USING A LEVEL-SET MODEL TO ESTIMATE DWELL TIME IN A VACUUM DEWATERING PROCESS FOR PAPER

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Outline

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- Purpose/Aim
- Dewatering process
- Computational domain
- Governing equations
- Volume forces
- Mesh study
- Results
- Conclusion
- Future work

Purpose/Aim

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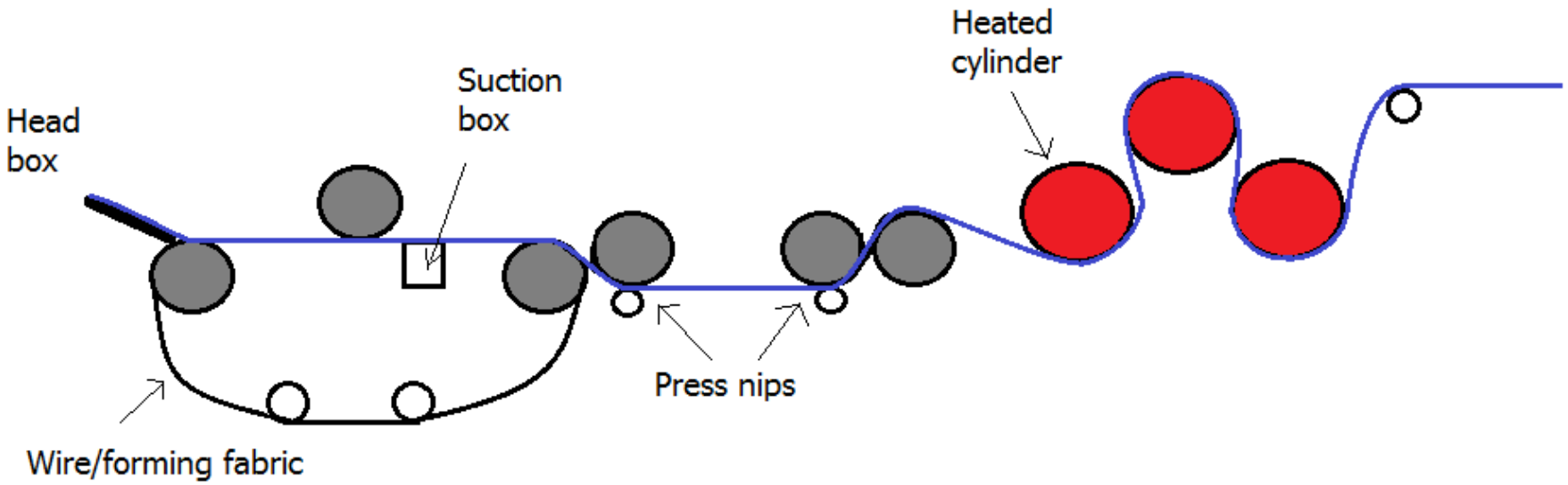
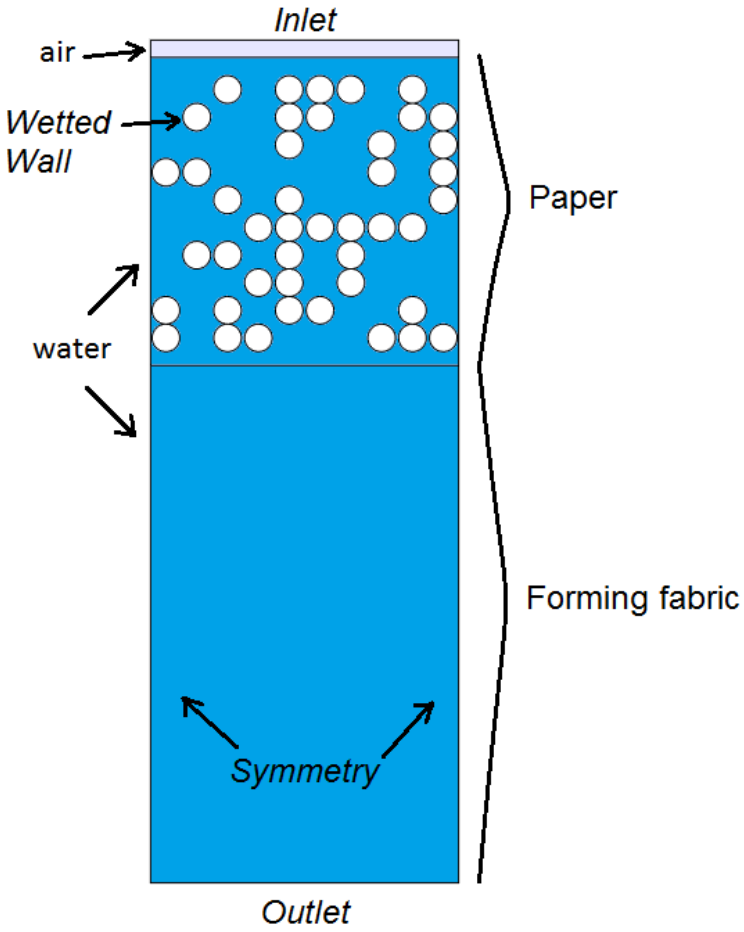
- To physically understand the mechanisms which determines the dewatering rate during the vacuum process.
- The aim is to estimate dry content as a function of dwell time numerically
- Obtaining better methods of dimensioning industrial equipment

