CFD BASED OPTIMISATION OF A LABORATORY SCALE SILO

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A Pannon Egyetem átfogó intézmény-fejlesztése az intelligens szakosodás elősegítése érdekében
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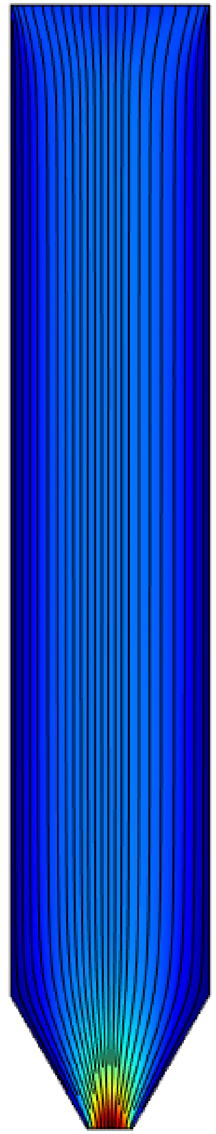

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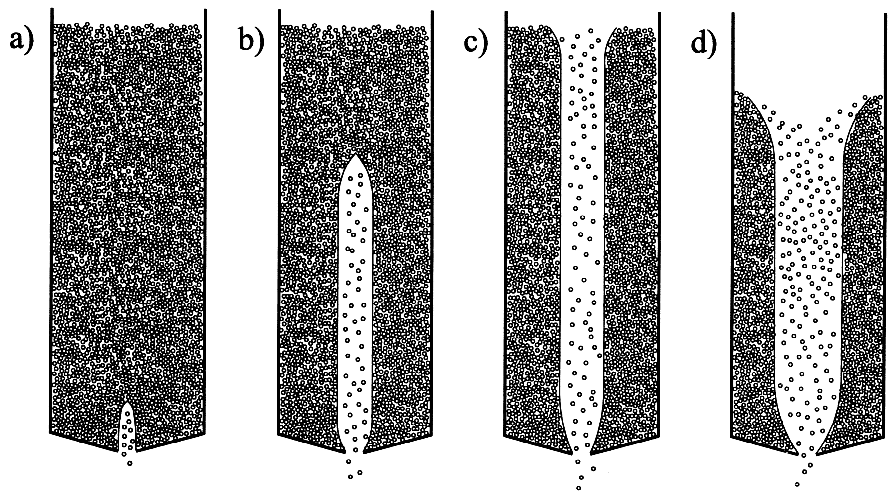
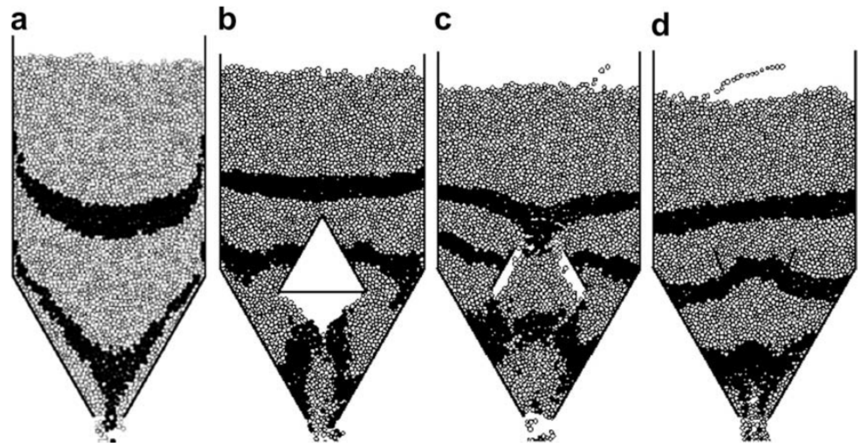
INTRODUCTION - SILOS

- Mostly used for the storage of solid particles (wheat, iron, sand, cement etc.)
- Most of the reagents and products, salts, powder are stored in silos (75%)
- Different type of devices, insert, or structural materials

INTRODUCTION – FLOW TYPES

- Plug flow
- Funnel flow
- Mass flow (desired)





