Study of hardness and thermal conductivity of polymeric blend reinforced with Kevlar fibers

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Abstract

This work includes preparation of composite material by reinforcing blend of (EP80% + UPE20%) with different layers of Kevlar fibers (2, 4, 6 and 8) at volume fraction of 30%. Hardness and thermal conductivity of all samples were studied before and after (UV) irradiation. The Experimental results showed that, the hardness value increases with increasing the number of Kevlar layers for all samples before and after (UV) irradiation. The thermal conductivity slowly increases with increasing Kevlar layers before and after (UV) irradiation.

Keywords: Kevlar fiber, blend (EP +UPE), UV radiation.

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Study of hardness and thermal conductivity of polymeric blend reinforced with Kevlar fibers

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دراسة تأثير الأشعة فوق البنفسجية على الصلادة والتوصيلية الحرارية لخليط بوليمري مدعم بألياف الكفلر

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الخلاصة

يتضمن هذا البحث تحضير مادة متراكبة من تدعيم خليط بوليمري (EP80% + UPE20%) بألياف الكفلر وبطبقات مختلفة (2, 4, 6 and 8) وبكسر حجمي 30%. تم دراسة اختبار الصلادة والتوصيلية الحرارية للعينات قبل وبعد التشعيع بالأشعة فوق البنفسجية وقد أظهرت النتائج العملية بأن قيمة الصلادة تزداد بزيادة عدد الطبقات للعينات كافة قبل وبعد التشعيع بالأشعة فوق البفسجية. التوصيلية الحرارية تزداد بصورة بطيئة مع زيادة عدد الطبقات لألياف الكفلر المضافة قبل وبعد التشعيع بالأشعة فوق البنفسجية.

الكلمات المفتاحية: ألياف الكفلر، خليط بوليمري(أيبوكسي+بولي أستر غير مشبع)، أشعة فوق البنفسجية.

Introduction and the Theoretical Part

The overlapping materials are known as those solid systems resulting from blending two or more blended materials so that they do not get a chemical reaction [1]. The increasing importance of the use of polymers in the industry has led to the use of resins reinforced with industrial fibers because of that their important properties are easily formed in different shapes and sizes, not rusted and not corroded, and have good resistance to moisture and chemicals in addition to light weight and high density [2]. Polymer blends with common characteristics have shown the need to mix two or more polymers, and this method depends on polymer quality and mixing method [3]. In 1965, the polyamide fibers were developed. They were less rigid and stronger than other fibers, but their performance differed from other fibers. The use of imitation Kevlar fibers resulted in the formation of overlapping materials [4].The most important factors influencing the properties of the fibers used and affecting the strengthening process are fiber diameter, fiber fracture, length and direction of fiber [5]. Coextensive fiber-reinforced materials can be used in many industrial applications, including the manufacture of bullet-proof armor, conveyor belt manufacture, and military helmets [6]. The effect of ultraviolet radiation on polymeric polymer complexes and their mechanical and physical properties was also studied. The most important researches and studies in the field of our current research are:

* In 2009 Ali Ibrahim Al-Moussawi, studied the change in the percentage of fiber reinforcement on the mechanical properties of the compound consisting of epoxy resin reinforced with imitation Kevlar fibers in the form of two-way (0-45) bidirectional The properties of resistance to shock, tensile strength, bending resistance, and hardness. of the mechanical properties increased with the increase in the ratio of the added fibers.
* In 2016 Maiss Sabah Mahdi, prepared a polymer mixture consisting of mechanical mixing of epoxy resin with polycarbonate at different rates (20, 15, 10, 5 and 0)% of polycarbonate. The shock test was performed on the mixture (20%) Has a high resistance compared with other ratios. This ratio was adopted for the composition of composite materials. The manual mixing method was used to prepare single composite materials and a hybrid with volume fraction of 15% by reinforcing the mixture with fiberglass and Kevlar as reinforcement materials. It was concluded that the reinforced composite (EP + K.F, blend + K.F) have volume higher than the others [8].

Hardness

Hardness is defined as the surface resistance of penetration or scratching, and the resistance of the material to localized malformation:

Hardness from shore (D) = $\frac{FORCE(\,N\,)}{AREA\,(\,mm^2)}$ -------------------------- (1)

Hardness also gives a good idea of the strength of the material and the cohesion of the material mass, which are important mechanical properties for the study of the surface of the material. Hardness of the testis is easy because it does not require complex and expensive devices, and damaged [10]. Shore (D) method is used to measure the hardness of samples as shown in Fig. 1, [11, 12].

