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STUDY OF SOME PROPERTIES FOR COLD-CURING ACRYLIC RESIN REIENFORCED WITH NANO YTTRIUM OXIDE

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ABSTRACT

Through the last two to three dictate, composite materials had being applied enormously in many industry fields. This is as fact that this type of materials possess; high strength to weight ratio, high stiffness, and limit thermal conductivity. In this work Nano-Yttrium oxide with (0%, 1%, 2%, 3% and 4%) weight fraction had been added, as reinforcement phase, to acrylic resin (cold curing). Various physical and mechanical tests had done for determining the development in the properties of the prepared composite samples like: hardness, tensile strength, thermal conductivity, water absorption and density. The results show: decreasing tensile strength with increasing Nano-Y_2O_3 weight fraction, maximum decline in tensile strength was at (4) % Y_2O_3, about (16.2) % of Acrylic strength; increasing in hardness with increasing Nano-Y_2O_3 weight fraction, maximum hardness was at (4) % Y_2O_3, about (107) % of Acrylic hardness, no obviously density change with increasing Nano-Y_2O_3 weight fraction, decreasing water adsorption with increasing Nano-Y_2O_3 weight fraction, maximum decreasing in water absorption percentage was at (4) % of Y_2O_3, about (93) % of Acrylic water absorption, decreasing thermal conductivity with increasing weight fractions of Nano-Y_2O_3, maximum decline in thermal conductivity was at (4)% of Y_2O_3 , about (90)% of Acrylic thermal conductivity

Keywords : acrylic resin (cold curing), Nano Yttrium oxide particles, Rreinforcement, some mechanical and physical properties .

دراسة بعض الخصائص لراتنج الاكريليك البارد المعزز بنانو أوكسيد اليتريوم

محمد رميض غركان بسام ابراهيم خليل احمد حسين علي سالي عبد الحسين كاظم احمد هاشم

الخلاصة

خلال العقدين الماضيين استخدمت المواد المركبة في العديد من التطبيقات الصناعية. ويرجع ذلك إلى حقيقة أن هذا النوع من المواد تمتلك: نسبة مقاومة إلى وزن عالية ،صلادة عالية، وتوصيل حراري منخفض. في هذه الدراسة أضيفت دقائق نانو أوكسيد اليتريوم بنسب وزنية (1%,2%,3%,4%) كتعزيز لراتنج الاكريليك (المعالج على البارد). وقد اجريت العديد من الاختبارات الميكانيكية والفيزيائية والحرارية لتحديد التطور في خصائص المواد المركبة المحضرة مثل الصلادة، مقاومة الشد، امتصاصية الماء ، الكثافة ، والتوصيل الحراري. أظهرت النتائج نقصان مقاومة الشد مع زيادة الكسر الوزني لأوكسيد اليتريوم النانوية، ازدياد الصلادة (لجميع النسب الوزنية) مع زيادة نسبة الوزنية لنانو أكسيد اليتريوم، تناسب عكسي بين التوصيلية الحرارية ونسبة الكسر الوزني من أوكسيد اليتوريوم، تناسب عكسية بين نسبة الماء الممتص والكسر الوزني لأوكسيد اليتريوم، وأخيرا أقصى الكثافة كانت عند (4%) كسر وزني من أوكسيد اليتريوم النانوي .