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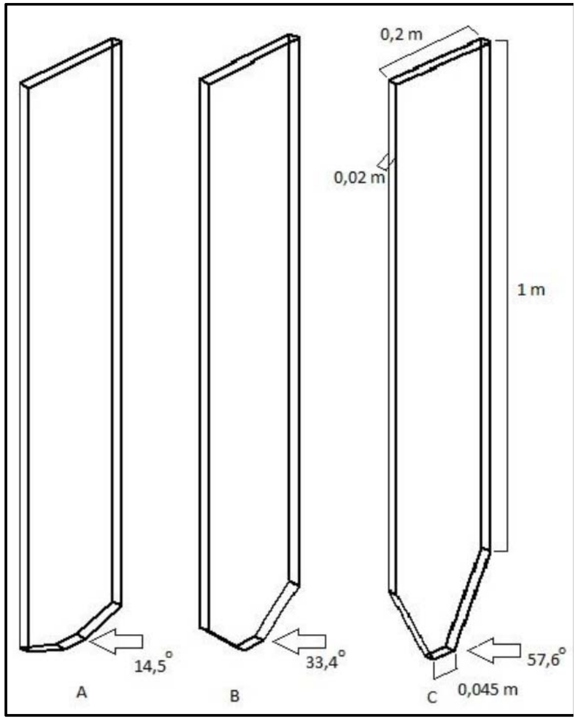
EXPERIMENTAL

- Quasi 2D Plexiglas experimental device
- 3D printed inserts
- Plastic granulates as material



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CFD MODEL - MOMENTUM

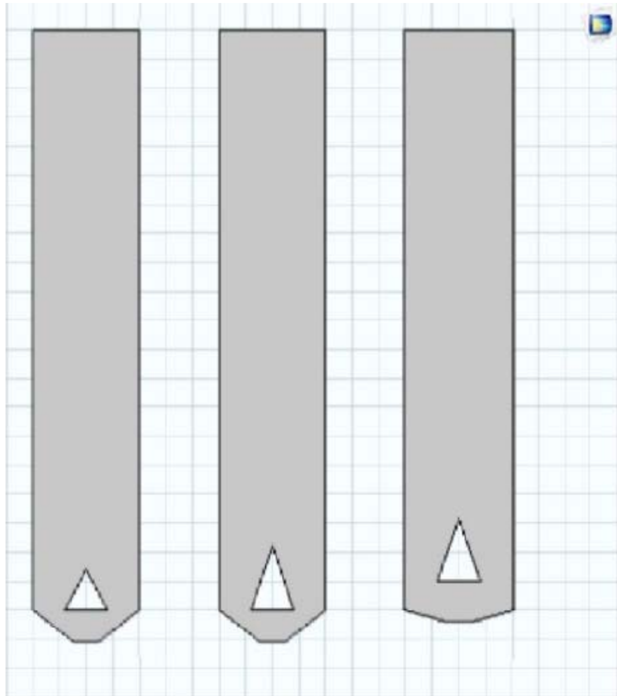
- Laminar flow model

$$\rho \frac{\partial u}{\partial t} + \rho(u \cdot \nabla)u = \nabla \cdot [-pI + \mu(\nabla u + (\nabla u)^T)] + F$$

- Pseudoplastic solid phase

$$\mu = m \cdot (\gamma)^{n-1}$$

$$\gamma = \max\left(\sqrt{D:D}, \gamma_{min}\right), D = \frac{1}{2}[\nabla u + (\nabla u)^T]$$

