Al-Nahrain University, College of Engineering Journal (NUCEJ) Vol.19 No.1, 2016 pp.56 - 65

Investigation on Thermal and Acoustic Properties of Hybrid Polymer Composite Reinforced by Date Palm Fibers and Rice Husks as a Construction Material

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Abstract

This paper presents the versatility of date palm fibers and rice husks and its applications in different branches of engineering, particularly in civil engineering as a construction material. date palm fiber and rice husks are one of the natural materials abundantly available in tropical regions, and is extracted from agricultural or agro-industrial residues as an insulating material resource has various economic and environmental advantages such as reduction in the materials dependency on imported insulating and minimization of waste disposal. In this study date palm fibers and rice husks waste particleboards as insulation boards were manufactured. The boards were fabricated from unsaturated polyester resin as a matrix reinforced by rice husk and date palm fibers they have a total volume fraction (30%) with the ratios of (0/30, 5/25, 10/20 15/15, 20/10, 25/5 and 30/0) volume fraction of rice husk / date palm fibers Two groups of hybrid composite were prepared depending on the fibers length (palm fibers its length 2-3 mm and short fibers its length less than 1mm). The fabricated boards were evaluated for the thermophysical (thermal conductivity, specific heat and thermal diffusivity) properties and acoustic properties (sound absorption coefficient) for all the samples prepared. The results showed that thermal and acoustic insulation properties increase with increased the volume fraction of date palm fiber and rice husks in hybrid composite, whereas decrease with increased fiber length, moreover the thermal insulator of the polyester composite reinforced with rice husk gave a better thermal insulator whereas polyester composite reinforced by date palm fibers gave the best acoustic insulation.

Keywords: Polymer composites; rice husk; date palm fibers, acoustic properties, construction material

1. Introduction

Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly.

Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications. The composites materials “green” have already proven their worth, especially in the building sector the current challenge is to make them cost effective[1].

Composite is a combination of at least two different materials. Composites offer superior properties when compared to their essential components. Three dimensional nature is obtained with combining components that any of the components does not exist this desired property alone. The composite materials are used generally to develop one or more of the following features: mechanical properties, fatigue resistance, corrosion resistance, fracture toughness, high temperature resistance, thermal conductivity or thermal resistance, sound conservatism or sound absorption, weight, appearance and some other properties [2].

The greatest advantages of lightweight building material are its low density, allowing for construction on the ground with only moderate bearing capacity, the ability to construct taller structures, greater economy in lifting and the use of more thermally efficient material [3].

Utilization of agricultural or agro-industrial residues as an insulating material resource has various economic and environmental advantages such as reduction in the materials dependency on imported insulating and minimization of waste disposal. Main sources of biomass include agriculture waste. Rice husks, as an organic waste, Dewangan, and Neeraj they used rice husks as a thermal insulator they found that the using rice husks solve this environmental problem and provide an advantage in producing lightweight and low-cost concrete [4].

Kush and Alok revealed that the incorporation of rice husk particles results in reduction of thermal conductivity of polyester resin. It is found that with incorporation of about 11vol% of raw rice husk in the polyester resin reduces its thermal conductivity by about 15 % [5].

The influence of sintering temperature on the thermal conductivity of rice husk ash refractory was examined by Celestine, Mbakaan et al [6].

Natural filler it have many significant advantages over synthetic filler and fibers such as light-weight, low cost, ability to reduce abrasion of machinery and also non-toxicity. Currently, many types of natural fillers have been investigated to be used in the industry including flax, hemp, wood, wheat, barley, and oats. They are now fast evolving as potential alternatives to inorganic or synthetic materials for various applications as building materials and automotive components [7].

Many research centers have developed new sustainable materials, with interesting acoustical properties. And in order to combine high acoustic and thermal performance with a low impact on the environment and human health. The natural fibers have very low toxicity and their production processes can contribute to protect the environment.