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INTRODUCTION

Acrylic resin has excellent aesthetic properties, low solubility, adequate strength, low water sorption, odorless, tasteless and relatively low toxicity. Acrylic resin can reproduce surface details accurately, can be easily manipulated and repaired. On other hand, this resin has a few inherent limitation like humble strength mainly under fatigue action inside mouth, addition to high thermal expansion coefficient that responsible to release internal stresses during processes stage resulting inaccuracy of dimension and polymerization shrinkage [A.N. Abdulhamed, et al., M. R. Gharkan, et al.]. Cold curing Acrylic has usually used in man application like denture based materials, temporary and removable prosthetic base building materials [Ibrahim M Hamouda, et al. 2014, Ahmad Sodagar et al. 2012]. Chemically cured (Self-cured) Polymethylmethacrylate PMMA has auto polymerized. Polymerization reaction begin as soon as the liquid and powder ingredients are mixed together. The present of benzoyl peroxide initiator in pre-polymerized which activated by chemicals can produce polymerization reaction without external heat. Dimethyltoluidine (a tertiary amine) is applied to activate the polymerization in chemically cured PMMA [Grant, A. A.]. Cold cured acrylic has less degree of polymerization compare that of heat cured system so, it has more unreacted residual monomer, which can consider as plasticizer that responsible of high lateral deflation values consequently, decrease resin transverse strength [I. K. Farhood, et al.]. Investigation the development of resin properties via incorporation of various kinds of particles and fibers, had attempted in many researches. It had noticed in some published researches that addition of (TiO_2 and SiO_2) nanoparticles to acrylic resins, had adversely affect into the flexural strength, and this dwindling into the strength was directly proportional with the amount of nanoparticles [Ahmad Sodagar, et al., 2013], on other research it is found that addition of (Nano SiO_2 filler) particles to heat-curing-acrylic resin can improve its transverse strength, impact strength, and surface hardness [Ibrahim M Hamouda, et al. 2014, Ahmad Sodagar et al. 2012], effective fiber reinforcing is decided by many variables like: volume fraction, length, orientation and modulus of fibers. Many type of fiber reinforcing materials had used like polyethylene, carbon, glass on purpose of improving its mechanical properties [T. K. Bashi, et al.]. The goals of this work were evaluate the influence of reinforcing cold acrylic resin denture base material by used Nano Yttrium oxide on physical and mechanical resin characteristics.

EXPERIMENTAL PART

Raw materials and preparation method:

The raw materials used in this work are:

I) Nano-Yttrium oxide (Y_2O_3) particle with mean particle size (25) nm (Chengdu Haoxuan Technology Co.),

II) Cold-Curing denture base resin (Duracryl® Plus), (it is a denture resin applied to repair removable dentures and fabricate immediate dentures), this resin consist from two types of ingredients (liquid and powder) as following:

Powder ingredients involve a PMMA pre-polymer or co-polymer (fine particle size), (1-2) % of Di-benzoyl peroxide initiator (DBP), and (1) % Pigment.

Liquid ingredient involve Methyl-methacrylate monomer MMA, (1-2) % cross-linking agents (glycol di-methacrylate), less than (1) % inhibitor (Hydroquinone), activator (Dimethyl-p-toluidine).

Casting's mold

Iron mold consist from two parts with (30 cm x 21cm) dimension had used for preparation composite samples. The mold contains two holes for tensile tests samples and four cylindrical holes for thermal properties tests samples (hot disk) as shown in figure (1). Vaseline used as lubricant to facilitate removing samples.

Preparation of samples

The raw materials, resin (super acrylic plus) and the cross-linked denture addition to Nano particle Y_2O_3 mixed and poured into the molds. Preparation method including addition cross-linked to (super acrylic plus) in ratio (3 to 1). Then after weighting prepared standard samples of resin composite preparation by added proposal reinforcing Nano particles weight percentage (1%, 2%, 3%, and 4%) to matrix finally, the samples left for 24 hr. for drying released from mold.

Mechanical and Physical properties inspection

Tensile tests

A flat, dog-bone shape, straight sided piecemeal with and tabs specimens, and (150) mm length were used for performing tensile test according to ASTM stander (638-01). The test had performed by universal testing machine had (50) K.N loading capacity. (5) mm/min cross head speed had applied for testing samples. Finally, the average value of tested samples' results was consider for analysis [Alaa Abd Mohammed, 2013].

