Data-Driven Modelling Towards the Digital Twin of Micro Injection Moulding

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Abstract

Micro injection moulding is a widely used manufacturing process for polymer micro parts production. In the field of micro engineering, high-quality part production is crucial. In response to these increasing demands, the need for digital twins of micro injection moulding has surged, necessitating a data-driven approach to simulate the effects of key process parameters on process and product quality characteristics.

In this research the Design of Experiment (DOE) technique is employed to study the influence of Melt Temperature, Mold Temperature, and Injection Speed when processing several polymeric material grades for the production of a 25 mm^3 micro moulded tensile bar part (see Figure 1a) with a micro injection moulding machine (see Figure 1b). Responses such as Part Weight, Cavity Injection Time, and Maximum Injection Pressure, are predicted through Finite Element Analysis simulations for all considered materials (see Figure 1c). Data-driven modelling techniques are then applied to incorporate the influence of both process parameters and material-specific characteristics (through shear viscosity and pressure-specific volume-temperature models coefficients), using (1) statistical regression analysis and (2) supervised machine learning with Artificial Neural Networks (ANNs).

The analysis reveals that Part Weight and Maximum Injection Pressure are influenced by all three input parameters, while Cavity Injection Time primarily depends on Injection Speed. Both statistical and machine learning models perform with sufficient accuracy and generalize effectively to predict outcomes for materials not used for the models training data set (see Figure 1d).

The data-driven approach enhances the understanding of micro injection moulding, optimizing processes, reducing waste, and improving product quality. The results show the potential of using data-driven modelling for fast, cost-effective, and relatively accurate predictions in micro manufacturing optimization.

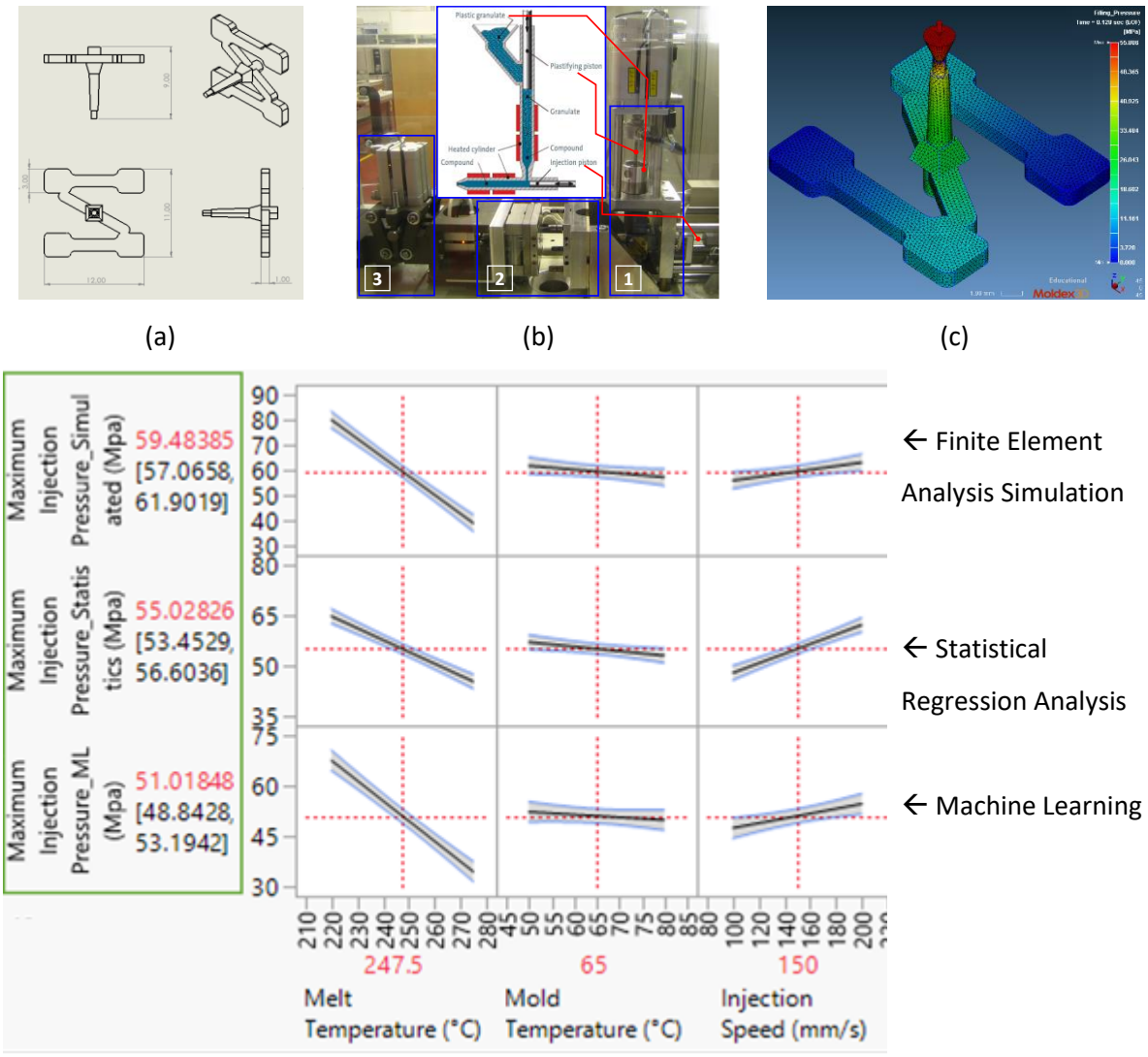

Figure 1: (a) Main dimensions and 3D model of the micro moulded part: (b) details of the micro injection moulding machine: (1) injection unit, (2) tool, (3) clamping unit; (c) micro injection moulding process simulation; (d) maximum injection pressure results comparison between the prediction of finite element analysis simulation, statistical regression analysis, machine learning.