IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology
Vol. 3, Issue 4, April 2016

Determination of Specific Heat of Low Conductive Polymers Using Locally Made Low Cost Calorimeter and Study of Mechanical Properties of Polypropylene

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Abstract: To evaluate the performance of locally made plastic box calorimeter, developed method heat (Q) vs. temperature (T) was used for measurement of specific heat. Specific heat of the three different types of pure polypropylene (pure PP beads, single rolled PP sheets and double rolled PP sheets) and jute fiber reinforced (5%) polypropylene samples were determined. The measured specific heat of samples were showed excellent agreement with the literature value. The mechanical properties like tensile strength, percent elongation at break& young's modulus were measured for corresponding samples. The tensile strength as well as elongation at break was decreased as the rolling number of PP sheets increased but at the same time young's modulus showed increasing trends.

Keywords: Specific heat, single and double rolled PP, tensile strength; elongation at break, young's modulus.

I. INTRODUCTION

Polymer is a large molecule, composed of many repeated subunits. Because of their broad range of properties, both synthetic and natural polymers play an essential and ubiquitous role in everyday life [1]. Polymers are becoming increasingly important as engineering materials and polymer industries are one of the rapidly growing industries in recent times. Composite materials are made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure.

The development of polymer based composites has heightened the need for the multi-scale understanding of their properties. The increasing use of these materials for weight saving purpose, has led to the optimization of filler content in order to enhance thermal and mechanical properties [2]. In present days, a lot of polymeric materials in our day to day life. These materials must be stronger, lighter and less expensive when compared to traditional materials. In modern times recycled polymeric materials which completely fill our criteria of strength, lightness and economy. The investigations conducted ranged from the surface modifications, composite processing methods; to determination of physical properties [3–7].That's why we have to specify these properties for better application. The important physical properties are specific heat, heat conductivity, tensile strength and specific weight.

Specific heat is the quantity of heat required to raise the temperature one gram of gram of material one degree Celsius. Specific heat capacity is important because it determines how quickly a substance will heat up or cool down. The smaller the specific heat capacity of a substance, the quicker the substance heats up or cools down. Specific heat has a very large impact on the usage of the polymeric substances. Substances having different specific heat have different application because of their different thermal behaviour. It is important to determine the specific heat of every polymeric material. Total heat capacity of the calorimeter depends on the thermal diffusivity of the heat to the surrounding [8]. Dissipation of heat from calorimeter and water also considered for determining of specific heat of polymer.

Calorimetry is usually used to determine the specific heat of varying materials. Calorimeter is used to determine the amount of heat evolved or absorbed during a chemical or physical change. From the amount of heat change, the specific heat of substances can be calculated. Specific heat (or specific heat capacity) of materials were mainly measured by differential scanning calorimetry [9, 10] or by transient plane source method [11]. Different method of calorimetry is developing now a day and also the equipment used is always changing.

In this research work, the intention was to fabricate a low cost calorimeter by using locally available material. Also measure the specific heat of low conductive materials and characterized polyethylene by measure mechanical properties.

II. EXPERIMENTAL

A. Object for characterization

Object used for measuring specific heat with plastic box calorimeter are Iron bar, Copper wire, Polypropylene (PP) bar -1 cycle, polypropylene (PP) bar -2 cycle (recycled) and jute reinforced (5%) polypropylene bar. Iron bar, copper wire, PP beads and jute fiber were collected from local market. PP bar and 5% jute reinforced PP bar was prepared in our department by using two roll mixer machine and injection molding machine.

B. Instruments

Two roll mixer machines (model) were used for mixing homogenously. Vertical injection molding machine was used to make the PP bar and jute-PP composites bar. Tensile strength, elongation at break and Young's modulus were measured by universal testing machine (L82-52) in Large unit operation lab, department of chemical engineering and polymer science, Sylhet.

C. Sample preparation

PP bar was prepared from PP beads. The beads first mixed, melted and rolled in a two roll mixer at constant temperature 120^0C for five minutes, transformed to a thin PP sheet. These sheets are then cut into small pieces and put into a vertical injection molding machine where it transformed into PP bar in the mold. This PP bar is called 1 cycle PP bar.

Now to make the PP bar- 2 cycles the PP sheets after one operation from two roller mixers was used, cut into smaller pieces and again feed into the two rollers to make the recycled PP sheet. These recycled PP sheet used in the vertical injection molding machine to make the PP (2 cycle) bar.