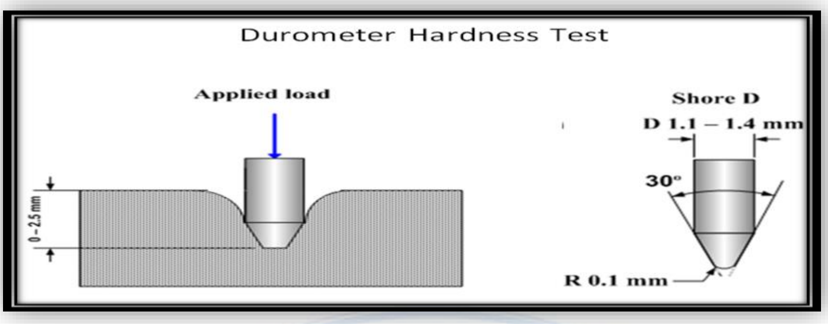


Figure 1: The needle of the D-hardness measurement device and the penetration depth of the sample surface [13]

Thermal conductivity

The material's ability to transfer heat from high-temperature zones to low-temperature zones is called thermal conductivity [14]. Thermal conductivity is different depending on the type of material. Thermal energy is transmitted due to the fluctuation of atoms or molecules with temperature changes. The difference in conductivity is that the solid is either conductive or dielectric. Free electrons are responsible for the transfer of heat energy in the solids [15].

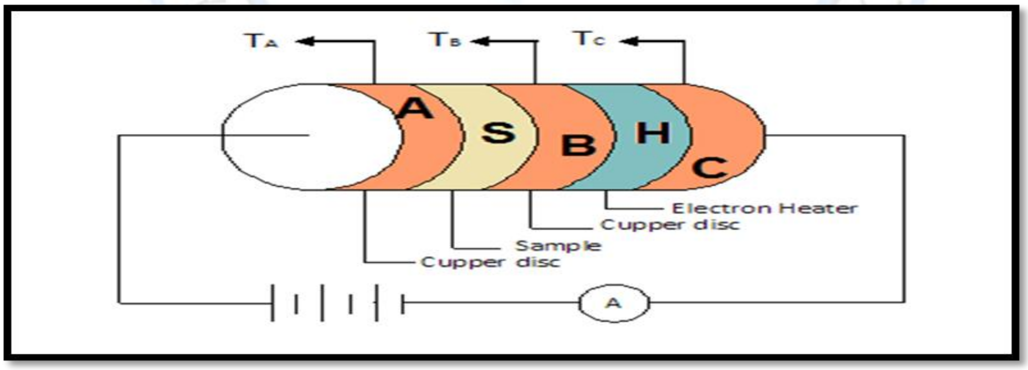


Figure 2: The diagram of the thermal conductivity measuring device (Lee's disk) [16]

The thermal conductivity factor for the test specimen, as shown in Fig (2), in this instrument, the heat is transferred from the heater to the followed disc till it reaches the last disc, and the temperatures (TA, TB and TC) for the three discs can be specified by using the thermometers inside them respectively, one of the most important influences is to ensure that the surfaces of the copper discs are clean and compatible to obtain the best heat transfer through them. The dimension of specimen (disk) [r = 3 cm, d = 0.5 cm]. The value of thermal conductivity (K) can be calculated by the following equation (2) [17].

$$K\left(\frac{T_B - T_A}{d_S}\right) = e\left[T_A + \frac{2}{r}\left(d_A + \frac{1}{4}d_S\right)T_A + \frac{1}{2r}d_S T_B\right] \ldots\ldots\ldots\ldots(2)$$

Where (e) represents the amount of thermal energy transferred through unit area of the disc per second (W / m2. K) and it calculated from the following equation (3):

$$\mathrm{H} = \mathrm{IV} = \pi r^2 e(T_A + T_B) + 2\pi r e\left[d_A T_A + d_S \frac{1}{2}(T_A + T_B) + d_B T_B + d_C T_C\right] \ldots \ldots \ldots(3)$$

Where (TA, TB and TC) represent the temperature of discs (A, B and C) respectively.
d: disc thickness (cm), **r**: disc radius (cm), **I:** current (Ampere), **V**: voltage (volt).
When putting specimen between (A, B) discs and applied power for circuit and let it for (l) hrs to reach all discs at equilibrium case in temperature and recorded the values of (TA, TB and TC) and let it (discs) to cool gradually for (45 min) and repeat the experimental again for all discs.

