FLEXURAL AND IMPACT PROPERTIES OF PMMA NANO COMPOSITES AND PMMA HYBRIDS NANO COMPOSITES USED IN DENTAL APPLICATIONS

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ABSTRACT :-

Due to the enjoyment of poly methyl methacrylate material of significant advantages in mechanical and physical properties, which encouraged many researchers in recent years working on the used it's as a prosthodontics denture base material. In the present research, efforts are made to develop the properties of PMMA resin that used for upper and lower prosthesis complete denture, by addition four different types of nanoparticles powders, which are fly ash, fly dust, zirconia and aluminum that added with different ratios of volume fractions of (1%, 2% and 3%) to poly methyl methacrylate (PMMA), cold cured resin (castavaria) is the new fluid resin (pour type) as a matrix. In this work, the Nano composite and hybrid Nano composite for prosthetic dentures specimens, preparation was done by using (Hand Lay-Up) method as six groups which includes: the first three groups consists of PMMA resin reinforced by fly ash , fly dust and ZrO_2 nanoparticles respectively, the second three groups consists of three types of hybrid Nano composites, which includes ((PMMA: X%nF.A)+(1%Al+3%ZrO_2)), ((PMMA: X%nF.D)+ (1%Al + 3%ZrO_2)) and ((PMMA - nZrO_2)+(1%F.A + 3%F.D)) respectively. The flexural and impact tests results show that the values of the flexural strength, Maximum Shear stress, flexural modules, impact strength and fracture toughness increased with the addition of nano powders (fly ash, fly dust, zirconia and aluminum). And the results showed that the maximum values of flexural strength and Maximum shear stress reaches to 101Mpa and 2.4738Mpa respectively for (PMMA: 2%nF.D) Nano composite. Moreover, the results showed that the maximum values of flexural modules for hybrid Nano composite ((PMMA: 3% nF.A) + (1%Al + 3%ZrO_2)) reach to 13.95 Gpa, whereas the maximum values of impact strength reaches to 7.8KJ/m^2 for (PMMA: 1% nF.D) Nano composite. And, the results showed that the maximum values of fracture toughness for Nano composite reach to 26.8 Mpa.$m^{1/2}$ for (PMMA: 3% nF.D) Nano composite.

KEY WORDS: Hybrid Nano Composites, Nano Composites, PMMA, Fly Ash nanoparticles, Fly Dust nanoparticles, Aluminum nanoparticles, Zirconium Oxide nanoparticles, Flexural and Impact Strength.

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خصائص الأنحناء و الصدمة لمتراكبات البولي مثيل ميثا اكريليت النانوية و متراكبات البولي مثيل ميثا اكريليت النانوية الهجينة المستخدمة في تطبيقات طب الأسنان

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الخلاصة :

نظرا لما تتمتع بها مادة البولي مثيل ميثا اكريليت من مزايا هامة في خواصها الميكانيكية والفيزيائية، مما شجع العديد من الباحثين في السنوات الأخيرة في العمل على استخدامها كمادة قاعدة أسنان تعويضية. في هذا البحث تم أجراء عدة محاولات لغرض تطوير مواصفات راتنج البولي مثيل ميثا اكريليت المستخدم كقاعدة طقم أسنان أصطناعي كامل علوي أو سفلي. وقد حضرت المواد المتراكبة من راتنج البولي مثيل ميثا أكريليت المعالج ذاتياً (كاستافاريا) كمادة أساس وقد تم تقويتها بأربعة أنواع مختلفة من المساحيق النانوية تضمنت: دقا ئق الرماد المتطايرالنانوية، دقائق الغبار المتطايرالنانوية، دقائق أوكسيد الزركونيوم النانوية ودقائق الألمنيوم النانوية، أضيفت الدقائق النانوية بكسور حجمية مختارة هي (1%, 2% and 3%). في هذا البحث حضرت ستة مجاميع من العينات كأطقام للأسنان الأصطناعية المتراكبة النانوية و المتراكبة النانوية الهجينة بطريقة (الصب اليدوي). المجاميع الثلاثة الأولى تضم راتنج البولي مثيل ميثا اكريليت المقواة بدقائق الرماد المتطايرالنانوية، دقائق الغبار المتطايرالنانوية ودقائق أوكسيد الزركونيوم النانوية على التوالي، المجاميع الثلاثة الثانية تضم ثلاثة أنواع من المتراكبات النانوية الهجينة وهي ((PMMA: X% nF.A) + (1%Al+3% ZrO2)) ، (PMMA: X%) ((1%Al +3% ZrO2)+nF.D) و ((PMMA -nZrO2) + (1%F.A + 3%F.D)) على التوالي. أظهرت نتائج أختبارات الأنحناء و الصدمة أن قيم مقاومة الأنحناء ، أجهاد القص الأعظم، معامل الأنحناء، مقاومة الصدمة و متانة الكسر زادت مع إضافة دقا ئق الرماد المتطاير النانوية، دقائق الغبار المتطايرالنانوية ودقائق أوكسيد الزركونيوم النانوية. وأظهرت النتائج بأن القيم القصوى لمقاومة الانحناء و أجهاد القص الأعظم وصلت إلى 101Mpa و 2.4738Mpa بالتعاقب للمتراكبة النانوية (PMMA: 1% nF.D). أيضا، أظهرت النتائج بأن القيم القصوى لمعامل الأنحناء وصلت إلى 13.95Gpa للمتراكبة النانوية الهجينة ((PMMA: 3% nF.A)+(1%Al+3% ZrO2)) ، وعلاوة على ذلك، أظهرت النتائج بأن القيم القصوى لمقاومة الصدمة وصلت إلى $7.8\ KJ/m^2$ للمتراكبة النانوية (PMMA: 1% nF.D)، كما وبينت النتائج بأن القيم القصوى لمتانة الكسر وصلت إلى $26.8\ Mpa.m^{1/2}$ للمتراكبة النانوية (PMMA:1% nF.D)

الكلمات المرشدة : المتراكبات النانوية الهجينة ، المتراكبات النانوية ، بولي مثيل ميثا أكريليت، دقائق الرماد المتطاير النانويه، دقائق الغبار المتطاير النانوية، دقائق الألمنيوم النانوية، دقائق أوكسيد الزركونيوم النانوية، مقاومة لانحناء و الصدمة.

1-INTRODUCTION :-

A biomaterial can be defined as any synthetic or natural material that is used to replace or restore function to a body tissue and is continuously or intermittently in contact with body fluids. Complete or partial denture base material represented one type of biomaterials that must be have good mechanical properties such as stiffness, toughness, hardness and resistance to wear and abrasion, and good thermal properties such as thermal conductivity, thermal diffusivity, and Dimensional stability, tissue compatibility (non-toxic or allergic), Color stability, good chemical stability, in addition to esthetical pleasing and use in the oral cavity (Anusavice K.J., 2008). Particulate composite materials consisting of polymer resin as matrix and particles as reinforcement phase. The particles in these composites are smaller than in large particles strengthened composites. The particle diameter is typically on the order of a nano meter. In this case, the particles carry a major portion of the load. The particles are used to increase the modulus and decrease the ductility of the matrix. Particle reinforced composites are much easier and less costly than making fiber reinforced composites. Polymer composite materials reinforced with particles (ceramic, metal particles) can be used for various engineering applications to provide unique mechanical and physical properties with a low specific weight. In order to achieve better mechanical strength, it is usually reinforced with ceramic powders or fibers (aramid, carbon and glass). Ceramic particles with small size are known to enhance the tribological and mechanical properties of polymers (Bernd W. et. al., 2003). Fly ash, an industrial waste, can be used as a potential filler material in polymer matrix composites because it is a mixture of oxide ceramics. It improves the physical and mechanical properties of the composites (Amar P. et. al., 2009).

Chow Wen Shyang, (2013), studied the effect of the addition of hydroxyapatite (HA) particles on the flexural properties of a heat polymerizing PMMA denture base resin. The results showed that the flexural modulus, flexural strain and flexural strength of PMMA/HA composites were decreased with the addition of hydroxyapatite (HA) particles.

Hanan Abdul et. al, (2013), investigated the effect of the addition of siwak micro powder on the Certain Mechanical Properties of Acrylic Resin. The results showed that the addition of (7 %) siwak powder to the Acrylic Resin revealed a significant decrease in compressive strength, impact strength and tensile strength.

Mohamed Ashour Ahmed, (2014), investigated the effect of the addition of zirconium oxide (ZrO_2) nano powder with different weight fraction on the some mechanical properties of heat-polymerized acrylic resin. The results showed that significantly increased the fracture toughness, hardness and flexural strength of heat-polymerized acrylic resin, and the best mechanical properties were achieved by adding 7%wt ZrO_2.