Jute reinforced (5%) PP bar was prepared by mixing the dried jute fiber and PP beads homogenously and melted in a two roller mixer machine to make thin composite sheets. These sheets were cut into smaller pieces and fed into injection molding machine to make the composite bars with desired shape.

D. Theory

Adiabatic calorimeters are built in such a way that no heat can be loss from system to surrounding. For this it requires very good insulation to prevent the heat to dissipate from the system boundary. Water is used as a heat transferring fluid in adiabatic calorimeter.

To calculate the specific heat of any materials, to know the value of specific heat of the calorimeter is necessary. A known amount of water (m_w) with known temperature (T_i) has been poured in the calorimeter and the temperature of the calorimeter system is monitor. After certain period the heated water loses some heat and the lost heat is gain by the calorimeter, eventually the system came to equilibrium with a temperature (T_f). For adiabatic system, the energy balance equation of the calorimetric system can be expressed as followed:

$$m_w s_w (T_i - T_f) = m_c s_c (T_f - T_a) \ldots.. \quad \text{(i)}$$

Here,s_w , m_c,s_c and T_a were specific heat of water ,mass of the calorimeter ,specific heat ofcalorimeter (unknown) and room temperature respectively.

By putting the known values of all these parameters into equation (i), the value of the specific heat of the calorimeter (s_c) is measured.

Unless our relentless effort, some of the heat dissipate into the surrounding from the calorimetric system. Practically, it is highly challenging to made a system completely thermally insulated hence some heat have escape. To measure the specific heat of the sample precisely it is necessary to account this heat loss. In this research work, intension was to formulate mathematical expressions to calculate the specific heat by taken the dissipation heat into consideration.

To measure dissipation heat it is assume that the rate of heat dissipation is proportional to the temperature difference between the calorimetric fluid and the environment i.e.

$$\frac{dQ}{dt} = K(T - T_a)$$

Where, dQ/dt is rate of heat dissipation, K is dissipation rate constant, T is the system temperature and T_a is the environment temperature.Another assumption is that there is no temperature gradient in the calorimeter system.Mathematically heat dissipation by calorimeter can be quantified by the following equation

$$Q = k\int_{t_0}^{t_f} (T - T_a)dt = (m_c S_c + m_w s_w)(T_i - T_f) \ldots \text{(ii)}$$

A calorimeter was made by thick plastic hotpot named plastic box calorimeter. The plastic served as an insulating material. The inside part of the plastic box is made of aluminum coating. An alcohol thermometer was used for measuring temperature. Distilled water is used as the liquid and external water heater is used to heat the water.

Dissipation rate constant (K) and heat capacity of the calorimetric system ($m_C S_C$) is determined graphically [12], which is described our previous paper.

E. Measurement of the Specific heat (s_s) of the sample

Including dissipation heat specific heat of any sample can be calculated by using following equation,

$$k\int_0^{t_s} (T - T_a)\,dt + m_s s_s (T_s - T_a) = m_c s_c + m_w s_w\,(T_i - T_s)$$

Here, T_s and T_a are the saturation temperature and room temperature respectively, $m_S$and $m_W$are the mass of the sample and the mass of the water respectively, T_i is the

IARJSET
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International Advanced Research Journal in Science, Engineering and Technology
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initial temperature of the water, $\mathbf{t_S}$ is the saturation time and k is the rate constant.

To calculate the value of T_S, at first calculate the value of Q (amount of heat absorbed by the sample) for different amount of water from initial temperature to final temperature of the calorimetric system. This can be calculated from the following equation,

$$Q = (m_c s_c + m_w s_w)(T_i - T_f) - k\int_{t_0}^{t_f} (T - T_a)dt \;....(iii)$$

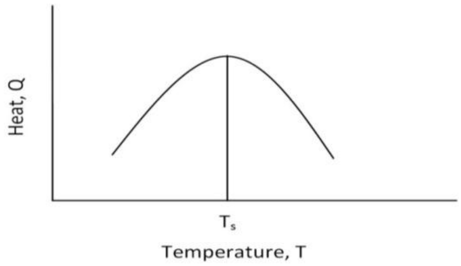

Fig. 1: Heat (Q) profile with respect to Temperature (T)

Increment of the heat absorption means the sample is approaching to the saturation temperature and at the peak it indicates to attain the saturation temperature. After this saturation temperature decrease of the absorption energy ascertain the loss of energy due to the dissipation of energy to the surrounding. At the corresponding temperature when the Q reaches at peak point is counted as T_s.

