MONOLITHIC APPROACH OF STOKES-DARCY COUPLING FOR RESIN INFUSION BASED PROCESS MODELLING

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Abstract

A robust numerical method for simulating Liquid Resin Infusion processes is presented. The computational domain can be divided into a purely fluid domain and a porous medium. A level set method is used to capture the interface between the purely fluid and porous domains as well as the moving flow front. In the purely fluid domain, the fluid flows according to the Stokes' equations, while the fluid flows into the preforms according to the Darcy's equations. Specific conditions have to be considered on the Stokes/Darcy interface. Under the effect of a mechanical pressure applied on the high deformable preform/resin stacking, the resin flows and infuses through the preform which permeability is anisotropic and very low, down to 10^{-15} m^2*. A mixed velocity-pressure variational formulation is established for the fully Stokes-Darcy coupled problem and discretized using finite element method stabilized with a sub-grid scale stabilization technique (ASGS). Finally, This monolithic approach is shown to be robust and allows us to consider complex shapes for manufacturing process by resin infusion.*

1. Introduction

Liquid Resin Infusion processes, used for manufacturing composite materials parts with high quality, allow to investigate new designs for large dimension pieces especially in aeronautic field. These processes consist in infusing a liquid resin into a stacking of fibrous preforms under the action of a mechanical pressure field applied onto this stacking where a stiff-distribution medium is also placed to create a resin feeding (Figure 1(a)). However, despite numerous advantages, the control of these processes is difficult, especially for the most critical properties related to the final piece like its dimensions and its fibre volume fraction. The aim of this work is to propose a robust numerical finite element solution to simulate these processes in order to provide process parameters (filling time, final dimensions, volume fraction...). To control these processes, we develop a model based on the coupling between the resin flow within the porous domain (Darcy), and the purely fluid domain (Stokes) (Figure 1(b)). A specificity of this modelling is the order of magnitude of the permeability which is very low (10^{-15} m^2). The zero isovalue of two level set functions are used to describe the Stokes-Darcy interface and the moving flow front (Cf. section 4.2). The coupled problem is classically solved by formulating first a mixed velocity - pressure problem. The difficulty of the choice of a stable finite element

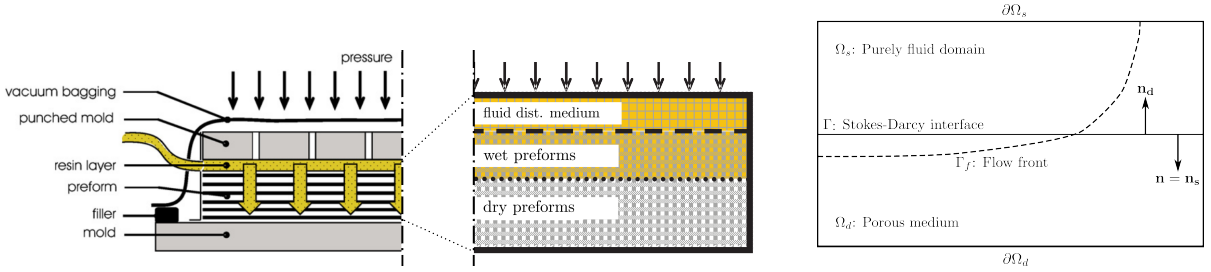


Figure 1. Domain decomposition into three zones for the modelling of resion infusion process: fluid distribution medium with resin, dry and wet preforms (a), 2D representation of the Stokes-Darcy domain (b).

pair for Stokes-Darcy coupled problem results from the fact that the stable elements for stokes are not stable for Darcy and vice versa. Two different strategies for coupling Stokes and Darcy equations can be found in the literature, called decoupled and monolithic strategies. Decoupled strategies consist in using two different meshes and consequently two different FE spaces for Stokes and Darcy [1, 2]. On the contrary, monolithic approaches, as the one presented here, is based on the use of one single finite element mesh and then one single finite element space [3]. In this work, we use a robust approach which yields improvements compared to the the approach proposed by G. Pacquaut *et al.* [3]. The robustness of the approach is ensured by using ASGS method (Algebraic Subgrid Scale) to stabilize velocity and pressure approximated by piecewise linear continuous functions in Stokes and Darcy domains.

