The effect of particle compositions on the activation energy of the pa6/bagasse composite

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Abstract. The Activation energy of PA6/Bagasse particles blends was evaluated as a function of particle compositions. The composite was prepared in compositions of weight %PA 6%/weight Bagasse particles, that is 95/5, 90/10 and 87.5/12.5 respectively using a twin screw extruder at 40 rpm and 220 °C blending temperature. The Activation energy is determined based on rheological testing with using a capillary rheometer on constant heating method. In this test, it is obtained the relationship of viscosity and temperature of melting composite. Arrhenius linear plot between viscosity to 1 / T. can be obtained the activation energy.

1. Introduction

Composite materials have long been known in various forms, such as the use of bitumen which was reinforced with woven straw fibers in ancient Babylonian times [1]. In modern history, composite materials were introduced in 1937 when the company Owens Corning Fiberglass began trading in glass fiber [2]. This composite material has become a substitute for materials that are commonly used before; this is because the mass is light and can be processed easily. In the process of making composite materials, natural fibers can replace artificial fibers as reinforcement [3].

The use of cellulose derived from natural fibers as a reinforcement of thermoplastic materials has been studied [4]. Thermoset matrix composites are increasingly using cellulose as reinforcing the material, but the use in the thermoplastic matrix is still limited because of the lack of compatibility between fibers and matrices, and it is difficult to achieve good distribution [5]. Natural fibers that are hydrophilic cause a bad bond between fibers and polymer matrix, to improve the interface bond is modified the surface of the fiber [6]. Particle-reinforced composites need to be studied in rheological properties to determine process capability, equipment design, process modeling, and for process control. Quality control plays important rules to reduce costs that occur due to manufacturing errors related to scrap, rework of the resulting product does not meet specifications [7]. Viscosity is one of the parameters that can be determined by rheology testing and is strongly influenced by temperature. The viscosity of the solid material will decrease according to the increase in temperature. If the temperature changes,
The movement of molecules due to heating will change the molecules or structure of the material. The effect of temperature on viscosity for a particular composite material can be ascertained. Most polymers in the temperature range for viscosity data are far below the melting point. Molecular chains that are firmly held between each other will begin to slip and break when there is an increase in temperature.

The effect of temperature on viscosity can be known by using the Arrhenius equation, as follows:

\[ \eta = A_0 \exp \left( \frac{E}{RT} \right) \]  

Which \( \eta \) is viscosity, \( A_0 \) is the fluid coefficient, \( R \) is the ideal gas constant (8,314 J/mol/K), \( T \) is the temperature in Kelvin and \( E \) is the activation energy of the flow at a certain shear rate. Activation energy is the most important parameter for composite processing, and this energy is the energy needed to flow the thermoplastic polymer matrix.

This study studies the effect of natural fiber particle composition on the activation energy of PA6 composite material / Bagasse particles that have undergone chemical treatment as a filler.

### 2. Experimental Method

The material in this investigation uses polyamide-6 as a matrix and Bagasse powder has undergone benzylolation as a filler. The mixing of the two materials using twin screw extruder at a temperature of 220 °C, 40 rpm. The composition of the mixture is prepared (weight% PA6 / weight% Bagasse) 95/5, 90/10 and 87.5/12.5, the particle size used is 40 μm. To determine composite melting behavior, rheology testing was performed using capillary rheometer; capillary diameter is 1 mm and length is 10 mm (l / d = 10) with the constant heating method. The test is carried out with a load of 150N. In this test, it is known the relationship of viscosity and temperature, and from this relationship, it can be determined the activation energy based on Arrhenius linear plot.

### 3. Results and discussion

The effect of temperature on the viscosity of PA6/Bagasse particle composites that have undergone benzylolation can be seen in Figure 1. The log viscosity relationship with 1/T at various temperatures can be seen in Figure 2.

The plot of the relationship log viscosity vs. 1/T shows a linear relationship. From this relationship can be obtained activation energy from PA6/Bagasse particle composite based on Arrhenius equation relationship. PA6/Bagasse particle composite activation energy can be seen in Table 1.

The results showed that the activation energy for PA6/Bagasse particles had the lowest activation energy in the composition of 2% particles, i.e., 34.44 Kj/mol. While the highest activation energy was obtained in the composition of 12.5% particles, which it was 68.93 Kj/mol. The PA6/Bagasse particle composites showed that the greater the Bagasse particle content, the greater the activation energy. This is appropriate as obtained by previous researchers [8].
Figure 1. Viscosity vs. Temperature for the various particulate composition of Bagasse using an average particle size of 40μm with a load of 150 N

The effect of temperature on rheological properties shows that the viscosity decreases as the temperature of the thermoplastic increases or for a mixture of particles and thermoplastic. The effect of temperature on PA6/Bagasse particle composite is following Arrhenius’ relationship. From the log (η) vs. 1/T relationship, the E/R value can be obtained, E is the activation energy, and R is the ideal gas constant 8.314. So that the value of E can be determined. The value of E can be seen in Table 1. Materials that have higher activation energy are materials that are more sensitive to temperature. The composite of a PA6/Bagasse particle on Bagasse composition 12.5% become more sensitive to temperature because it has the highest activation energy of 68.93 KJ/mol. According to [9], when the activation energy of material increases, there will be an increase in thermal stability of the material. Because of that composite PA6/Bagasse particles at a composition of 12.5% are more thermally stable compared to other composite compositions.

Figure 2. The log (viscosity) vs. 1 / T relationship for various bagasse particle contents using an average particle size of 40 μm with a load of 150N

Table 1. activation energy of PA6/Bagasse particle

| Particle size | Particle compositions | Activation energy (KJ/mol) |
|---------------|-----------------------|---------------------------|
| 40 μm         | 2%                    | 34.44                     |
| 40 μm         | 5%                    | 38.47                     |
| 40 μm         | 7.5%                  | 33.75                     |
| 40 μm         | 10%                   | 52.47                     |
| 40 μm         | 12.5%                 | 68.93                     |
4. Conclusions
Based on the results of the rheology test and Arrhenius linear plot it can be summarized as follows:
1. The effect of temperature on rheological properties shows that the viscosity decreases as the thermoplastic temperature increases or for a mixture of particles and thermoplastic.
2. The composite of PA6/Bagasse particle showed that the greater the bagasse particle content the greater the activation energy. The lowest activation energy in the composition of 2% particles is 34.44 kJ/mol, and the highest activation energy was obtained in the composition of 12.5% particles which is 68.93 Kj / mol. Because of that composite PA6/Bagasse particles at a composition of 12.5% are more thermally stable compared to other composite compositions.

5. References
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