Dewatering process



Computational domain



- 2D structure
- Basis weight 20 g/m^2
- Porosity 0.72
- Aligned fiber orientation
- Constant cross-section area of fiber

Governing equations

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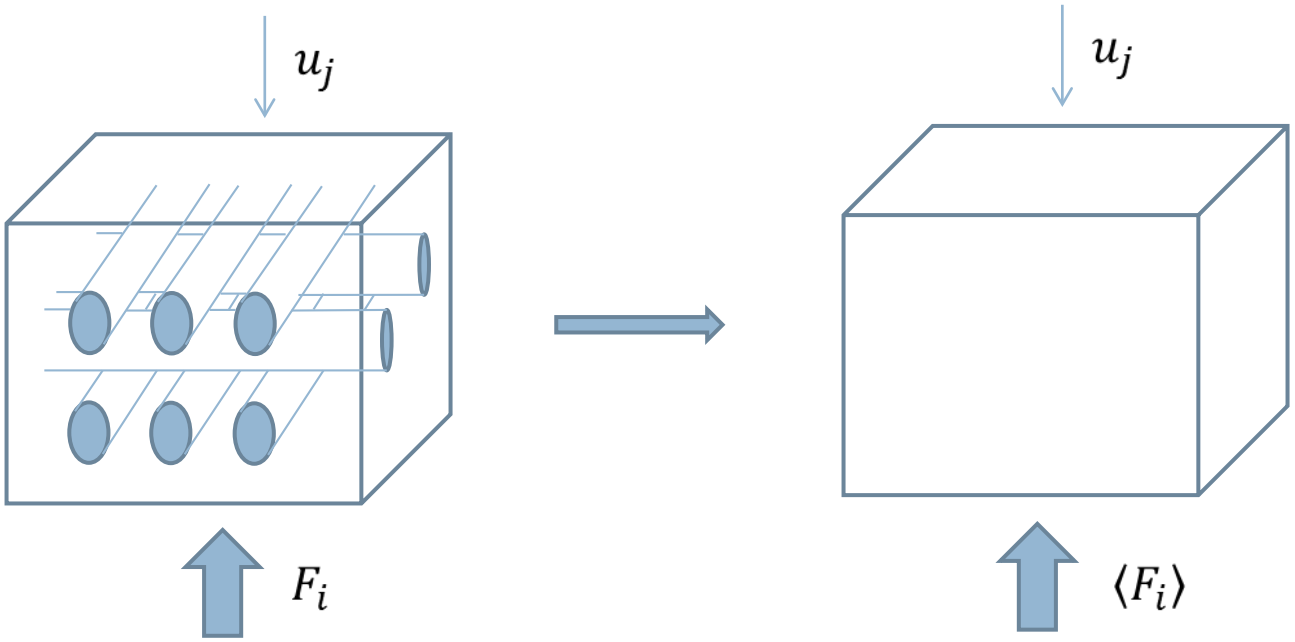
- Level-Set equation with a re-initialisation term
  - $\frac{\partial \varphi}{\partial t} + u_j \frac{\partial \varphi}{\partial x_j} = \gamma \frac{\partial \varphi}{\partial x_j}\left(\varepsilon \frac{\partial \varphi}{\partial x_j} - \varphi(1-\varphi)\frac{\partial \varphi}{\partial x_j}\left|\frac{\partial \varphi}{\partial x_j}\right|^{-1}\right)$
- Continuity and momentum equation
  - $\frac{\partial u_i}{\partial x_i} = 0$
  - $\rho \frac{\partial u_i}{\partial t} + \rho u_j \frac{\partial u_i}{\partial x_j} = -\frac{\partial p}{\partial x_i} + \mu\left[\frac{\partial}{\partial x_j}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)\right] - \rho g_i + F_i + F_{st,i}$