Experimental

The Material Used

Two types of material were used:

1. Epoxy Resin

Epoxy is defined as a substance polymeric solid thermally (Thermoset) contains one or more groups of Epoxide and the simplest his formula is Oxirane as it represents by oxygen an atom linked with two atoms of carbon. Epoxy are comprised of an epoxy resin and a curing specialist (likewise called a hardener or impetus). Epoxy is thermosetting epoxide polymer that contains at least two epoxide bunches. It is one of most usually utilized thermosetting large scale atomic engineered materials. An epoxy resin is defined as a molecule with more than one epoxy group, which can be hardened into a usable plastic. The epoxy group, which is also called the glycidyl group, has through its characteristic appearance given the name to epoxy.

2. Unsaturated Polyester Resin

The term ‘polyester resin’ is applied to the condensation reaction products of diacids and diols (glycols). Polyesters are non-linear resins. They have a good resistance to oils and solvents. A good example is polyethylene terephthalate, PET, made from ethylene glycol and terephthalic acid and used in the form of fibre. Terylene, for clothing or molded into bottles for carbonated drinks. Polymers of this type are termed ‘saturated polyesters’. UP’s are derived in a similar manner but at least one of the raw materials used in an ethylenically unsaturated compound.Thesepo lymers are therefore capable of further reaction.

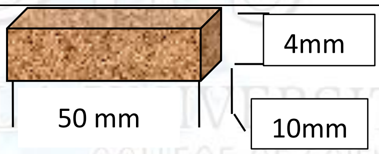
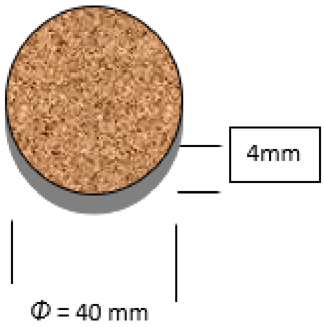
Reinforcement Material

The Kevlar fibers were used as polymers for the polymer mixture and are of yellow color belonging to the Aromatic Poly type density (1.45 g / cm^3) and characterized by light weight and high durability.

Preparation of Sample

Hand lay_up molding was used in the preparation of samples. This method is one of the simplest methods. A polymer mixture (EP 80% + UPE% 20) reinforced by a number of layers of Kevlar fiber (2L, 4L, 6L and 8L) with a volumetric fraction of 30%. The preparation of Hardness and Thermal conductivity samples were be according to the standard specification as shown in Table (1). The photographs of Hardness and Thermal conductivity samples are shown in Figure (3).

Table 1: The standard dimensions of the samples

Global standard specifications	Standard dimensions	Test type
ASTM-D256-87		Hardness Test
The standard dimensions of the samples are suitable for selecting a disc for Lees' Disk		Thermal Conductivity Test

