二軸スクリュ押出機の一般化Hele-Shaw流れ定式化に基づくFEM解析

FEM simulation based on
generalized Hele-Shaw flow formulation
for twin screw extruder

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株式会社HASL
○谷藤　眞一郎　　　吉川　秀雄
株式会社プラスチック工学研究所
鬼防　崇　　　辰巳　昌典

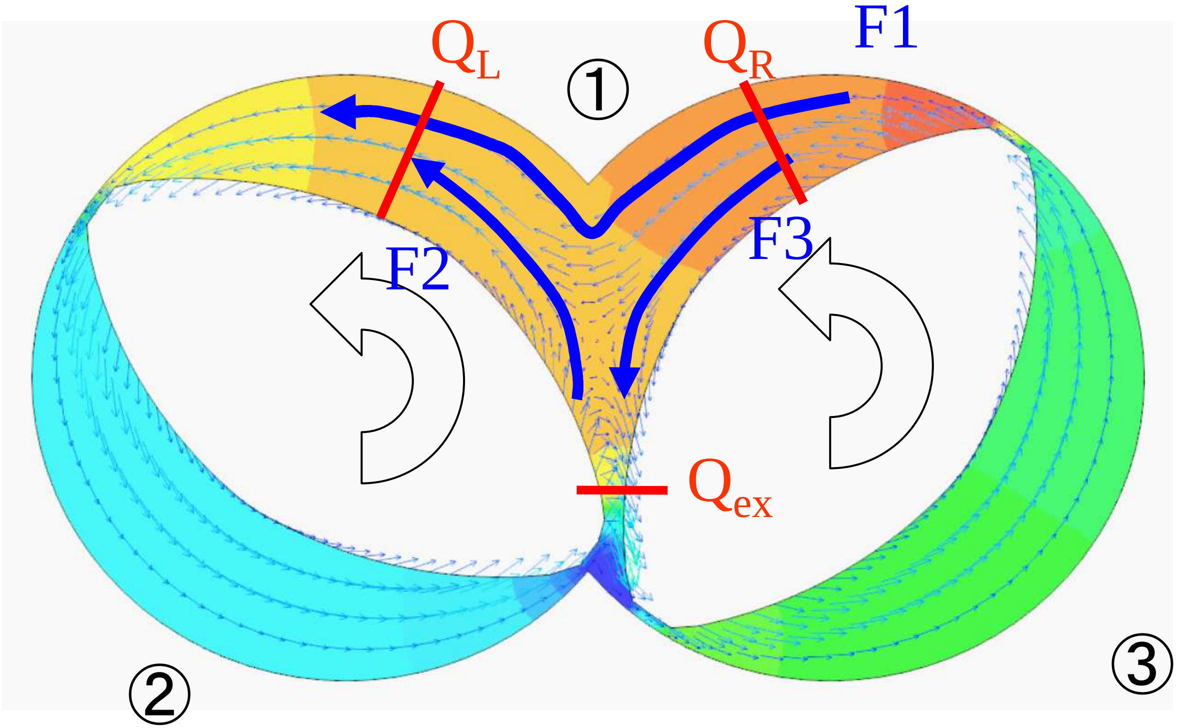
☐Background

Comparison of analysis method for twin screw extruder

Method	Accuracy	Computational cost	Availability	Operability
3D	◎	△	○	△
1D	△	◎	△	◎
2.5D	○	○	○	○

◎ : Excellent, ○ : Good, △ : Moderate

□Modeling method



Self wipe intermeshing co-rotating twin screw

F1:right to left flow

F2:left to left flow

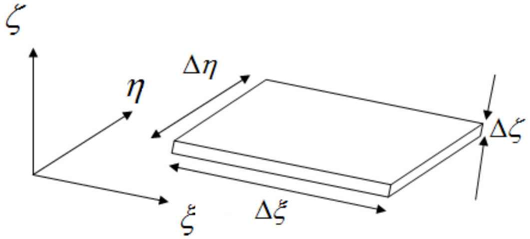
F3:right to right flow

$Q_{ex} \fallingdotseq 0$ on the average estimation in the thickness direction

⇩

$Q_L = Q_R$

Generalized Hele-Shaw Formulation



Assumption:

$$\frac{\partial p}{\partial \zeta} = 0$$ Good

$$\left|\frac{\partial U}{\partial \zeta}\right| >> \left|\frac{\partial U}{\partial \xi}\right|, \left|\frac{\partial U}{\partial \eta}\right|$$ Doubtful, but…

