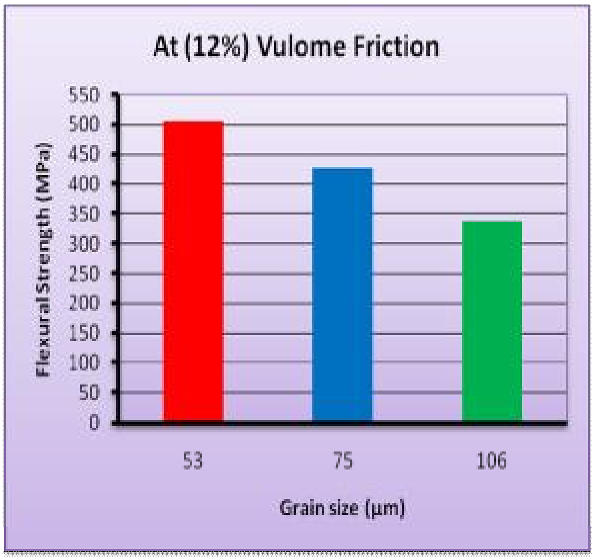


Figure (7): shown the effect of particle size on Flexural strength at volume fraction of (12%).

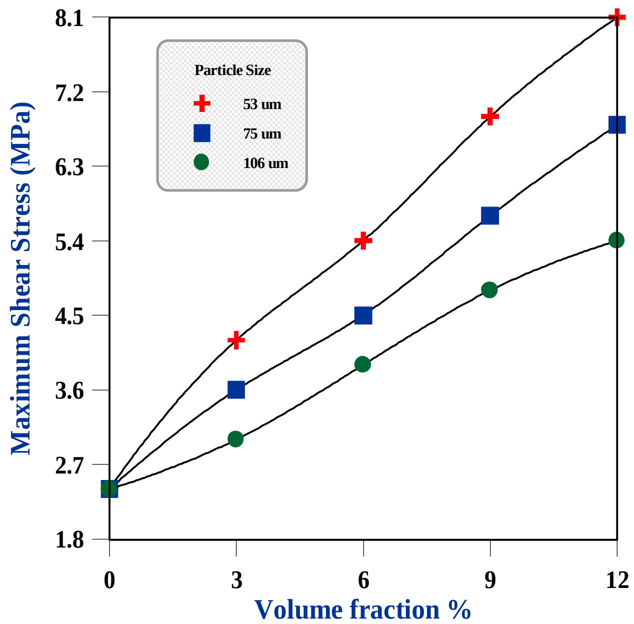


Figure (8): shown the effect of volume fraction on maximum shear stress

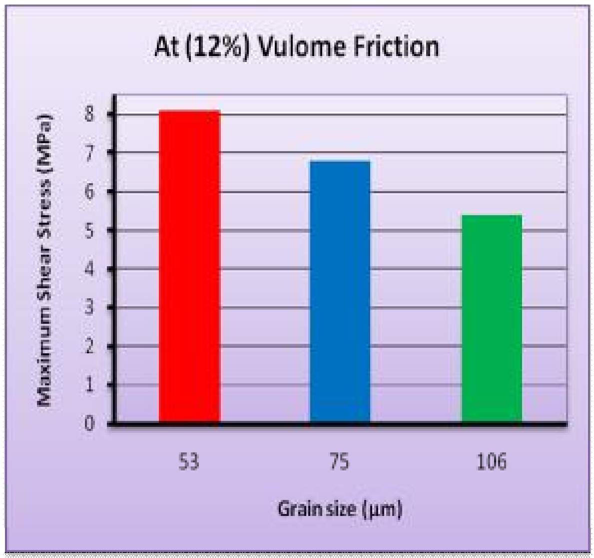


Figure (9): shown the effect of particle size on maximum shear stress at volume fraction of (12%).

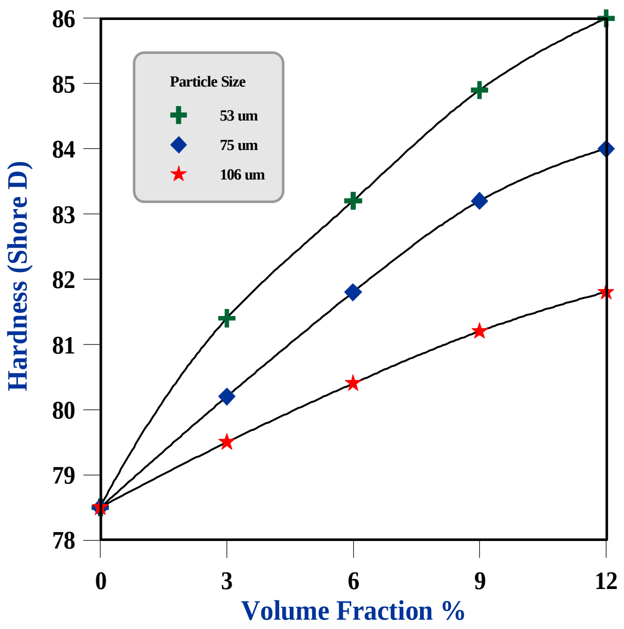


Figure (10): shown the effect of volume fraction on hardness

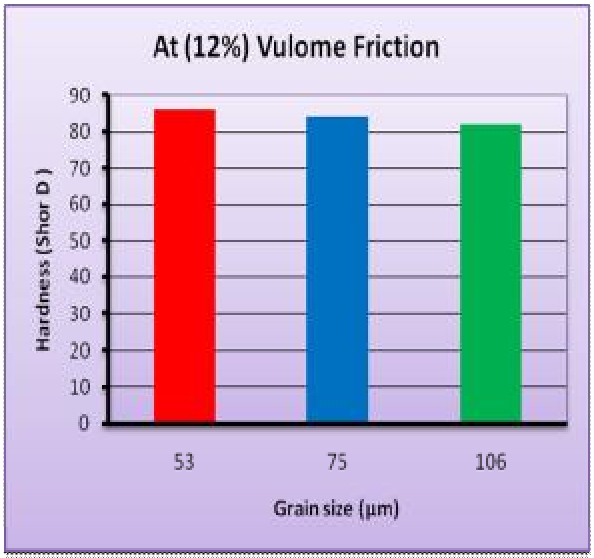


Figure (11): shown the effect of particle size on the hardness at volume fraction of (12%).