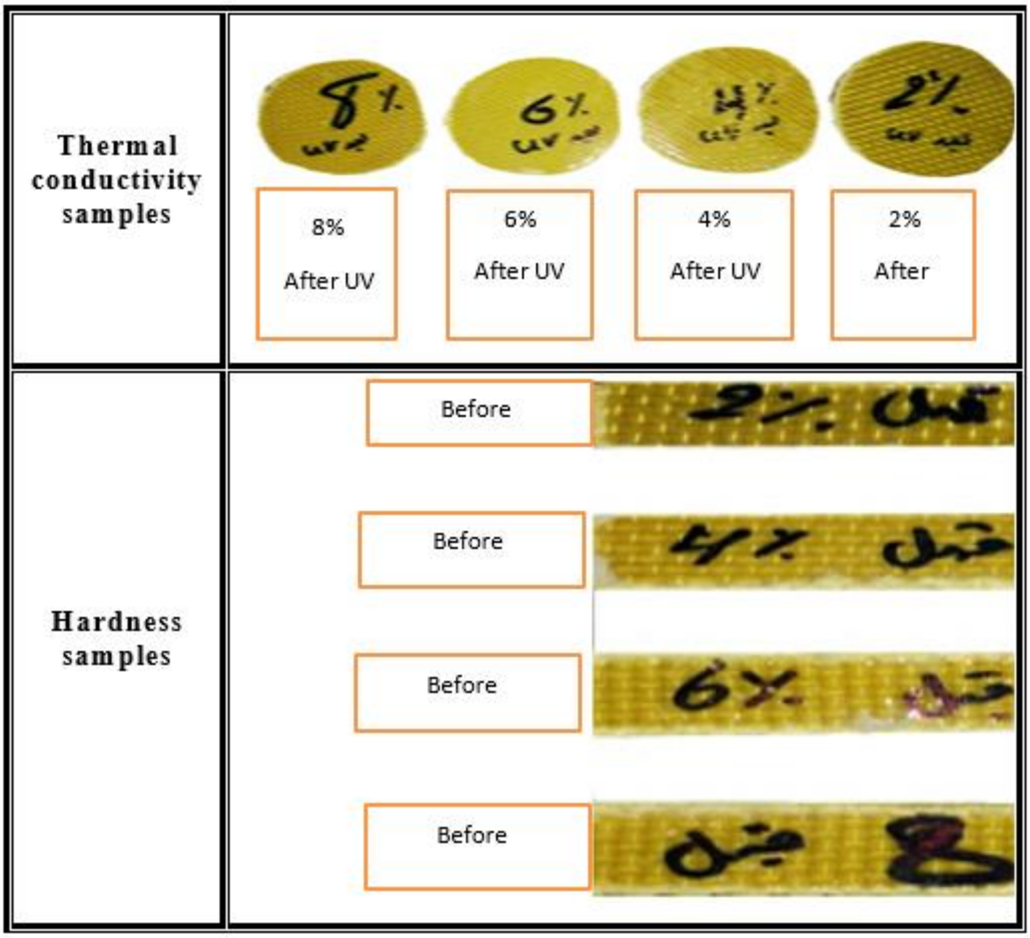


Figure 3: The photographs of the samples

Results and Discussion

Results of Hardness Test

Figure (4) shows that the hardness increases with increasing the number of Kevlar layers in the normal condition this belong to the effect of applied stress on the Kevlar fibers, which decreases with increasing the number of Kevlar fiber layers and this cause the increment of material surface restance to the penetration and deformation. Figure (5) shows the hardness increasing with the number of Kevlar layer after (UV) irradiation, because the (UV) ray improving the mechanical proportion of sample by increasing the cross-link of polymer chains the comparison between figure (4, 5) is illustrated in figure (6) this results consistent with the results of researcher [8].

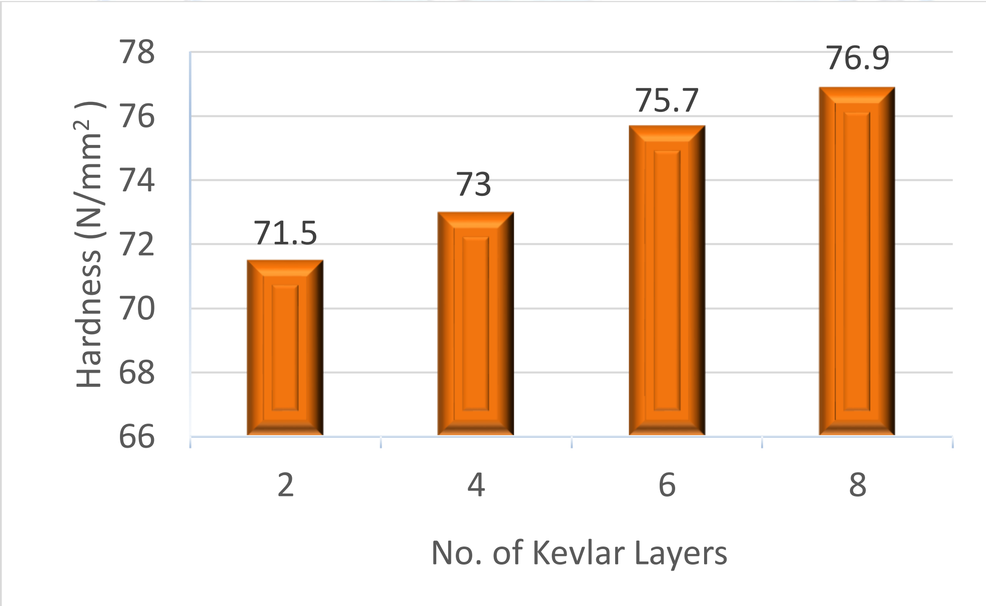


Figure 4: The relationship of hardness with the number of Kevlar layers in the mixture under normal conditions