The time required to reach the temperature at saturation point is called the saturation time, t_S. Putting the values of T_s and Q in equation (iii) determine the saturation time, t_S.

III. RESULT AND DISCUSSION

A. Determination of dissipation rate constant (k) and heat capacity of the calorimetric system $(m_C S_C)$

By using equation (i), plotting $m_w S_w$ vs $\int_{t_0}^{t_f} \frac{((T-T_a)}{(T_i-T_f)} dt$ the value of dissipation rate constant (k) can be determined from slope and value of heat capacity of calorimeter $(m_C S_C)$ determined from intercept.

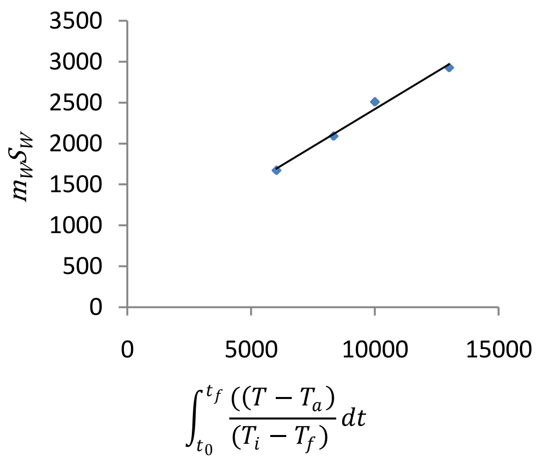

Fig. 2: Determination of dissipation rate constant (k) and heat capacity of calorimeter $(m_C S_C)$

B. Measurement of specific heat of iron

Plastic box calorimeter were using 700ml, 600ml ,500ml and 400ml of water for saturation temperature determination(T_S) and corresponding saturation time(t_S) determination.

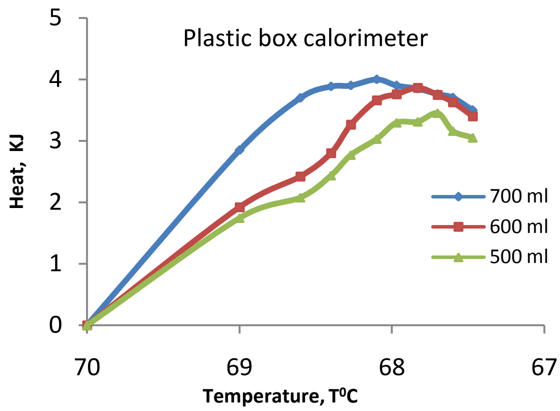

Fig. 3: Measurement of saturation temperature of iron bar

From the figure the saturation temperature for 700ml, 500 ml and 400 ml were 68.2 ^{0}C, 67.2 ^{0}C and 68.2 ^{0}C respectively and corresponding heat absorbed by the sample were 2042.47 J, 1988.18J and 2225.6 J .From this data using equation (ii), average specific heat of iron, S= 0.503 J/g.^{0}C, where literature value of iron is 0.50 J/g.^{0}C.

C. Measurement of specific heat of polypropylene (PP) bar (1 cycle) ,PP bar (2 cycles) and jute reinforced (5%) polypropylene composite bar

Specific heat of iron was so close of literature value with ±0.001 confidence limit, which proved the accuracy of developed method and instruments. In the following section developed method and instruments was used for determination of specific heat of polymer and composites materials.

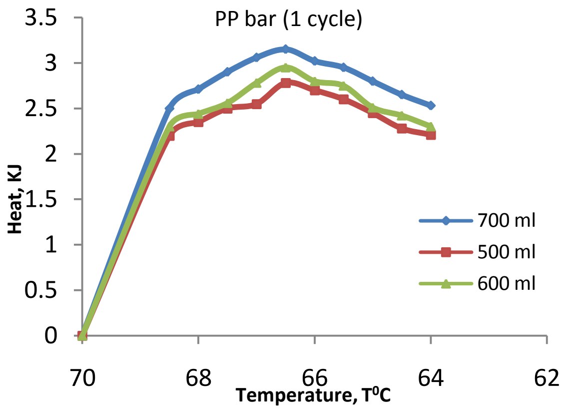

Fig. 4: Measurement of saturation temperature of PP bar (1 cycle)

From fig 4 and fig 5 it is seen that the specific heat decreases due to increasing heat treatment (2 cycles) of PP bar. The average specific heat of PP bar (1 cycle), S= 1.95 J/g.^{0}C and average specific heat of PP bar (2 cycles), S= 1.66 J/g.^{0}C, where literature value of average specific heat of PP bar is 1.90 J/g.^{0}C.

