# SIMULATION OF 3D PREPREG CONSOLIDATION PROCESS USING SOLID SHELL ELEMENTS

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**Keywords**: *Compression moulding, Solid shell element, Dual scale flow, Consolidation, Abaqus UEL.*

### Introduction

In process simulation of composite materials, 3D simulation of manufacturing processes is desirable considering the manufacturing trend where parts became more complex leading to complex 3D stress-strain states. Moreover, coupling of sub-processes that are happening simultaneously such as macro-scale preform processes, micro-infiltration and solid and fluid interaction requires full 3D description of the problem.
The development is exemplified considering compression moulding process of prepregs where the main focus of the modeling will be on the compression and compaction of directional prepreg laminate and flow consolidation. To this end, the theory of two phase porous media is used along with assuming hyper-elastic material response for the laminate to formulate the problem. A finite element formulation and implementation of the two-phase problem is developed for incompressible constituents and is implemented in a user defined element (UEL) to be used with Abaqus.

### Homogenized theory of porous media

Theory of porous media is the back-bone of the simulation framework which is used in this contribution. The aim is to simulate compression moulding process and visualize it in 3D considering the laminate volumetric deformation, fiber compaction and micro infiltration using the solid shell element.

### 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 which is pre-impregnated with resin. The fluid motion through the preform is also important phenomena during the process. In this sense the laminate deformation is considered coupled to the fluid motion [1]–[3].

### Governing equations

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

$$\nabla \cdot \boldsymbol{v}^s - n^s \dot{\varepsilon}^s = -\nabla \cdot \boldsymbol{v}^d, \qquad \bar{\boldsymbol{\sigma}} \cdot \nabla + \hat{\rho} \boldsymbol{g} = \mathbf{0} \ \forall \boldsymbol{x} \in B. \tag{1}$$

where we solve them using FE method. The solid volume fraction is governed by the equation (2), where $\varepsilon^s$ is the compaction strain of the solid constituent.

$$n^s = \frac{e^{\varepsilon}}{J} n_0^s \tag{2}$$

The constitutive equations representing the solid compaction and micro-infiltration are presented in [2].

## Solid Shell Element

Normally such a problem is treated using solid elements; however, those are not practical for industrial purposes due to computational costs. In this context, shell elements are very efficient and robust in capturing mechanics of structures with thickness span much smaller than other two directions. However, standard shell elements are incapable of capturing out of plane responses, which are ever more important in composite manufacturing. Therefore, in this work the focus is on implementation of the solid shell element, illustrated in figure (1) [4], which is capable of handling out of plane responses and full porous media theory as well as small thickness to in-plane length ratio.

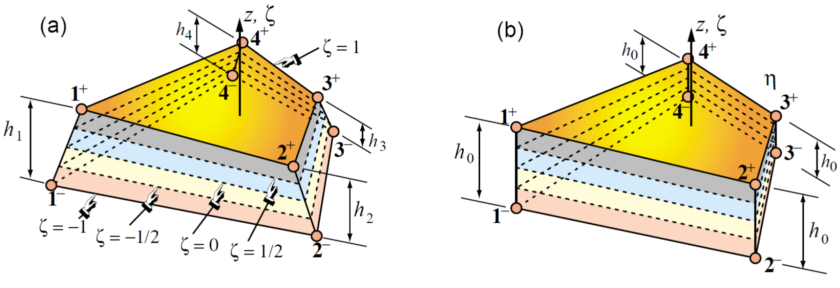

**Figure 1:** *Wall fabrication assumption for solid shell element. (a) constant thickness, (b) variable thickness. [4]*

## Results

In order to demonstrate the results, a model example consisting of loads and boundary conditions is considered as in Figure 2. In particular the model is able to distinguish three different state variables: i) saturation degree, ii) fibre volume fraction, iii) and resin rich areas along with reaction forces under compression.

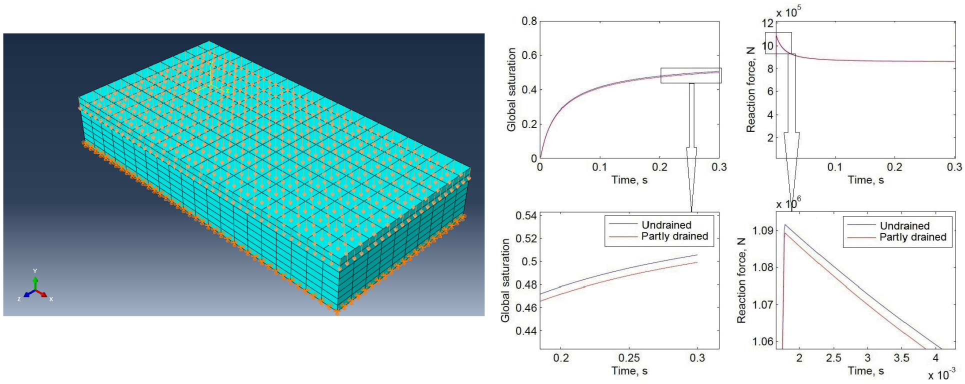

**Figure 2:** *The sample mesh and reaction forces*

## References

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