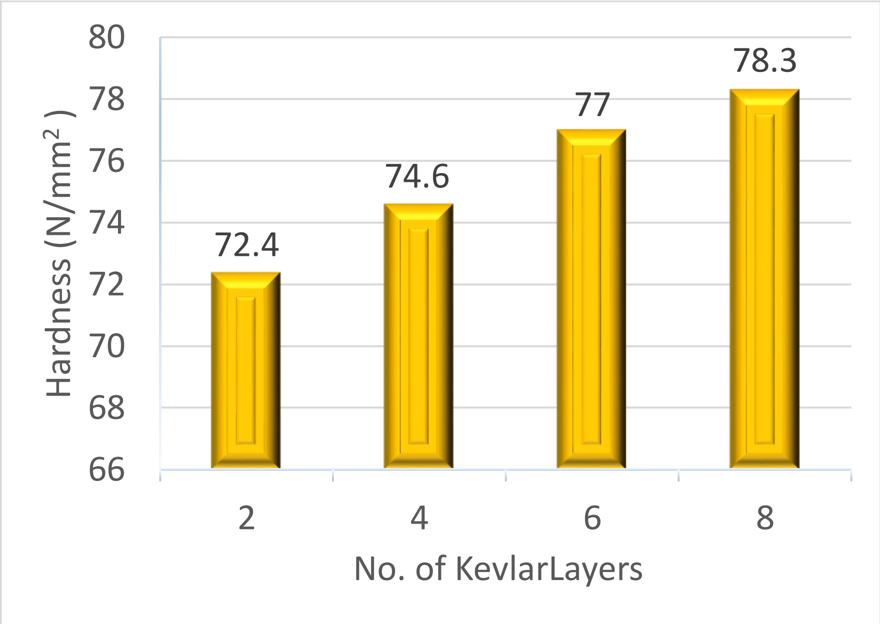


Figure 5: The relationship of hardness with the number of Kevlar layers in the mixture after UV irradiation

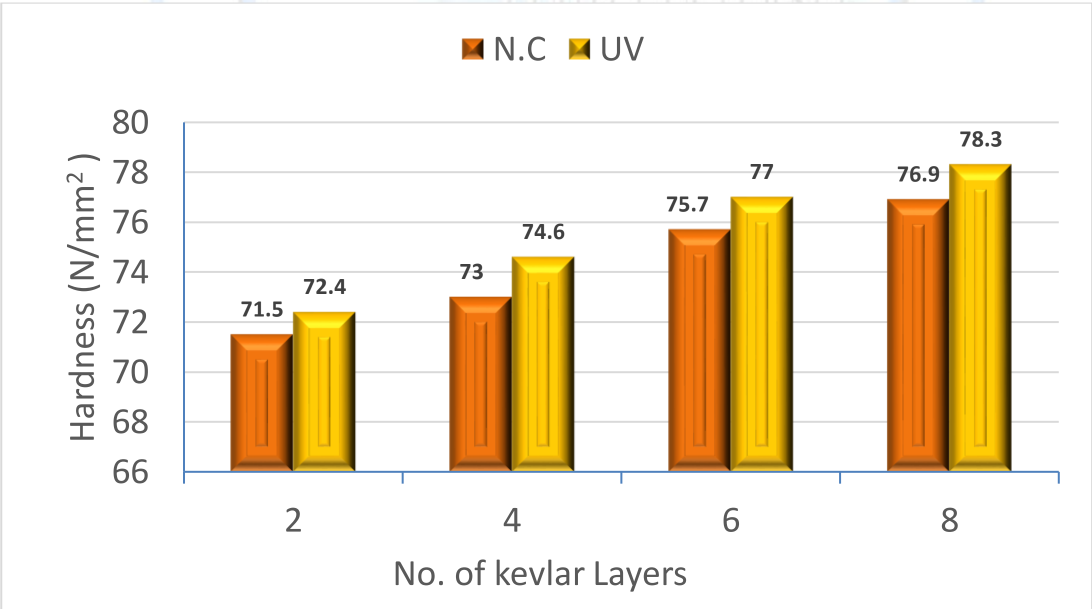


Figure 6: The comparison of hardness with the number of Kevlar fiber layers in the mixture before and after UV irradiation

