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Volcanic Ash Reinforcement Concentration Effect on Thermal Properties of Polyvinyl Chloride Composites

S. Fidan*

Kocaeli University, School of Civil Aviation, 41285 Kartepe/Kocaeli, Turkey

This paper reports the results of experiments evaluating the thermal properties of volcanic ash (VA) reinforced polyvinyl chloride (PVC) composites with various concentrations. PVC matrix composites reinforced with various VA concentrations (5, 10, 15, 20 and 25 wt.%) were manufactured by using a twin screw micro-compounder and an injection molding machine. Thermogravimetric analysis (TGA) was used to monitor the changes in physical and chemical properties of VA reinforced PVC composites as a function of increasing temperature and time. Measuring the changes in weight of the material as a result of heating gives valuable information about thermal degradation of VA reinforced PVC composites. Therefore by using TGA, effect of volcanic ash concentration on thermal stability and degradation extent of PVC matrix composite was evaluated

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1. Introduction

Poly(vinyl chloride) (PVC) is an extensively used thermoplastic material because of its valuable properties, such as superior mechanical and physical properties, high chemical and abrasion resistance, and is widely utilized in durable applications, e.g. for pipes, window profiles, house siding, wire cable insulation and flooring [1, 2]. However, in the radical polymerization of the vinyl chloride, a number of isomeric forms and structural defects resulted from the formation of the main chain [3]. These anomalous structures could induce thermal instability of PVC during the polymer usage, because thermal dehydrochlorination of PVC often begins with internal allylic chloride and tertiary chloride structural defects in the main chain [2]. Hence the experimental studies about thermal stability of PVC are vital.

Recently, with increasing environmental awareness and expanding global waste problems, eco-friendly bio-fillers have been increasingly recognized as a promising alternative to inorganic fillers in the reinforcement of thermoplastic and biodegradable plastics [4, 5]. Bio-fillers have several advantages compared to inorganic fillers, such as a non-hazardous nature, low cost, low density, low manufacture energy (low CO_2 emission), renewability and biodegradability [4–6]. These bio-filler filled thermoplastics and biodegradable plastic composites, commonly called bio-composites and eco-composites, are experiencing fast growth in various applications such as automotive parts, outdoor decking products, window and door frames, consumer products, and so on [6–8].

Volcanic ash (VA) is formed during volcanic eruptions. Over the last decade the use of porous organic fillers such as VA were increased due to their environmental friendly characteristics. As VA particles have high surface area due to their large porosity characteristic, they increase the effect of surface adhesion when they used as fillers in composites.

The aim of this study was to investigate the thermal properties of volcanic ash (VA) reinforced polyvinyl chloride (PVC) composites with various concentrations by using thermogravimetric analysis (TGA).

2. Materials and methods

2.1. Materials

PVC used as the matrix resin for the micro-compounding and injection molding was D100 TE provided by Ankara Granül Co. in Turkey. The D100 TE is an unfilled grade for extrusion applications and has a density of 1.37 g/cm^3. VA samples were taken from Guneydag tuff ring, which is located 13 km southwest of Nevsehir/Turkey. Nearly all vitric grains are angular and highly vesicular. Density and porosity parameters determined by helium pycnometer and mercury porosimeter are 1.8–2.4 g/cm^3 and 36–55%, respectively.

2.2. Sample preparation

PVC/VA composite materials were prepared by melt compounding and injection molding processes. DSM Xplore 15 ml micro-compounder was used for melt compounding with a maximum processing temperature of 400 °C and a co-rotating twin screw speed of 250 rpm. DSM Xplore 12 ml injection molding machine was used for injection molding of compounded melt. Maximum processing and mold temperatures are 400 °C and 200 °C, respectively and also its maximum pressure capacity is 16 bar. All the samples were compounded at 195 °C with 40 rpm of screw speed and then injected in to the mold at 50 °C with an injection pressure of 10 bar.

*e-mail: sinanfidandr@yahoo.com

2.3. Thermogravimetric analysis (TGA)

The thermogravimetric analysis (TGA) for PVC composite samples with different concentrations of VA were performed by TA Instruments Q50 TGA equipment. The samples about 10 mg were heated from ambient (25 °C) to 600 °C at a heating rate of 20 °C/min under a nitrogen atmosphere with flow rate of 50 ml/min. From TGA curves, the thermal degradation characteristics were determined. The temperature at 10 wt.% loss (T_{10}) was taken as the onset of degradation. And also the maximum degradation temperature (T_m) was determined as the peak maximum obtained by the first-order derivative weight curve.

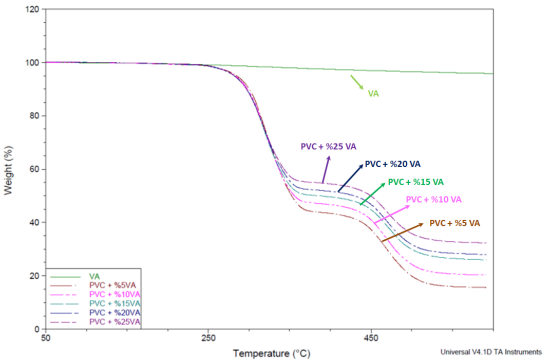

Fig. 1. Thermogravimetric curves and thermal stability properties of PPS composites with various VA concentrations.

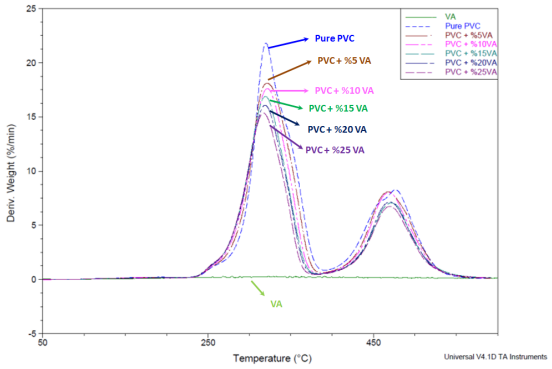

Fig. 2. Derivative weight versus temperature curves of PVC composites with various VA concentrations.

3. Results and discussion

To analyze the thermal stability of the prepared PVC/VA composites, TGA experiments were performed under nitrogen atmosphere. From the thermogravimetric curves shown in Fig. 1 and Fig. 2, it was found that PVC and its composites with different VA concentrations present a relatively good thermostability because no significant mass loss occurred until 250 °C. As shown in Fig. 1, the VA particles exhibited no weight loss in this range of temperature; in contrast, PVC composites filled with various VA concentrations exhibited obvious weight loss. TGA curves of PVC composites reinforced with different concentrations of VA follow a degradation stage that initiates at ≈275 °C and shows the maximum rate of weight loss at around 350 °C. While the residual mass for %5 VA was about 18% of the initial weight, the residual mass for %25 VA concentrations was about 38% of the initial weight at 550 °C. So, the residual weight increases with incorporation of filling VA material.

4. Conclusions

- Thermal stability of PVC composites were improved with incorporation of VA particles.
- VA particles exhibited no weight loss during TGA analysis in test temperatures (Test temperatures between 25 °C and 600 °C).
- VA filler can be used up to %25 concentration with PVC composites in order to improve thermal stability.

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