Hardness tests:

Hardness tests had been performed by using Shore hardness type (D), according to ASTM stander (D2240) at room temperature. Average hardness value of five tests at different part within specimen had consider for analyzing. [Hayder Raheem Kareem,2013]

Density tests

The density investigations had been done depending to ASTM stander (D792). The test procedure includes weighing specimen in air, and when immersed in distilled water, then applied the following the relation:

$$\text{Specific gravity S.G} = W_d / W_d - Wi \qquad (1)$$

Where W_d: is the weight of dry specimen in gram, Wi: is the weight of specimen immersed and suspended in distillation water specimen in gram. S.G can be converted to density by multiplying by the density of distilled water in which equal (0.9975) [Annual Book of ASTM Standard, 2006]

Water Absorption Test

The water absorption investigations had been done depending upon ASTM stander (D570). The procedure of this test include entirely immersing of the samples in distilled water at room temperature (23 ±2) for (24) hr., then the samples withdrawal from water, and wiped all surfaces from water by dry cloth before weighing. Water absorption can be gotten by using the next formula [Al-Kadi. F. K. A., 2004]:

$$\text{Water Absorption \%} = (W_S - W_d - / W_d) \times 100 \qquad (2)$$

Where W_d: is the weight of dry sample, W_S: is the weight of sample after immersing into distilled water at room temperature for (24) hr.

Thermal conductivity examinations:
Thermal conductivity investigations had been performed by using thermal analyzer device, (hot disk type TPS 500, Sweden). Cylindrical shape samples with (40) mm diameter and (10 mm) thickness had used in this tests.

RESULTS AND DISCUSSION

The development of physical and mechanical properties can be discussed in light results of previous mentioned tests for prepared samples resin of cold curing acrylic before and after addition reinforcement phase Nano yttrium oxide with (1%, 2%, 3%, and 4%) weight fractions. All results are plotted on curves, using available curve fitting software to emphasize the fine details that serve in explaining the relevant mechanisms responsible for such behavior.

The results of tensile tests:
The effect of addition nano yttrium oxide to the resin can discussion depending on figure (3). It can observe dramatic deterioration into the tensile strength with increasing weight fraction of nano yttrium oxide, where maximum decline in tensile strength was recorded at addition (4) % Y_2O_3, (16.2 % of pure Acrylic strength). Generally, mechanical behavior of composite materials depends upon mechanical raw materials of matrix, reinforcement phases and the adhesion bond between them. The catastrophic decline in tensile strength might be results of poor adhesion between resin matrix and reinforcing phase, which might cause development of harmful cracks around reinforce particles, consequently decrease the tensile strength of composite material, or might be result of adversely effects of dispersion nano Y_2O_3 into degree of Acrylic conversion, consecutively rise the number of residual non-reaction monomers, which doing as plasticizer, which decrease mechanical strength of composite, on other hand addition of nano materials to resin can produce aggregation and agglomeration, which acts as stress concentration sites within matrix and that decline mechanical properties of resin. Actually the results of tensile strength shown in figure (3) agree with related researches [Ibrahim M Hamouda et al. (2014), Ahmad Sodagar et al. (2012), and Takeshi Shibatan et al. (2007)].

The results of hardness tests:
The results of hardness tests, which performed by shore (D), and after take the average value of five tests at different positions within sample, shown in figure (4). It can be observed humble increasing in hardness values with increasing reinforcement weight fraction comparing with Acrylic resin. Maximum increasing was at (4) % Y_2O_3, (about (107) % of Acrylic hardness). This behavior is related to high hardness of oxide phase comparing with resin, and this results agree with expectation of rule of mixture.

$$H_c=H_r\,.W_r + H_m\,.W_m$$

Where
H_c : composite hardness, H_r : reinforcement phase hardness H_m: matrix phase hardness
W_r: reinforcement phase weight fraction W_m: matrix phase weight fraction.
However the improvement in hardness was much lower than what expected according to the rule of mixture, this may relate to the adversely effects of adding nano particles to resin as previously mentioned.

