

Investigation on thermal properties of Styrene Acrylonitrile (SAN) matrix with Polytetrafluoroethylene (PTFE) particle reinforced composites

R.Mahesh Kumar, N.Rajini, K.Mayandi*, M.Gnanaguru, S.Haja Jasim Farid.

*Department of Mechanical Engineering, Kalasalingam Academy of Research and Education,
Krishnankoil-626126, Tamilnadu, India*

*E-Mail of the corresponding author: *k.mayandi@gmail.com*

Abstract— Temperature utilization of composites materials depends on its thermal conductivity and co-efficient of thermal expansion. Polymers are exceptionally combustible because of their structure and they can't fulfill a few applications. Thermal treatment of soften polymer because of the preparing setup by injection molding fabrication process able to control polymer structure (fitting) and in this manner deciding its thermal conduct. The fundamental point of this work is to contemplate the impact of Polytetrafluoroethylene polymer (PTFE) as particle with Styrene Acrylonitrile polymer (SAN) as matrix to examine its thermal properties. Samples of 100% SAN and 10% PTFE by weight, 20% PTFE by weight blended specimens with SAN are prepared successfully by Injection molding process. Heat capacity, Thermal expansion, Thermal conductivity and Thermal degradation are the thermal properties examined. From the observations it was found that PTFE particles blended samples exhibits maximum thermal conductivity and good dimensional stability.

Keywords — Polytetrafluoroethylene particle, Styrene Acrylonitrile matrix, Injection molding fabrication process, Thermal properties investigation.

1. Introduction

The utilization of Polymer-based materials is quickly expanding. The enterprises of today are progressively seeking techniques to supplant metal parts with polymer based materials as a result of light weight, simple support and modest costs [1]. The ceaselessly developing requirement for composite materials with new or enhanced properties brings about the preparation of different polymer mixes with various arrangements, morphologies and properties.

The change of the thermal properties of SAN has been the subject of various fascinating logical investigations. One of the effective techniques for this reason conceivably making utilization of added substances, for example, particles, enhances thermal conductivity and coefficient of thermal expansion [2]. The acknowledgment of natural fiber as fillers in the plastic business has additionally been developing widely as a result of their simple openness, biodegradability, moderateness, and ecological maintainability. Additionally, there is an abnormal state of enthusiasm for utilizing polymer particles for making polymer composites with enhanced thermal and combustion properties [3].

SAN is a broadly utilized designing thermoplastic inferable from its alluring properties, which incorporates great mechanical properties, synthetic protection and simple preparing attributes. It has numerous imperative applications, for example, fittings of portable industry and home appliances, instrument board, and different switches, and so on. In this article, we utilized PTFE particles as support of SAN matrix to set up the high thermal stability SAN/PTFE composites by melt shaping procedure [4].

PTFE is an excellent material with high insulation (i.e. better than SAN), finds many potential applications in thermal and medical fields [5-6]. This investigation deals with the improvement of thermal properties of SAN composites over pure SAN. In this regard, SAN/PTFE composites were prepared by means of melt, and the thermal properties of the readied composites were contemplated [7]. To the best of our insight, the thermal properties of SAN/PTFE composites have not been yet detailed. From this investigation it is expected that thermoplastic composites with high thermal properties can be created for use in various applications.



2. Materials and methods

Materials

Polytetrafluoroethylene powder particles (PTFE) were used for reinforcement in this work [8]. Powder PTFE polymers were procured from M/s. Modoplast Company Pvt. Ltd, Kolkata, West Bengal, India. Styrene Acrylonitrile (SAN) resin was used as an effective matrix system in polymer reinforced composites to investigate its thermal properties. SAN polymer resin in pellet form is commercially available and procured from Sree Meenakshi Plastics, Madurai, Tamilnadu, India. The average diameter of SAN pellets was approximately 2mm. The particle size of PTFE powder was about 5 to 15 μm . For fabrication of test sample specimens size (200x140x3mm), polymer injection mold suitable for semi-automatic injection molding machine (MACFIELD, MAC60) were prepared by using EN8 mild steel plates and obtained from Mahesh Plastics, Madurai, Tamilnadu, India.

Sample Preparation

The samples used for this work are: Sample 1: 100% virgin SAN polymer resin, Sample 2: 90% by weight composition of SAN polymer resin + 10% by weight composition of PTFE powder particle and Sample 3: 80% by weight composition of SAN polymer resin + 20% by weight composition of PTFE powder particle. The materials procured, SAN pellets and PTFE powder were pre-dried to moisture free condition at 100°C in vacuum oven for 24 h separately. The materials as per requirement are taken in three batches, mentioned as samples and ready for injection molding. The three batches one by one were fed into the hopper of semi-automatic reciprocating screw injection molding machine DGP Windsor, 50T - **figure 1** to produce rectangular size (200x140x3mm) molded test plate samples [9-11]. The processing temperature was maintained at 220°C for SAN resin and 280°C for SAN/PTFE composites.