The paper is organized as follows. The first section presents the mathematical modelling for the Stokes-Darcy coupled problem. The next section introduces both the velocity-pressure mixed formulation for the Stokes-Darcy problem and the variational multiscale method used for the stabilization. Finally, the last section shows numerical tests and results in severe regimes (very low permeabilities, complex geometries) to illustrate the capability of modelling manufacturing processes by resin infusion.

2. Governing equations

2.1. Mathematical model

Let us define $\Omega \subset \mathbb{R}^m$ ($m = 2$ or $m = 3$) as a bounded domain made up by two non overlapping sub-domains Ω_s and Ω_d separated by a surface $\Gamma = \partial\Omega_s \cap \partial\Omega_d$ (Figure 1(b)). Index s is used to denote everything that concerns the purely fluid domain (governed by the Stokes' equations) and index d for the porous medium (governed by the Darcy's equations). Γ is the interface between the Stokes and Darcy domains. In this work, the inertia terms are neglected and the resin is considered as an incompressible fluid. The Stokes' equations, which express momentum and mass balances, are written as, find the velocity $\mathbf{v_s}$ and the pressure p_s such that

$$\begin{aligned} -\boldsymbol{\nabla}\cdot(2\eta\dot{\boldsymbol{\varepsilon}}(\mathbf{v_s})) + \nabla p_s &= 0 && \text{in} \quad \Omega_s \\ \nabla\cdot\mathbf{v_s} &= 0 && \text{in} \quad \Omega_s \\ \mathbf{v_s} &= \mathbf{v}^1 && \text{on} \quad \Gamma_{s,D} \\ \boldsymbol{\sigma}_{n,s} &= -p_{ext,s}\mathbf{n_s} && \text{on} \quad \Gamma_{s,N} \end{aligned} \tag{1}$$

with p_s the pressure, $\boldsymbol{v_s}$ the velocity, η the viscosity assumed to be constant (Newtonian fluid), $\dot{\boldsymbol{\varepsilon}}(\mathbf{v_s}) = \frac{1}{2}(\nabla\mathbf{v_s} + \nabla\mathbf{v_s}^T)$ the strain rate tensor. $\mathbf{v^1}$ is the velocity prescribed on the boundary $\Gamma_{s,D}$,

$\mathbf{n_s}$ is the unit vector normal to the boundary of Ω_s, $\boldsymbol{\sigma_{n,s}}$ is the normal stress prescribed on $\Gamma_{s,N}$ to be equal to $-p_{ext,s}\mathbf{n_s}$. The Darcy's equations are then expressed as, find the velocity $\mathbf{v_d}$ and the pressure p_d such that

$$\begin{array}{lcll} \eta\,\mathbf{K^{-1}}\mathbf{v_d} + \nabla p_d &=& 0 & \text{in } \Omega_d \\ \boldsymbol{\nabla}\cdot\mathbf{v_d} &=& 0 & \text{in } \Omega_d \\ \mathbf{v_d}\cdot\mathbf{n_d} &=& g_d & \text{on } \Gamma_{d,D} \\ p_d &=& p_{ext,d} & \text{on } \Gamma_{d,N} \end{array} \tag{2}$$

with with p_d the pressure, $\boldsymbol{v_d}$ the velocity, $\mathbf{K}$ the permeability tensor, $p_{ext,d}$ a pressure to be prescribed on $\Gamma_{d,N}$, $\mathbf{n_d}$ the outward unit vector normal to the boundary of Ω_d.