The results of density tests:

The results of density tests is shown in figure (5), in general it can observe very humble increasing in density with increasing weight fraction of nano Y_2O_3, indeed the varying in density is not exceeding (1)% at (4) % Y_2O_3, This might relate to that nano-yttrium oxide has approximately the same density of cold curing Acrylic, depending to rule of mixture

$$\rho_c = \rho_r W_r + \rho_m W_m$$

Where ρ_c : is density of composite, ρ_r : density of reinforce phase, ρ_m: density of matrix phase

W_r: reinforce weight fraction, W_m: matrix weight fraction

The results of water absorption tests:

Acrylic has great water tendency. The addition of nano Y_2O_3 to cold curing resin can be discussed according to the results of water absorption tests, shown in figure (6), the figure shows humble decline in water absorption percentage with increasing weight fraction of Y_2O_3, maximum decrease in water absorption percentage was at (4) % of Y_2O_3, (about (93) % of Acrylic water absorption), this behavior might relate low water absorption of oxide and that agree with rule of mature of composite.

The results of thermal conductivity tests:

The results of thermal conductivity tests results is shown in figure (7), It is clear from this figure that the values of thermal conductivity decreases with the increase in weight fraction of Y_2O_3. Thermal conductivity in Acrylic is dominated by phonon transport. In unfilled samples, moderate to high values are observed for thermal conductivity samples as a result of strong covalent bonding between the atoms. Thus increase in phonon means free path of samples. As the percentage of Nano yttrium oxide weight fraction increases the phonon transport decreases and consequently the thermal conductivity decreases. Maximum decline in thermal conductivity was at (4)% of Y_2O_3 , about (90)% of Acrylic thermal conductivity [S. Agarwal, N. S. Saxena and V. Kumar (2015)] .

CONCLUSIONS

The addition of Nano-yttrium oxide to resin of cold curing acrylic can improve some mechanical properties. Following are the conclusions had reached: For the prepared resin-yttrium oxide composite material, the results show that some mechanical properties, like hardness, which show improvement with increasing weigh fraction percentage of Nano-yttrium oxide at all ratio. Furthermore, the increasing in weight fraction percentage of Nano-yttrium oxide revealed a decreasing in the tensile strength for all ratio. Thermal conductivity decrease with increasing weight fraction percentage of Nano-yttrium oxide. Maximum density value was obtained when addition (4%) wt. of Nano-yttrium oxide. Water absorption percentage declined with increasing of weight fraction percentage of Nano-yttrium oxide.

Figure (1): iron mold used for preparation samples .