Fig. 1 Injection molding machine

Thermal conductivity and Coefficient of thermal expansion tests

The heat energy (Q) transfer across a plane of area (A), with a temperature gradient ($\Delta T/\Delta l$) can be expressed as $Q = kA (\Delta T/\Delta l)$, where k is the thermal conductivity of the material. The unit for ' k ' is W/m-K and for polymers its value in the order of 0.3 [7]. As per ASTM E1530 disc shaped specimens with diameter of 50mm and thickness of 3mm are used for measuring thermal conductivity under steady state condition [12]. The experiment was conducted by heat flux method: Fox 50-110 where heat is applied from one side of the specimen.

Coefficient of linear thermal expansion (α) is the change in length per unit by the addition of heat energy given by $\alpha = \epsilon / \Delta T$, where ϵ is the strain. The unit for thermal expansion co-efficient is $^{\circ}\text{C}^{-1}$, and its values for polymers in the order of 50 to 400 $\times 10^{-6}$. The materials having strong atomic bonds have high melting point and low thermal expansion coefficients [6]. Dilatometer instrument was used to measure the thermal expansion coefficient. According to ASTM D 696 rectangular plate specimens with 50 X 10 mm and thickness 3mm are used for coefficient of linear thermal expansion measurements.

Optical Microscopy

The PTFE distribution was analysed using Motic Optimal Microscope (Fig 2) that was equipped with moticam 2500 camera, digitally controlled by motic images plus 2.0 ML image processing software.

The PTFE distribution images were taken for pure SAN, 10% by wt. composition of particle reinforced PTFE, and 20% by wt. composition of particle reinforced PTFE particle filled composite materials.

Thermogravimetric analyzer test

The powder sample taken in a crucible can be heated in a steady rate in a gas environment (inert-Nitrogen gas) to obtain weight loss values for the samples at various time and temperature [13]. This test provides us a graph depicting the nature of the sample at various loading conditions. TGA measures the percent volatile, water, solvent by weight.

3. Results and discussion

Thermal conductivity analysis

The heat transfer rate of a material depends on its thermal conductivity [14]. The values measured in five samples are taken in each category and the average is plotted in **figure 2**. The experimental analysis reveals that sample 2 and Sample 3 exhibited maximum thermal conductivity. The composite sample has good thermal conductivity because PTFE powder enhances the heat transfer rate. It is observed that composites filled by 10% and 20% by wt. composition PTFE particle, also exhibited good thermal conductivity than pure SAN.

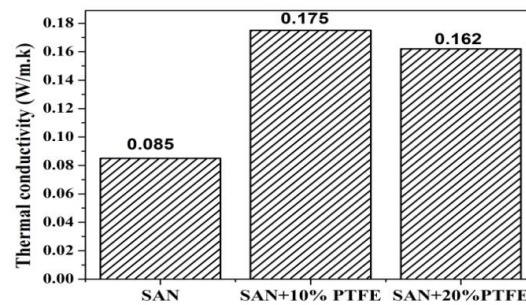


Fig. 2 Thermal conductivity for different composition of composite materials

Coefficient of linear thermal expansion analysis

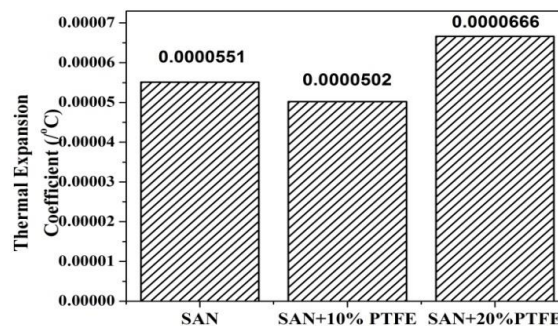


Fig. 3 Thermal expansion coefficient for different composition of composite materials

The thermal expansion coefficient is a measure of thermal property and lower values finds many applications. From literature survey, composite material with particle fillers has a lower thermal expansion coefficient [15]. From **figure 3** SAN Composites with PTFE particle fillers (10% by weight) has low thermal coefficient ($5.02 \times 10^{-5}/^{\circ}\text{C}$) when compared with other (20% by weight) composites. The measurement of the thermal conductivities of composite samples indicated that PTFE would be a better thermal barrier in the presence of SAN.