The alternative raw materials those are of low cost, renewable, and plentiful and save for environment and human health is needed. For instance the coir fiber has good sound absorption at higher frequencies but less for the lower frequencies, so did the oil palm fiber. Higher noise absorption of oil palm is due to its higher density [8,9]. It was found that the deformation the palm fibers improves insulation properties the thermal and acoustic for polymeric composite [10].

In this study, the date palm fibers and rice husks were used to produce particle boards hybrid composite, and study their thermal and acoustical property (the sound absorption coefficients) at different ratios of rice husk/ palm fibers content in hybrid composite, as well as verification of the possibility of the use of palm fiber and rice husks as a construction material in civil engineering.

2. Material and Methods:

In this investigation used rice husk and date palm fibers as the filler materials whereas the unsaturated polyester resin was selected as the binder.

Unsaturated polyester resin (UP) was used as matrix material, supplied by (SIR) Saudi company. Was a viscous liquid, transparent at room temperature. It's one types of polymers hardening thermally, was mixed with hardener (which is a Methyl Ethyl Keton peroxide supplied by the company itself) to form a strong permanent band converted to a solid state. The weight ratio between hardener and resin was 2 gm of hardener per 100 gm of the resin. Date palm fibers as the filler material were collected locally from the date trees obtained mainly from Baghdad former in middle of Iraq. The fibers were taken from petiole of date palm. The second filler material is rice husk which is obtain from Al-Najaf rice farm, there is series of operations had been carried on the rice husks, at first the rice husk used were taken from rice mills.

2.1. Preparation of Rice-Husk and Date Palm Fibers:

The rice-husk and date palm fibers were initially underwent a treatment process in order to strengthen the sample structure. The treatment was also done to obtain the cleanest appearance to the rice husk and date palm fibers. Initially, the rice-husk and date palm fibers were washed thoroughly with detergent powder in order to remove dust and mud. After that these fibers were soaked in hot distilled water for 2h, dried for 72h in air at room temperature. Then, these fillers were immersed with the 95% mixture of Natrium Hydroxide (NaOH) and 5% of water. This immersion process took time up to 24 hours. Next, the immersed rice husk and date palm fibers were washed with distilled water several times and then exposed to the heat of the sun for about 24 hours. In order to ensure the rice husk and date palm fibers was totally clean and strong, the rice husk and date palm fibers was dried in the oven with 80ºC for about 10 hours. Finally, the rice husk was blended by using Variable Rotor Mill machine to get a micro-size powder particle Figure (1, a) The palm fiber was classified based on the dimensions of diameters. The fiber was selected with the identical diameters almost Figure (1, b), these fibers have been used in two forms, as shown below:

- Date palm fibers were chopped into (2-3) mm length these fibers were used as short fibers Figure (1,c).
- Some of the cleaned date palm fibers were ground in the rotary cutting mill type (bran bender Duisburg 880804) to get fine powder with length less than 1 mm (micro-size fibers) Figure (1,d).

In this research prepared hybrid composite materials reinforced with the rice husk and date palm fiber with total volume fraction of (30%) with the ratios of (30/0, 25/5, 20/10 15/15, 10/20, 5/25 and 0/30) volume fraction of rice husk /date palm fibers as indicated in the Table (1).

Table 1: The composition of the prepared hybrid composite.

composition	Vol.% of polyester resin	Vol.% of date palm fibers	Vol.% of rice husk
1	7o	0	30
2	70	5	25
3	70	10	20
4	70	15	15
5	70	20	10
6	70	25	5
7	70	30	0

(a)

(b)

(c)

(d)

Figure 1: (a) rice husk particles, (b) data palm petiole fibers, (c) short petiole fibers (d) micro-size petiole data palm fibers.

