THERMAL CONDUCTIVITY CHARACTERISTICS OF POLYMER COMPOSITES BASED ON POLYETHYLENE WASTES FILLED WITH POST – INDUSTRY WOOD WASTES

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ABSTRACT

Polymer composites mixes based on low- density polyethylene wastes filled with post- industry (saw dust) were prepared and fabricated to sheets using standard procedures. An experimental set- up based on ASTM-C177 (2000) and ISO 8302 (1998) standard is built up in our laboratory to measure the thermal conductivity characteristics of the prepared composites. The effects of % weight of saw dust and its particle size, thickness of the insulating sheets, and temperature on the thermal conductivity coefficient values were investigated. The results obtained confirmed that optimum insulation can be obtained with 50% weight and 0.5 mm particle size of the waste filler.

INTRODUCTION

The challenge and opportunity of using cellulosic materials as reinforcing fillers for thermoplastic is very appealing. Composites of polyethylene and polypropylene with sawdust, called (Woodstock), were developed by I.C.M.A (Milan, Italy) company. This company manufactured approximately 26 million tons of Woodstock panel for automotive interior trim market in (1991) (1).

The utilization of cellulosic materials as reinforcing fillers for both virgin and recycled thermoplastics has been established because of environmental pollution issues and because of the various potential advantages, they offer compared with those of conventional reinforcing fillers e.g. talc, mica and glass. Some of their advantages are: low cost, low density and renew ability, nonabrasive nature which permits the use of high fiber loadings without the extensive damage to compounding and modeling equipment that can occur with much harder mineral filler(2).

On the other hand plastics constitute presently 10 to 15% of municipal refuse. Polyolefins constitute the majority 70% of plastics in the disposal area followed by styrene polymers. PVC packaging waste constitutes the majority 60% of the plastic components of the solid waste.

Municipal refuse can be treated as a potential source of raw materials. The scarcity of raw materials and the concern about environmentally safe disposal of refuse have added a new dimension to question of the recycling solid wastes(3).

Plastics wastes are the one problem, which face the world by what cause as injury in the environmental and human. Production of LDPE and HDPE grow quickly, specially, in the last years. So the problem is how we disposal from these large quantities as it is the object in our investigation.

There is a great diversity of application for which plastics are used. One of the main application sectors is in energy conservation.

Plastics are used as insulators, they have major contribution to offer in the maintenance of temperature above and below ambient. Thermal insulation plastics are used in many industrial processes such as glass, petroluim, chemical, steel and Aluminum industries in addition to that, they have great role in building structures.

Thermal conductivity of polymer composites is caused mainly by conduction in the polymer phase which resists the heat flow through polymer matrix.

The scope of this study was focused on preparation of plastic insulators from waste materials, the plastic matrix is the post consumer low- density polyethylene packagings filled with the post- industry wood saw-dust. The effects of % weight and particle size of saw dust, temperature, and thickness of the insulator on thermal conductivity characteristics of the prepared composites.

Theory

In order to determine the solid thermal conductivity, k, of polymer composites mixes, the Fourier equation was used to show that the heat is transfer in one dimensional at steady state as below(4):

$$q = -k_m A \frac{dT}{dx} \quad (1)$$

where:

q = the heat flow through sample, in (W), by one dimensional, km= thermal conductivity coefficient in (W/moC), A = area of heat transfer in (m2), $\frac{dT}{dx}$ = the temperature gradient in (°C/m), and the minus sign is a consequence of the fact that heat is transferred in direction of decreasing temperature.

Eq.(1) can be expressed as below:

$$K_m = \frac{q \cdot x}{A \cdot \Delta T} \quad (2)$$

For the prepared composites, the thermal radiation and convection can be neglected because the radiative and convective are inversely proportional to pore diameter of the solid cells(5), and as the polymer composites mix was fabricated using heating compression under a load of 15 tons, pores are not valid in the prepared composites.