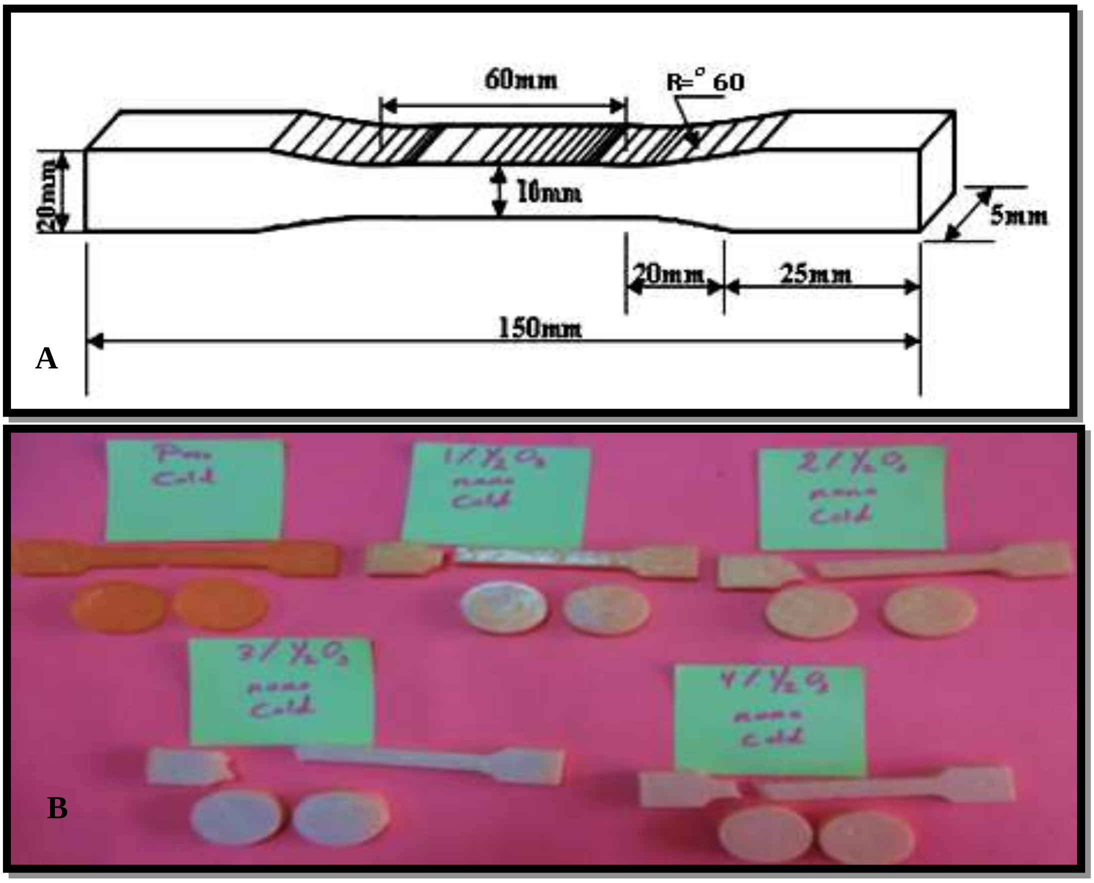

Figure (2): tensile specimen:
(A) graphical shape of specimen (B) specimens after testing.

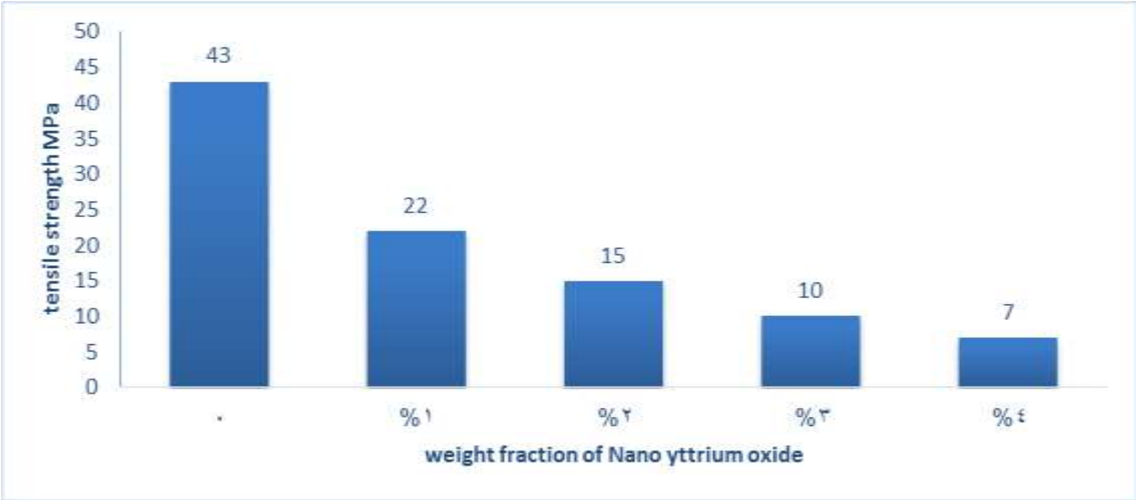

Figure (3): the effect adding Nano-yttrium oxide into the cold curing acrylic resin tensile strength.