Optical Microscopy

The PTFE distribution images taken for 10% by wt. composition of PTFE particles reinforced composites and 20% by wt. composition of PTFE particles reinforced composites materials are given.

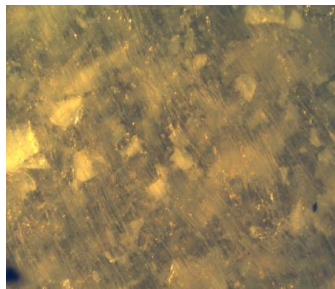


Fig. 4 SAN + 10% PTFE Composite

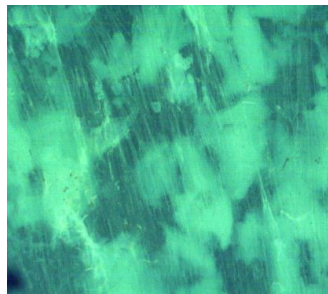


Fig. 5 SAN + 20% PTFE Composite

Thermogravimetric Analysis

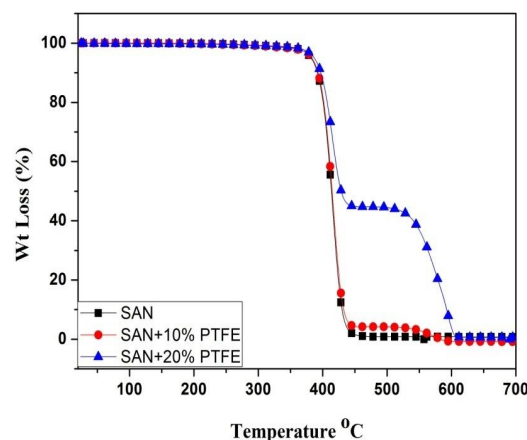


Fig. 6 TGA test report of SAN & SAN Composites

Thermogravimetric (TGA) analysis were completed utilizing a METTLER STAR SW15.00 thermo analyzer instrument from 25-700°C utilizing a continuous heating rate of 10°C/min under nitrogen stream. The nitrogen flow was 25ml/min. Powdered Samples for SAN and SAN/PTFE composites one by one were estimated in a crucible closed, with a lid on the hole with a mass of around 10mg [16]. From **figure 6** the decomposition temperature curves obtained from the three samples the radius of curvature is bigger at the beginning than at the end of the heating process. The decomposition temperature curve for 20% by wt. composition of PTFE particle reinforced composite has two steps. The result obtained explains that the thermal stability of this sample has remarkable potential value. The PTFE particle plays an essential role on thermal stability. The TGA curve shown in **figure 6** depicts the mass change in the process. The SDTA curve (measures exothermic effects in similar to DSC) gives the enhancement of thermal stability of SAN/PTFE composites. The thermal decomposition curves for SAN/PTFE particle reinforced composites withstand higher temperature range than SAN sample.

Table 1. The TGA and DTGA data SAN and SAN/PTFE particle composites

Samples	T _{-5 wt%} degradation (°C)	T _{-50 wt%} degradation (°C)	T _{max} (°C)
Sample 1 Pure SAN	381	413	439.3
Sample 2 10% PTFE	381.5	415	443
Sample 3 20% PTFE	386	429	666

Table 1 gives the degradation temperature values. From the values obtained SAN/PTFE particle reinforced composite has the maximum values. This enhancement is due to the physical protective barrier of the PTFE particles on the surface layer of the matrix. The PTFE particle behaves as thermal guard to the volatile materials generated during the thermal decomposition as a result of higher thermal stability.

4. Conclusions

- The PTFE particle reinforced SAN polymer composites fabricated successfully by injection molding process possess higher thermal conductivity and low thermal diffusivity than existing individual SAN copolymer.
- The thermal conductivity and thermal expansion co-efficient values of SAN, 10% by wt. composition of PTFE particle reinforced composite and 20% by wt. composition of PTFE particle reinforced composite are (0.085 W/m.K, 5.51×10^{-5} /°C); (0.175 W/m.K, 5.02×10^{-5} /°C); (0.162 W/m.K, 6.66×10^{-5} /°C) respectively.
- The characterization of the morphology of all three samples investigated by Optical Microscopy and TGA ensures improved morphology with PTFE particle based SAN has significant structure. By physical transitions, the adsorption of gaseous substances on samples such as active charcoal residue at 700° C is less for PTFE particle reinforced composite samples 2 and 3.
- From overall analysis made in Thermal properties, Sample 2 and Sample 3 have better thermal properties.

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