Volume forces

- $F_i = \alpha_{V_{ij}} u_j + \alpha_{I_{ij}} u_j |u_j|$
- $\langle F_i \rangle = \alpha_{V_{ij}} \langle u_j \rangle_{FRV} + \alpha_{I_{ij}} \langle u_j \rangle_{FRV} \langle |u_j| \rangle_{FRV}$

Viscous resistance

Inertial resistance



Mesh study

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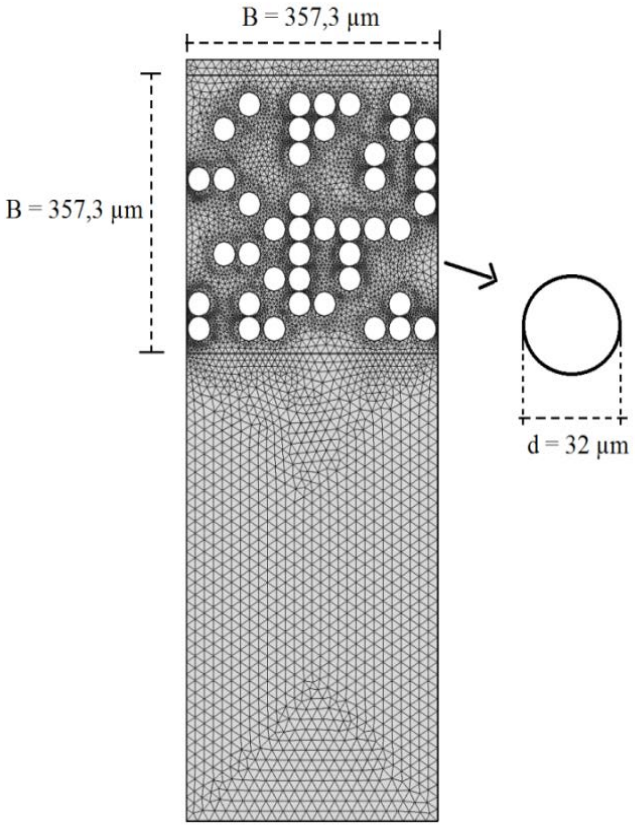
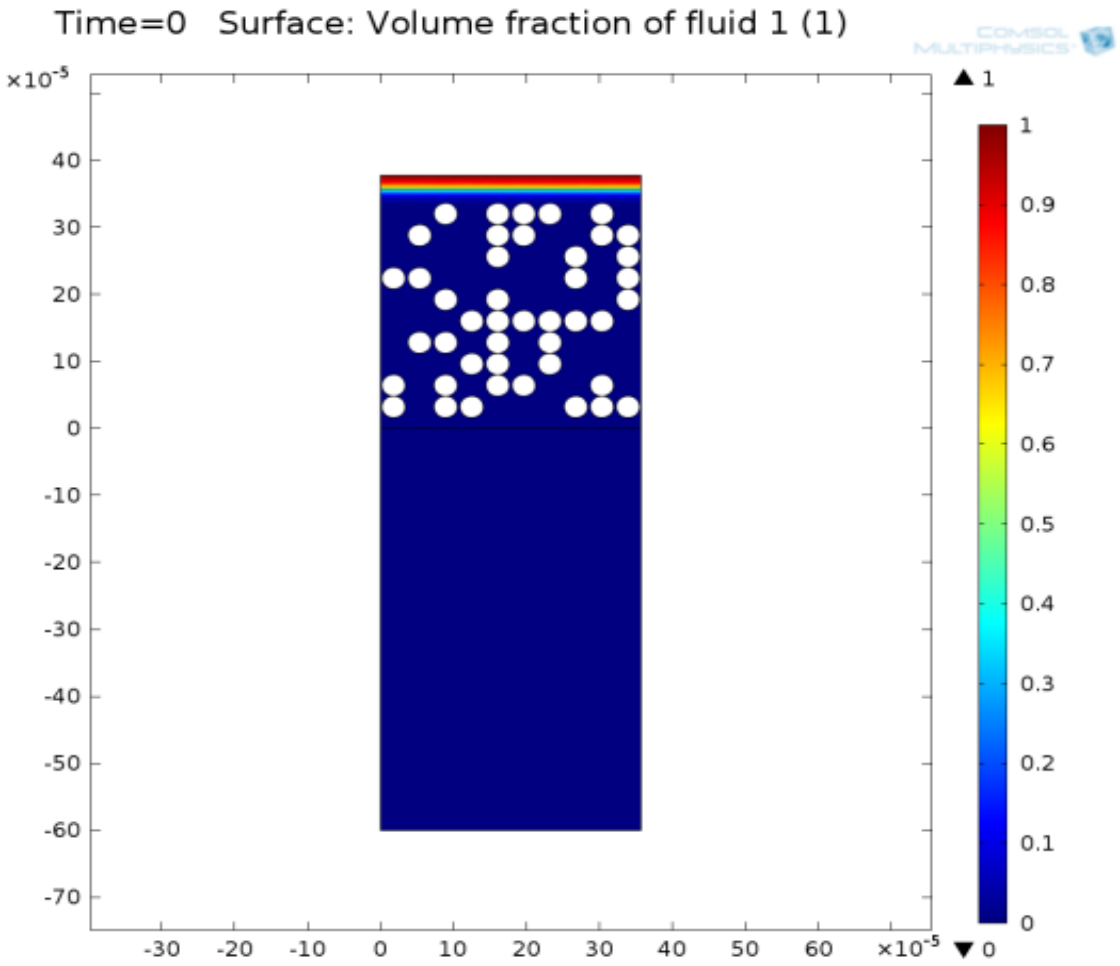
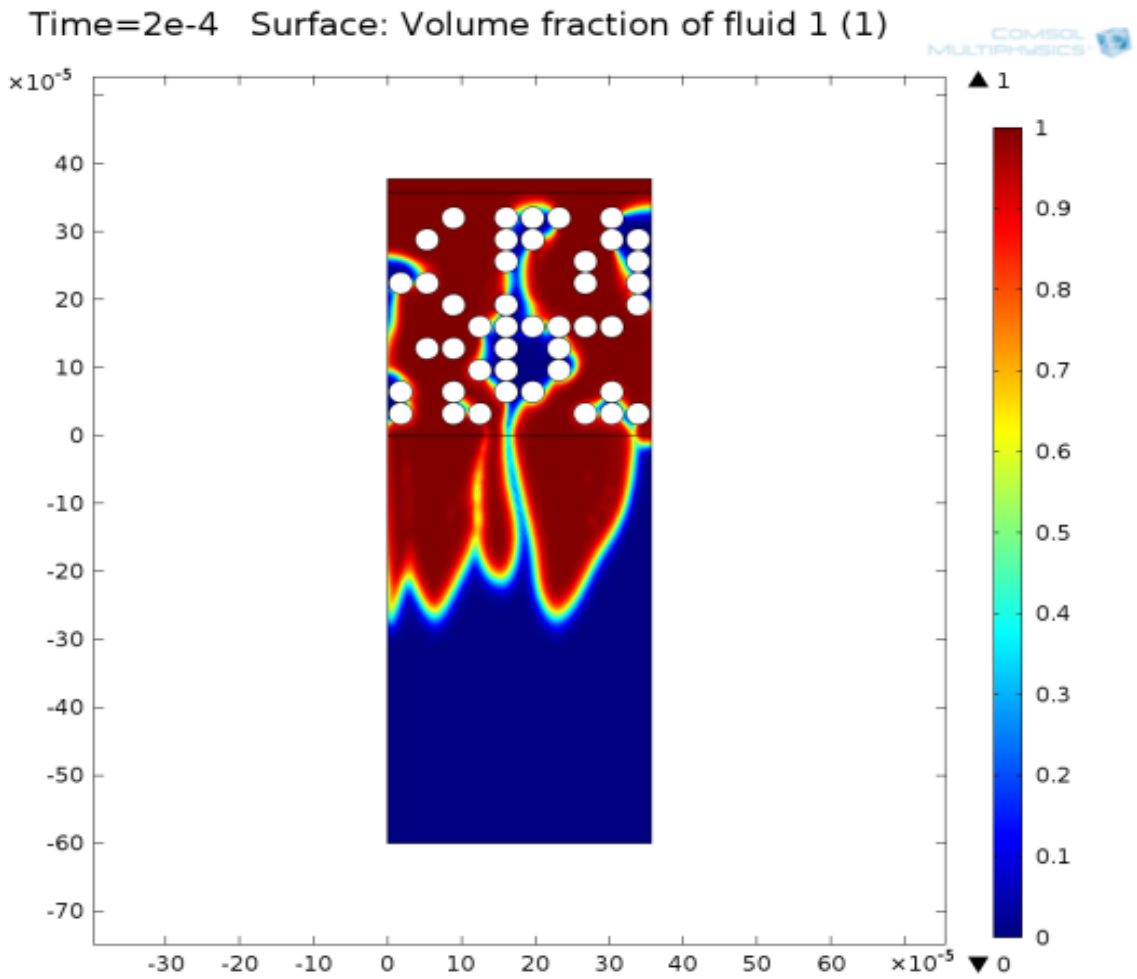