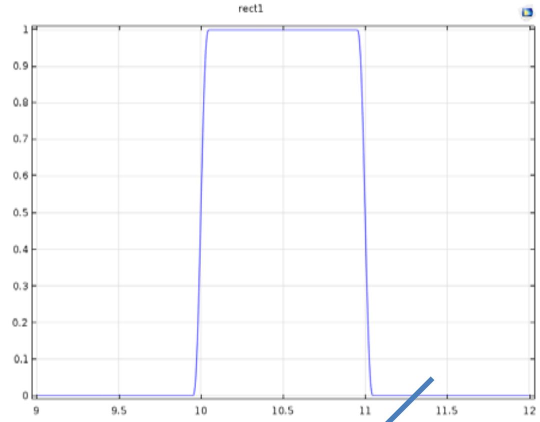


Stationary

CFD MODEL - COMPONENT

- Transport of diluted species

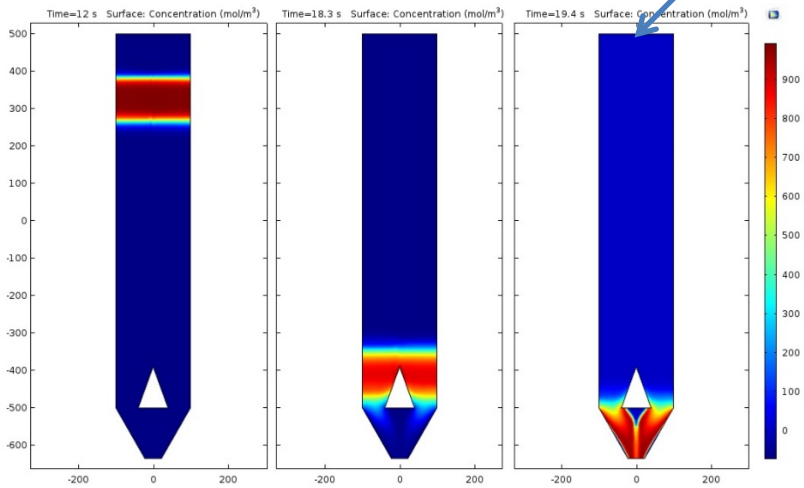
$$\frac{\partial c_i}{\partial t} + \nabla \cdot (-D\nabla c_i) + u \cdot \nabla c_i = 0$$



- Indicator injection, and RTD

$$E(t) = \frac{B \cdot c(t)}{\int_0^{\infty} B \cdot c(t) \cdot dt}$$

$$\tau = \int_0^{\infty} t \cdot E(t) \cdot dt$$



Time-dependent

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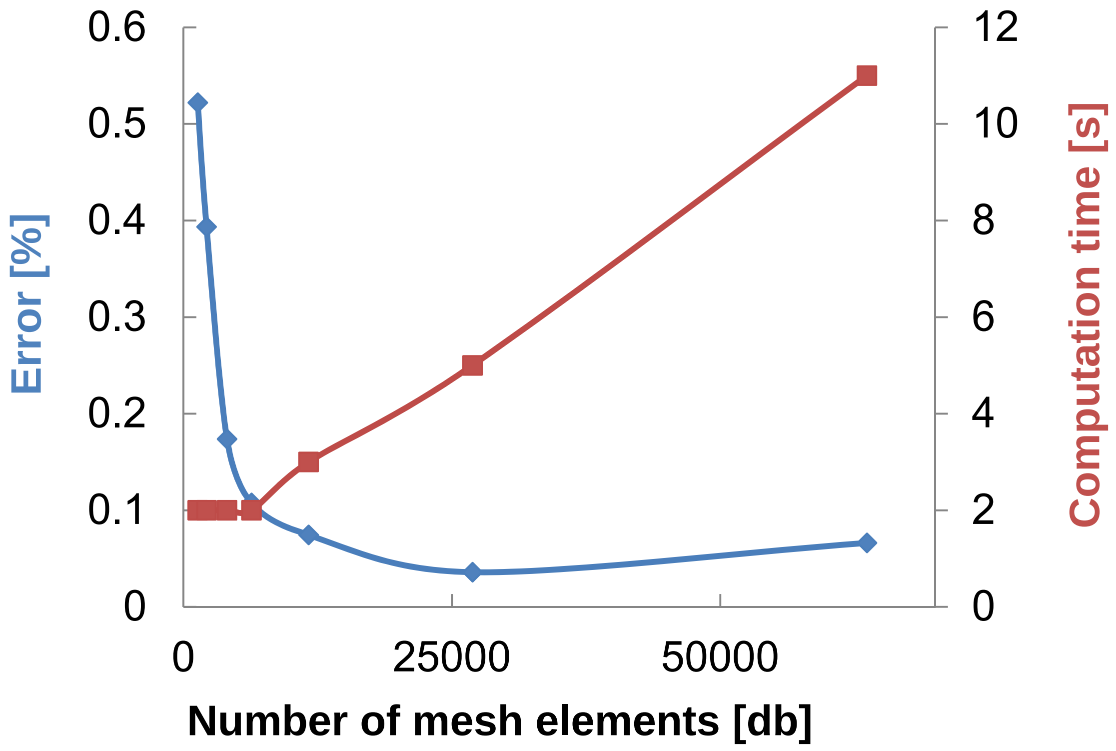
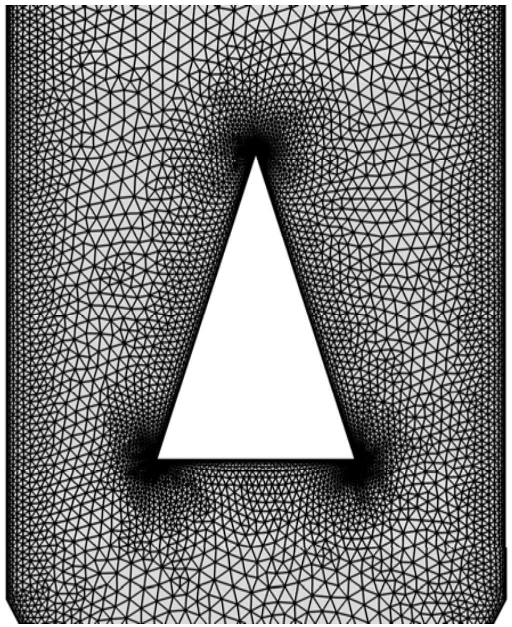
MESH INDEPENDENCE