H. K. Hameed, (2015), investigated the effect of the addition of silanized zirconium oxide (ZrO_2) nano powder to acrylic resin cured by autoclave. The results showed that the addition of silanized Zirconium oxide improved transverse and impact strength of denture base nano composite reinforced with5% weight fraction of nano- ZrO_2, also, the results showed slightly increases the surface roughness; hardness and the apparent porosity also decrease by addition of nano ZrO_2 weight fraction increase.

S.I. Salih et al., (2015), investigated the comparative study of the flexural properties and impact strength for PMMA prosthetic complete denture base reinforced by different particles. The result showed the flexural properties increased with increasing of the volume fraction of (nHA) and (ZrO_2) particles in polymer composite, while, the impact strength decreased. The results one recent study showed that the addition of 3% wt of treated (silanized) titanium oxide nano filler into heat cured acrylic denture base material will a highly increases the impact strength and transverse strength, and a significant increase in surface hardness and surface roughness (S. A. Alwan et al., (2015) . **The objective** of the current work is attempts to develop a PMMA resin which is used in the denture base and in dental prosthesis applications. Through study the effect of adding different nanoparticles powders, on the flexural strength and impact properties for PMMA Nano composites, and hybrids Nano composites.

2- MATERIALS AND METHODS :-

2-1 Materials Used

In this research poly methyl methacrylate (PMMA) cold curing as new pour (fluid) resin type (Castavaria) has been used, provided from (Vertex – Dental Company). Table (1) shows some of the mechanical and physical properties of cold cure PMMA according to the supplied Company. Four types of nanoparticles powders were used as reinforces materials with selection volume fraction ratios of (1%, 2% and 3%) including: the fly ash nanoparticles (nF.A) class B Obtained from the England with dark gray color, fly dust nanoparticles (nF.D) obtained from the cement plants in Kufa with Yellowish brown color. Table (2) and Table (3) shows the chemical composition analyses of fly ash and fly dust nanoparticle powders respectively which was used in this research, zirconium oxide nanoparticles ($nZrO_2$) were supplied as partially stabilized particles form, which provided from (ZIRCON Company in England) and aluminum nanoparticles with dull gray color. Atomic Force Microscope (AFM) is used to measuring the average particle size of the nano powders materials, which is shown that the average diameter for each of fly ash, fly dust, ZrO_2 and aluminum are (64.94nm), (84.23nm), (84.35nm) and (53.87nm) respectively. The results of particle size distribution for these nano powders is show in the Figure (1 (a, b, c and d)) respectively.

2-2 Preparation Methods and Curing Cycle of Test Specimens

The PMMA Nano composite materials and hybrid Nano composite materials specimens were prepared by using the Vertex™ - Castavaria. According to the manufacturer's instructions of Manufacturer Company, the standard proportion in mixing ratio for cold cure PMMA resin is (1 ml) (0.95g) monomer liquid (MMA) and (1.7 g) acrylic powder (PMMA).

The Vertex acrylic Castavaria is moldable, where the liquid monomer (MMA) was placed in dry glass container, followed after that with slow addition of dry powder (PMMA) to the liquid monomer (MMA). After pouring completion into the metallic mould, the metallic mould was placed in the multi cure system (Ivo met) manufactured by Vertex-dental company according to the polymerization curing instructions at temperature equal to (55°C) and pressure equal to (2.5 bar) for (30 min) in order to complete the polymerization process of the acrylic specimens. After the polymerization curing completed, the specimens were de molding to remove from the metallic mould with very smooth upper and lower surface.

2-3 Composites and Hybrid Composites Specimens

Six groups of specimens which preparation in this research for the prosthetic denture base , includes, the first three groups, is prepared as a Nano composite specimens divided into nine Nano composites ,consists of PMMA resin reinforced by fly ash , fly dust and ZrO_2 nanoparticles, with selection volume fraction ratios of (1%, 2% and 3%) respectively, and the second three of groups, divided into nine specimens consists of three groups of hybrid Nano composites, which are ((PMMA: X% nF.A)+(1%Al + 3%ZrO_2)), ((PMMA: X% nD.A)+(1%Al + 3%ZrO_2)) and ((PMMA -X%nZrO_2)+ (1%F.A + 3%F.D)) respectively. According to the concentration of the reinforcement materials for all specimens of these groups are shown in the Table (4).

3- MECHANICAL TESTING :-

In order to evaluation of the flexural strength and impact strength properties for all the prepared composites and hybrids composites samples, flexural test and impact test were performed in this research. According to (ADA Specification No.12, 1999), all the test specimens after preparation and polishing processes must be stored in distilled water at (37± 1℃) for 48 hr.

3-1 Flexural Test

The denture base materials are subjected to the many and complex stresses such as compressive stress at the denture base interior surface (upper surface), maximum shear stress at the denture base interface and tensile stress at the external surface (lower surface). Depending on the bond strength between the reinforcement and matrix materials, and the type of reinforcement and matrix materials, the fail of the composite materials take place as a result of effect one of these stresses. In the impact test the sample is exposed to the rapid motion stress, while in the flexural test the sample is exposed to the slow motion stress. Flexural strength is one of the most important property because under flexural load (after measuring it from flexural test), fracture resistance and stiffness of the materials can be measured . The flexural test was performed according to the international standard (ISO 178, 2003) at room temperature by using the universal tensile test machine manufactured by (Laryee Company in china); type is (WDW-50). The strain rate (cross head speed) was (0.5mm/min) and the load was applied gradually until the fracture of the specimen occurs (Abdel R. H, 2012 and Annual Book of ISO Standard, 2003).
The flexural strength, flexural modulus and Maximum Shear stress can be calculated from the following equations: (A. Brent Strong, 2000).

$$\sigma = \frac{3\,FL}{2wh^2} \quad (1)$$

$$E_f = \frac{FL^3}{4\partial wh^3} = \frac{mL^3}{4wh^2} \quad (2)$$

$$\tau_{max} = \frac{3F}{4wh} \quad (3)$$

Where:-

σ: Flexural strength (MPa). E_f: Flexural modulus (GPa). ∂: Is the deflection of the beam when a force F is applied. τ_{max}: Maximum shear stress (MPa). F: Is the fracture load (N). L: Is the distance between the two supported points. W: Is the width of the specimen (m). H: Is the thickness of the specimen (m).

3-2 Impact Test

Impact strength can be defined as the ability of the material to absorb and dissipate energies. Impact strength can be used to measure the strength of material under shock or impact loading. The acrylic denture base materials have tendency to fracture if by accident fall on the hard

surface, therefore Impact strength represented very important property for acrylic denture base materials.
According to the to the international standard (ISO – 180, 2006) with some modifications, the impact test was performed at room temperature by using the Izod Impact test machine, manufactured by (Time Testing Machine in China), type is (XJU series pendulum Izod testing machine). The impact energy of the pendulum required for fracturing the specimen was equal to (5.5 J) and impact velocity equal to (3.5 m/s). In this test, the impact test specimens without notch (Annual Book of ISO Standard, 2006). Fracture toughness can be calculated from the following relationship: (N.N.B. Mohammad et. al., 2013).

$$Kc = \sqrt{G_c E_f} \quad (5)$$

Where:-
K_c: Is fracture toughness of the sample ($Pa\sqrt{m}$). G_c: Is impact strength of the material (KJ/m^2). E_f: Is Flexible modulus (GPa).

4- MECHANICAL TESTS RESULTS AND DISCUSSION :-

4-1 Results and Discussion of Flexural Test

The flexural strength, Maximum shear stress and flexural modules values of pure PMMA, PMMA Nano composite and PMMA hybrid Nano composite materials for all samples that were prepared in this research are presented from the Figure (2) to Figure (13) respectively.