EXPERIMENTAL WORK

Preparation of the Composites

The matrix polymer materials are low-density polyethylene flakes cut from post- consumer packagings without any washing. The post-industry wood waste is saw- dust, which is sieved to different particle size.

The compounding of polymer and filler was carried out in a twin screw extruder (haake rheochrder torque rheometer). Usually 250 gm. of total weight (polymer and filler) feed to the extruder at temperature (120-180oC). The extrudate pass through water path and then cut to pellets with (2×4mm.). Square shape specimens (15x15 cm.) were obtained by compression molding in a carver laboratory press at 175oC under 15 ton. Several composite sheets were fabricated with different thickness(from 3 mm to 18 mm) and different particle size of the waste fillera(from 0.5 to 3.5 mm).

Experimental Setup

The guarded hot plate (GHP) apparatus had been fabricated in our laboratory to measure the thermal conductivity of the new thermal insulations. It is based on the ASTM- C177 and ISO 8302(6). The apparatus consists of a GHP, a temperature controller, a digital multimeter recorder, and power supply (DC and AC). A schematic diagram of the set up is shown in figure (1).

The GHP was calibrated by reference materials e.g. polyurethane, polystyrene, glass wool, and wood fiberboard. It works at range temperature between 20oC to 250oC.

The steady state flat method is adopted in this measurement. The equilibrium temperature was reached after 110 minute as shown in figure (2).The thermal conductivity coefficient can be calculated using equation (2).

The experimental thermal conductivity coefficient values measured by GHP may be differ from the actual values owing to some errors in fabrication and/or application such as, errors caused by poor side insulations, and errors caused by unbalance between main and guard heater. Optimum performance of our instrument was adopted using the following equation(7):

$$k = \frac{k_m A \cdot \Delta T / x - q_o / 2}{A \cdot \Delta T / x + \frac{4(W + d_g)}{\pi} \cdot \ln \frac{4}{1 - \exp(-2\pi d_g / x)}} \quad (3)$$

where:

k= the actual thermal conductivity through the samples, in (W/moC), W= width of the main heater, in (m), dg= width of the gap, in (m), and qo= the heat enter or outer caused by unbalance between main and guard heater, in (W). The GHP fabricated is with accuracy of ± 4.76%.

RESULTS AND DISCUSSION

The relationship between thermal conductivity coefficient and % weight of saw dust, particle size of saw dust, average hot surface temperature, and thickness of the composites specimens are shown in figure (3), (4), and (5) for the polymer composites prepared in this study.

It can be seen that the thermal conductivity coefficient of polymer composites decreased with increasing % weight. of saw dust. The results can be attributed to the restriction of heat flow through the polymer matrix by the anisotropy effect caused by the presence of saw dust in the homogenous polymer phase. Good insulation may be obtained as the content of saw dust reached 50% weight as shown in figure (3) (a,b).

The effect of particle size of the filler on thermal conductivity characteristics of the polymer composites is shown in figure (4). The best insulation can be provided with the smaller particle sizes rather than larger particle sizes. The situation can be attributed to increasing the contact points with decreasing particle size of saw dust, and as contact points increase, heat transfer through the sample is restricted.

The hot surface temperature slected in this study seemed to have little effect on thermal conductivity characteristics as shown in figure (3b). The reason for this may be explained such that the solid conduction is the predominant mechanism in such insulators and solid conduction is less effective by temperature compared to gas conduction and radiation(8). Solid conduction is due primarily to lattice vibration mechanism(9).

On the other hand, the thermal conductivity coefficient of the polymer composites prepared seemed to increase with increasing the thickness of the specimens reaching a constant value with specimens of a thickness > 10 mm as shown in figure (5). This is expected, as it is well known that when the amount of the solid matrix increases insulation efficiency increases too.

CONCLUSIONS

Plastic based on low density polyethylene cut from post consumer packagings filled with post industry wood wastes (saw-dust) can be fabricated to produce good insulators for various applications. The optimum insulation was obtained with 50% weight and 0.5mm particle size of the waste filler.