2.2. Interface conditions

Conditions (mass conservation and continuity of the normal stress) have to be considered at the interface Γ of normal $\boldsymbol{n} = \boldsymbol{n_s} = -\boldsymbol{n_d}$ (Figure 1(b)). The mass conservation through the interface Γ is expressed by the continuity of the normal velocity field $\mathbf{v}$ across Γ: $\mathbf{v_s}\cdot\mathbf{n_s} + \mathbf{v_d}\cdot\mathbf{n_d} = 0$ on Γ. The continuity of normal stress over the interface Γ is expressed by: $\mathbf{n}\cdot\boldsymbol{\sigma_s}\cdot\mathbf{n} = \mathbf{n}\cdot\boldsymbol{\sigma_d}\cdot\mathbf{n}$ on Γ. The Beaver Joseph Saffman condition allows the tangential velocity to be specified on the interface Γ [4] and writes : $2\mathbf{n}\cdot\dot{\boldsymbol{\varepsilon}}(\mathbf{v_s})\cdot\boldsymbol{\tau_i} = -\frac{\alpha}{\sqrt{tr(\mathbf{K})/m}}(\mathbf{v_s}\cdot\boldsymbol{\tau_i})$, $i = 1,..,(m-1)$, where α is a dimensionless parameter, so-called slip coefficient, $\boldsymbol{\tau_i}$ are the tangential vectors on the interface.

3. Weak formulation

The weak formulation of the Stokes-Darcy coupled problem is obtained by summing up the Stokes and Darcy's weak formulations and by taking into consideration interface conditions described in the section 2.2. All details concerning both the weak formulation of Stokes' and Darcy's systems separately are given in [5, 6, 7]. For a sake of simplicity, we choose to write the L^2 inner product in $\Omega_{d/s} \subset \mathbb{R}^m$ as $< \cdot,\cdot >$. The following functional spaces are first defined for any bounded region $A \subset \mathbb{R}^m$ (A may be Ω_s or Ω_d):

$$\begin{aligned} Q(A) = \mathcal{L}^2(A) &= \left\{ q : A \to \mathbb{R}\,;\, \int_A q^2 dA < \infty \right\} \\ V(A) = \mathcal{H}^1(A) &= \left\{ q \in \mathcal{L}^2(A)\,;\, \nabla q \in \left(\mathcal{L}^2(A)\right)^m \right\} \\ V_\Gamma(A) = \mathcal{H}^1_{\Gamma_D}(A) &= \left\{ q \in \mathcal{H}^1(\Omega_s)\,;\, q = 0 \text{ on } \Gamma_D \right\} \\ W(A) = \mathcal{H}(div, A) &= \left\{ \mathbf{u} \in \left(\mathcal{L}^2(A)\right)^m\,;\, div(\mathbf{u}) \in \mathcal{L}^2(A) \right\} \\ W_\Gamma(A) = \mathcal{H}_{\Gamma_D}(div, A) &= \{ \mathbf{u} \in \mathcal{H}(div, A)\,;\, \mathbf{u}\cdot\mathbf{n} = 0 \text{ on } \Gamma_D \} \end{aligned}$$

The mixed variational formulation of the Stokes-Darcy coupled problem is established by considering a velocity $\mathbf{v}$ on Ω and a pressure field p on Ω such as $\mathbf{v}_{|\Omega_i} = \mathbf{v}_i$ and $p_{|\Omega_i} = p_i$ with $i = s$ or $i = d$. The integrals over Ω_s and Ω_d must be re-defined on Ω. This is achieved by introducing the Heaviside function H_i equal to 1 in the domain i and vanishing elsewhere. These functions allow us to write $\int_{\Omega_i}(...)d\Omega = \int_\Omega(...)H_i d\Omega$ with $= s$ or $i = d$. Hence, the mixed variational formulation of the Stokes-Darcy coupled problem consists in finding $(\mathbf{v}, p) \in (V_c \times Q_c)$ such

that $B_c[(\mathbf{v}, p), (\mathbf{w}, q)] = L_c[(\mathbf{w}, q)]$ with the bilinear form B_c and the linear form L_c defined by