Figure (2), Figure (3) and Figure (4) shows the effect of adding various types of nanoparticles powders (fly ash, fly dust and zirconium oxide) on the flexural strength, Maximum shear stress and flexural modulus, addition of the fly ash, fly dust and zirconia nanoparticles powders leads to increase the flexural strength and Maximum shear stress as well as flexural modulus of the PMMA Nano composites, moreover it can be observed from Figures (2, 3 and 4), that flexural strength and Maximum shear stress reach to maximum value at (2%) ratio of volume fraction as comparing with pure PMMA, whereas flexural modulus, was increased with all ratios of the volume fraction of the nanoparticles content in the Nano composites. The reasons behind such a behavior are that the high interfacial shear strength between the PMMA matrix and nanoparticles because of the formation of supra molecular or cross-links bonding which shield or cover the nanoparticles and this in turn prevent the propagation of the cracks inside the material, as well as the propagation of the crack can be changed by good bonding between the PMMA matrix and nanoparticles (N.N.B. Mohammad et. al., 2013). Moreover, the incorporation of the hard nanoparticles into the polymer matrix improves the stiffness of the Nano composites by restricted the mobility of the matrix chains (Abdel R. H, 2012). Also, the good distribution of nanoparticles especially at the low percentages of nanoparticles additives to the Nano composites materials, and this will reduce agglomeration of the nanoparticles and that may be lead to reduces stress concentration in composite materials near the agglomerated nanoparticles and such small stresses are not sufficient enough to break the weak interactions at the interface (Bernd Wetzel et. al., 2003). Therefore, these small stresses can be easily transferred from the matrix to the hard nanoparticles, so allowing the particles to contribute its high flexural property to the Nano composites, and thus will increase the values of each of the flexural strengthl and flexural modulus as well as Maximum shear stress (R.Satheesh Raja et. al., 2013). Overtime, the formation of a strong structure of the PMMA Nano composite materials which depending on the formation of strong interfaces bonding between the reinforcing nanoparticles (F.A, F.D and

ZrO_2) and PMMA material, so that the resultant is Nano composite materials with strong physical bonding, therefore required high flexural and shear stress to break it and this lead to increasing flexural strength, flexural modulus and maximum shear stress. On the contrary, it can be noted from the Figures (2 and 3) that the addition of the zirconia nanoparticles leads to decrease the flexural strength and maximum shear stress of the PMMA Nano composites as comparing with pure PMMA. The reasons behind such a behavior are that the agglomeration and stick of the zirconium oxide nano powder together, so on this powder plays an important role in stress concentrators. So, when the flexural and shear stress was applied on the specimen, the value of the stress concentration increases dramatically near the agglomerated nanoparticles and making the de bonding between PMMA and zirconium oxide nanoparticles and this cause cracks propagate faster inside the material so that, the fracture occurs immediately (Arezou S et. al., 2015). Furthermore, the bad wettability between zirconia nanoparticles and PMMA matrix especially at high concentrations, so that the resultant is composite material with weak physical bonding, therefore required low flexural and shear stress to break it.

Furthermore, it observes from Figures (2 and 3) that the Nano composites materials which is reinforced with the fly dust nanoparticles have the higher values of flexural strength and maximum shear stress, as compared with their counter parts of the other groups of the Nano composites materials which reinforced with fly ash and zirconia nanoparticles. The reason behind such a behavior is that the chemical composition of the fly dust contain Alumina, lithium oxide and calcium oxide nanoparticles (Al_2O_3, LiO and CaO) as showed earlier in the Table (3) which possesses strong ionic inter atomic bonding, giving rise to the flexural strength and Maximum shear stress of the Nano composite materials (Majid Safarabadi et. al., 2014). Whereas it can be seen from Figure (4) that the Nano composites materials which is reinforced with the zirconia nanoparticles have the higher values of flexural modulus as compared with their counter parts of the other groups of the Nano composites materials which reinforced with fly ash and fly dust nanoparticles. The reason behind such a behavior is that the improvement of the mechanical properties that is associated with the addition of zirconium oxide nanoparticles, as well as has good compatibility between constituents of Nano composite materials.

The effect of the addition of the mixture of nanoparticles powders (1%Al and 3% ZrO_2) to the Nano composite materials (PMMA: X%nF.A) and (PMMA: X%nF.D), on the flexural strength, Maximum shear stress and flexural modulus for the product hybrid Nano composites it was show in Figures (5, 6 and 7) and (8, 9 and 10) respectively. It was noticed from Figures (5, 6, 8 and 9) that the addition of the mixture of nanoparticles powders with ratio of (1%Al+3% ZrO_2), leads to deccrease the flexural strength and Maximum shear stress of the product of hybrids Nano composites as comparing with their counter parts of Nano composites which are (PMMA: X%nF.A) and (PMMA: X%nF.D) of the same volume fraction ratio of fly ash and fly dust respectively. On the contrary, it was observed from Figures (7 and 10) that the addition of the mixture of nanoparticles powders with ratio of (1%Al+3% ZrO_2) leads to increase the flexural modules of the product of hybrids Nano composites, as comparing with their counter parts of Nano composites which are (PMMA: X%nF.A) and (PMMA: X%nF.D) of the same volume fraction ratio of fly ash and fly dust respectively. On the other hand, it can be noted from Figures (11, 12 and 13) that the addition of the mixture of nanoparticles powders with ratio of (1%F.A+3%F.D) to the Nano composite materials (PMMA: X%nZrO_2) leads to increase the flexural strength and Maximum shear stress as well as flexural modules of the product of hybrids Nano composites as comparing with its counter parts of Nano composites which is (PMMA: X%nZrO_2) especially at 2% and 3% ratio of the volume fraction for zirconia content in the Nano composite. The reasons behind such a behavior are related to the same reasons which mentioned in the previous item.

4-2 Impact Test Results and Discussion

The impact strength and fracture toughness values of pure PMMA, PMMA Nano composite and PMMA hybrids Nano composite materials for all samples that were prepared in this research are presented from the Figure (14) to Figure (21), respectively.

Figures (14 and 15), show the effect of adding various types of nanoparticles powders (fly ash, fly dust and zirconium oxide) on the impact strength and fracture toughness of PMMA Nano composites respectively. It can be noted from Figure (14) that the addition of these nanoparticles powders leads to increase the impact strength of the products of PMMA Nano composites and reach to maximum value at (1%) of volume fraction as comparing with pure PMMA. As well as, it can be noted from Figure (15) that the fracture toughness increased with increasing of the volume fractions of (fly ash, fly dust and zirconium oxide) nanoparticles in the PMMA Nano composites. The reasons behind such a behavior are mentioned earlier in the previous item (4-1). Furthermore, it can be noted from the Figure (14) that the addition of the fly ash and zirconia nanoparticles to larger than 2% ratio leads to decrease the impact strength of the PMMA Nano composites to the values less than it is in the case of neat PMMA. The reasons behind such a behavior are related to the bad distribution of nanoparticles especially at the high ratios of percentages of nanoparticles additives to the Nano composites materials, and this will be lead to the larger agglomeration of the nanoparticles and that may be lead to increase the stress concentration in composite materials near the agglomerated nanoparticles and such tresses are enough to break the interactions at the interface and making the de bonding between PMMA and nanoparticles powders and this cause cracks propagate faster inside the material so that, the fracture occurs immediately (A. Brent Strong, 2000 and Arezou S et. al., 2015). Besides, the reduction of the elasticity (toughness) of the material because of the addition hard nanoparticles which leads to reducing the deformability of the matrix by restricted the mobility of the matrix chains and also, the high concentrations of the nanoparticles leads to reduces the ability of the PMMA matrix to absorb energy and therefore, decreasing the toughness, so that the impact strength decreases (Majid Safarabadi et. al., 2014 and M.S.Sreekanth et. al., 2009).

Moreover, it observe from Figures (14 and 15) that the Nano composites materials reinforced with the fly dust nanoparticle have the higher values of impact strength and fracture toughness respectively, as compared with their counter parts of the other groups of the Nano composites materials which reinforced with fly ash and zirconium oxide nanoparticles.

The effect of the addition of the mixture of nanoparticles powders (1%Al and 3% ZrO_2) to the Nano composite materials (PMMA: X%nF.A) and (PMMA: X%nF.D), as well as the addition of the mixture of nanoparticles powders (1%F.A+3%F.D) to the Nano composite materials (PMMA: X%nZrO_2), on the impact strength and fracture toughness for the product of hybrids Nano composite materials [((PMMA: X%nF.A)+(1%Al and 3%ZrO_2)), ((PMMA: X%nF.D)+(1%Al and 3%ZrO_2)) and ((PMMA: X%nZrO_2)+(1%F.A and 3% F.D))], it was show in Figures (16 , 17 and 18) and Figures (19,20 and 21) respectively. It was noticed from these Figures that the addition of the mixture of nanoparticles powders with ratio of (1%Al+3%ZrO_2) to the Nano composite materials (PMMA: X%nF.A) and (PMMA: X%nF.D) respectively, as well as the addition of the mixture of nanoparticles powders with ratio of

(1%F.A+3%F.D) to the Nano composite materials (PMMA: X%nZrO_2) leads to decrease the impact strength and fracture toughness of the product of hybrids Nano composites as comparing with their counter parts of Nano composites which are (PMMA: X%nF.A), (PMMA: X%nF.D) and(PMMA: X%nZrO_2). But the fracture toughness values (figures 19, 20 and 21) remained higher values than they are in the (PMMA) original parent material. The reasons behind such a behavior are related to the same reasons which mentioned in the previous item (4-1).