Variable: (u,v,w,p)

$$\eta\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right)=\frac{\partial p}{\partial x},$$

$$\eta\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right)=\frac{\partial p}{\partial y},$$

$$\eta\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right)=\frac{\partial p}{\partial z},$$

$$\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}\right)=0$$

⇒

Variable: (S, p)

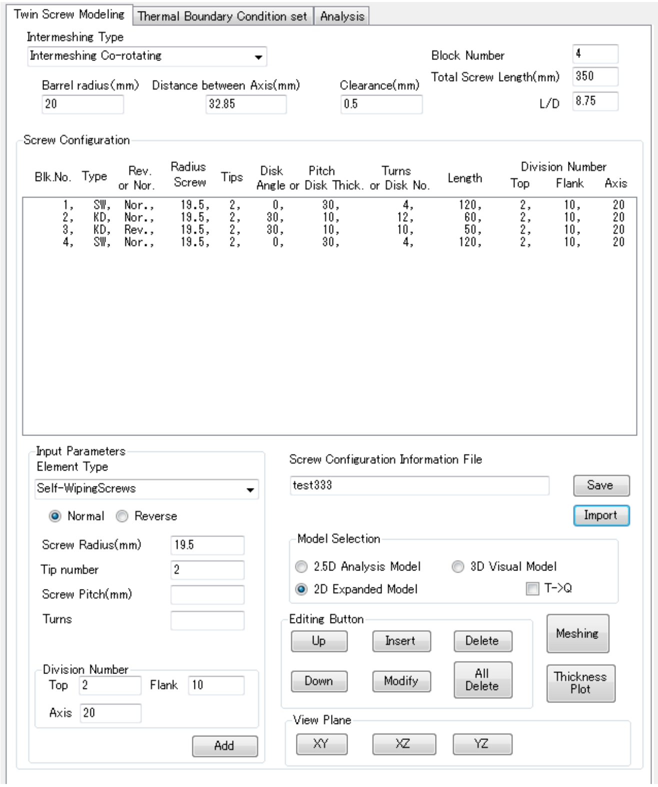
$$\langle u\rangle = -S\frac{\partial p}{\partial x}+\Phi_x,$$

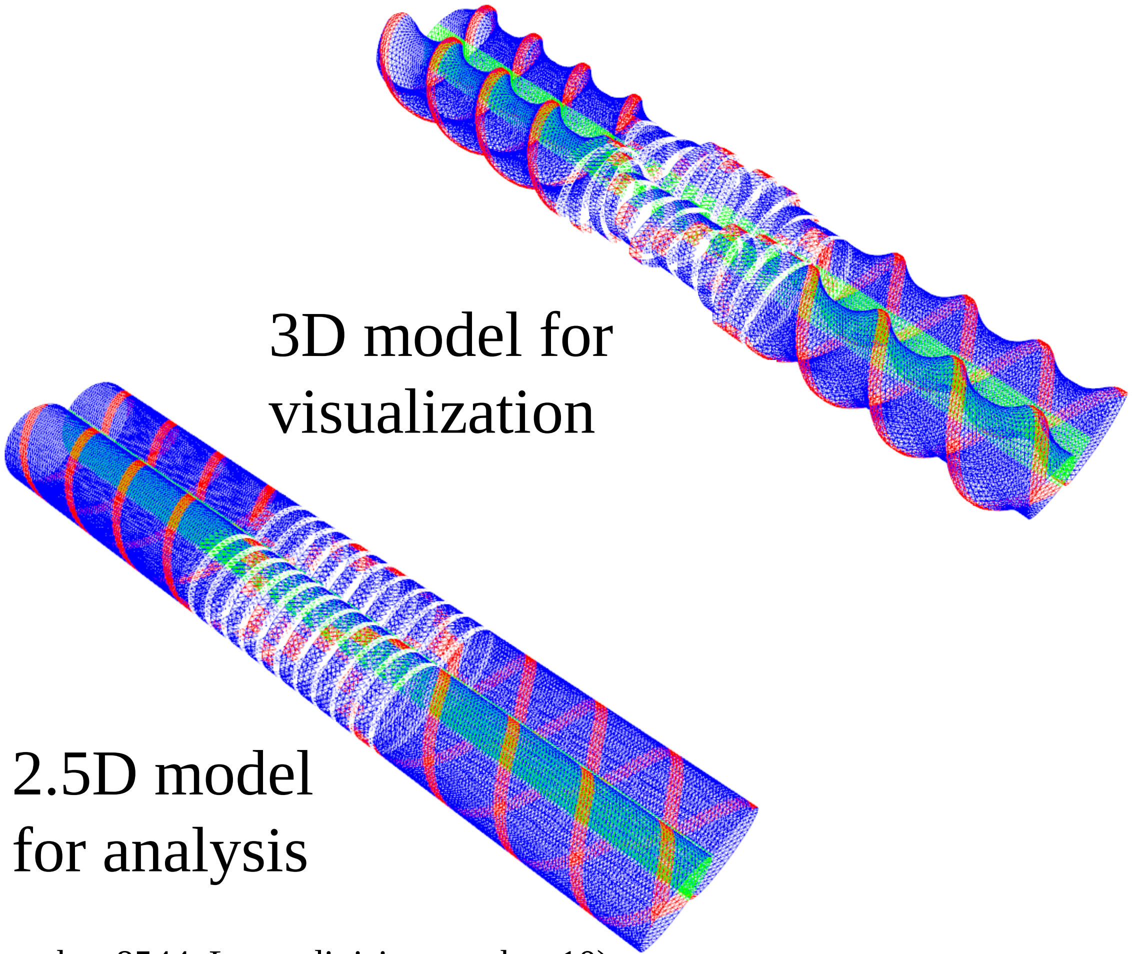
$$\langle v\rangle = -S\frac{\partial p}{\partial y}+\Phi_y,$$