The Results of Thermal conductivity

Figure (7) shows that the thermal conductivity increases with creasing the number of Kevlar layers because thermal conductivity of Kevlar layers is more than the mixture (EP80%+UPE20%) which cause the increasing of thermal conductivity in normal condition. After (UV) irradiation also the thermal conductivity increases with increasing the number of Kevlar layers, due to the effect of (UV) ray, as in figure (8). Figure (9) shows comparison between normal condition and (UV) irradiation from which seen that the thermal conductivity after (UV) irradiation is higher than that in normal condition, and this is consistent with the researcher [2]. For polymers with low thermal conductivity, phonons are responsible for thermal conductivity. The higher the number of Kevlar layers in a compound, the lower the free path distance. This means increased vibrations, thus increasing the heat transfer through the phonons. Figure (8) shows the thermal conductivity values after irradiation with ultraviolet radiation. The thermal conductivity of the layers (2L) is 27.44 W / mc$^{\circ}$ to 43.16 w / m.C$^{\circ}$ at layer (8L). We note that the thermal conductivity values of the samples are increased after irradiation. The reason is that the ultraviolet radiation has increased the bonding of the polymer chains thus improving the heat conduction process. This is consistent with the results of the researcher [18].

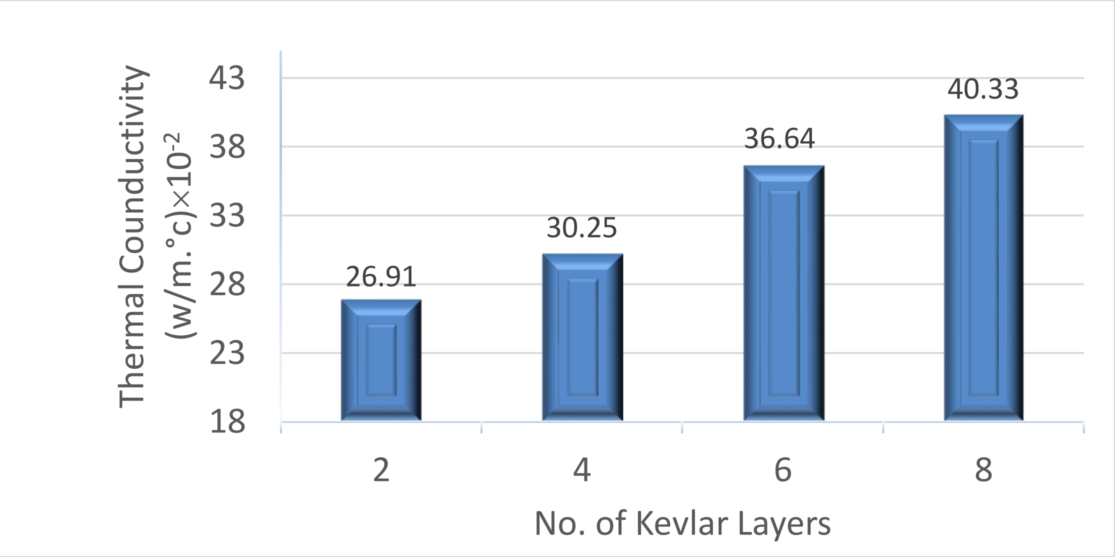


Figure 7: The relationship of thermal conductivity with the number of Kevlar layers in the mixture under normal conditions

