



HAL
open science

Numerical Modelling of Molding Compression Of Fibre-Reinforced Composites for Industrial applications

Patrice Laure, Luis Fernando Salazar Betancourt, Luisa Silva, Mustafa Sager

► To cite this version:

Patrice Laure, Luis Fernando Salazar Betancourt, Luisa Silva, Mustafa Sager. Numerical Modelling of Molding Compression Of Fibre-Reinforced Composites for Industrial applications. 10th Annual European Rheology Conference (AERC 2015), Apr 2015, Nantes, France. . <hal-01285046>

HAL Id: hal-01285046

<https://hal.science/hal-01285046v1>

Submitted on 8 Mar 2016

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization

Dr HDR
Patrice Laure
 MINES ParisTech, PSL - Research University,
 CEMEF - Centre for material forming, CNRS UMR 7635,
 CS 10207 rue Claude Daunesse 06904 Sophia Antipolis, France

PhD candidate
Luis Fernando Salazar Betancour
 MINES ParisTech, PSL - Research University,
 CEMEF - Centre for material forming, CNRS UMR 7635,
 CS 10207 rue Claude Daunesse 06904 Sophia Antipolis, France

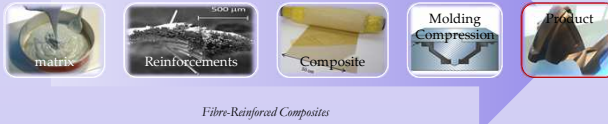
Dr
Luisa Silva
 Ecole Centrale de Nantes
 IQ - High Performance Computing Institute
 1 Rue de la Noe 44300 Nantes, France

Project Manager Innovation
Mustafa Sager
 Plastic Omnium AR Service
 Place de l'ain avenue du Bois des Vergnes
 01150 Sainte Julie, France

Abstract

A transverse isotropic viscous model accounting for the anisotropy exhibited in fiber-reinforced composites is integrated in the numerical platform of the software Rem3D®. Simulations under various mechanical loadings are tested for volume fiber concentrations of 3.5% and 14.7%. Equivalent stresses and equivalent strain rate deformations given by the software were compared to the ones coming from experimental data, finding very good agreements. As a second point developed on this paper, we comment on the slip condition between Die/Punch tool with the composite under compression. We noticed that the variation of the viscosity value on a small layer between the Die/Punch tool and the composite affects the nature of the contact. A viscous friction is then formulated as a technique to set slip/no-slip contact conditions. We found that the slip condition is recovered at lower values of the viscosity in the interface Die/Punch with the reinforced composite, whereas the no slip condition stated for higher viscosity values.

Process and Industrial Application



high performance and low density



Automotive: 10% weight reduction compared to all-aluminium design



Renewable Energy components

Rheological Behaviour of SMC under Compression

Homogenisation
 Fiber and Matrix are seen as a single phase
 Fiber Orientation $\perp n$
Rheology Model
 To account for the anisotropy exhibited in reinforced composite

$M = n \otimes n$

Composites with anisotropic properties

$D = \dot{\epsilon}$
 Strain rate deformation

Variables depending on the fiber fraction

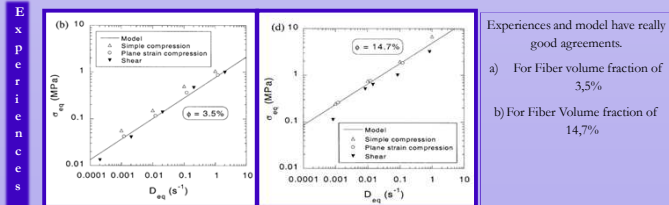
$\sigma = \alpha_0 K^f D_{eq}^{m-1} \left[D + \alpha_1 (M : D) M + \frac{\alpha_2}{2} (D \cdot M + M \cdot D) \right]$

$D_{eq}^2 = \alpha_0 [D : D + \alpha_1 (M : D)^2 + \alpha_2 (D \cdot M : D)]$

Test Cases

Three cases has been set to validate our numerical integration in Rem3D. Simple compression, plane strain compression and shear were the test used to obtain the rheology model [Dumont,2003]. In here; we repeat such tests and validate – verified with experimental results.

Comparison Model with Experiences [Dumont et al. 2003]

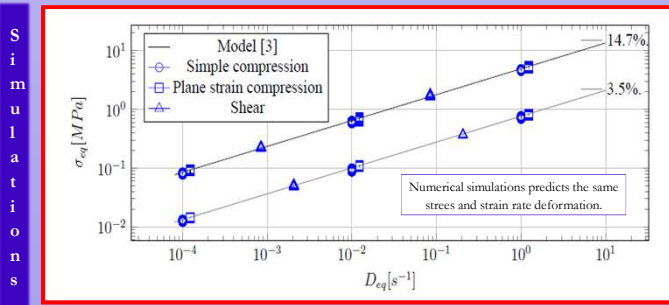


Experiences and model have really good agreements.

a) For Fiber volume fraction of 3,5%

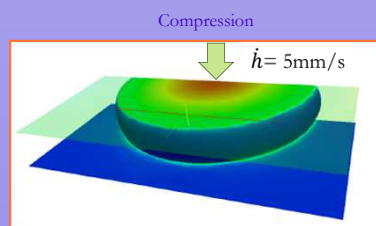
b) For Fiber Volume fraction of 14,7%

Comparison Model with Numerical Simulations [Salazar et al. 2015]

