Investigation of the influence of adding MWCNTS to an alkyd-urethane coating on the thermal conductivity coefficient of the coating

B E Eddin¹, A J Ali¹,²*, J M Hadi³ and E N Tugolukov¹

¹Technology and Methods of Nano Products Manufacturing, Tambov State Technical University, 106 Sovetskaya Street, 392000 Tambov, Russia
²Department of Biomedical Engineering, University of Technology, Baghdad, Iraq
³Mechanical Engineering Dept. University of Technology, Baghdad, Iraq

10678@ uotechnology.edu.iq

Abstract. In this study, the influence of adding MWCNTs to an alkyd-urethane coating has been studied on the thermal conductivity coefficient K of the coating, to determine its potential for use in solar water heating applications where the low value of the thermal conductivity coefficient of the polymeric coatings is an obstacle to their use as absorbent surfaces in solar collectors. A light source, a halogen lamp, was used as a heat source; the temperature measurement was done using an infrared thermometer. The results showed an enhancement in the thermal conductivity coefficient of 9.16% when it is added 4 % of the MWCNTs.

1. Introduction

Coating is one of the oldest materials that humans used. In ancient times, the coatings which were made of metal oxides such as iron oxide and copper oxide, were used to decorate buildings and temples [1]. With the development of chemistry, humans began to manufacture functional coatings for more important purposes than decorating, where humans recognized that coating can provide good protection for the surfaces from the surrounding environment. Later with the development of science and the emergence of nano-technology, new types of coatings have been manufactured which called nano-coatings [2]. The properties of nanocoatings differ according to the added nanomaterials. Nanomaterials can improve the properties of coatings to be suitable for specific applications. As an example, a flame retardant coating is manufactured by adding nano-concentrates with nano-TiO₂ and nano-SiO₂ to an ammonium polyphosphate-pentaerythritol-melamine (APP/PER/MEL) coating [3]. Also, a type of anti-corrosion coating was obtained by adding nano ZnO to the epoxy coating [4]. It is well known that coatings based on polymeric materials have a low thermal conductivity coefficient [5], and this limits their usage as absorbent layers in solar collectors, but by the possibilities that nanomaterials can provide when adding them to these coatings, it is now possible to enhance the thermal properties of these coatings. Alkyd-urethane coating is one of the coatings types which based on polymeric materials. This coating consists of alkyd resins modified with urethane resin. This coating is intended for interior/exterior use in industrial environments. It can be applied easily by brush, roll, or spray. This coating has many important properties, including its excellent adhesion to the surface to which it is applied, the external durability of coated surfaces, corrosion resistance, and
chemical resistance, etc. [6]. Carbon nanotubes are a good candidate for adding to these coatings because carbon nanotubes have a high thermal conductivity coefficient [7]. In this study, the influence of adding MWCNTs to an alkyd-urethane coating on the thermal conductivity coefficient of the coating was investigated.

2. Experimental methods

In this section, the materials and equipment used to conduct the experiment and how to conduct it were explained.

2.1 Materials and equipment used

In order to conduct the experiment, three copper plates were used, one of these plates was coated with an unmodified alkyd-urethane coating, and the second plate was coated with a modified alkyd-urethane coating using MWCNTs, while the third uncoated plate is used to measure the heat flux which is coming from the heat source (light source, a halogen lamp 2000 w, was used as a heat source). The modified alkyd-urethane coating was prepared by adding the solvent (white spirit) to the alkyd-urethane coating to become the required consistency after this, 24 g of the coating has been taken and 1 g of MWCNTs was added to them. Then the coating and MWCNTs well mixed and have been exposed to ultrasound for 90 minutes to achieve homogeneity better between the coating and carbon nanotubes. It is worth noting that, before applying a coating layer, the copper plates were well cleaned, according to the manufacturer's recommendations [6]. The coating layer was applied with a brush made by a natural fiber paintbrush according to the manufacturer's recommendations too [6]. In Figure 1, the used copper plates were shown. To measure the temperature an infrared thermometer WH 380 is used with an accuracy of ± 0.1°C.