1.2. Composite Preparation

Hand lay-out technique was used to prepare the composite specimens, a mould of size (250×250×5) mm^3 was made from glass. Sheet of polyvinyl alcohol substance was fixed on the inner mould faces before casting to facilitate the releasing of casting polymer and having smooth faces. Palm fibers with dimension (2-3 mm) after proper purification surface modification and drying, divides into two parts as mentioned earlier. Then each part were thoroughly mixed with rice husk and polyester resin by different loading in terms of volume fraction as mentioned in Table (1), then the mixture was poured into the mould and allowed to cure for 48h at room temperature (27°C). After solidification, all the specimens (sheets) released from the mould then post cured in an electrical oven at 55°C for 2h. Composite sheets of size (240×240×5) mm^3 were prepared for acoustic insulation test, and anther composite sheets cut off and machined according to standard specifications to produce samples conforming for thermo physical Properties test.

2. Thermo physical Properties Test.

Thermal conductivity, thermal diffusivity and specific heat per unit volume were measured using Hot Disk Thermal Constants Analyzer [11].

The Hot Disk sensor (Figure 2) consists of an electrically conducting pattern in the shape of a double spiral, which has been etched out of a thin metal (Nickel) foil

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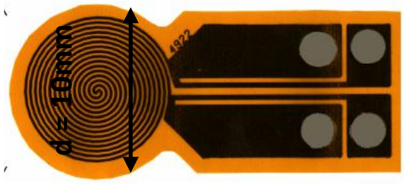

Figure 2: Hot disk sensor.

The plane hot disk sensor is placed between two pieces of the sample material of an insulating material as shown in Figure (3) and is then heated by an electrical current for a short period of time. The dissipated heat generates temperature rise of both the sensor and the surrounding sample material. In order to avoid influence from outside boundaries of the sample, the sample should be larger than the sensor diameter to ensure stable values of both thermal conductivity and diffusivity. The values of thermal conductivity, thermal diffusivity and specific heat are read from the computerize gauge. Figure (4) shows the specimen of this test.

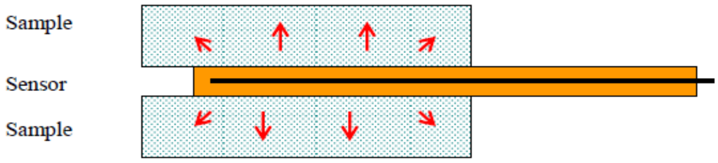

Figure 3: Hot disk sensor operation between two pieces of the sample material

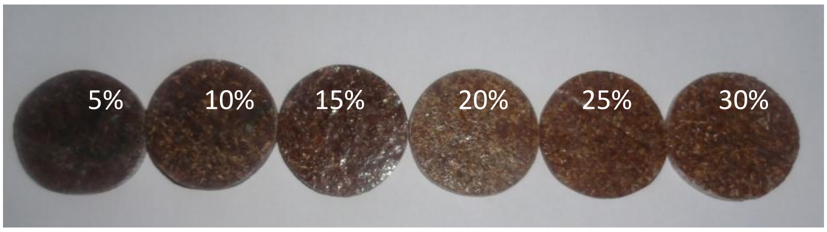

Figure 4: shows the specimen of thermo-physical properties Test.

4. Sound Absorption Coefficient Test

The sound absorption coefficient (SAC) measurement was carried out according to ASTM E-336. SAC of the test specimen was determined by comparing the noise levels sampled inside the source and receiving rooms between which the test specimen (Figure 5 (dimensions (240×240×5) mm^3)) separating them. Sound measurement was carried out inside the two rooms. The loudspeaker is fed with white noise in 1/3 octave band. The averaged sound pressure level was measured in1/3 octave band frequencies, from 100Hz to 5000Hz. If the sound absorption of the source room is A_1 and the sound absorption of receiving room is A_2, the sound absorption coefficient of the test sample is given by [12]:

$$a = (A_1 - A_2) / S \qquad \ldots\ldots (1)$$

Where A_1 and A_2 are sound absorption of the room

S = Surface area of the sample (m^2)

Sound absorption of the room (A_1 and A_2) is calculated by:

$$A = 0.92VD / C \qquad \ldots\ldots (2)$$

Where

V = Volume of room,m^3

C = Speed of sound, m/sec

D = Rate of decay, dB/ sec.