5- CONCLUSIONS :-

In the present work, attempts are made to development PMMA polymer which is used in the denture base and in dental prostheses applications. So the Nano composites and hybrid Nano composites with desirable properties were attended, by adding three types of nano powders (fly ash, fly dust and ZrO_2) at the same ratio to it, and it was concluded the following:-

- The addition of fly dust nanoparticles to PMMA has a noticeable effect on the flexural strength, Maximum shear stress, impact strength and fracture toughness of the Nano composite and hybrid Nano composite as prosthetic denture base specimens as compared with the F.A and ZrO_2 nanoparticles.
- The addition of ZrO_2 nanoparticles to PMMA has a noticeable effect on the flexural modules of the Nano composite and hybrid Nano composite as prosthetic denture base specimens as compared with the F.A and F.D nanoparticles.
- In the current work, the maximum values for the flexural strength and Maximum shear stress (101MPa), (2.474MPa) respectively, were obtained in the Nano composite material (PMMA-2% nF.D), the maximum value for the flexural modules (13.95MPa) was obtained in the hybrid Nano composite material ((PMMA – 3% nF.A) + (1%Al + 3% ZrO_2)), the maximum value for the impact strength (7.8KJm^2) was obtained in the Nano composite material (PMMA-1% nF.D) and the maximum value for the fracture toughness (26.8MPa $m^{1/2}$) was obtained in the Nano composite material (PMMA-3% nF.D).
- The mechanical properties such as (flexural strength, Maximum shear stress and impact strength) increased with the addition low concentrations of (fly ash, fly dust and zirconium oxide) nanoparticles and decreased with the addition high concentrations to larger than 2% of the all nanoparticles to the PMMA Nano composites and PMMA hybrid Nano composites.
- The flexural modules and fracture toughness increased with increasing of the volume fractions of (fly ash, fly dust and zirconium oxide) nanoparticles in the PMMA Nano composites and PMMA hybrid Nano composites.

(Table 1): Some Mechanical and Physical Properties of Pour PMMA Polymer used in this Rsearch According to (Vertex – Dental Company).

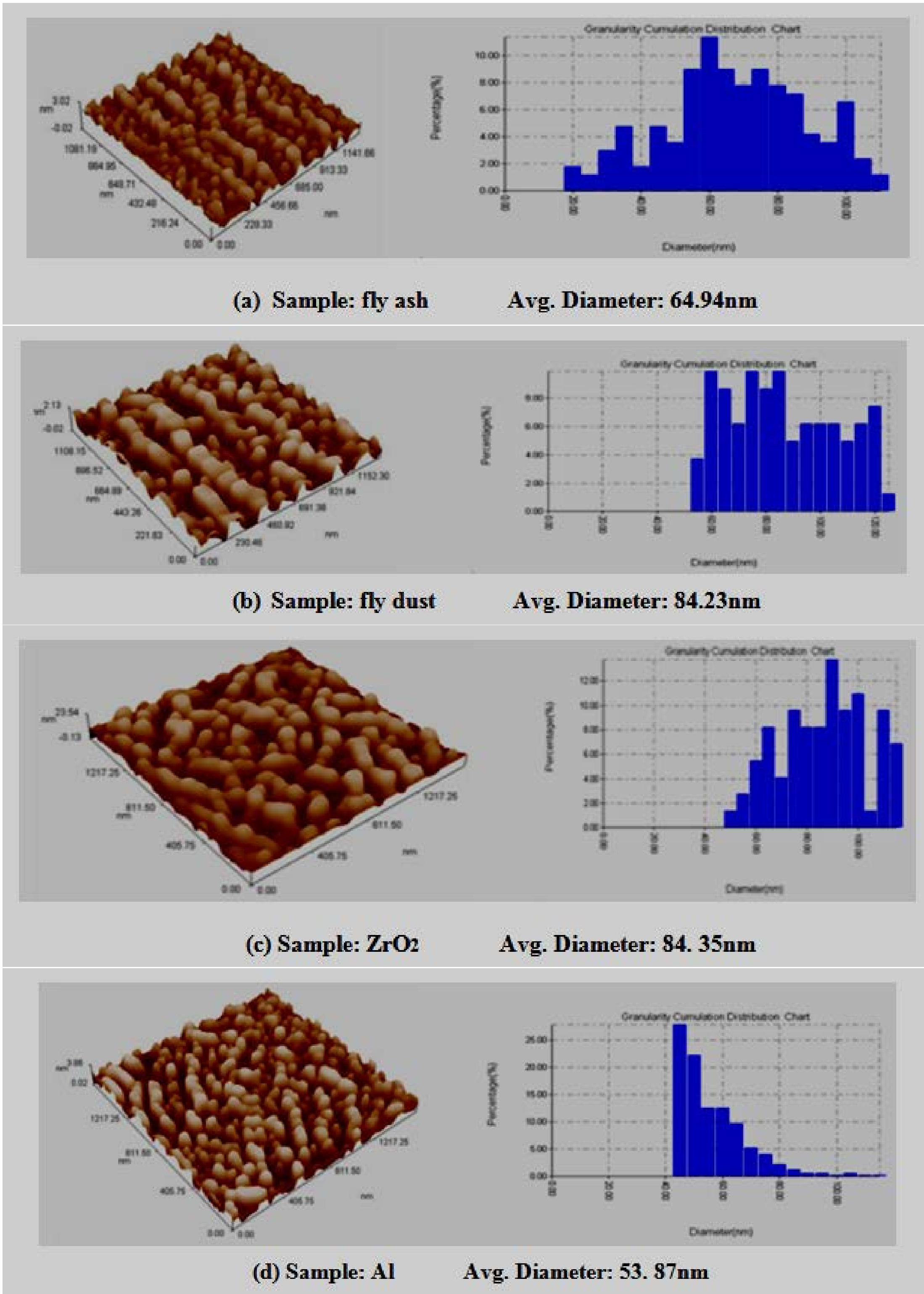
Young's Modulus (GPa)	Impact Resistance (KJ/m^2)	Flexural Strength (MPa)	Flexural Modulus (GPa)	Water Sorption (µg/mm^3)	Solubility (µg/mm^3)	Water Absorption (%)	Density (gm/cm^)
1.63-3	8.3	79	2.3	23.2	1.8	2.5	1.19

(Table 2): Chemical Composition Analyses of Fly Ash used in this Research.

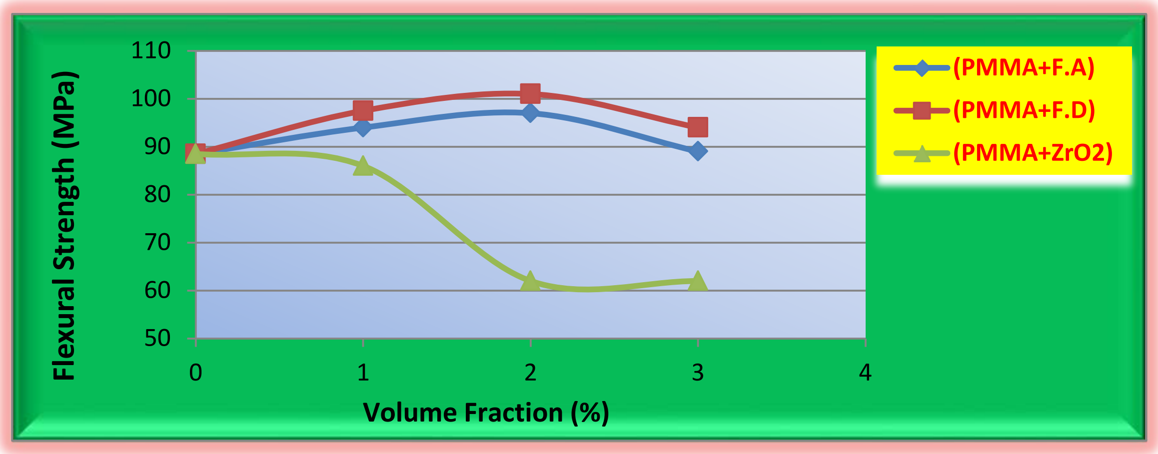
Element Oxide	SiO_2	Al_2O_3	TiO_2	MgO	K_2O	CaO	Fe_2O_3	Mn_2O_3	Na_2O	P_2O_3	L.O.I
The weight (%)	58.2	27.7	1.4	0.05	3.59	0.84	4.99	0.31	0.74	0.34	1.84

(Table 3): Chemical Composition Analyses of Fly Dust used in this Research.