	Maximum element size [µm]	Minimum element size [µm]	Element growth rate	Resolution of narrow regions
Case S	16.5	7.15	1.15	1
Case 1	**12.5**	7.15	1.15	1
Case 2	**10.0**	7.15	1.15	1
Case 3	16.5	**3.57**	1.15	1
Case 4	16.5	**1.43**	1.15	1
Case 5	16.5	7.15	**1.05**	1
Case 6	16.5	7.15	**1.025**	1
Case 7	16.5	7.15	1.15	**3**
Case 8	16.5	7.15	1.15	**5**

Results


Time=0 Surface: Volume fraction of fluid 1 (1)
×10⁻⁵
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-30 -20 -10 0 10 20 30 40 50 60 ×10⁻⁵
▲ 1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
▼ 0

Results (con.)


Time=2e-4 Surface: Volume fraction of fluid 1 (1)
×10⁻⁵
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-30 -20 -10 0 10 20 30 40 50 60 ×10⁻⁵
▲ 1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
▼ 0

Results (con.)

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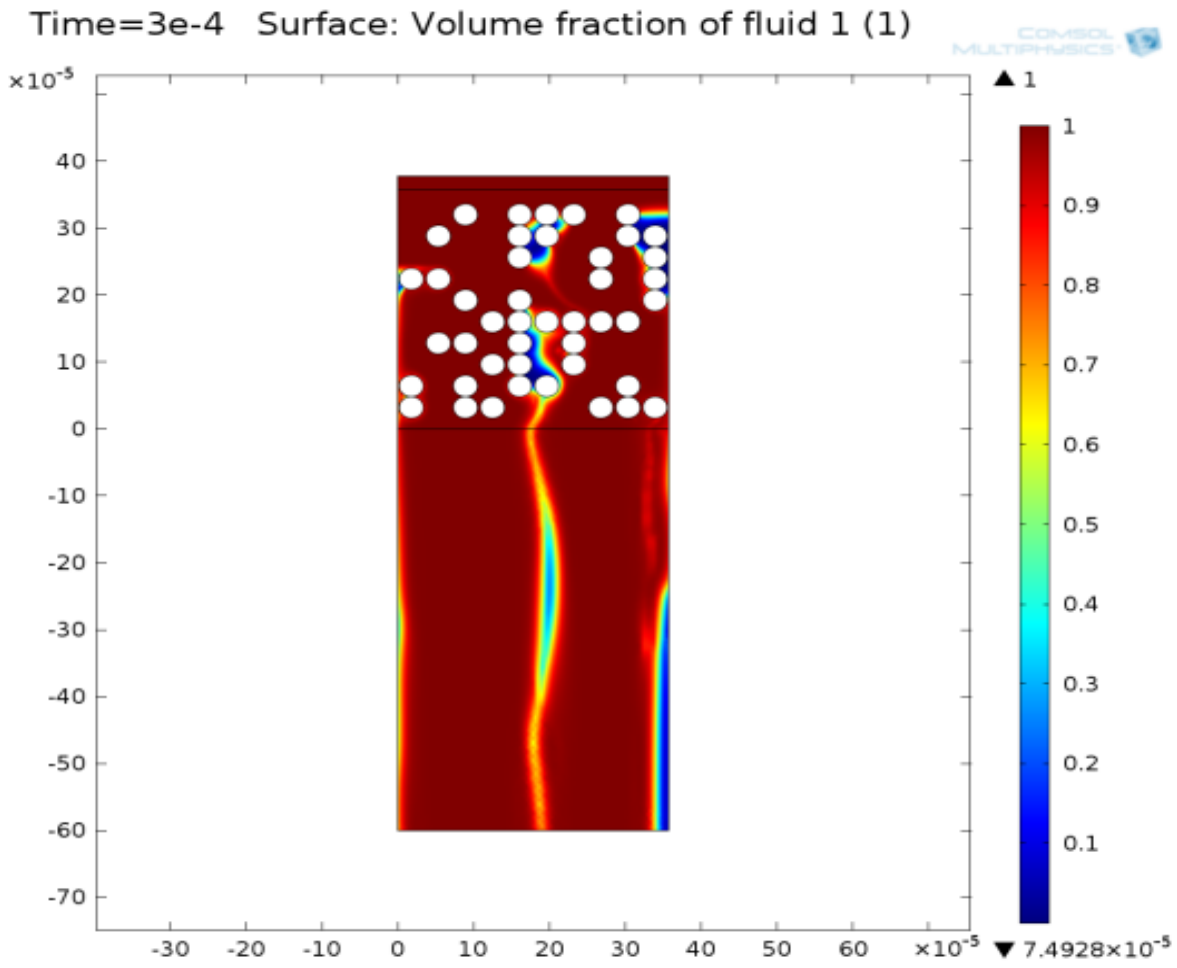

Results (con.)