4.1. Noise Reduction Coefficient, NRC

The Noise Reduction Coefficient NRC of a material is the average value of the absorption coefficient of the material at the frequencies of 250, 512, 1024, and 2024 Hz. It is normally used as a simplified descriptor for convenience. The noise reduction coefficient, NRC is more convenient to be used because it is a single number than using several of data depending on the frequency [13].

$$\mathrm{NRC} = \frac{\alpha_{250} + \alpha_{512} + \alpha_{1024} + \alpha_{2024}}{4} \quad \ldots\ldots (3)$$

Where α is absorption coefficient of the material

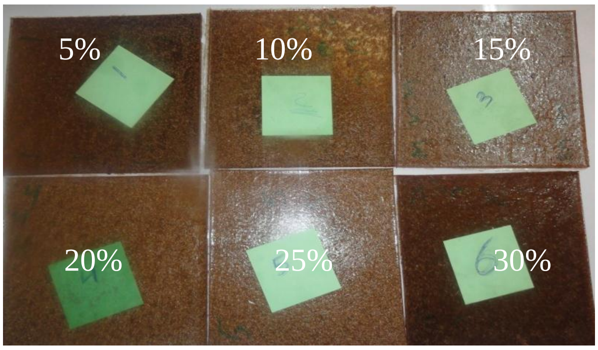

Figure 5: shows the specimen of the sound absorption Test.

5. Result and Discussion

5.1. Thermal Conductivity

The thermo-physical Properties (thermal conductivity, specific heat and thermal diffusivity) of many engineering materials depends upon the nature of constituents, volume fraction of different phases, the shape and size of reinforcement materials and the nature of interaction reaction and interface adhesion between the components of the composite materials. Moreover the thermo-physical properties, connected with the heat flows within a material by the transmission of phonons for insulator material and free electrons for conductor material. Both of these carriers have a certain mean free path between collisions. The mean free path of a phonon is structure sensitive so the thermal conductivity is affected with the thermal properties of each phase in the composite material and the nature of interaction reaction between all components, as well as interface adhesion between these components. Since the conductivity may be impaired by the presence of an interfacial layer of some sort, or by voids and cracks in the vicinity of the interface [14]. The variation in the thermo-physical Properties for hybrid composite materials having a total volume fraction (30%) of fillers material consist of rice husk and date palm fibers with the ratios of (0/30, 5/25, 10/20 15/15, 20/10, 25/5 and 30/0) volume fraction of rice husk / date palm fibers and for different fibers length, are plotted in Figures 6, 7 and 8 respectively. It was observed from Figures 6 and 7 that the thermal conductivity and specific heat of the hybrid composite decreased with increasing the rice husk ratio in the total volume fraction of the fillers in the composite as compared to ratio of date palm fibers in the fillers. it is clear that the thermal conductivity of the polyester hybrid composite decreases to a greater extent when reinforced with rice husk at ratios larger than the ratio of date palm fibers content in composite. The major reason for this is the thermal conductivity value for the rice husk (0.0359 w/m.K [15]) is lower than the palm fiber (K= 0.743w/m.K)[23]. Moreover the hybrid composite material content, the short date palm fibers (length less than 1mm) have the lower values of the thermal conductivity and the specific heat as compared with their counterparts of the other samples reinforced by palm fibers Length of 2-3 mm. these result it was similar to that mentioned in [16]. And on the contrary the values of thermal diffusivity of the hybrid composite were increased with increase the rice husk ratio in the total volume fraction of the fillers in the composite as compared to ratio date palm fibers in the fillers, furthermore the hybrid composite material content, the short date palm fibers (length less than 1mm) have the higher values of the thermal diffusivity as compared with their counterparts of the other samples reinforced by palm fibers Length of 2-3 mm. From the foregoing results it is clear show that the thermal conductivity of the polyester matrix decreases to a greater extent when reinforced with rice husk and date palm fibers, because these fibers content high weight ratio of cellulose which have good thermal insulation properties, therefore as the load of fillers increases the thermal conductivity of the prepared composite decreased, moreover the nature of palm fibers as a hollow tubular structure [17], which leading to the transfer heat energy through it in two method (conduction and convection) then the elastic waves (phonon) transfer through the rice husk, matrix material and solid part of the palm fiber by vibration motion of the atoms and due to the covalent band, and upon the arrived of phonon to the hollow part of palm fiber phonon will suffer obstruction in there motion because the medium presence is different from the first medium, which will lead to decrease thermal conductivity values of the prepared composites. According to the results mentioned above these polyester hybrid composite can be classified as low thermal conductivity behavior as compared with other composite materials.