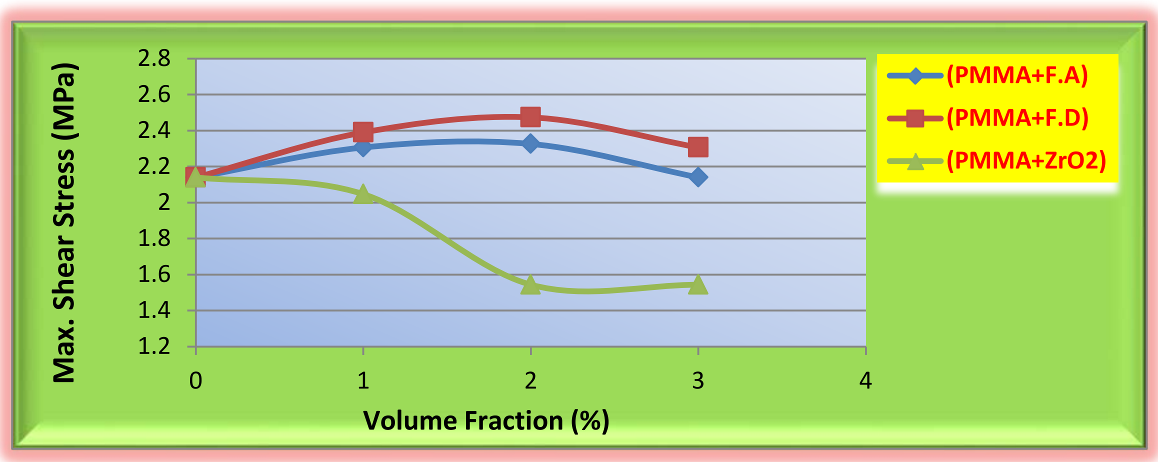
Element Oxide	SiO_2	Al_2O_3	LiO	MgO	CaO	Fe_2O_3	L.O.I
The weight (%)	12.30	3.02	29.30	4.80	38.08	2.91	9.48



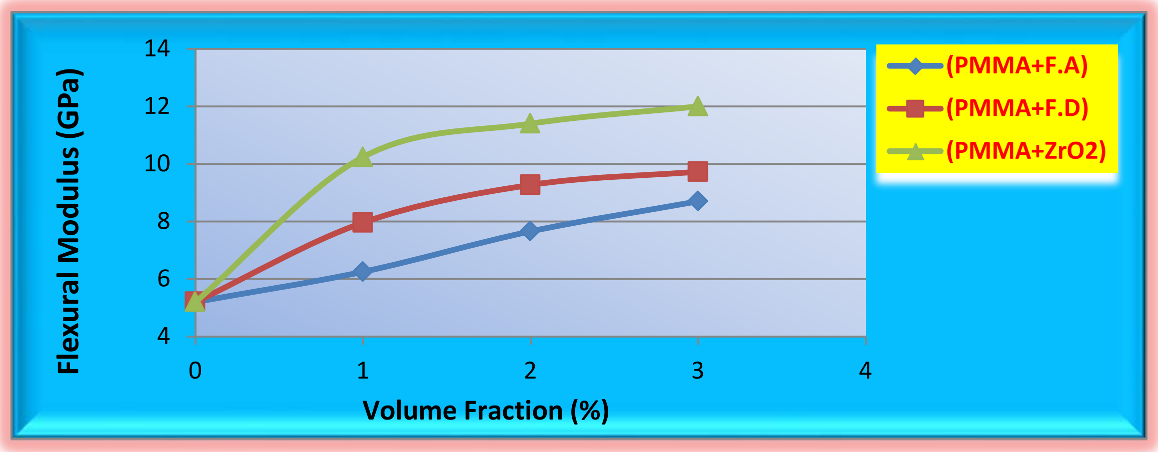
(Fig. 1): Atomic Force Microscopy Test for Nano powders (a) fly ash (b) fly dust (c) Zirconium oxide and (d) aluminum



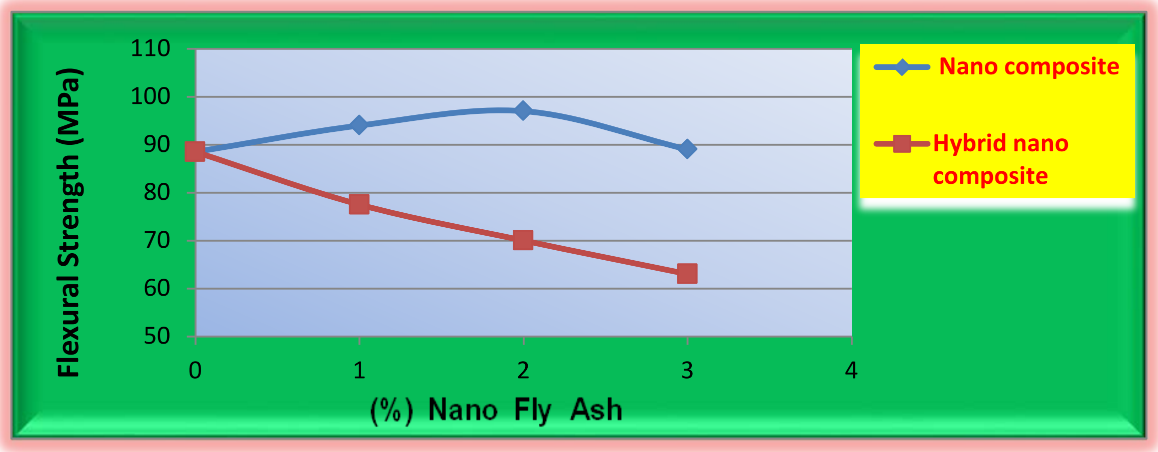
(Fig.2): Flexural Strength of PMMA Nano Composite Materials as a Function of volume fraction of nanoparticles (F.A, F.D and ZrO_2) in PMMA matrix.



(Fig.3): Max. Shear Stress of PMMA Nano Composite Materials as a Function of volume fraction of nanoparticles (F.A, F.D and ZrO_2) in PMMA matrix.

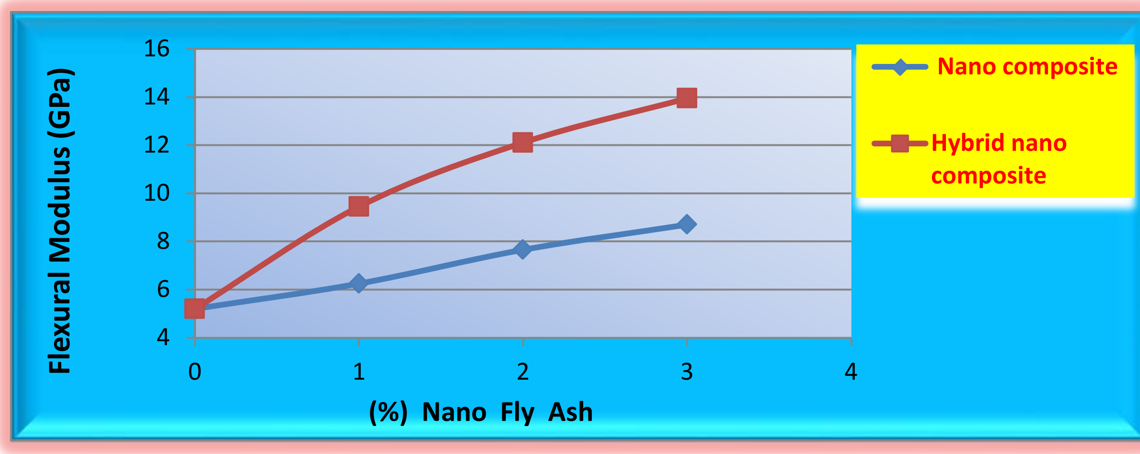


(Fig.4): Flexural Modules of PMMA Nano Composite Materials as a Function of volume fraction of nanoparticles (F.A, F.D and ZrO_2) in PMMA matrix.

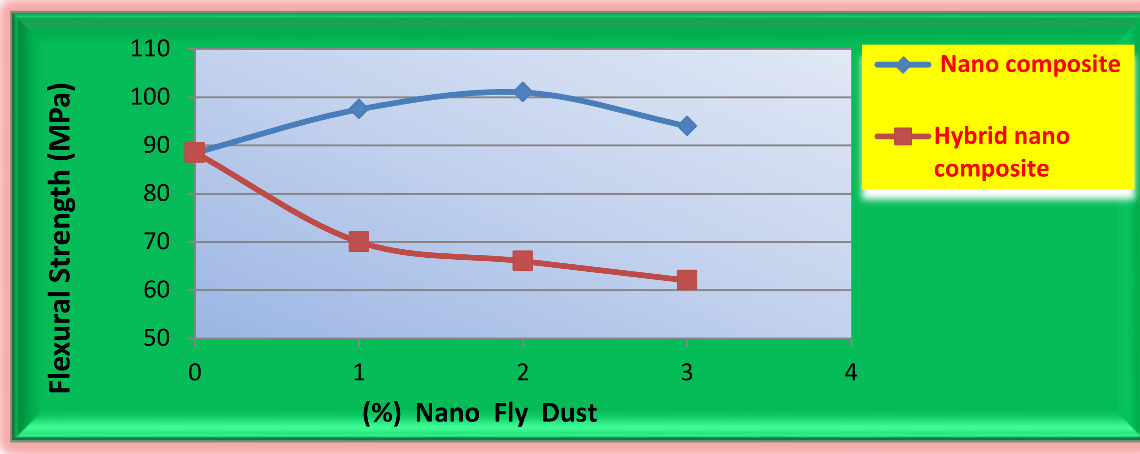


(Fig.5): Flexural Strength of PMMA Hybrid Nano Composite Materials as a Function of volume fraction of Fly Ash nanoparticles in PMMA Composites.