$$\langle w\rangle = -S\frac{\partial p}{\partial z},$$

$$\left(\frac{\partial}{\partial x}\left(-S\frac{\partial p}{\partial x}+\Phi_x\right)+\frac{\partial}{\partial y}\left(-S\frac{\partial p}{\partial y}+\Phi_y\right)+\frac{\partial}{\partial z}\left(-S\frac{\partial p}{\partial z}\right)\right)=0$$

An efficient method for generating of the FEA model





(Element number:16896,Node number:8544, Layer division number:10)

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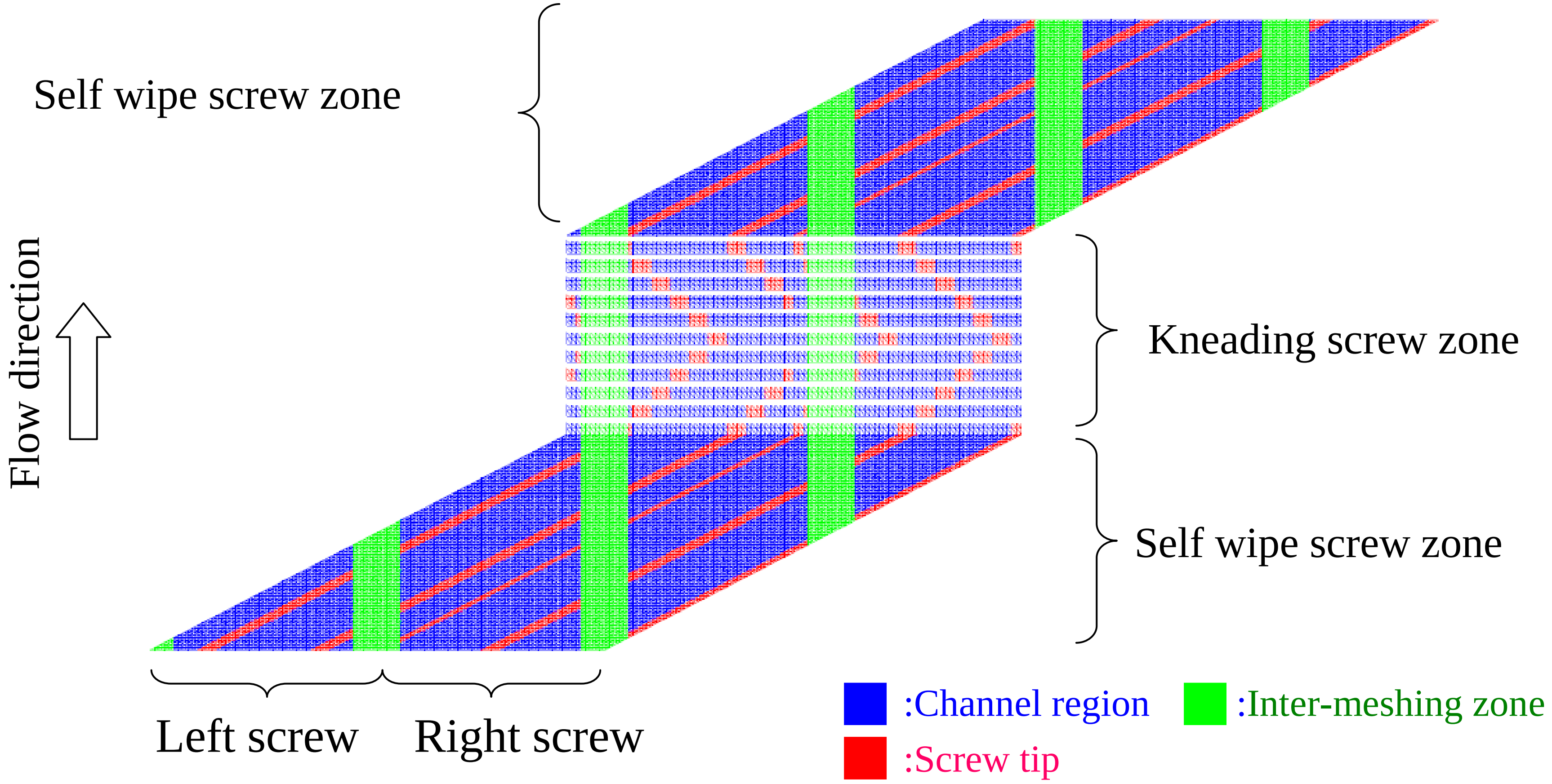
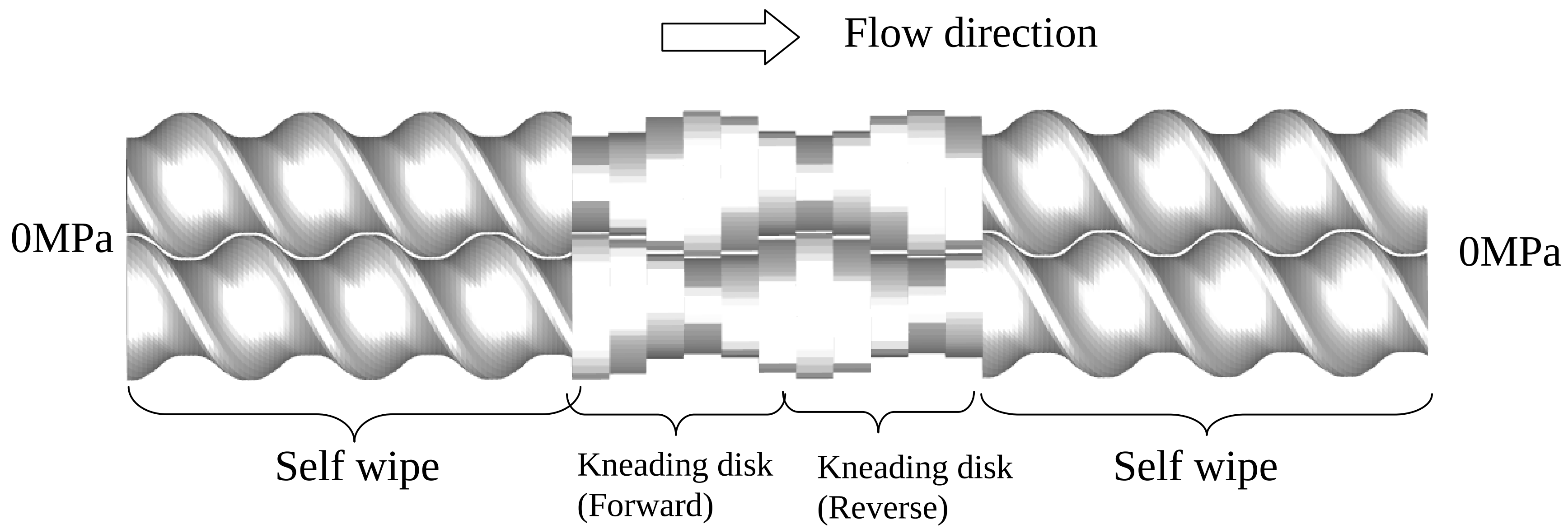
UV unwound FEA model