$$\begin{aligned} B_c([\mathbf{v}, q], [\mathbf{w}, q]) &= < 2\eta\dot{\boldsymbol{\varepsilon}}(\mathbf{v}) : \dot{\boldsymbol{\varepsilon}}(\mathbf{w})H_s >_\Omega + < \eta\,\mathbf{K}^{-1}\mathbf{v}, \mathbf{w}\,H_d >_\Omega - < p\,, \nabla\cdot\mathbf{w} >_\Omega \\ &\quad + < q,\ \nabla\cdot\mathbf{v} >_\Omega + < \frac{\alpha\eta}{\sqrt{tr(\mathbf{K})/m}}\,\mathbf{v}\cdot\tau\,, \mathbf{w}\cdot\tau >_\Gamma \qquad (3) \\ L_c([\mathbf{v}, p], [\mathbf{w}, q]) &= < p_{ext,s}\mathbf{n}, \mathbf{w} >_{\Gamma_{s,N}} + < p_{ext,d}\mathbf{n}, \mathbf{w} >_{\Gamma_{d,N}} \end{aligned}$$

for any trial functions $\mathbf{w} \in V_c^0$ and $q \in Q_c$ with $V_c = V(\Omega_s)^m \times W(\Omega_d)$, $Q_c = Q(\Omega_s) \times Q(\Omega_d)$ and $V_c^0 = V_\Gamma(\Omega_s)^m \times W_\Gamma(\Omega_d)$.

4. Numerical strategy

4.1. Stabilized finite element method

We consider the bounded domain $\Omega \subset \mathbb{R}^m$ discretized into n_{el} non-overlapping elements. This one single unstructured mesh is made up of triangles if $m = 2$ and of tetrahedrons if $m = 3$. The Galerkin approximation of both the Stokes and the Darcy problems requires the use of velocity-pressure interpolation that satisfy the adequate *inf-sup* condition. Different interpolation pairs are known to satisfy this condition for each problem independently, but the key issue is to find interpolations that satisfy both at the same time. In this paper, we choose the use of stabilized finite element methods. The philosophy of the stabilized methods is to strengthen classical variational formulations so that discrete approximation which would otherwise be unstable becomes stable and convergent. One of the Variational MultiScale (VMS) method for Stokes-Darcy problem is ASGS (Algebraic Subgrid Scale) method [8]. An important feature is that the finite element spaces in Stokes' and Darcy's domains are the same because we use a monolithic approach. The finite element discretization is carried out by restricting the variational formulation (3) to the finite the finite element space $(V_h^m \times Q_h)$, where $V_h \subset V$ and $Q_h \subset Q$ are the approximation spaces for velocity and pressure, respectively. In this paper, both velocity and pressure are approximated by continuous and piecewise linear functions. The basic idea of the VMS methods is to approximate the effect of the component of the continuous solution which cannot be captured by the finite element solution. It consists in splitting the continuous solution for velocity and pressure into two components, one coarse corresponding to the finite element scale $(\mathbf{v_h}, p_h)$, and a finer component corresponding to lower scale $(\mathbf{v}', p')$ for resolutions. The velocity is approximated as $\mathbf{v} = \mathbf{v_h} + \mathbf{v}'$ and the pressure field is approximated as $p = p_h + p'$. We consider a subgrid space $V \times Q = (V_h \times Q_h) \oplus (V' \times Q')$. Invoking this decomposition in the continuous problem (3) for both solution and test functions, one gets the two-scale systems

$$B_c[(\mathbf{v_h}, p_h), (\mathbf{w_h}, q_h)] + B_c[(\mathbf{w}', p'), (\mathbf{w_h}, q_h)] = L_c[(\mathbf{w_h}, q_h)] \qquad (4)$$

$$B_c[(\mathbf{v_h}, p_h), (\mathbf{w}', p')] + B_c[(\mathbf{v}', p'), (\mathbf{w}', q')] = L_c[(\mathbf{w}', q')] \qquad (5)$$

for all $(\mathbf{w_h}, q_h) \in V_h \times Q_h$ and $(\mathbf{w}', q') \in V' \times Q'$. After approximating (5) with an algebraic formulation, by introducing an operator of projection onto $V' \times Q'$, the approximated fields $(\mathbf{v}', p')$ are taken into account in the finite element problem (4) [5]. For Stokes and Darcy flows coupled through their interfaces, the stabilized problem with ASGS can be written as follows

