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Effect of zirconia addition on thermal and mechanical properties of poly-methyl methacrylate composites

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The goal of this study was to improve the mechanical and thermal properties of Poly-Methyl Meth Acrylate (PMMA) by adding Zirconia nanoparticles in various weight fraction percentages (0, 1, 1.5, 2, 2.5, 3)%. The cast technique was utilized of to prepare the (PMMA/zirconia) nanocomposites. The thermal and mechanical characterized of (PMMA/zirconia) nanocomposites were studied. Increased zirconia percentages in (PMMA/zirconia) nanocomposites lead to increase thermal conductivity (K), glass transition temperature, specific heat capacity (Cp), effusivity, impact strength, hardness, flexural strength, compressive strength and reduced wear rate, enhancing the thermal and mechanical properties of Poly-Methyl Meth Acrylate (PMMA).

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Keywords: Poly-methyl meth acrylate (PMMA), Thermal properties, Composite, Zirconia and mechanical properties

1. Introduction

A polymer is a big molecule made up of hundreds or thousands of atoms that is created by linking one or two types or sometimes more small molecules (monomers) into a chain or lattice structures. One of these polymers was Poly-Methyl Meth Acrylate (PMMA) [1,2]. Since the beginning of the 20th century, poly(methyl methacrylate) has been utilized in biomedical applications. Is the preferred material for internal prostheses and the recommended material for complete dental prostheses [3,4]. There are many benefits of Poly-Methyl Meth Acrylate, including ease of processing, low cost, oral stability, acceptable aesthetics, biocompatibility, and great availability[5]; nevertheless, the mechanical properties of Poly -Methyl Meth Acrylate are not optimal[6]. We must improve the properties of Poly-Methyl Meth Acrylate by utilizing various fillers or fibers in order to increase interest in Poly(Methyl Meth Acrylate) in the medical and dental industries. One of these fillers is zirconia. Zirconia is a metal oxide that has been widely utilize because of its good properties such as high flexural strength , excellent toughness, hardness and corrosion resistance, which make it a good choice for polymer reinforcement[7]. Many researchers studied the improvement the characterized of polymer by adding various fillers or fibers and they get excellent result, such as Aveen ansaif jassim [8], Widad H. Jassim [9], Afya Qasem Fadhel [10] , Mohammed M. Yahyaa [11], Shatha H. Mahdi [12], Mahmood Radhi Jobayr [13] and Abbas Karim Saadon[14].

In this paper, we were studying the effect of adding zirconia nanoparticles with different percentages (0, 1, 1.5, 2, 2.5, 3) % on thermal and mechanical properties of Poly -Methyl Meth Acrylate.

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2. Experimental

2.1. Materials and method

Poly -Methyl Meth Acrylate and Zirconia powder with particle size larger than 20 nm utilize in this work. The purity of Zirconia powder is 99%.The (Poly-Methyl Meth Acrylate/Zirconia) nanocomposite samples prepared by using cast method (1). The samples were prepared by adding Zirconia powder to (0.3 g) Poly -Methyl Meth Acrylate with different percentages of weight (0, 1, 1.5, 2, 2.5, 3)% and dissolving with chloroform solvent by using magnetic stirrer. Cast mixture into dish and then let it at room temperature to dry.

2.2. Measurements

2.2.1. Thermal test

Thermal conductivity can be defined as phenomenon that takes place when there are different in temperatures between two surfaces; therefore the heat will flow from high temperature surface to low temperature surface.

The thermal conductivity was calculated by using Lee's disc test according to this equation [15]

$$k\left(\frac{TB-TA}{ds}\right) = e[TA + \frac{2}{r}\left(dA + \frac{1}{4}ds\right)TA + \frac{1}{2r}ds\ TB] \qquad (1)$$

The thermal energy can be calculated according to following equation [16]

$$I.V = \pi r^2 e\,(TA+TB) + 2\pi\, re[dA\ TA + ds\,\frac{1}{2}(TA+TB) + dB\ TB + dc\ Tc] \qquad (2)$$

where:

TA,TB and TC: temperature of (A,B,C) disk

dA, dB, dC : thickness of (A,B,C) disk

ds: sample thickness

k: thermal conductivity

DSC (separate EVO 131) was utilized to find the glass transition temperature of a samples, with heating rate (10 C^o / min) and temperature range (20-200 ^oC).

