PhD thesis

Title: Experimental and numerical investigation of the mould filling during compression process of nanocomposites.

Keywords: Materials and polymer processing, additive manufacturing, mechanical experiment, numerical modelling and simulation.

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Context

The manufacturing process with polymers and their composites have been widely developed in recent years: such as injection moulding process, compression moulding process and so on. The filling of the macro and micro cavities in the die mould is an essential step in these processes, because the filling ratio dominates the replication efficiency of the manufacturing structure. Polymers are considered as important materials in micro replication process due to their low cost and to their wide range of physical properties. It shows excellent integration and wide application of polymer based materials in electrical and mechanical engineering field. Even though a lot of polymer based components have been elaborated by using these processes, the numerical modelling approach associated with their mechanical behaviour is still lacking. The main scientific issues of the thesis are:

- Identification of the materials' viscoelastic and viscoplastic constitutive laws of nanocomposites to predict their deformation during the compression process.
- Analysis of the processing parameters, such as embossing temperature, compression pressure, mould wall friction, cooling temperature, demoulding temperature... to improve the filling efficiency of the mould die cavities.
- Numerical simulation of the whole compression process and analysis of the processing parameters sensitivity on the filling efficiency of mould with different geometry, dimensions and various polymers and nanocomposites.
- Experimental validation and optimization of the compression process in micro scale with different devices.

Objectives

The objective of this PhD thesis is to optimise the thermoplastic compression moulding process to elaborate competitive polymer based products. The research work will start by the characterization of the thermal and mechanical properties of the material. The die mould with specific geometry and dimension will be designed and fabricated by additive manufacturing, and then used to elaborate the polymer based components. The components obtained with various processing parameters will be compared to analyse their effects on the filling efficiency of the die mould cavities. The physical behaviours of the polymers and nanocomposites will be characterized by experimental tests. The tensile, compression and torsion tests with amorphous thermoplastic polymers have been performed in our previous study. These experimental devices could be used to carry on the creep, recovery and stress relaxation tests with the retained materials. The viscoelastic and viscoplastic constitutive laws based on integer and fractional order will be used to describe the materials' deformation during the compression process. The numerical simulation of the compression process will be achieved using finite element method. The comparison between the experimental and simulation results will be performed to verify the efficiency and accuracy of the proposed models.

Work program

The project, planned over 3 years, will be structured as follows:

Academic year	Research work description
1st year	– State of art on polymer physical behaviours (viscoelastic and viscoplastic). – Practice the experimental and numerical tools. – Compression process simulation with simple material models. – Mould design for the compression process (additive manufacturing).
2nd year	– Characterisation of materials' behaviour under various types of loading. – Identification of the material constitutive law in compression process. – Investigation of the possibility to filling mould with complex geometry. – Analysis of the material parameters' sensitivity.
3rd year	– Experimental validation of numerical predictions. – Optimisation the process with simulation approach. – Writing the Ph.D. thesis.

Equipment involved

- Injection and compression moulding machine
- 3D-printed press
- Tensile, compression and torsion test equipment
- Differential Scanning Calorimetry (DSC)
- Dynamic Mechanical Analysis (DMA)
- 3D optical profilometer for the metrology of component
- Abaqus, SolidWorks and Matlab softwares

Collaboration

This work will be conducted in collaboration with:
Professor Thierry BARRIERE
Univ. Bourgogne Franche-Comté, FEMTO-ST Institute, CNRS/UFC/ENSMM/UTBM, Department of Applied Mechanics, 25000 Besançon.

Candidate profil:

- Mechanical engineering
- Mechanical properties of material
- Polymer physical properties
- Good experimental skills
- Intermediate English level
- Autonomous and dynamic

References

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