$B_{c,stable}[(\mathbf{v_h}, p_h)(\mathbf{w_h}, q_h)] = L_{c,stable}$ with

$$\begin{aligned} B_{c,stable}([\mathbf{v_h}, p_h], [\mathbf{w_h}, q_h]) &= 2\eta < H_s \dot{\boldsymbol{\varepsilon}}(\mathbf{v_h}) : \dot{\boldsymbol{\varepsilon}}(\mathbf{w_h}) >_\Omega + \eta < H_d\, \mathbf{w_h}, \mathbf{K}^{-1}\mathbf{v_h} >_\Omega \\ &\quad - < \nabla \cdot \mathbf{w_h},\ p_h > + < \nabla \cdot \mathbf{v_h},\ q_h >_\Omega + \tau_{p,c} < \nabla \cdot \mathbf{v_h}, \nabla \cdot \mathbf{w_h} >_\Omega \\ &\quad + < \alpha \frac{\eta}{\sqrt{tr(\mathbf{K})/m}} (\mathbf{v_h} \cdot \boldsymbol{\tau}), (\mathbf{w_h} \cdot \boldsymbol{\tau}) >_\Gamma \\ &\quad + \boldsymbol{\tau_{u,c}} < \eta\, \mathbf{K}^{-1}\mathbf{v_h} + \nabla p_h, -\eta\, \mathbf{K}^{-1}\mathbf{w_h} - \nabla q_h >_\Omega \qquad (6) \\ L_{c,stable}([\mathbf{w_h}, q_h]) &= < p_{ext,s}\mathbf{n}, \mathbf{w_h} >_{\Gamma_{s,N}} + < p_{ext,d}\mathbf{n}, \mathbf{w_h} >_{\Gamma_{s,D}} \end{aligned}$$

$\tau_{p,c}$, $\tau_{u,c}$ are the stabilization parameters, that we compute as

$$\tau_{p,c} = c_p \frac{\eta}{\overline{K}} l_p^2 H_d + c_1 \eta H_s \qquad \boldsymbol{\tau_{u,c}} = \left(\frac{1}{c_1\, \eta} H_s \mathbf{I} + \frac{1}{c_u\, \eta\, l_u^2} H_d \mathbf{K} \right) h_k^2 \qquad (7)$$

with c_p and c_u some algorithmic constants. l_u and l_p are length scales which we choose equal to $(L_0 h_k)^{1/2}$, L_0 is a characteristic length of the domain and h_k is the element size. $\overline{K}$ is a "representative" permeability defined here, such as $\overline{K} = [max(K_I, K_{II}, K_{III}) + min(K_I, K_{II}, K_{III})]/2$, where the permeability tensor $\mathbf{K}$ in the structural frame $\mathcal{R} = (0; X_I, X_{II}, X_{III})$ is given by (orthotropic case)

$$\mathbf{K} = \left[\begin{array}{ccc} K_I & 0 & 0 \\ 0 & K_{II} & 0 \\ 0 & 0 & K_{III} \end{array} \right]_{(0;X_I,X_{II},X_{III})} \qquad (8)$$