![Figure 1. The copper plates](image)

2.2 The implementation of the experiment

Firstly, the uncoated copper plate is fixed against the heat source (light source), the distance between them equals to 50 cm and heated until it reaches a thermal stability condition (i.e. its temperature becomes almost constant). Note that the initial temperature of the plate before heating was equal to the room temperature, which is 21°C. Then using a thermometer, the temperature is measured on both sides of the plate (the side facing the light source and the side Shaded). Through the values of temperatures on both sides of the plate and based on the value of the coefficient of thermal conductivity of copper as well as the thickness of the copper plate, we can calculate the heat flux passing through the plate according to Fourier’s law [8]. Measurements are taken at several points from each side in order to calculate the mean temperature for each side, and taking many readings reduces the error resulting from the measurement process. In the same way, measurements are taken of other plates; taking into consideration that the coated side should be on the shaded side (This is to
isolate between the change in the thermal conductivity coefficient and the change in the optical absorption coefficient).

3. Determination of the thermal conductivity coefficient of an unmodified and a modified coating layer

In order for us to determine the amount of enhancement in the coefficient of thermal conductivity of the coating, the thermal conductivity coefficient of the coating must be known before and after modification.

3.1. Determination the value of the heat flux

In this research the experiment was conducted according to laboratory conditions (The initial temperature is stable and is 21℃), a heat source with a constant heat flux (a halogen lamp 2000 w, as a heat source) was used. According to the fact that the value of the heat flux issued by the used light bulb is unknown, this requires calculating these value through applying the heat transfer equation across flat surfaces (uncoated copper plate) in one direction [8], and the differential form of this equation was not chosen because the intensity of the heat flux is constant during the experiment. All factors used in Fourier’s law are known, where the copper plate thickness equals ΔX₁ =0.2 mm, The thermal conductivity coefficient of copper \(k_{cu}\) was assumed as 384 w/m.k [9], The temperature of both sides of the plate was measured in several points, and the average temperature for each side was calculated after the temperature for each side reached a thermal stability state. The following Table 1 shows the values of the measured temperatures for both uncoated plate's sides and the mean temperature them.

| Measurement №  | The Shaded side \(t_2\) | The side facing the heat source \(t_1\) |
|----------------|------------------------|-------------------------------------|
| Temperature \(t\) [℃] | 32.7 | 32.6 | 32.6 | 32.8 | 32.7 | 32.8 |
| mean temperature \(\bar{t}\) [℃] | 32.63 | 32.76 |

Now, the one-dimensional heat transfer equation is applied to calculate the heat flux value \(q\):

\[
q = \frac{k_{cu}}{\Delta X_1} \left(\bar{t}_1 - \bar{t}_2\right) = 24960 \text{ w/m}^2
\]  (1)

3.2. Calculation of thermal conductivity coefficients for an unmodified alkyd-urethane and a modified alkyd-urethane coating with MWCNTs:

After defining the heat flux passing through the uncoated copper plate that equals to the heat flux the passing through the coated plate with alkyd-urethane coating, and as the thickness value of both the copper plate \(\Delta X_1 = 2 \times 10^{-3} \text{ m}\) and the coating layer \(\Delta X_2 = 0.05 \times 10^{-3} \text{ m}\) [5] are known, the thermal conductivity coefficient of the unmodified coating plate \(K_2\) is calculated by means of the one-dimensional Fourier’s law For several layers as shown in equation (2). The following table 2 shows the values of the measured temperature for both sides of the plate coated with an unmodified alkyd-urethane coating and the mean temperature them.
The formula used to calculate the value of the thermal conductivity coefficient of the modified coating is the same one that was used in calculating the coefficient of thermal of the unmodified one, with considering the temperature difference between the two sides of the plate. The following table 3 shows the values of the measured temperature for both sides of the plate coated with a modified alkyd-urethane coating and the mean temperature them.