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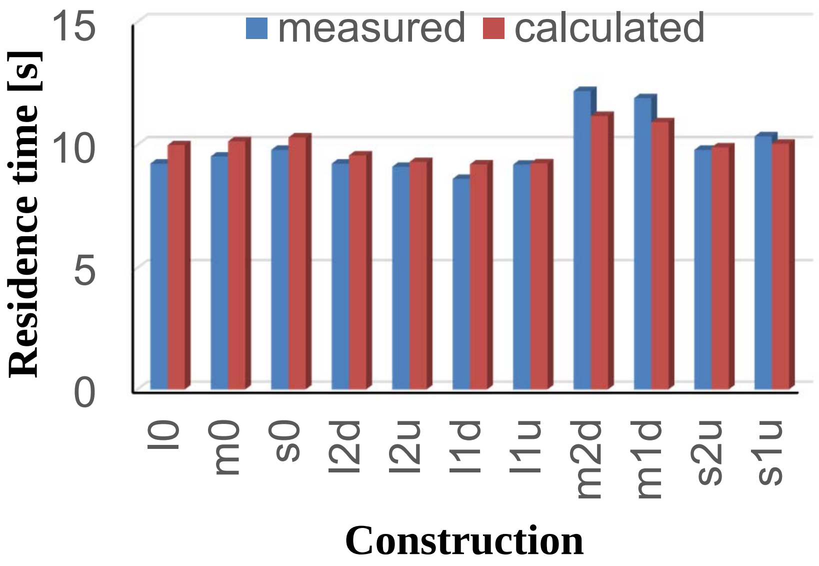
IDENTIFICATION AND VALIDATION

m\n	*0,35*	*0,36*	*0,37*	*0,38*
3	5,433	5,436	5,439	5,442
4	5,427	5,429	5,432	5,435
5	**5,426**	5,429	5,432	5,434
7	5,428	5,430	5,434	5,438
9	5,430	5,433	5,436	5,440



- The first letter is for the angle of the silo (l – large, m – medium, s – small).
- The second number tells us about the insert (0 if there is no insert present, 1 while the bigger and 2 while the smaller insert is applied).
- The third letter contains information about the insert position (u – 5 cm-s up, d – down at the baseline of the cylindrical part).