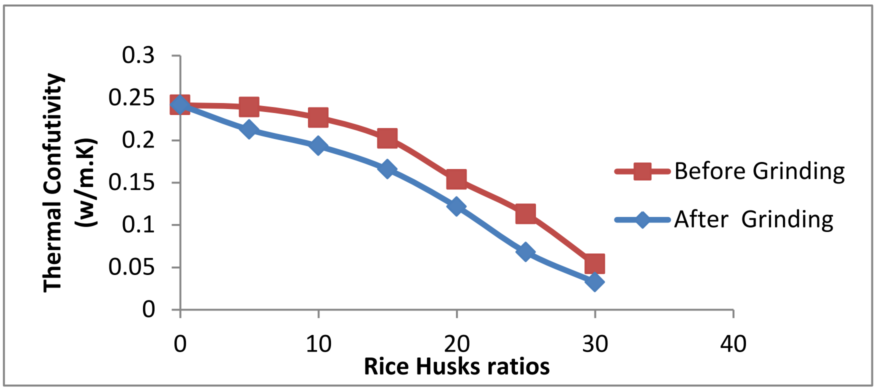

Figure 6: The thermal conductivity for hybrid composite as a function of rice husk ratio in the total volume fraction of the fillers (rice husks and date palm fibers) in the composite

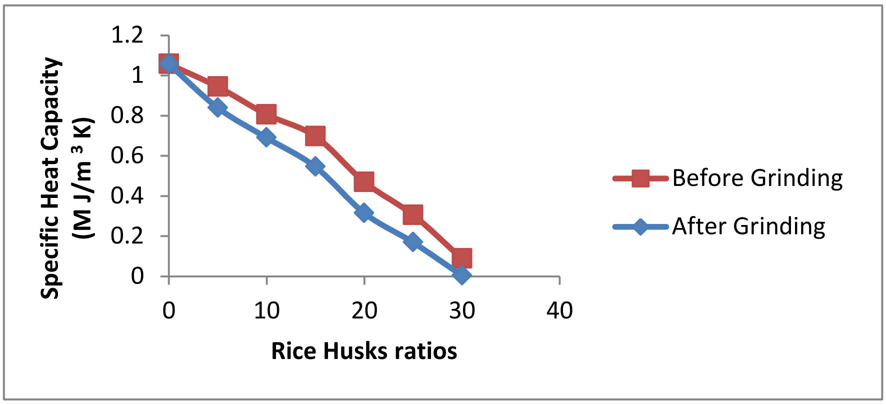

Figure 7: the specific heat for hybrid composite as a function of rice husk ratio in the total volume fraction of the fillers (rice husks and date palm fibers) in the composite