2.2.2. Mechanical properties

-Hardness:

The hardness test was performed on all samples using the device (TH2IO, Italy). The measurements of hardness take at different positions on composites surfaces to get the average hardness value.

-Impact test

Impact test was done on all samples by utilize Charpy impact instrument, this test was preformed according to the international system (ISO-179), the samples were casted with dimensions (100×10×8 mm).

-Flexural test

To find the flexural strength of samples with dimensions (100×10×4 mm).Three-point bending was used according to (ASTM-D790).

-compression

The test was done on all samples by using a universal compression test machine, the compressive stress was calculated by using Equation

Stress = $(N)/\,(mm^2)$

Where F: is the force. A: is the base area

3. Result and discussion

3.1. Thermal properties

The thermal properties of (PMMA/zirconia) nanocomposites with various percentages of zirconia (0, 1, 1.5, 2, 2.5, 3)% are shown in the Figure (1) and Table (1). it was noticed that thermal conductivity (K), glass transition temperature, specific heat capacity (C_p) and effusivity increase with increased the percentages of Zirconia in the samples because the number of fines area in the sample were increase. This is due to high amount of bounding between Zirconia and Poly -Methyl Meth Acrylate.

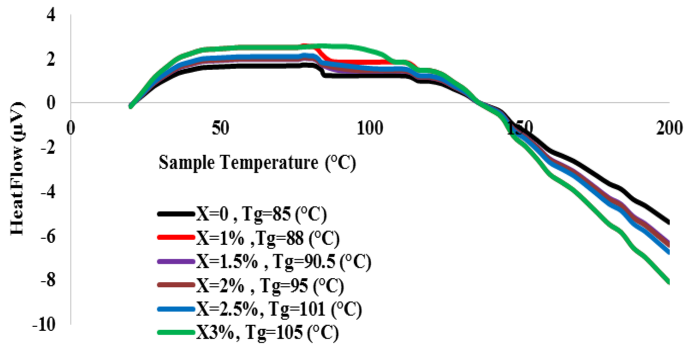

Fig. 1. Thermal characteristic of (PMMA/Zirconia) nanocomposites.

Table 1. Thermal characteristic of (PMMA/Zirconia) nanocomposites.

Zirconia percentages	thermal conductivity (K) (W/k.m)	glass transition temperature (C^O)	specific heat capacity (C_p) (J/kg.k)	Effusivity ($Ws^{0.5}/m^2k$)
0	0.23	85	0.46	0.356314
1	0.262	88	0.524	0.405889
1.5	0.311	90.5	0.622	0.481799
2	0.34	95	0.68	0.526726
2.5	0.35	101	0.7	0.542218
3	0.494	105	0.988	0.765302

3.2. Impact strength

Figure (2) show the changes of impact strength in the (PMMA/ Zirconia) nanocomposites at different percentage of Zirconia. The impact strength increase with increased the percentage of Zirconia in the (PMMA/ Zirconia) nanocomposites because capability of the Zirconia to absorb energy, which can stop crack propagation.

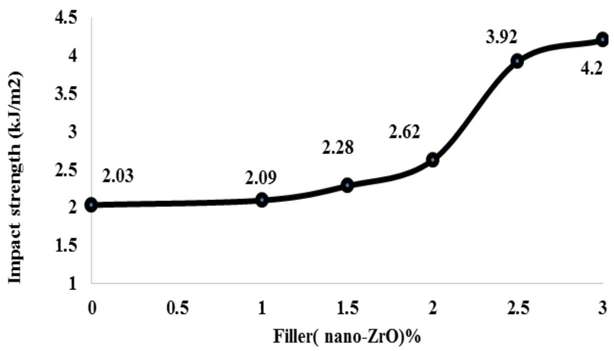

Fig. 2. Impact straight of (PMMA/Zirconia) nanocomposites

3.3. Hardness

Figure (3) show the effect of the added zirconia percentage on the hardness in the samples. it can be see that the hardness of the samples increase with increase the zirconia percentage.