4.2. Interface capturing

In our monolithic approach, both interfaces Γ separating the Stokes' and Darcy's domains and Γ_f the moving flow front, are not described by a set of boundary elements. These interfaces go through the mesh elements. Consequently, two functions ϕ and ϕ_f has to be introduced to depict these interfaces. ϕ, ϕ_f are chosen as signed distance functions, respectively to Γ and Γ_f. Γ and Γ_f are then respectively described by the zero iso-surface of $\phi : \Gamma = \{\phi = 0\}$ and $\phi_f : \Gamma_f = \{\phi_f = 0\}$. When considering the discrete problem, ϕ and ϕ_f are approximated by continuous and piecewise linear functions ϕ_h and ϕ_{fh} on Ω_h. The drawback of the monolithic approach is that the surface integrals are not easily and directly computable. There is two ways to compute the surface integral $< \alpha \frac{\eta}{\sqrt{tr(\mathbf{K})/m}} (\mathbf{v_h} \cdot \boldsymbol{\tau}), (\mathbf{w_h} \cdot \boldsymbol{\tau}) >_\Gamma$ involved in (6). Either the surface integral is turned into a volume integral by introducing a Dirac delta function, or it is computed exactly by rebuilding a piecewise linear interface. The exact computation of the surface integrals shows more accurate results than Dirac approximation [5].

The specificity of our approach is the introduction of a moving flow front, depicted above by the level-set function ϕ_f, separating the part of the domain which already filled with the resin from the part which is not filled yet. Because of our monolithic approach, the velocity and pressure fields have to be defined on the whole computational domain assuming that the empty part is filled with a Newtonian incompressible fluid (referred to the "air") having a very low viscosity $\eta_a \ll \eta_f$, where η_f is the fluid viscosity. Taking into account this moving flow front into (6) consists of simply replacing the constant resin viscosity η by the viscosity η_ϕ, equal to η_f in the filled domain (when $\phi_f > 0$) and equal to η_a in the empty domain (when $\phi_f < 0$): $\eta_\phi = H(\phi)\eta_f + (1 - H(\phi))\eta_a$. Once the velocity is computed, ϕ_f is transported by solving the

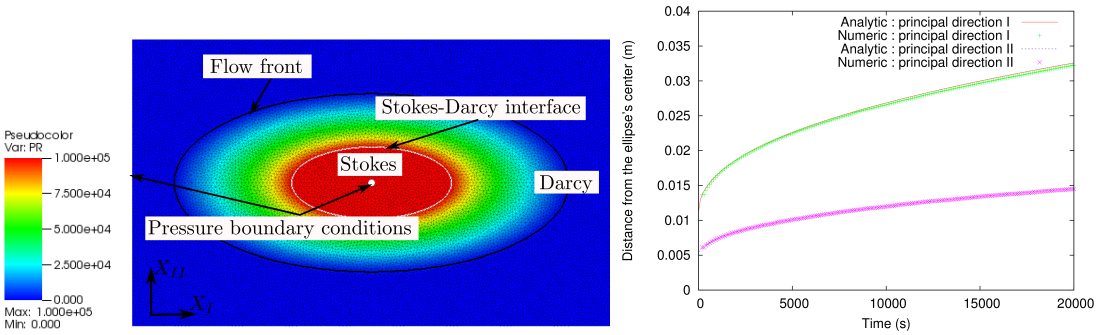
following transport equation

$$\begin{aligned} \frac{\partial \phi_f}{\partial t} + \boldsymbol{v} \cdot \boldsymbol{\nabla} \phi_f &= 0 \qquad \forall (x,t) \in \Omega \times (0,T) \\ \phi_f(x, t=0) &= \phi_0(x) \quad \forall x \in \Omega \\ \phi_f(x,t) &= g(x,t) \quad \forall x \in \partial\Omega^-, \forall t \in (0,T) \end{aligned} \tag{9}$$

where $\partial\Omega^- = \{x \in \partial\Omega; \boldsymbol{v} \cdot \boldsymbol{n} < 0\}$ is the inflow part of the boundary $\partial\Omega$. In order to avoid spurious oscillations when applying the continuous piecewise linear function ϕ_{f_h} approximation, the advection equation (9) is solved by using a classical SUPG method and by using an implicit Euler scheme for the time discretization. Hence, a reinitialization step may be necessary to ensure that the solution is not deteriorated and to recover the property of the signed distance function (i.e., $\|\boldsymbol{\nabla}\phi_f\| = 1$) without disturbing the position of the flow front.

