PROCESS MODELING OF COMPOSITE MATERIALS - A HOLISTIC AND GENERIC SIMULATION TOOL USING POROMECHANICS

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Introduction
We are developing a generic and unified poromechanical finite element framework, which can be used for modelling of all different range of manufacturing processes from infusion like processes via prepregs to forming and press-forming using a single element formulation. In the present contribution a continuum finite element framework is being used to model flows at two different scales, as well as the filling phase (flow front) of a deformable preform. In particular, the moving flow front is modelled using an inner boundary developed as intrinsic feature of our continuum framework without any use of other pre-developed methods; such as level-set. In consequence, both pre- (gas flow) and post-filing phases can be easily modelled by just changing boundary conditions.

Homogenized theory of porous media
Theory of compressible porous media is the back-bone of the simulation framework which is exploited in this contribution. The aim is to be able to simulate any type of processes in composite manufacturing and visualize it in the macroscopic level considering the flow motion, flow front and preform deformation while the micro infiltration is happening at the same time in the meso-scale.

Physical assumptions
In the development of the model, from the continuum mechanics perspective, the assumed medias are needed to be distinguished and assumptions with respect to time and scale are necessary to be made. In that sense the fiber bed during any process is being considered as a porous material with a solid fiber network with pores. The fluid motion through the preform is another important event during any composite manufacturing process. In this sense the preform deformation is considered coupled to the fluid motion.

Governing equations
The respective mass and momentum balance for the problem are formulated as below

$$\nabla \cdot \boldsymbol{v}^s - n^s \dot{\varepsilon}^s - n^f \dot{\varepsilon}^f = -\frac{1}{\rho^f} \nabla \cdot (\frac{\rho^f}{\xi^f} \boldsymbol{v}^d). \tag{1}$$

$$\bar{\boldsymbol{\sigma}} \cdot \nabla + \hat{\rho} \boldsymbol{g} = \boldsymbol{0} \;\; \forall \boldsymbol{x} \in B, \tag{2}$$

where we solve them using FE method. The governing equation to calculate the saturation degree, equation (3), will lead to distinguish the liquid and gas constituents through the relevant processes.

$$n^f \dot{\xi}^f + \left(\frac{\dot{J}}{J} - (1 - n^f)\dot{\varepsilon}^s \right) \xi^f + \nabla \cdot \boldsymbol{v}^d = 0 \qquad \forall \boldsymbol{x} \in D \qquad with \qquad \boldsymbol{v}^d = -\frac{1}{\nu}\boldsymbol{K}_{mac} \nabla p \tag{3}$$

Results

In order to demonstrate the framework, a model example consisting of infusion with post flow-front preform saturation process, is considered. In particular the model is able to distinguish four different processing zones:

1 fully saturated area

2 partially saturated area with micro saturation process

3 flow front

4 dry area consisting of compressible gas

as seen in figure (1).

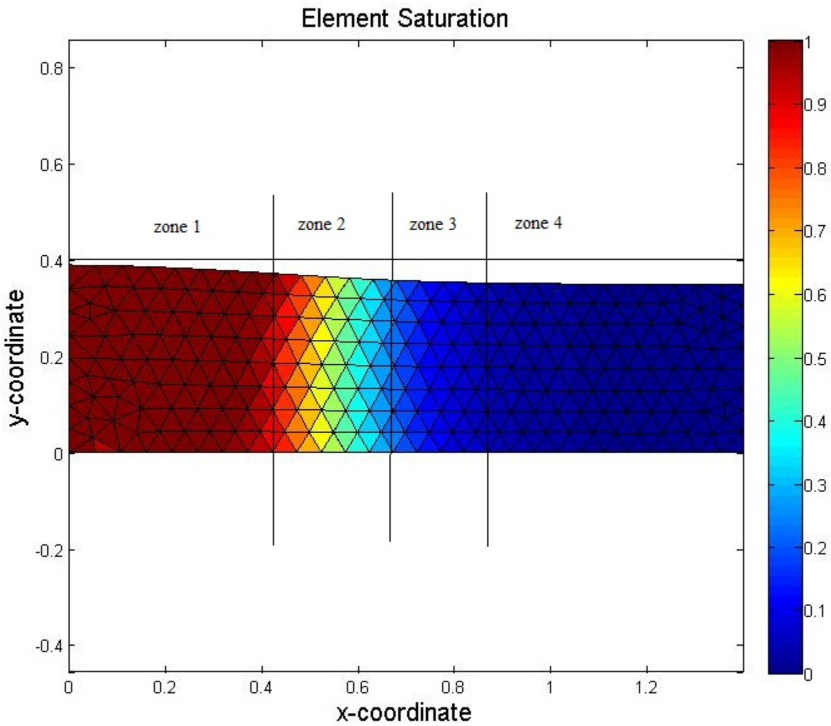

Figure 1: *The degree of saturation for different zone by different mechanisms.*

References

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