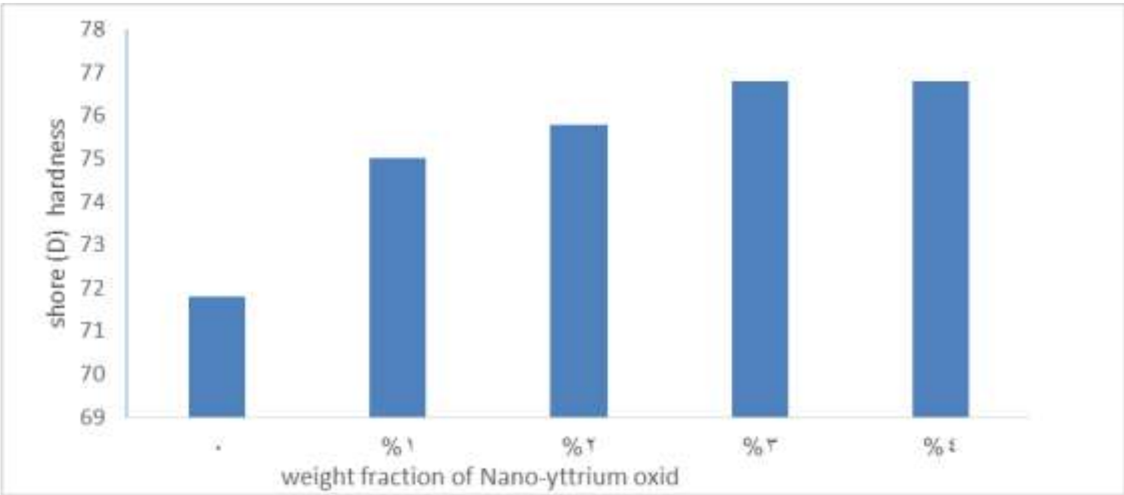

Figure (4): the effect of addition Nano-yttrium oxide into cold curing acrylic resin hardness

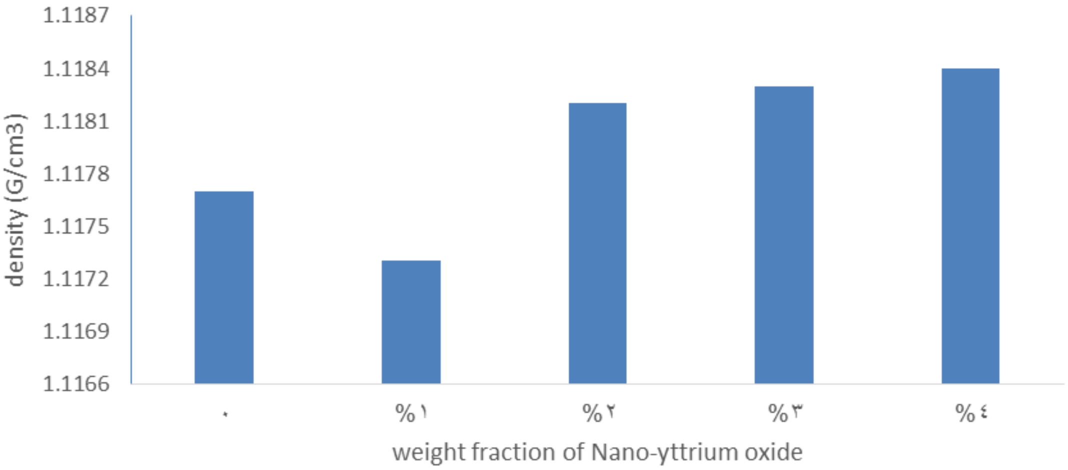

Figure (5): the effect of addition Nano-yttrium oxide into cold curing acrylic resin density