5. Numerical results

The first simulation consists in a bi-dimensional flow with an orthotropic permeability of the porous medium. The aim of the numerical test is to validate the Stokes-Darcy coupling presented in this paper for a transient flow with a very low permability. The simulation has been carried out by using the finite element software Z-set. The computational domain is divided into a purely fluid domain elliptical in shape (Stokes' domain at the center) and a porous medium (Figure 2). The Stokes-Darcy interface and the resin flow front are depicted by respectively the zero iso-surface coloured in white and the zero iso-surface coloured in black (Figure 2(a)). The physical parameters for this simulation are $\eta_a = 1.10^{-5} Pa.s$ and $\eta_f = 3.10^{-2} Pa.s$. The permeability tensor $\mathbf{K}$ is defined in the structural frame $\mathcal{R} = (0; X_I, X_{II})$ by the permeability $K_I = 5.10^{-15} m^2$ and $K_{II} = 1.10^{-15} m^2$. A pressure equals to $10^5 Pa$ is applied on the center of the computational domain and a pressure is enforced equal to zero on the boundary of the computational domain. This case has been investigated in [9]. An analytical solution allows to describe the position of the flow front during the simulation. Figure 2(a) shows the pressure iso-values provided by the simulation. A pressure gradient appears in the wet preform zone. Figure 2(b) compares simulation results to the analytical solution in the two main directions X_I and X_{II}. One can verify the good correlation between the analytical and the numerical solutions.



(a) (b)

Figure 2. Pressure field in a bi-dimensional Stokes-Darcy flow with an orthotropic permeability (a), evolution of the flow front (b).

The example proposed Figure 3 represents the manufacturing of a "Omega" shaped piece by resin infusion based process. The computational domain is depicted Figure 3(a) with an injection channel through which the resin is injected. The boundary conditions prescribed for this

simulation are a normal stress on the inflow part of the domain and a zero normal velocity on the other edges of the domain. The permeability tensor **K** is defined in the structural frame $\mathcal{R} = (0; X_I, X_{II})$ of each porous domain of the part, by the permeability $K_I = 1.10^{-13}m^2$ and $K_{II} = 1.10^{-15}m^2$. The computational domain is discretized with a fixed mesh of 27,248 triangular elements corresponding to 14,523 nodes. Figure 3 shows the evolution of the flow front highlighting the strong effect of the orthotropic permeability (Figures 3(b), 3(c), 3(d)) on the filling of the porous medium. The orthotropic permeability also affects the pressure field in the porous domain and then the flow in the curved part. Moreover, the results seem to show that when the front reaches the top of an horizontal part of the domain, air is entrapped, this could results defects. These defects may be reduced by placing properly the vents in an optimization process. The robustness of our approach to simulate realistic geometries with thin flow media in the context of the manufacturing processes of composite materials has been demonstrated. These simulations were conducted with a Stokes-Darcy monolithic approach with a moving flow front and very low orthotropic permeabilities ($10^{-13} \sim 10^{-15}m^2$). All the developments have been extended to 3D cases and numerical simulations of the manufacturing process by resin infusion have been performed but not included in this paper.