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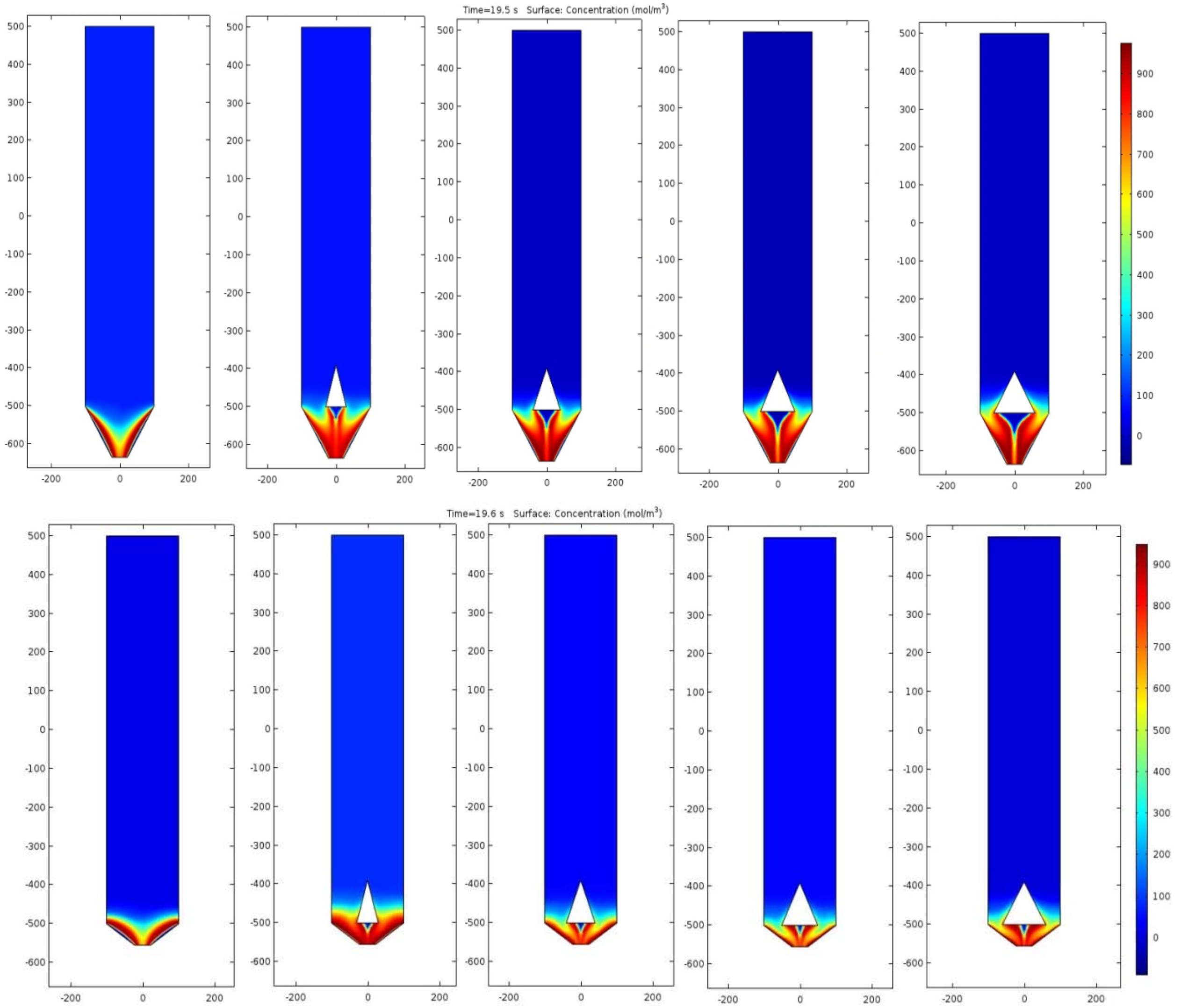
OPTIMISATION

