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Consolidation Process Boundaries of the Degradation of Mechanical Properties in Compression Moulding of Natural-Fibre Bio-Polymer Composites

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Abstract

In spite of the volume of literature on natural fibres, bio-matrix materials and their composites, the choices of optimum process parameters such as moulding temperature, pressure and compression time are still largely based on experience, rules of thumb and general knowledge of the chemical and physical processes occurring in the melt during consolidation. The moulding process itself is a complex balance between processes that must occur for the composite to successfully consolidate and the onset of thermal degradation of the natural fibre and/or matrix materials. This paper brings together models of thermal penetration, melt infusion, thermal degradation and chemical degradation of natural polymers to construct an ideal processing window for a bio-composite. All processes are mapped in terms of normalized consolidation progress parameters making it easier to identify critical processes and process boundaries. Validation of the concept is achieved by measuring changes in the mechanical properties of a flax/PLA bio-composite formed over a range of processing conditions within and outside of the optimized window.

Keywords: Bio-polymer composites; Chemical degradation; Natural fibres; Mechanical properties; and Thermal processing degradation

1. Introduction

The use of natural fibres as the reinforcement for composites has been comprehensively reviewed by the authors of this paper [1-5] and others. One of the key challenges for the use of natural fibres for reinforcing thermoplastics and thermosets is minimizing the thermal degradation of the cellulosic material that can occur during hot processing of the composite [6]. For bio-composites, plant-derived resins such as poly (lactic acid) (PLA) and poly(L-lactic acid) (PLLA) also suffer from thermal degradation for temperatures that typically occur during the compression moulding process [7-10]. Thus the temperature and time are the key process parameters for controlling thermal degradation in both the natural fibre and the bio-based matrix material. The temperature of the hot press should be sufficiently above the melting point of the matrix to lower its viscosity and the time sufficiently long for penetration of the melt into the fibres achieving a strong bond between matrix and fibre. In competition with these requirements, the melt temperature should be as low as possible to slow the rate of thermo-chemical degradation and the time as short as possible to limit the progress of these undesired chemical reactions [7, 11]. This leaves a narrow window of