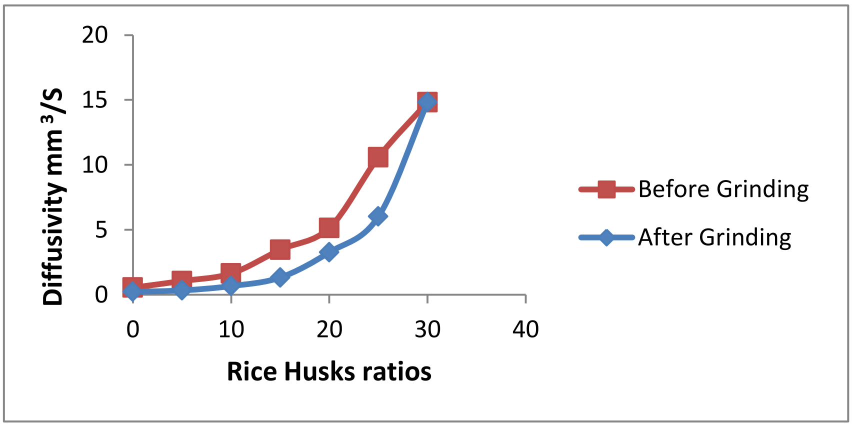

Figure 8: the thermal diffusivity for hybrid composite as a function of rice husk ratio in the total volume fraction of the fillers (rice husks and date palm fibers) in the composite

5.2 Acoustic absorption coefficient

The main parameters critical in the determination of the acoustic properties are the acoustic absorption coefficient. Figures (9 and 10) shows the experimental results obtained for pure polyester material and hybrid composite materials having a total volume fraction (30%) of fillers material consist of rice husk and date palm fibers with the ratios of (0/30, 5/25, 10/20 15/15, 20/10, 25/5 and 30/0) volume fraction of rice husk / date palm fibers and for different fibers lengths, the hybrid composites samples shows higher a absorption coefficient compared to the pure polyester material, this related to the natural of rice husk and the palm fibers which have higher acoustic insulation compared to polyester, as well as it was noticed that the polyester composite reinforced with 30% date palm fibers having higher a absorption coefficient compared to the other polyester composite reinforced with 30% rice husk, this related to the date palm fibers content high weight ratio of cellulose which have good acoustic insulation, furthermore date palm fibers as a hollow tubular (cellular fibers) structure is expected to yield good reinforcement with high damping properties, and have the capacity of reduce the transmission of vibration by mechanical distribution to a structure [18].

Furthermore grounding the date palm fibers to the length less than 1mm (micro-size) enhanced the acoustic absorption coefficient and noise reduction coefficient values Figure 11 of hybrid composite material that contain a short date palm fibers (micro-size length) as compared with their counterparts of the other samples reinforced by palm fibers Length of 2-3 mm, this occurs due to increased flow resistivity with decreased fibers length. There are many factors which effective on absorption coefficient such as cell size, porosity, material density and material thickness. Generally the thicker material exhibits maximum sound absorption coefficient at high frequencies.

However decreased in fiber length can be a useful factor for enhancing the absorption this effect due to increased density and flow resistivity of the material. Moreover the, the short date palm fibers makes micro-pore media that causes the large frictional effect on sound energy when sound is transmitted in the fluid part of the porous media [19]. Otherwise, there will be a probability of sound waves to be reflected by congested material surface rather than absorption due to compact material [20].