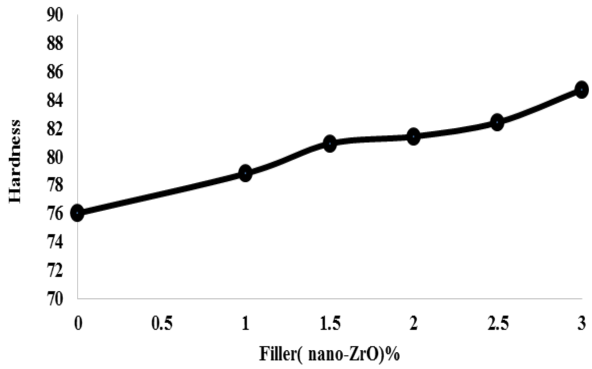

Fig. 3. Hardness of (PMMA/Zirconia) nanocomposites.

3.4. Flexural strength

The flexural strength of (PMMA/ zirconia) samples is shown in the figure (4). Increase the percentages of addition zirconia in composites lead to increase the flexural strength.

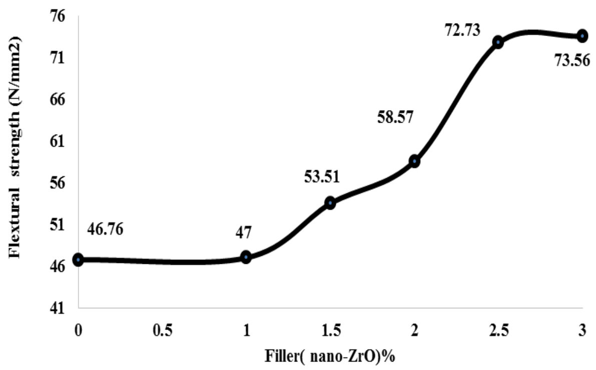

Fig. 4. Flexural strength of (PMMA/Zirconia) composites.

3.5. Compressive

Figure (5) show the effect of the addition zirconia at different percentages on the compressive of the samples. The compressive of the (PMMA/ zirconia) nanocomposites increase with the increase the addition percentage of zirconia because Poly -Methyl Meth Acrylate has great compressive, with a good interface between zirconia and PMMA polymer

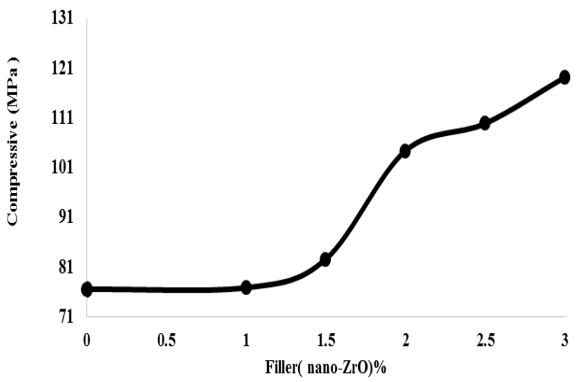

Fig. 5. Compressive of (PMMA/Zirconia) composites.

3.6. Wear test

The wear test was carried out for all samples using four load (5, 10, 15 and 20) N, sliding time 30 sec, velocity 940 rad/sec and hardness 45 HRC. The wear rate of (PMMA/Zirconia) nanocomposites are shown in the figure (6). The wear rate decrease with the increase the addition percentage of zirconia.

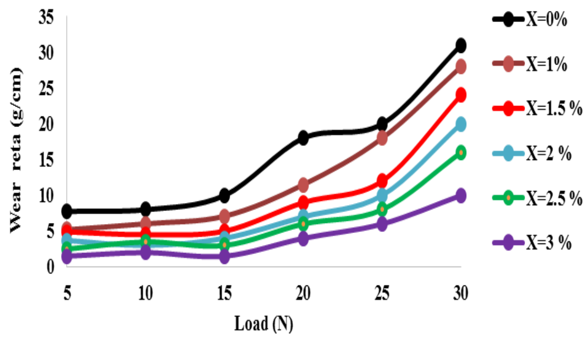

Fig.6 The Wear Rate of (PMMA/Zirconia) nanocomposites for Different Addition Percentage of Zirconia (X=0, 1, 1.5, 2, 2.5 and 3).

4. Conclusion

In this work, we were obtained the following conclusion: Increased the addition percentages of Zirconia in the samples lead to increase the thermal conductivity (K), glass transition temperature, specific heat capacity (C_p) and effusivity.Increased the addition percentages of Zirconia in the samples lead to increase the impact strength , hardness, flexural strength and compressive. Increased the addition percentages of Zirconia in the samples lead to decreased the wear rate. Zirconia caused an enhancement in thermal and mechanical characteristic of zirconia/PMMA composites.

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