□Test example



Intermeshing co-rotating twin screw extruder

Screw rotational	100 rpm
Material	Newtonian (η =1000Pa・s)
Calculation cycle	48 (corresponding to the mesh division number in the circumferential direction)

List of the time consumption for a simulation

Operation	Time consumption
Pre-processing	Ignorable(<1 minute for numeric parameter input)
Analysis	CPU time : 40 sec (for 48 cycles flow simulation)
Post-processing (Particle trace simulation to estimate the stream line in a snap shot information)	Turn around time : 10 sec (200 particles,1500 cycles calculation)
Post-processing (Particle trace simulation to estimate the particle path line in periodic flow fields)	Turn around time: 7 minutes (30 ~ 5430 particles,7500 cycles calculation:60 rotations)

(Computation environment: DELL Studio XPS 8100, 2.80GHz, 4.00GB)

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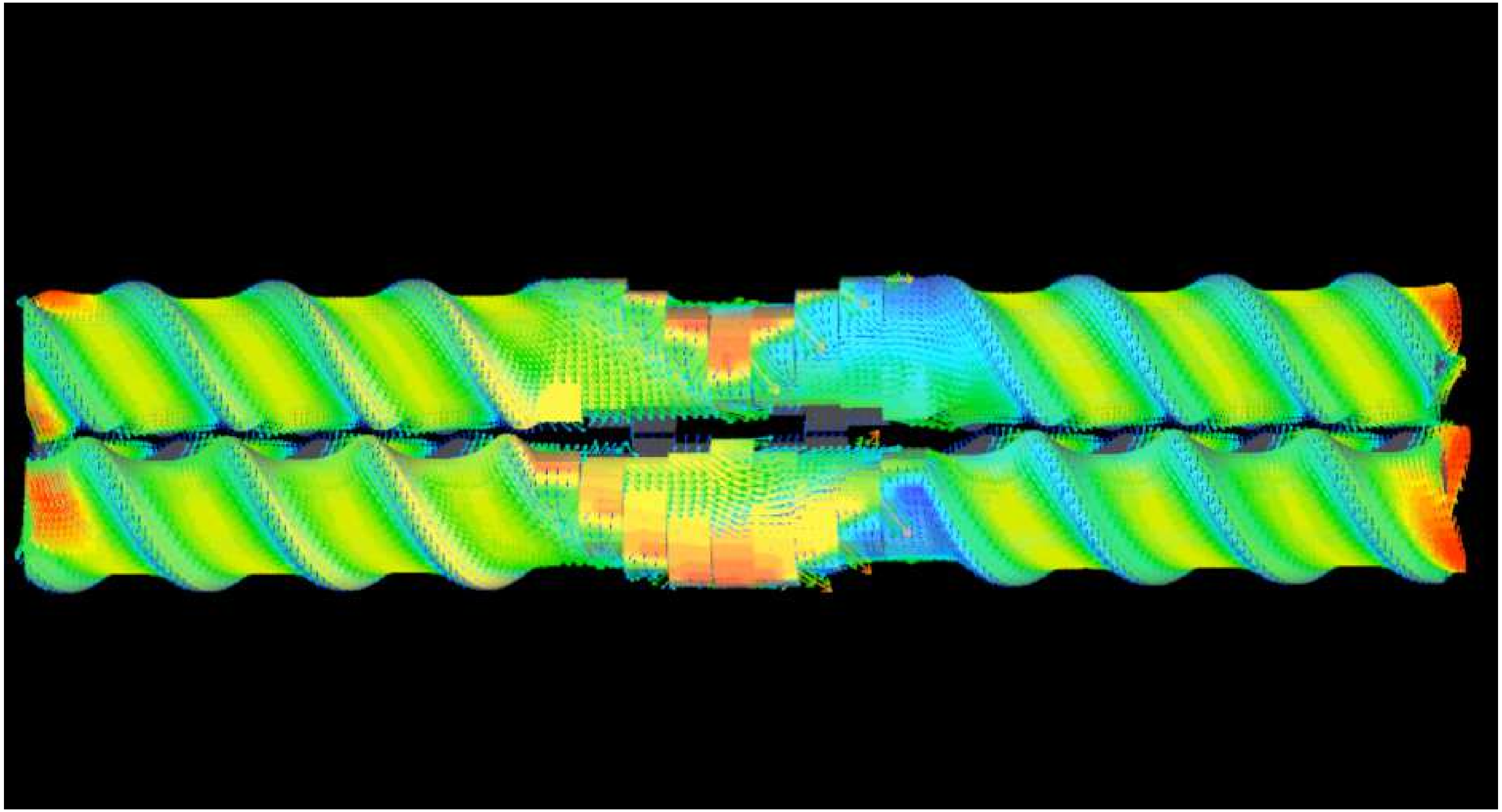
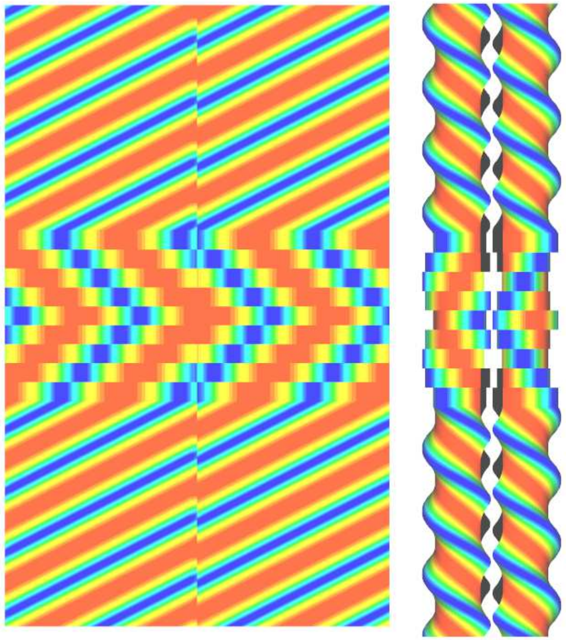
Flow direction