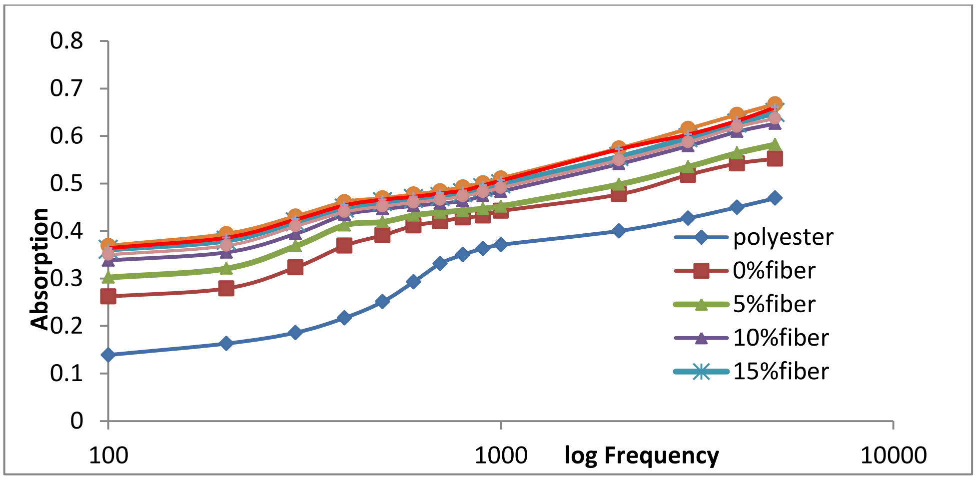

Figure 9: Sound Absorption coefficient versus frequencies sound wave of pure polyester and hybrid polyester composite as a function of palm fibers ratio in the total volume fraction of the fillers (rice husks and date palm fibers) in the composite palm (fibers Length of 2-3 mm).

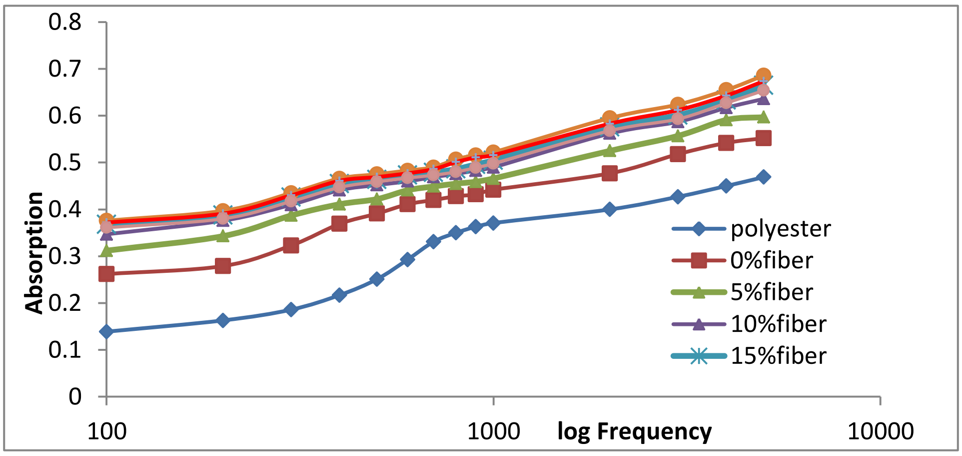

Figure 10: Sound Absorption coefficient versus frequencies sound wave of pure polyester and hybrid polyester composite as a function of palm fibers ratio in the total volume fraction of the fillers (rice husks and date palm fibers) in the composite palm (fibers Length less than 1mm).

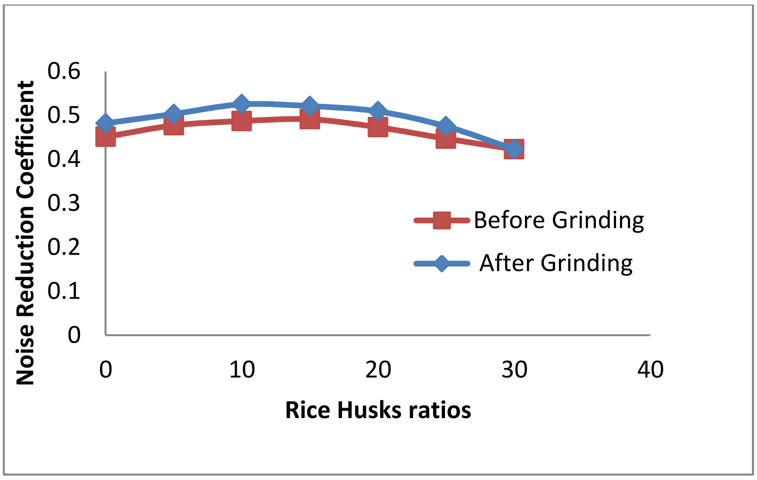

Figure 11: the noise reduction coefficient for hybrid composite as a function of rice husk ratio in the total volume fraction of the fillers (rice husks and date palm fibers) in the composite

