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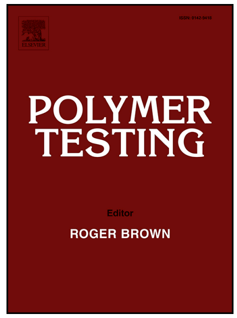

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Polymer Testing

A Soft Sensor for Prediction of Mechanical Properties of extruded PLA sheet using an Instrumented Slit Die and Machine Learning Algorithms

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Abstract

A soft sensor has been designed to accurately predict the yield stress of extruded Polylactide (PLA) sheet inline, during extrusion processing using an instrumented slit die. A number of experiments over a wide range of processing conditions have been carried out to develop the soft sensor model. The instrumented slit die had a number of embedded sensors monitoring pressure and temperature. The data collected from the slit die sensors was then used to predict the yield stress of the extruded PLA sheet using machine learning algorithms. The yield stress of the extruded sheet, which was measured offline, is compared to the model predictions to check the performance of the model. The soft sensor has the potential to provide real time feedback into the process and become a Quality Assurance (QA) tool which indicates if a product is going out of specification. This model can lead to reduced scrap rates and lower manufacturing costs by reducing machine downtime and making the process more energy efficient. Soft sensors have the potential to be introduced as part of a smart manufacturing process in keeping with the developments of Industry 4.0.

Keywords: Polylactide (PLA); mechanical properties; extrusion; slit die; soft sensor; PCA-Random Forest

Declarations of interest: none

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1. Introduction

This work presents a novel hybrid Principal Component Analysis Random Forest (PCA-RF) soft sensor model for the inline prediction of tensile properties of polylactide (PLA) during twin screw extrusion processing. PLA is a bioresorbable polymer used in the production of a number of medical devices [1,2]. PLA suffers from poor thermal stability which results in difficulty in determining optimal processing conditions for twin screw extrusion. Typically, a method of trial and error is applied to tuning of process settings. This is accompanied by lengthy offline laboratory testing, which assesses the product characteristics to determine whether the product is within specification. Changes to the batch of material can result in having to undergo the entire trial and error process again. All of this leads to high scrap rates and lengthy and expensive product development.

Mechanical properties are key performance metrics when evaluating processed PLA [3–5]. Yield stress (σ_y) is viewed as a critical mechanical characteristic when assessing PLA samples [6–8]. The yield point on the stress-strain curve indicates the limit of elastic behaviour of a sample and the stress at which this occurs is referred to as the yield stress. Currently there are no inline monitoring technologies which can quantify whether a PLA sample's yield stress will be within specification post processing. This work aims to minimise the time between production and receiving feedback about the extruded material's quality. This real time feedback will allow manufacturers to state, with a degree of confidence, whether a product will be within specification during processing.

During extrusion, PLA undergoes process induced degradation which has a significant effect on its final properties. The mechanical properties of an extruded PLA product are influenced by a number of factors including temperature [9] and molecular weight [4]. PLA is particularly susceptible to thermal degradation [5,9–11] meaning it has a very narrow processing window. A key indicator of thermal degradation is a reduction in molecular weight [4,10–12]. The method applied in this work aims to link the relationships between thermal degradation, molecular weight and a polymer's mechanical properties by using an instrumented slit die. There