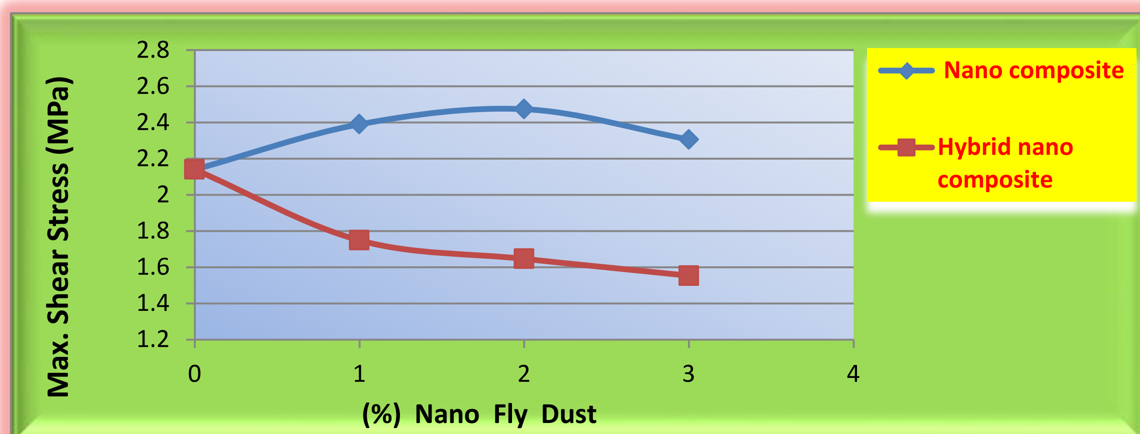
(Fig.6): Max. Shear Stress of PMMA Hybrid Nano Composite Materials as a Function of volume fraction of Fly Ash nanoparticles in PMMA Composites.



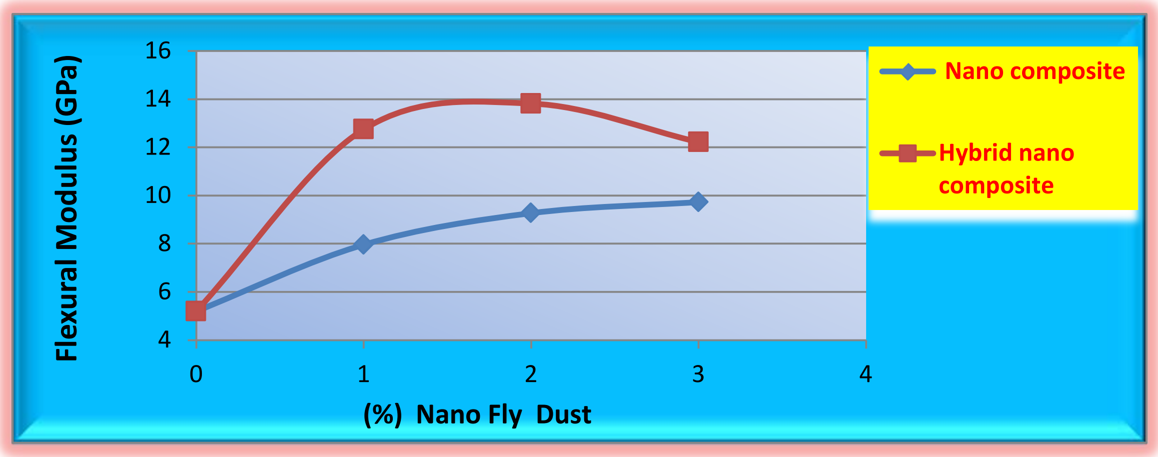
(Fig.7): Flexural Modules of PMMA Hybrid Nano Composite Materials as a Function of volume fraction of Fly Ash nanoparticles in PMMA Composites.



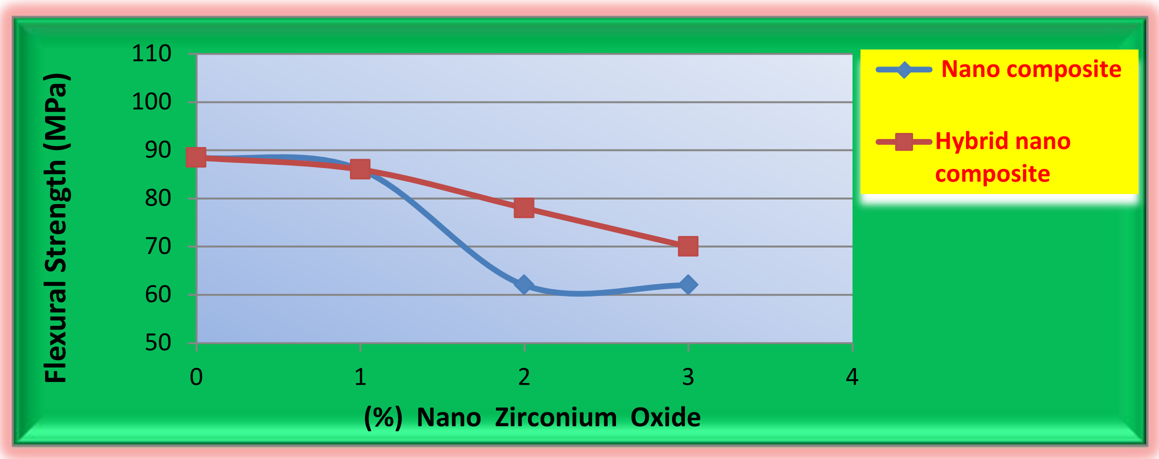
(Fig.8): Flexural Strength of PMMA Hybrid Nano Composite Materials as a Function of volume fraction of Fly Dust nanoparticles in PMMA Composites.



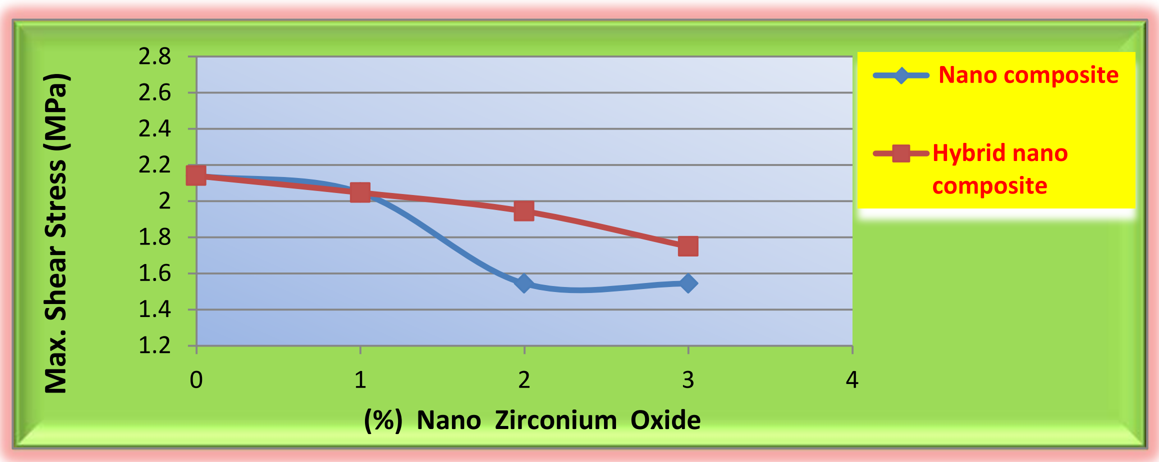
(Fig.9): Max. Shear Stress of PMMA Hybrid Nano Composite Materials as a Function of volume fraction of Fly Dust nanoparticles in PMMA Composites.