6. Conclusions:

In this research it was chose hybrid composite materials having a total volume fraction (30%) of fillers material consist of rice husk and date palm fibers. The thermo-physical properties (thermal conductivity, specific heat and thermal diffusivity) and acoustic properties of these hybrid composites were investigated as a function of fillers content in composite and for different fibers lengths, it was concluded the following items:-

1. The thermal conductivity of hybrid composites reinforced with higher ratio of rice husk it was found to be lower than the parent polymer matrix. And the thermal conductivity of the polyester hybrid composite decreases with increased rice husk at ratios larger than that of date palm fibers content in composite.
2. The thermal insulator of the polyester composite reinforced with rice husk is better than polyester composite reinforced by date palm fibers. And on the contrary the best acoustic insulation it was found for polyester composite reinforced by date palm fibers.
3. The acoustic insulation of hybrid composites it was found to be higher than the parent polymer matrix.
4. Increasing the volume fraction of the fillers (rice husk and date palm fibers) in hybrid composite material led to improved (thermal and acoustic) insulation properties of prepared composites.
5. Decreasing the length of date palm fibers from (1-3mm) to length less than 1mm led to improved (thermal and acoustic) insulation properties of prepared composites.
6. Polyester hybrid composite can be classified as low thermal conductivity and higher a absorption coefficient behavior as compared with other composite materials.

- Depending on what progress can be seen that the polyester hybrid composites it has low thermal conductivity and higher a absorption coefficient, it can be used in the thermal insulation and acoustic insulation applications in structures buildings.

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البحث في الخصائص الحرارية والصوتية للمتراكب المصنع من البوليمر الهجين المقوى بألياف النخيل وقشور الرز كمادة بناء

عمار موسى حسن
الجامعة التكنولوجية / قسم هندسة المواد

الخلاصة:

البحث الحالي يوضح اهمية ألياف النخيل وقشور الرز وتطبيقاتها في مختلف الفروع الهندسية، وخاصة في الهندسة المدنية كمادة بناء. ألياف النخيل وقشور الرز هي واحدة من المواد الطبيعية المتوفرة بكثرة في المناطق الاستوائية، وتستخرج من المخلفات الزراعية أو الصناعية الزراعية كمصدر للمواد العازلة .لها العديد من المزايا الاقتصادية والبيئية مثل الحد من الاعتماد على المواد العازلة المستوردة و التقليل او التخلص من النفايات. في هذه الدراسة صنعت ألواح من ألياف النخيل و مخلفات قشور الرز. صنعت الألواح العازلة من راتنجات البوليستر غير المشبعة كمادة اساس مقواتي بقشور الرز وألياف النخيل بكسر حجمي إجمالي (30%) وان نسبة الكسر الحجمي لقشور الرز نسبة لالياف الخيل هي (30/0، 25/5، 20/10 15/15، 20 / 10، 5/25 و0/30). صنعت نوعين من المواد المتراكبه الهجينه بألاعتماد على طول ألياف النخيل (الياف نخيل ذات طول 2-3 ملم والياف قصيره ذات طول اقل من 1 ملم). جرى تقييم اللوحات المصنعه من حيث الخواص الفيزياويه الحراريه (التوصيل الحراري، الحرارة النوعية وانتشار حراري) والخصائص الصوتية (معامل امتصاص الصوت) ولجميع العينات المحضره. أظهرت النتائج أن خصائص العزل الحراري والصوتي تزداد مع زيادة الكسر الحجمي للألياف النخيل وقشور الرز في المتراكب الهجيني، في حين انخفاض خصائص العزل مع زيادة طول الألياف، علاوة على ذلك أعطى متراكب البوليستر المقوى مع قشر الرز عزل حراري أفضل في حين أن متراكب البوليستر المقوى بألياف النخيل أعطى أفضل عزل صوتي.