

ENERGY BALANCE OF A BIOCOMPOSITE COMPOUNDING PROCESS

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New environmentally-friendly ways to think and to design call for the introduction of new polymers and composites with an enhanced sustainability based on (1) renewable raw materials, (2) environmentally-friendly end-of-life treatment and (3) low impact manufacturing processes. Poly(lactic-acid) is bio-based and biodegradable and then fulfil the two first criteria. In our case, compounding of PLA with cellulose fibres was studied using a batch mixer and the influence of the material formulation and the compounding process parameters on melt viscosity and energy balance was observed.

Inside a batch mixer, the rotors bring mechanical energy which is function of torque, screw speed and time [1]. The mixing chamber is regulated and the heat transfer between its wall and the polymer is assumed to be convective [2]. The energy input is the addition of specific mechanical energy (SME) and specific thermal energy (STE). During the melting phase, a torque peak is observed as well as a strong increase of the material temperature and of the pressure inside the mixing chamber. Once the melting phase is over, the torque and temperature reach a plateau and the pressure drops off. At this steady state, the heat transfer from the polymer to the walls is compensated by viscous dissipation. The heat transfer coefficient can be determined by estimating this viscous dissipation using the double-Couette approximation proposed by Bousmina et al. [3]. Using torque and temperature data for different process parameters, viscosity was fitted with a power law taking into account the effects of temperature and SME [4]. Energy consumption decreases with the chamber temperature and increases with the rotor speed. The energy required for the melting phase decreases with the rotor speed but does not significantly vary with the chamber temperature. Temperature only has an influence on the mixing phase; the higher the temperature, the lower the viscosity and then the lower the mechanical energy requirements. For pure PLA, energy consumption has been converted into energy efficiency considering the theoretical energy required for the melting is a function of heat capacity and melting enthalpy. This energy efficiency was plotted as a function of viscosity. A given rotor speed implies a given range of viscosity and the more energy is brought to the system, the more the viscosity decreases. An increasing temperature will shift toward lower viscosity the range of viscosity corresponding to a given rotor speed at the reference temperature. It will also decrease the rate at which viscosity is decreased by the energy input. From these considerations, it was possible to determine shift factors to obtain master-curves of energy efficiency. For composites, it was shown that energy consumption strongly increases with the fibre content in the case of concentrated suspensions and that the aspect ratio of the fibres has no significant influence for diluted and semi-diluted suspensions. The influence of the process parameters is similar for composites and pure polymers.

References:

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