### Table 3. Temperature values on both sides of the plate coated with a modified alkyd-urethane coating.

| Measurement № | The Shaded side t₃ | The side facing the heat source t₁ |
|---------------|--------------------|----------------------------------|
| Temperature value t [°C] | 1 2 3 | 1 2 3 |
| 29.3 | 29.3 | 29.4 |
| 32.7 | 32.7 | 32.8 |
| mean temperature t̅ [°C] | 29.33 | 32.73 |

3.3. Calculation the rate of enhancement

The rate of enhancement due to the modification of coating can be obtained as:

\[
\text{Percentage increase} = \frac{K'_2 - K_2}{K_2} = 9.16 \%
\]

That is, adding MWCNTs to the alkyd-urethane coating enhanced its thermal conductivity by 9.16 %.

4. Results and Discussion

From Tables 2 and 3, it was observed the temperature difference the shaded side by 0.3 °C. This difference can be explained as a result of the high thermal conductivity coefficient of MWCNTs. It can also be observed that the temperatures on the shaded side in the case of the uncoated copper plate are
much higher than the temperatures on the shaded side in each of the two cases of the coated plates (in the first experiment), due to the presence of a layer of coating which causes, in turn, to additional thermal resistance in case of coated plates [10]. It has been observed that adding carbon nanotubes to the coating matrix led to an improvement of enhancement in the coefficient of thermal conductivity of the alkyd-urethane coating after the modification is 9.16%, and this value is acceptable, in spite of the high thermal conductivity of nanotubes, but their random orientation and interfacial resistance between carbon nanotubes and polymer molecules lead to reducing the thermal conductivity of the composite [11].

5. Conclusion
The results had showed that it is possible to improve the thermal properties of the alkyd-urethane coating by adding carbon nanotubes to it so that it can be used for energy applications, but it should be noted that excessive increase in the addition of carbon nanotubes can cause damage to the polymeric matrix. As the lengths of the nanotubes are in the same range of the thickness of the coating layer therefore, when agglomerated, they lead to distortions in the form of the polymeric matrix, and this will have a negative effect on the thermal properties of the coating. The development of hybrid polymeric coatings for energy use is important as these materials have good resistance to surrounding conditions and also have a relatively low cost compared to materials used for selective surfaces. It is worth noting that additional studies must be conducted on the effect of adding nanomaterials on the adhesion strength of polymeric coatings to the surfaces to which they are applied, as well as studying the economics of this modification.

References
[1] Jaksh C and Egyptian B1983 Naturwissenschaften 535 525–35
[2] Tobergte D and Curtis S 2013 J. Chem Inf Model. 531689–99
[3] Wang Z, Han E and Ke W 2006 J. Can Metall Q 45 485–92
[4] Hasnidawani J, Hassan N, Norita H, Samat N, Bonnia N and Surip S2017 J. Mater. Sci. Forum. 894 76–80
[5] Ellis B and Smith R 2008 Polymers: a property database. CRC Press
[6] https://www.paintdocs.com/docs/webPDF.jsp?SITEID=STORECAT&doctype=PDS&lang=E&prodno=B54W151
[7] Porter WD 2005 Thermal Conductivity 27 Thermal Expansion 15 Joint Conferences Knoxville, Tennessee USA. DEStech Publications, Inc
[8] Black FKWZ and Kreith F1980 Basic heat transfer
[9] Pawar PM, Ronge BP, Balasubramaniam R and Seshabhattar S 2016 Techno-societal. Conf. Proc. ICATSA p 9
[10] Mitchell JW and Braun JE 2012 Principles of heating, ventilation, and air conditioning in buildings ( John Wiley & Sons)
[11] Grady B P 2011Carbon Nanotube-Polymer Composites Manufacture, Properties, and Applications. Carbon Nanotub Compos Manuf Prop App