DOI 10.17148/IARJSET.2016.3424

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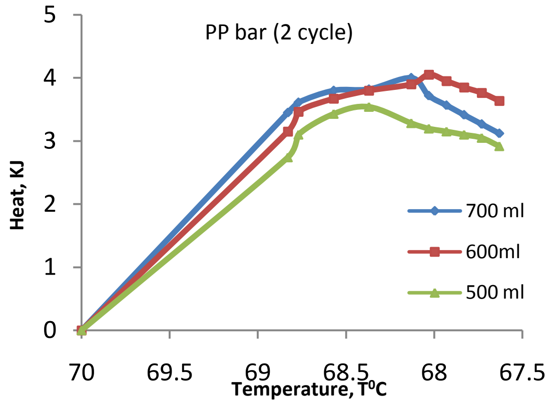

Fig. 5: Saturation temperature of recycled (2 cycle) PP bar

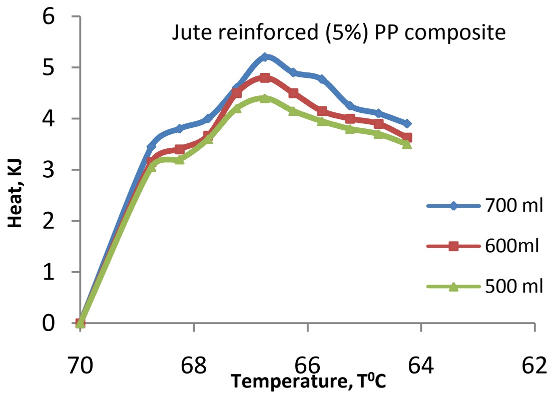

Fig. 6: Measurement of saturation temperature of jute reinforced (5%) PP composite

Same ways as before using equation (ii),. Average specific heat of jute reinforced (5%) PP composite, S= 2.65 J/g.^{0}C

D. Measurement of mechanical properties of PP bar(1 cycle), PP bar(2 cycles) and jute fiber(5%) reinforced PP composites

Mechanical properties like as tensile strength, strength at break, percentage elongation and Young's modulus were measured by universal testing machine.

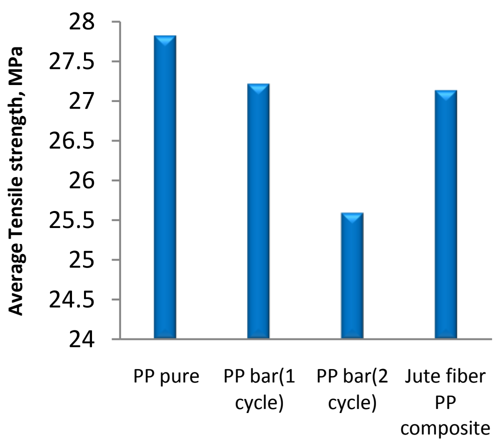

Fig .7: Tensile strength of different polymeric samples based on polypropylene

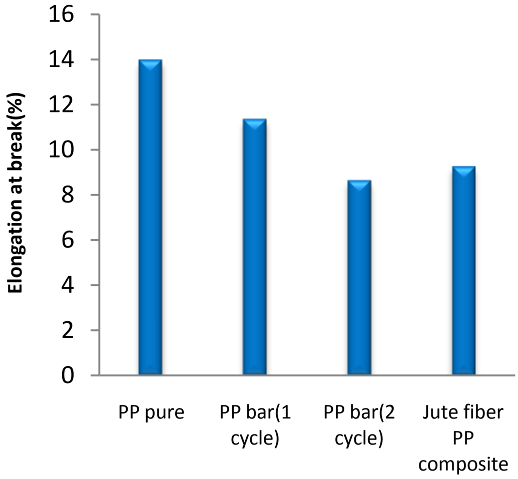

Fig.8: Comparison of elongation at break (%) for PP based polymer

From fig 7 & fig 8 it can be seen that the value of tensile strength and elongation at break decreases with increasing cycle number. This is because as the number of cycle increases, the chain length of polymer decreases due to molecular degradation. Jute fiber PP composite showed good tensile strength and elongation at break due to better adhesion of fiber with PP matrix. From fig.7 and fig.8 it is also obvious that tensile properties of recycled PP decrease due to repeated heat treatment during processing.