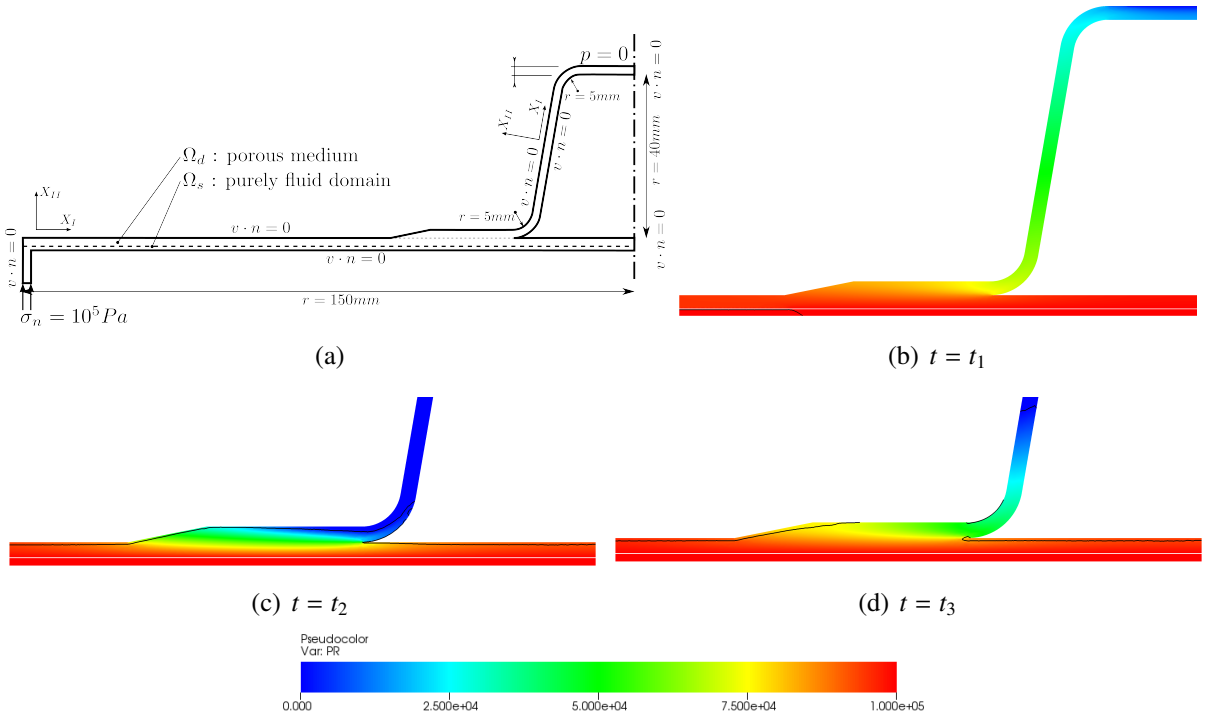


Figure 3. Geometry and boundary conditions used for the simulation of the manufacturing process by resin infusion (a), Evolution of the resin flow front and pressure fields for three different times for orthotropic permeability $K_I = 1.10^{-13}m^2$ and $K_{II} = 1.10^{-15}m^2$ (b), (c) and (d).

6. Conclusion

A unified strategy has been developed to solve the Stokes-Darcy coupled problem. A stabilized finite element method has been proposed to stabilize Stokes-Darcy coupled problem in the case where the Brezzi-Babuska stability condition is not fulfilled. This stabilization method is based on a variational multiscale technique called ASGS method. Convergence of this method was validated in [5] showing the accuracy of the results. A numerical simulation of a bi-directional flow was presented for the validation of the Stokes-Darcy coupling with orthotropic permeabil-

ities. Finally, a 2D simulation of the manufacturing process by resin infusion was presented. In these simulations, two signed distance functions were used, one to represent the interface between the purely fluid domain and the porous medium and a second one to capture the flow front. It was shown that our monolithic approach is relevant to simulate the resin infusion processes in severe regimes (very low orthotropic permeabilities, thin flow media...). Regarding the prospects for future works, we shall take into account the deformation of preforms by using an Updated Lagrangian scheme relying on displacement-based finite element. A special care will be paid to the interaction of the preform deformation and the resin infusion. Indeed, the resin pressure will be modified by the permeability change induced by preform compaction, and conversely the mechanical response of the porous medium will be represented via a Terzaghi's model modified according to the current resin pressure.

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