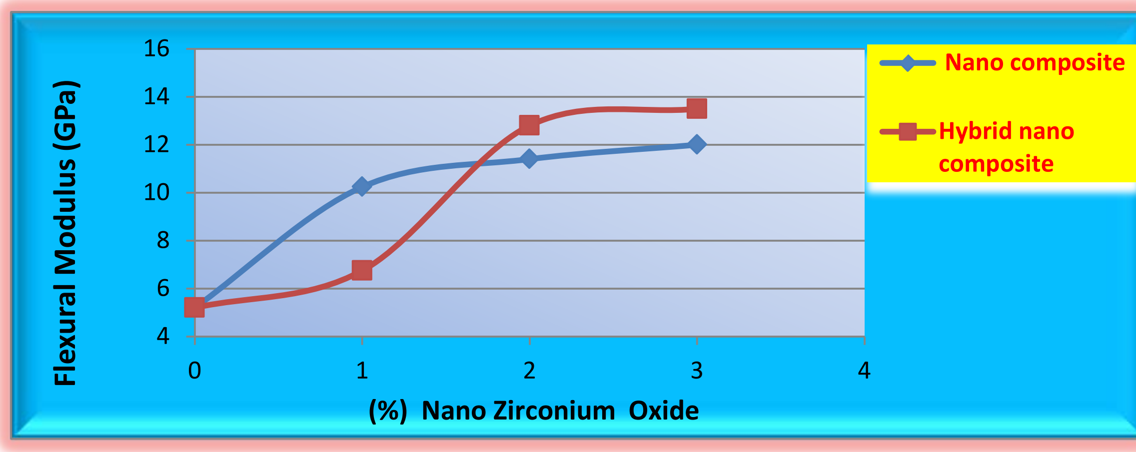
(Fig.10): Flexural Modules of PMMA Hybrid Nano Composite Materials as a Function of volume fraction of Fly Dust nanoparticles in PMMA Composites.



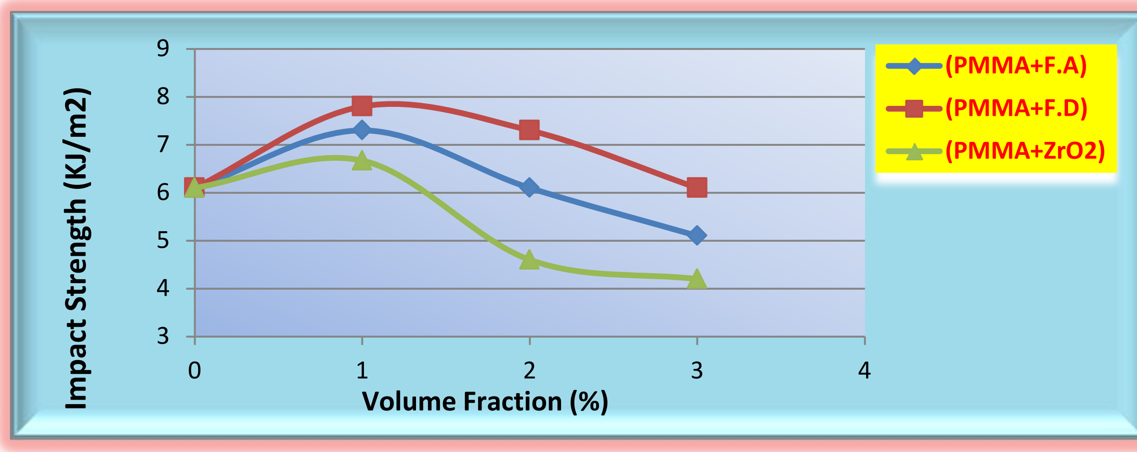
(Fig.11): Flexural Strength of PMMA Hybrid Nano Composite Materials as a Function of volume fraction of Zirconium Oxide nanoparticles in PMMA Composites.



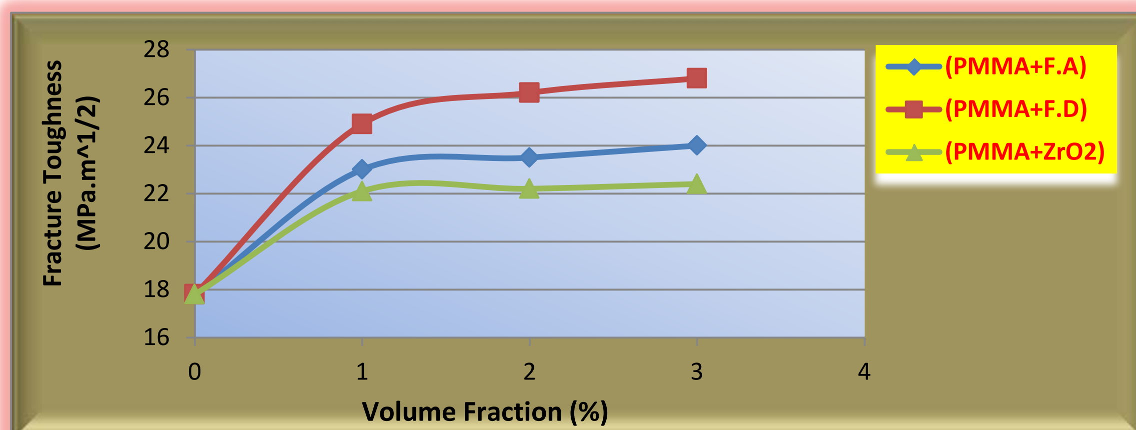
(Fig.12): Max. Shear Stress of PMMA Hybrid Nano Composite Materials as a Function of volume fraction of Zirconium Oxide nanoparticles in PMMA Composites.



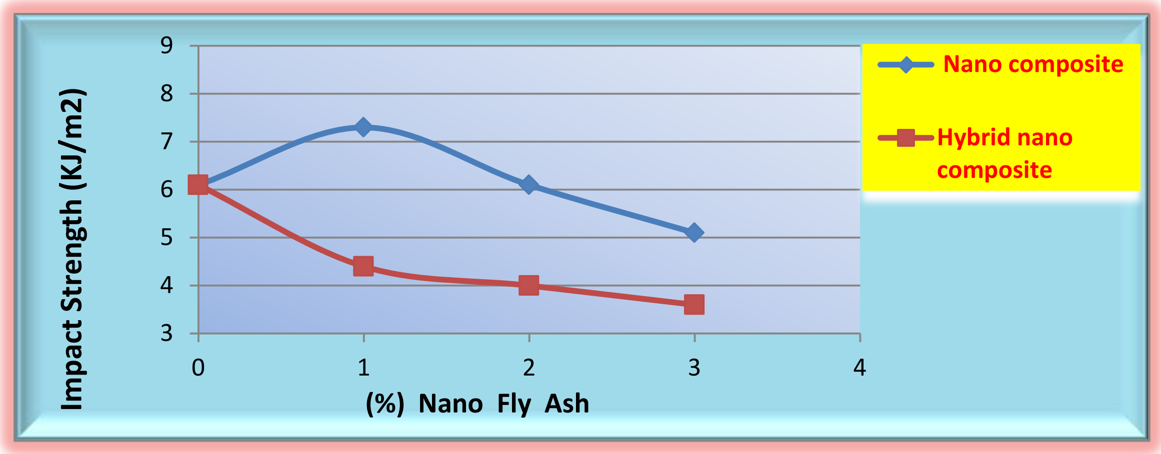
(Fig.13): Flexural Modules of PMMA Hybrid Nano Composite Materials as a Function of volume fraction of Zirconium Oxide nanoparticles in PMMA Composites.



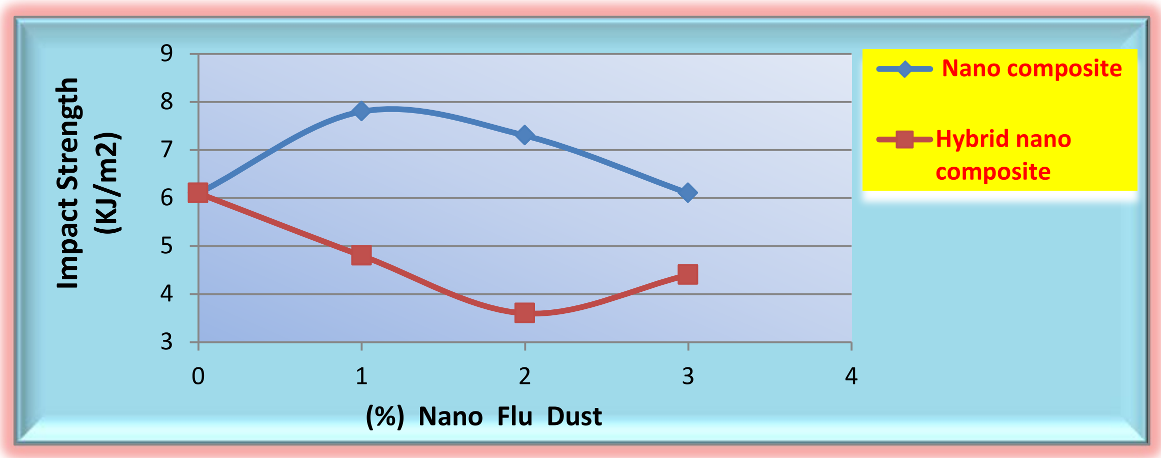
(Fig.14): Impact Strength of PMMA Nano Composite Materials as a Function of volume fraction of nanoparticles (F.A, F.D and ZrO_2) in PMMA matrix.