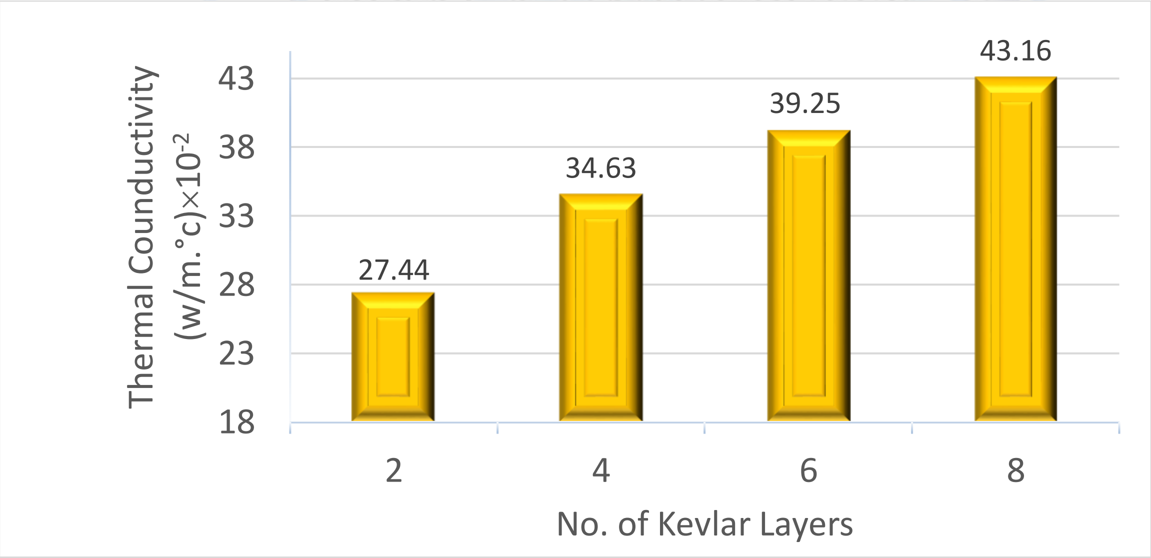


Figure 8: The relationship of thermal conductivity with the number of Kevlar layers in the mixture after UV irradiation

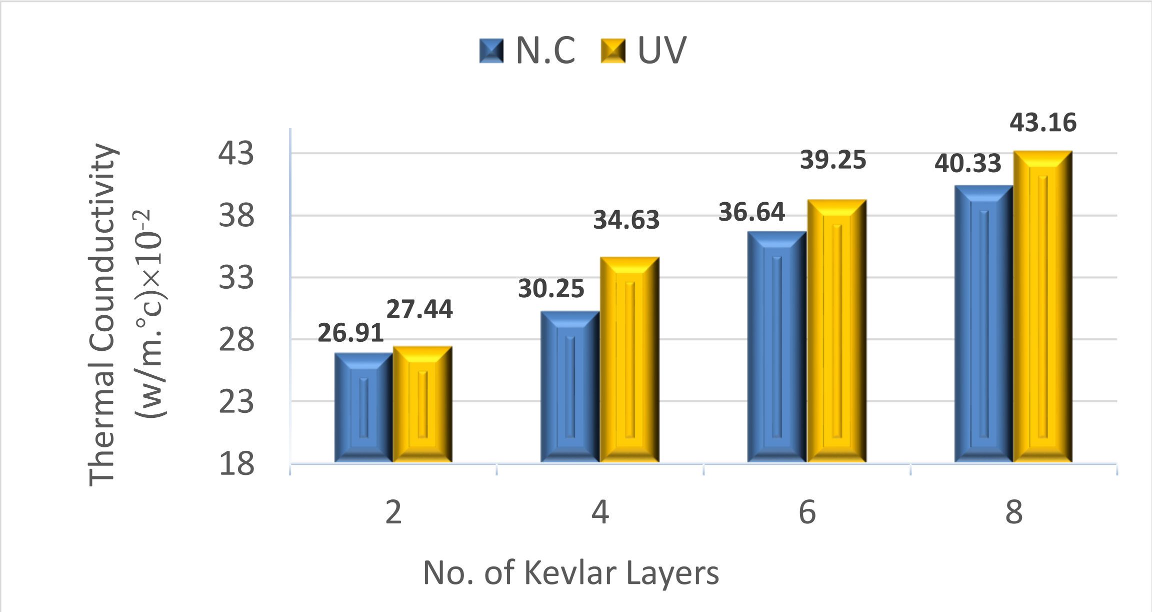


Figure 9: The comparison of thermal conductivity relationship with the number of Kevlar layers in the mixture before and after UV irradiation

Conclusions

1. The value of hardness increases by increasing the number of Kevlar layers before and after UV irradiation. The increase at the eighth layer is the highest of the hardness values.
2. Thermal conductivity increases with increase this number of Kevlar fiber layers in (N-C) and (UV) irradiation, and this value at (UV) irradiation is higher than that in normal condition.

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