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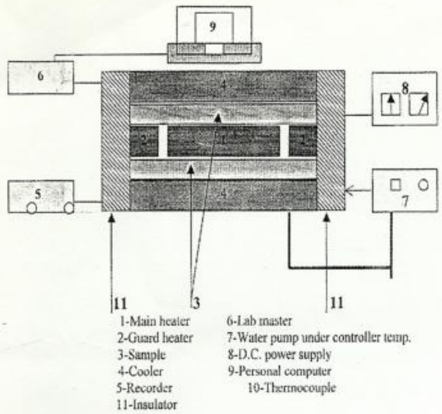

Fig. (1) Schematic diagram of the setup

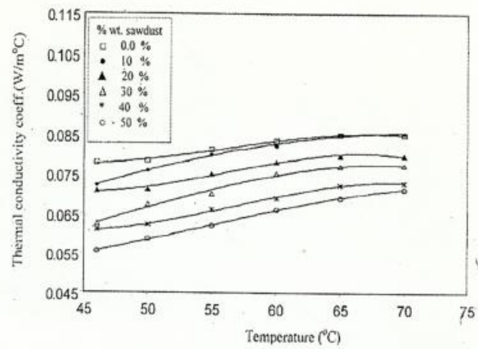

Fig. (3.b) Thermal conductivity coeff. Of polymer composite with different % wt. saw dust as a function of temperature t

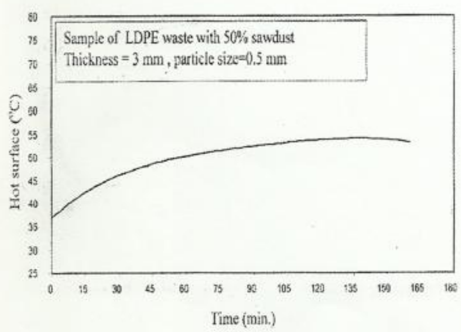

Fig. (2) Relationship between temperature of hot surface and equilibrium time of guarded hot plate

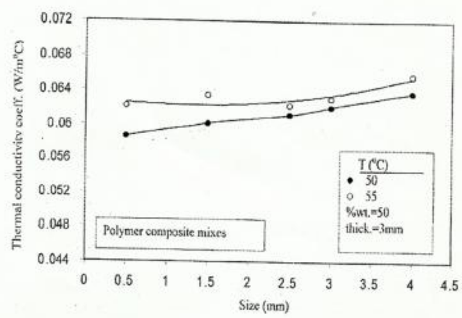

Fig. (4) Thermal conductivity coeff. As a function of saw dust particle size for different temperature

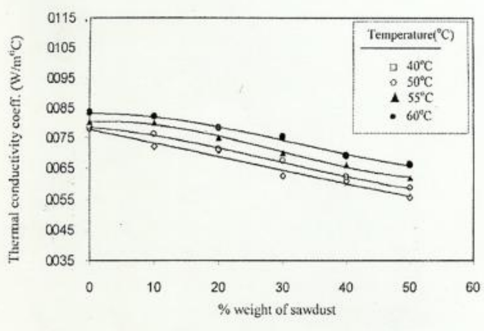

Fig. (3.a) Thermal conductivity of polymer composite as a function of sawdust for different temperature

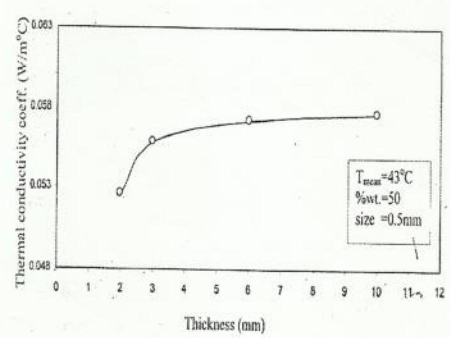

Fig. (5) Thermal conductivity coeff. Of polymer composite as a function of thickness of the insulator