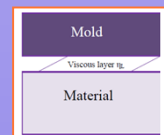


- Compression of fiber material with 14,7% weight fiber concentration.
- Friction coefficient has been set. $\epsilon_1 = 2.10^{-4}$

Compression with friction



Viscous Layer is used to set the lubrication condition in the interface Mold/Composite



Numerical Resolution: Rheological Model for Reinforced Fibre composites is used to described the mechanics

• Conservative equations

$$\left\{ \begin{array}{l} \nabla \cdot (2 \eta_b D(v^{i+1}) + \sigma_s(v^{i+1})) - \nabla p^{i+1} = 0 \\ \nabla \cdot v^{i+1} \\ + B.C \end{array} \right.$$

$\Rightarrow (v^{i+1}, p^{i+1}) \rightarrow \eta_{b+1}$

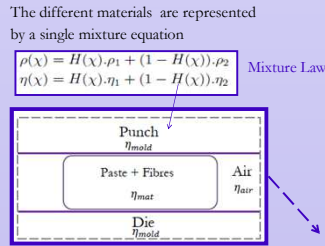
• Transport Equation

$$\frac{\partial \chi^{i+1}}{\partial t} + (v^{i+1} + v_s^{i+1}) \cdot \nabla \chi^{i+1} = f(\chi^i)$$

$\Rightarrow (\chi^{i+1})$

Immersed Method

[Coupez et al. 2010]

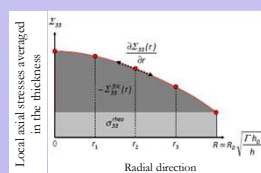


FEM Resolution

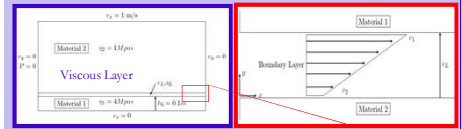
$$\rho(x)(\partial v_t + v \nabla v) - \nabla \cdot \sigma = \rho(x)g$$

$$\nabla \cdot v = 0$$

Friction Modeling



The normal stress depends on the size of the specimens, due to friction effect



Simple Shear test performed on 2x1(m)

Viscous friction approach

Friction Law

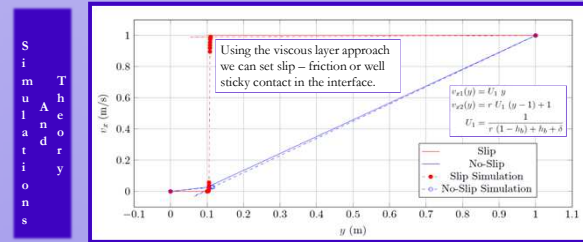
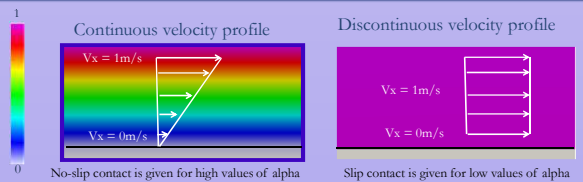
$$\tau = \alpha v_t$$

coefficient relation

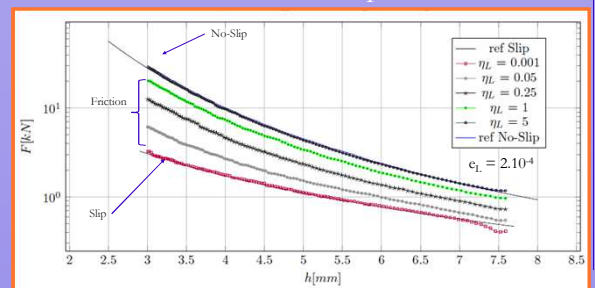
$$\alpha = \frac{\eta_L}{e_L}$$

In our immersed domain, we insert a layer assigned with a thickness and a viscosity. These two factors enable the setting of a friction coefficient.

Numerical difficulty: obtaining a discontinuous velocity profile in an immersed volume method with mesh adaptation and automatic remeshing



Friction effect on the compression force



[1] P. Laure, L. Silva and M. Vincent. Modelling short fibre polymer reinforcements for composites *Composite reinforcements for optimum performance* Edited by P.Boisse, Woodhead Publishing, Limited, 616-650 (2011).
 [2] S. Le Corre, L. Orgéas, D. Favier, A. Tourabi, A. Maazouzi, C. Venet. Shear and Compression Behaviour of Sheet Moulding Composites. *Composites Science and Technology*, (25:71-77)(2012).
 [3] P. Dumont, L. Orgéas, S. Le Corre, D. Favier . Anisotropic viscous behaviour of sheet molding compounds (smc) during compression molding. *International Journal of Plastics*, 19:625-646 (2003).

[4] Software Rem3D. A real 3D Polymer Processing Simulating Tool. Transvalor S.A., Parc de Haute Technologie 694, avenue du Dr Maurice Donat 62255 Mougins Cedex-France.
 [5] T. Coupez, H. Dignonnet, E. Hacheb, P. Laure, L. Silva. Multidomain Finite Element Computations: Application to Multiphase Problems. *Arbitrary Lagrangian-Eulerian and Fluid-Structure Interaction. Numerical Simulation* Edited by M.Souk and D.J. Berson. Wiley, 221-289 (2010).
 [6] J. Engmann, C. Servais, A. Burbidge. Squeeze Flow theory and applications to rheometry: A Review. *Journal of non-Newtonian fluid mechanics*, 132:1-27 (2005).