- Insert geometry
- Position
- Different cone angles



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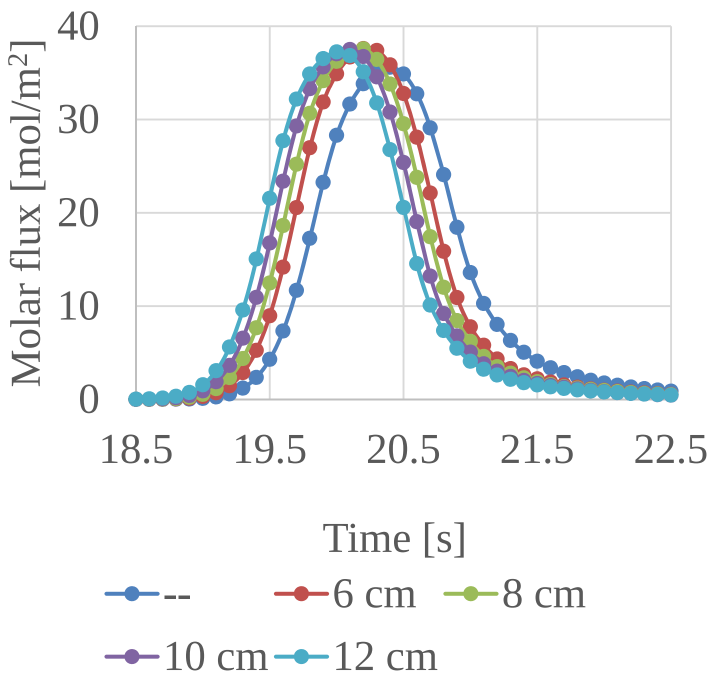
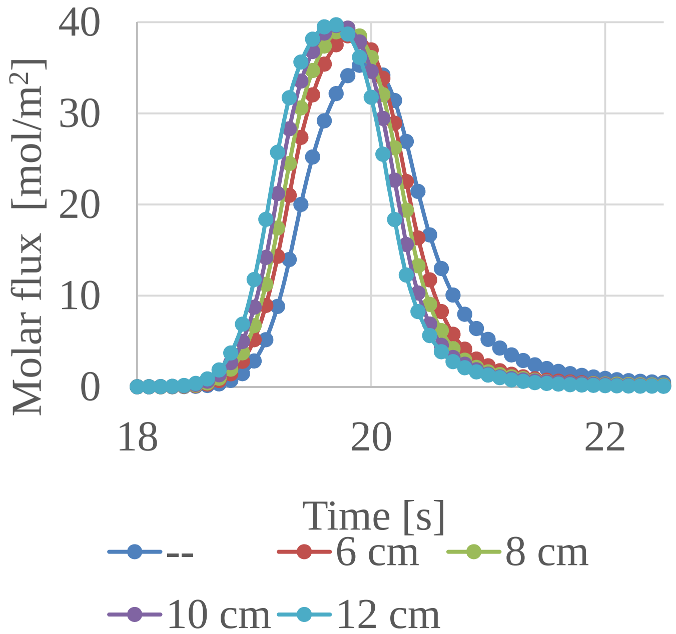
RTD STUDIES

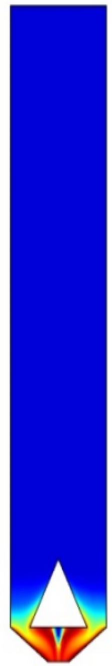
16.6%



Insert width	Residence time [sec]	Standard deviance
--	10,39	1,484
6 cm	10,30	1,224
8 cm	10,27	1,239
10 cm	10,24	1,257
12 cm	10,20	1,273



Insert width	Residence time [sec]	Standard deviance
--	10,17	1,293
6 cm	10,07	0,965
8 cm	10,04	0,930
10 cm	10,01	0,899
12 cm	9,98	0,837



35.3%

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SUMMARY

- In this study, a laboratory scale silo device
- The effect of the different inserts and cone angles was tested both experimentally, and using COMSOL Multiphysics.
- The solid phase was treated as a pseudoplastic fluid, calculation of the viscosity using a shear rate based equation.
- After a mesh independence study, we identified the remaining model parameters and compared our results to the experimental results using residence times.

SUMMARY

- With the validated model the triangular inserts width was optimized. There is a 16.6% performance increase in the best insert for the larger cone angle, and a 35.3 % performance increase of the standard deviance in case of the smaller insert.
- In the future, the model can be used for further simulation studies. Facilitating the advantages of Livelink to MATLAB even more proper optimization can be performed, and the number and type of the inserts can be extended for rectangular or circular ones as well

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