REVIEW OF THE NUMERICAL MODELLING OF COMPRESSION MOULDING OF SHEET MOULDING COMPOUND

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Introduction

A review of the numerical modelling of compression moulding of Sheet Moulding Compound (SMC) is presented. These types of Fibre Reinforced Plastics (FRPs) are becoming increasingly attractive in, for instance, the automotive industry for their combination of good mechanical properties, low weight and relatively low cost. The quality of the finished products is however sensitive to variations in the manufacturing process, which means that it might be difficult to predict the mechanical properties with quality and trust. Several commercial software packages, such as Moldex3D and Autodesk Moldflow, are capable of modelling the process; however, these packages were developed for injection moulding, and there is not a significant amount of material regarding the validation with regards to compression moulding (1)

The focus of this paper will be on the issues encountered when attempting to numerically model the process, and various models for these issues.

Process description

To set up the process sheets consisting of a thermosetting polymer, chopped fibre bundles and possibly filler material are loaded into a heated mould. The mould is then closed and the compound will flow and cover it. As shown in (2, 3, 4), there will be complicated three-dimensional effects at the flow front.

Rheological properties of the process

The SMC will have complicated rheological properties for a number of reasons, including: the relatively high fibre content, the length of the fibres, the fibre orientation, the flexibility of the fibres, the displacement of air and variations in the material. Measuring the rheological properties is also complex, since ordinary rheometers usually cannot be used due to the long fibres.

Early experimental studies of the rheology were done by Lee et al (5). Vahlund and Gebart (6) developed equipment for measuring the rheology in large tools tackling the problem of long fibres.

Models for the viscosity

The viscosity of the compound has been shown experimentally to depend on a number of factors, but most importantly the strain rate (5), the volume fraction of the fibres and the temperature (7). It has also been suggested that the viscosity depends on the fibre orientation (8)

Models for the dependence of the viscosity of fluid on the volume fraction of the solid material can be traced back from Einstein (9), who studied the forces on a single spherical particle immersed in a fluid. More recently, an empirical model was suggested by Le Corre et al (7), which has since been implemented numerically by, among others, Kluge et al (10).

Modelling of fibre orientation

Much of the existing work regarding fibre orientation originates from the work done by Jeffery (11), who described the forces on an ellipsoid body immersed in a fluid.

Folgar and Tucker (12) extended Jefferys work by adding a term to account for the interactions between the particles, which was then extended by Advani and Tucker (13) into a less computationally expensive form. This model has since then been widely used, despite issues with overprediction of the speed of fibre alignment (14). Several models have also been suggested to address this behaviour (14, 15, 16).

It has also been suggested that the fibre network can be modelled as a deformable porous medium (17, 18, 19). There is however significant work to be done before such a model could be applied to real case.

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