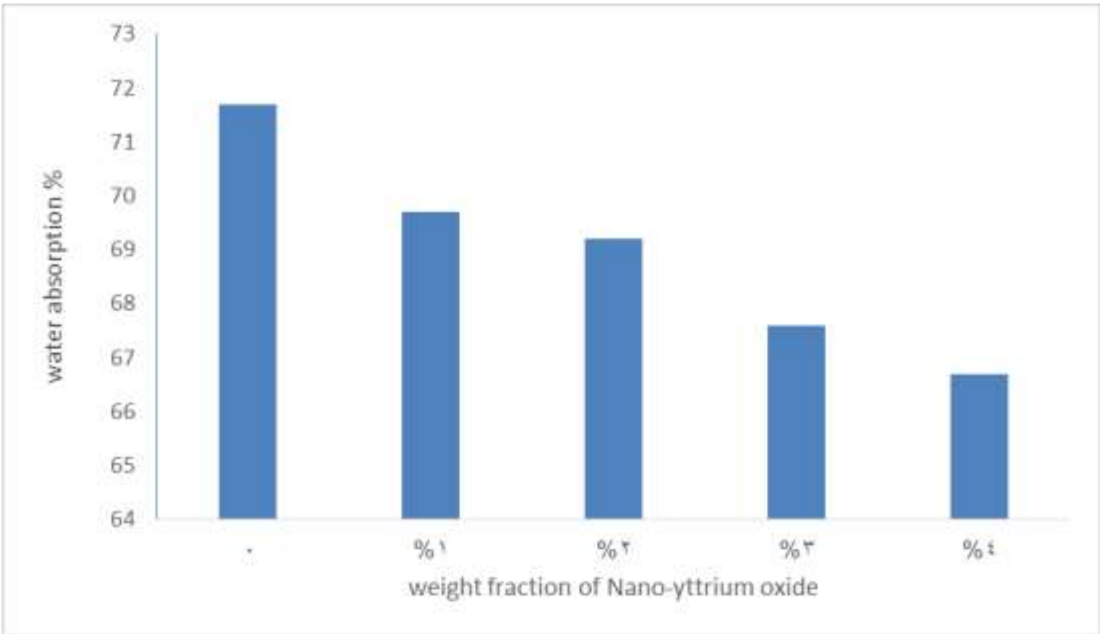

Figure (6): the effect of addition Nano-yttrium oxide into cold curing acrylic resin water absorption

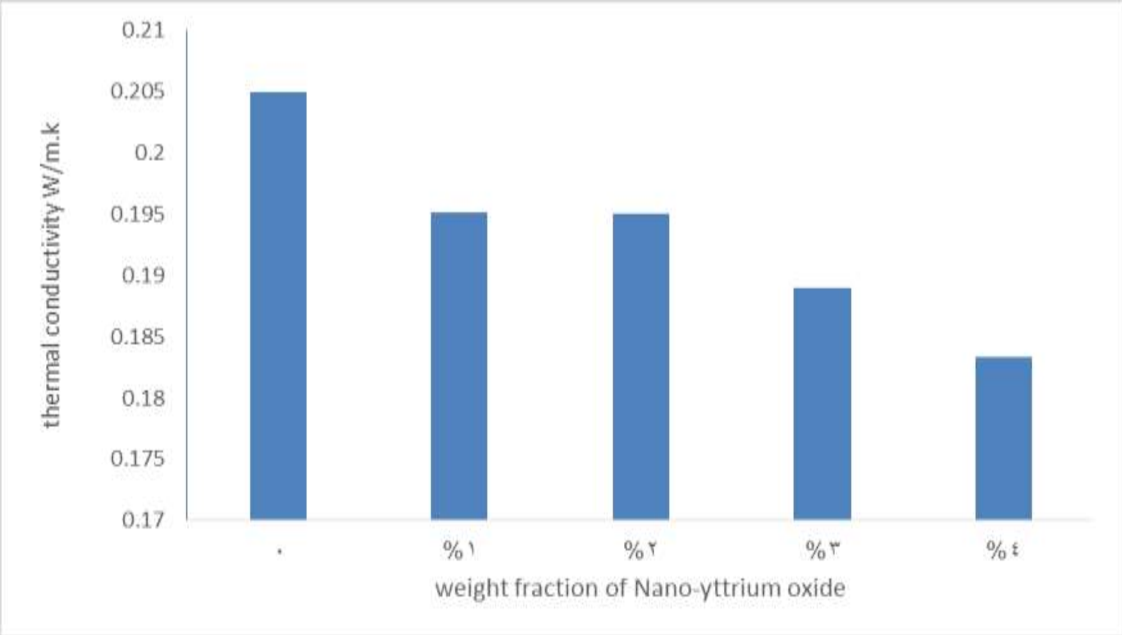

Figure (7): the effect of addition Nano-yttrium oxide into cold curing acrylic resin thermal conductivity

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