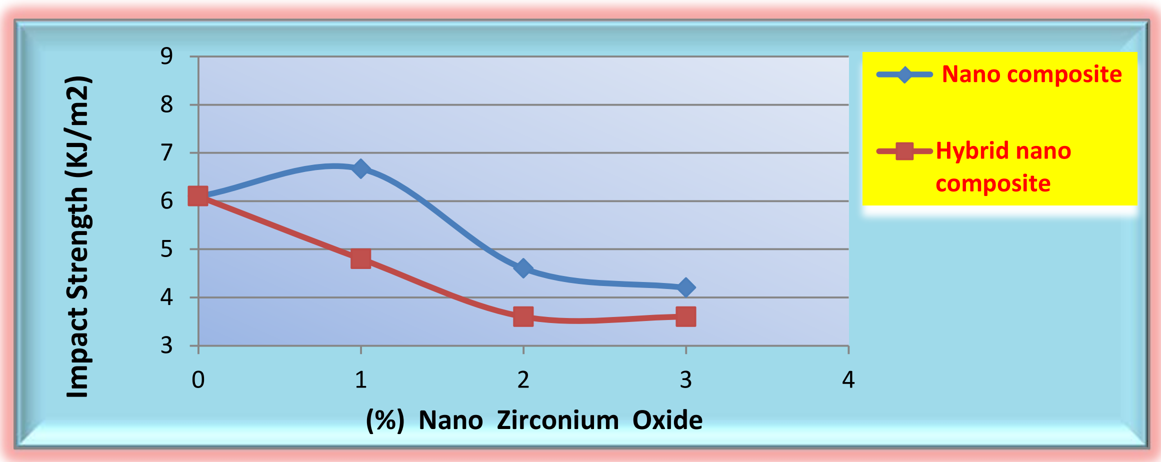
(Fig.15): Fracture Toughness of PMMA Nano Composite Materials as a Function of volume fraction of nanoparticles (F.A, F.D and ZrO_2) in PMMA matrix.



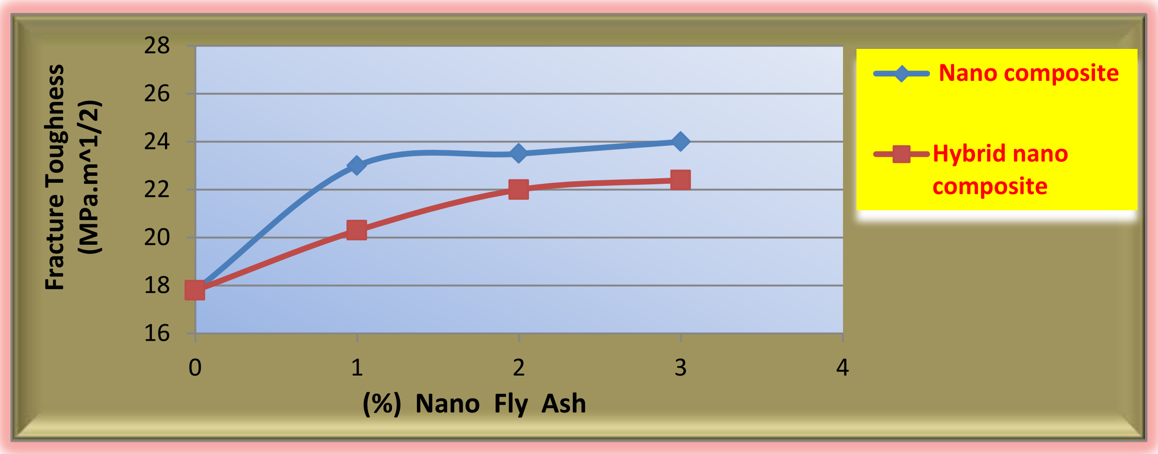
(Fig.16): Impact Strength of PMMA Hybrid Nano Composite Materials as a Function of volume fraction of Fly Ash nanoparticles in PMMA Composites.



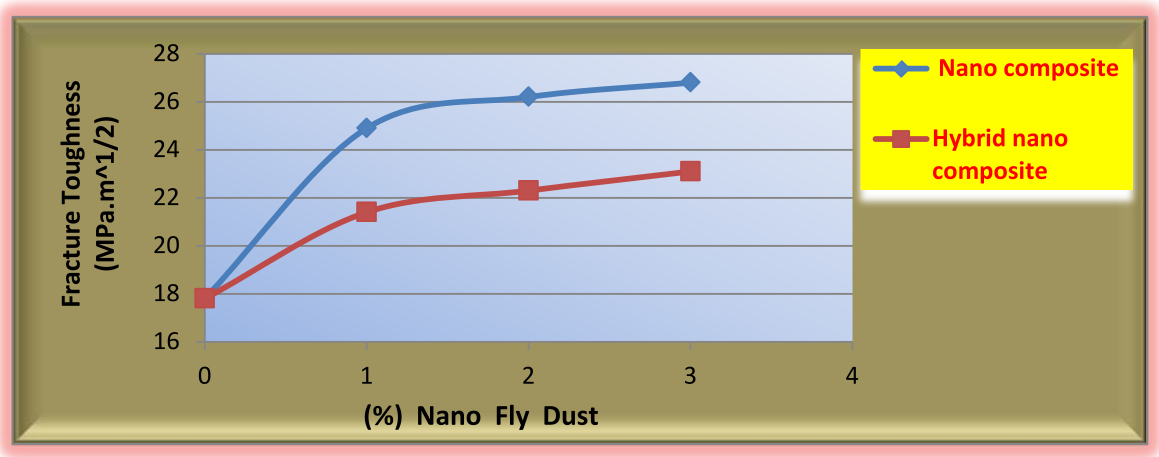
(Fig.17): Impact Strength of PMMA Hybrid Nano Composite Materials as a Function of volume fraction of Fly Dust nanoparticles in PMMA Composites.



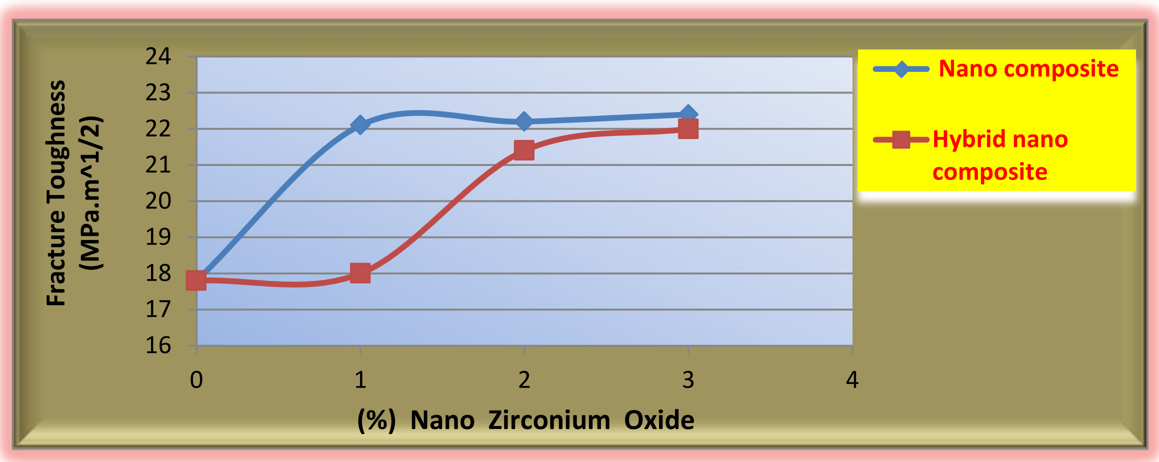
(Fig.18): Impact Strength of PMMA Hybrid Nano Composite Materials as a Function of volume fraction of Zirconium Oxide nanoparticles in PMMA Composites.



(Fig.19): Fracture Toughness of PMMA Hybrid Nano Composite Materials as a Function of volume fraction of Fly Ash nanoparticles in PMMA Composites.



(Fig.20): Fracture Toughness of PMMA Hybrid Nano Composite Materials as a Function of volume fraction of Fly Dust nanoparticles in PMMA Composites.



(Fig.21): Fracture Toughness of PMMA Hybrid Nano Composite Materials as a Function of volume fraction of Zirconium Oxide nanoparticles in PMMA Composites .

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