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

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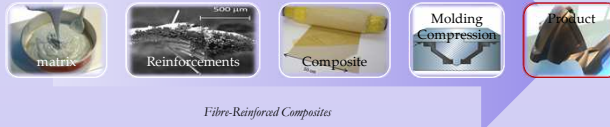
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Abstract

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

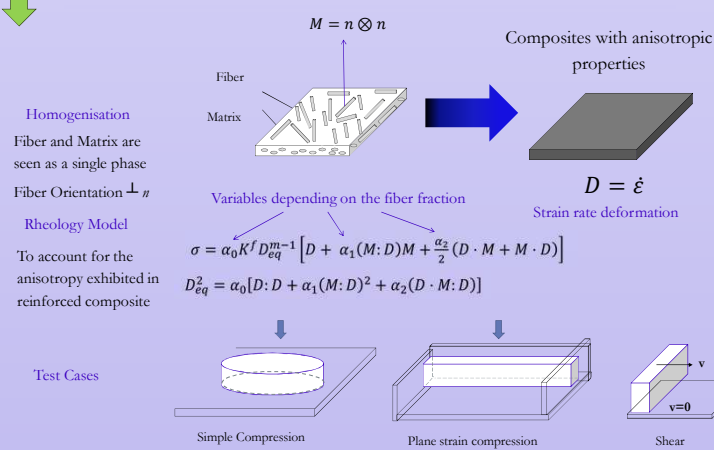


Automotive: 10% weight reduction compared to all-aluminium design



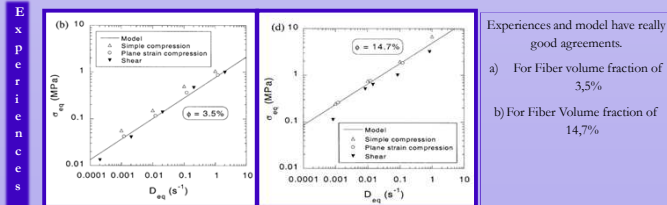
Renewable Energy components

Rheological Behaviour of SMC under Compression



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.

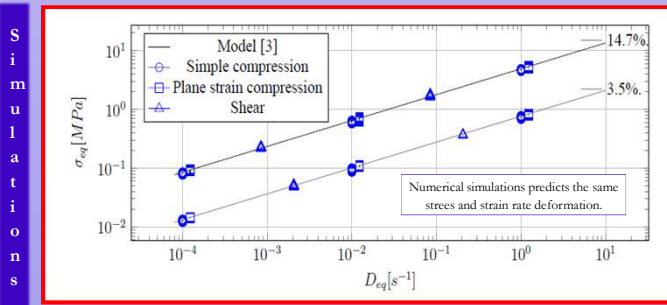
Comparison Model with Experiences [Dumont et al. 2003]



Experiences and model have really good agreements.

- a) For Fiber volume fraction of 3,5%
- b) For Fiber Volume fraction of 14,7%

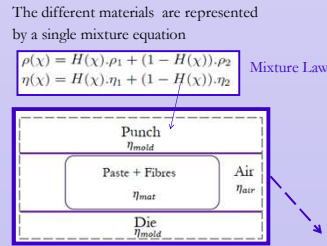
Comparison Model with Numerical Simulations [Salazar et al. 2015]



Numerical simulations predicts the same stresses and strain rate deformation.

Immersed Method

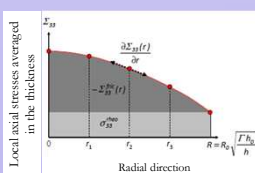
[Coupez et al. 2010]



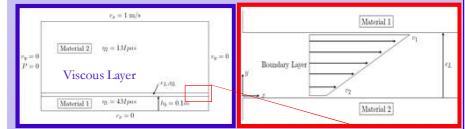
$$\text{FEM Resolution } \rho(x)(\partial v_t + v \nabla v) - \nabla \cdot \sigma = \rho(x)g$$

$$\nabla \cdot v = 0$$

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

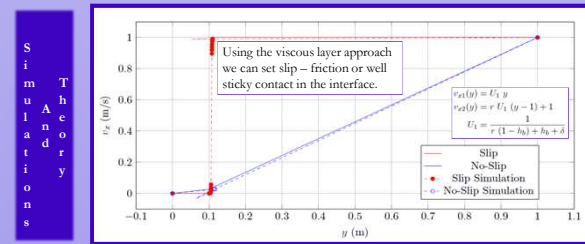
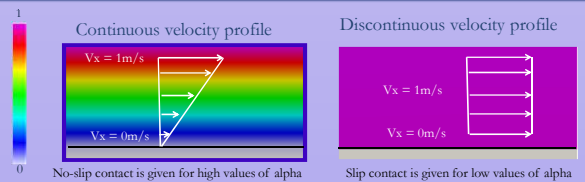
$$\text{Friction Law } \tau = \alpha v_r$$

coefficient relation

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

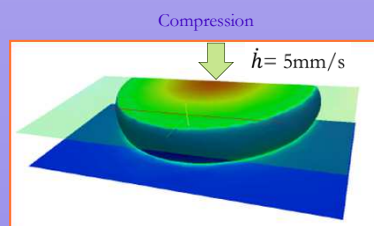
In our immersed domain, we insert a layer assigned with a thickness and a viscosity. These two factors enable the setting of a friction coefficient.

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

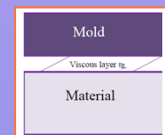


- Compression of fiber material with 14,7% weight fiber concentration.
- Friction coefficient has been set. $e_L = 2.10^{-4}$

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

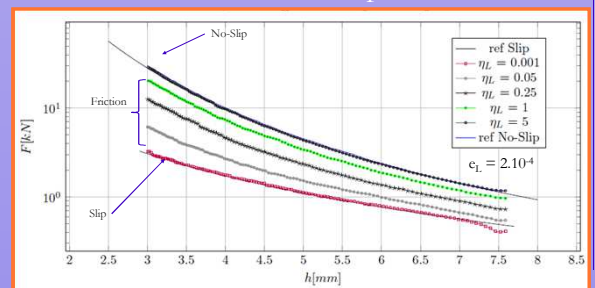
$$\left\{ \begin{array}{l} \nabla \cdot (2 \eta_D D(v^{t+1}) + \sigma_s(v^{t+1})) - \nabla p^{t+1} = 0 \\ \nabla \cdot v^{t+1} \\ + B.C \end{array} \right.$$

$$\Rightarrow (v^{t+1}, p^{t+1}) \rightarrow \eta_{k+1}$$
- Transport Equation

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

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

Friction effect on the compression force



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