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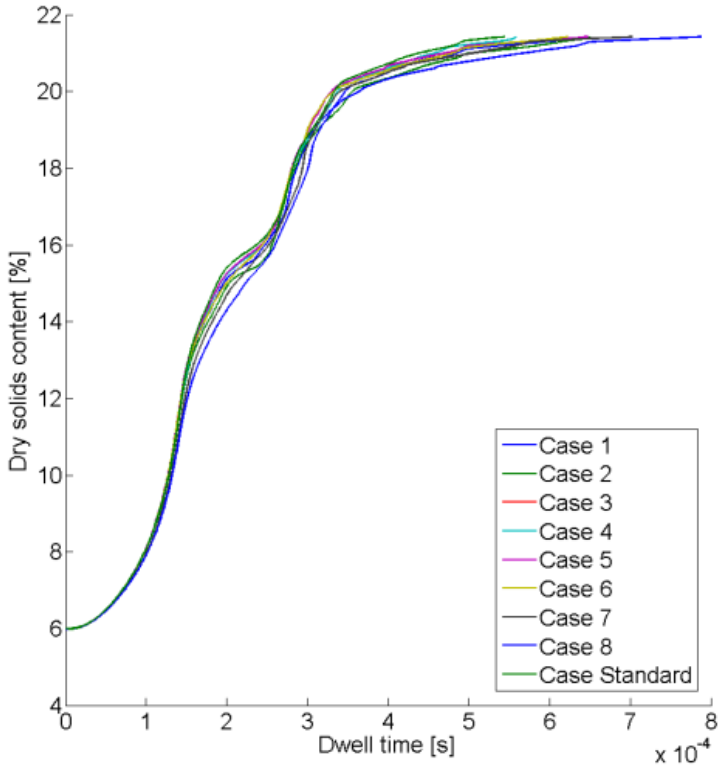

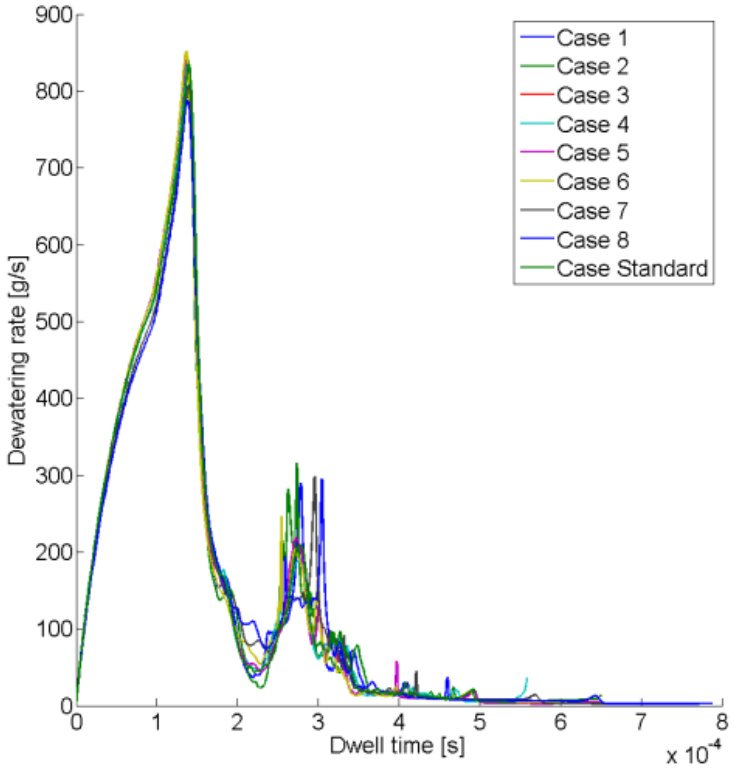

Conclusion

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- Random fiber positioning has a minor effect on the dwell time during high vacuum levels.
- The influence of the forming fabric has a minor effect on the dwell time
- The mesh case study indicates low sensitivity of the models which support their reliability.

Future work

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- Analyse fiber structures with a basis weight of 50 g/m^2 and compare these to experimental data.
- The influence of deformation and fiber displacement should be considered. A possible approach could be implementation of an Arbitrary Lagrange-Eulerian (ALE) method.
- Implementation of volume forces in order to analyse isotropic fiber structures in a new LS model

Thank you for listening!

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Questions ?

Comparison of different structures