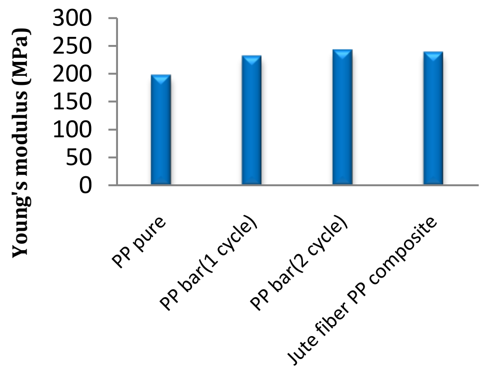

Fig.9: Effect of different treatment of PP on Young's modulus

In fig.9, Young's modulus increases with increasing cycle number and jute fiber incorporation due to the degreasing percent elongation.

IV. CONCLUSION

The value of specific heat of different types of polymer sample was measured using calorimeter made by locally available low cost materials .Characterization of calorimeter shows that plastic box calorimeter has low dissipation rate constant(K=0.208 J/s.^{0}C). Specific heat of iron measured by developed calorimeter was so close of literature value and confirms the feasibility of the plastic box calorimeter and methods of measurement. Comparison of measured value of polymer with literature value showed the potentiality of the developed method. The mechanical properties of recycled polypropylene showed that it has an adverse effect if reuse because the tensile strength decreases.

REFERENCES

[1] Sacchidanand S. S., Jayant A.K. and Milind V.K., Synthesis, Characterization and Electrical Property of Silver Doped Polypyrrole Nano composites, International Journal of Innovative Research in Science, Engineering and Technology (2014), pp-(21-26)

[2] L. Riviere, et al., Specific heat capacity and thermal conductivity of PEEK/Ag nanoparticles composites determined by Modulated-Temperature Differential Scanning Calorimetry, Polymer Degradation and Stability (2015) , pp-(1-7)

[3] J .Gassanand AK. Bledzki , The influence of fiber-surface treatment on the mechanical properties of jute–polypropylene composites. Compos Part A(1997), pp1001–5.

[4] KL Fung, et al. , An investigation on the processing of sisal fibre reinforced polypropylene composites. Compos SciTechnol (2003), pp(1255–8)

[5] Arbelaiz A, et al. , Mechanical properties of short flax fibre bundle/ polypropylene composites: influence of matrix/fibre modification, fibre content, water uptake and recycling. Compos SciTechnol (2005),pp-(1582–92)

[6] Garkhail SK, Heijenrath RWH, Peijs T. Mechanical properties of natural-fiber-mat-reinforced thermoplastics based on flax fibers and polypropylene. ApplCompos Mater (2000),pp-(351–72)

[7] P. Joseph, et al. The thermal and crystallisation studies of short sisal fibre reinforced polypropylene composites. Compos Part A: ApplSciManuf (2003),pp-(253–66)

[8] V. Singha et al. , Specific Heat of Teflon, Torlon 4203 and Torlon 4301 in the range of 30 - 400 mK, Cryogenics(2015), pp-(1-15)

[9] Weidenfeller B, Ho¨ fer M, Schilling FR. Thermal conductivity, thermal diffusivity, and specific heat capacity of particle filled polypropylene. Compos Part A: ApplSciManuf (2004),pp-(423–9)

[10] P. Wong et al., Melting behavior and thermal properties of high density polyethylene. PolymEngSci (1995),pp-(151–6)

[11] O. Almanza et al., Measurement of the thermal diffusivity and specific heat capacity of polyethylene foams using the transient plane source technique. PolymInt (2004),pp-(2038–44)

[12] H. Ahmad, M.A. Islam and M.F.Uddin, A novel method for determination of specific heat of low conductive polymers, 16th Asian Chemical Congress (2016)