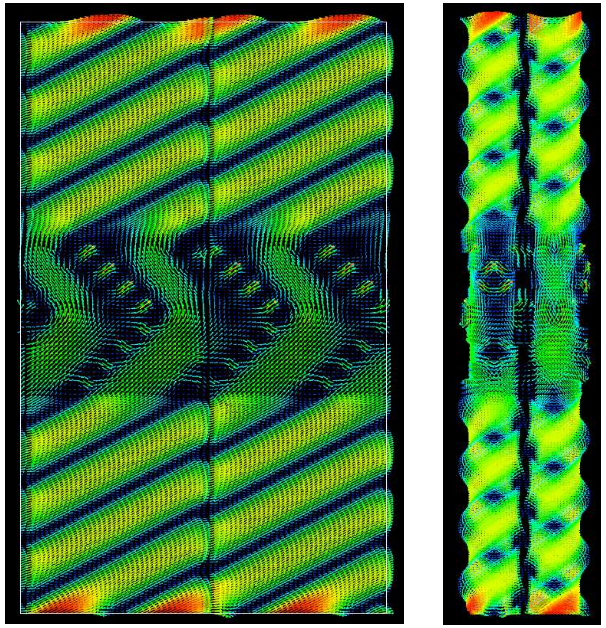
Animation 1: Pressure distribution & flow field in an intermeshing co-rotating twin screw extruder

UV mapping information



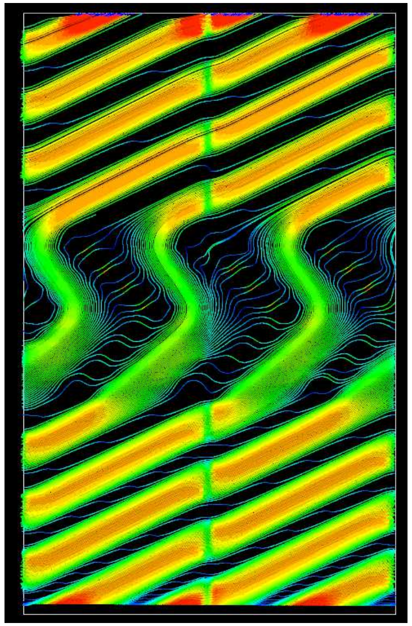
UV unwound model 3D model

Channel thickness



UV unwound model 3D model

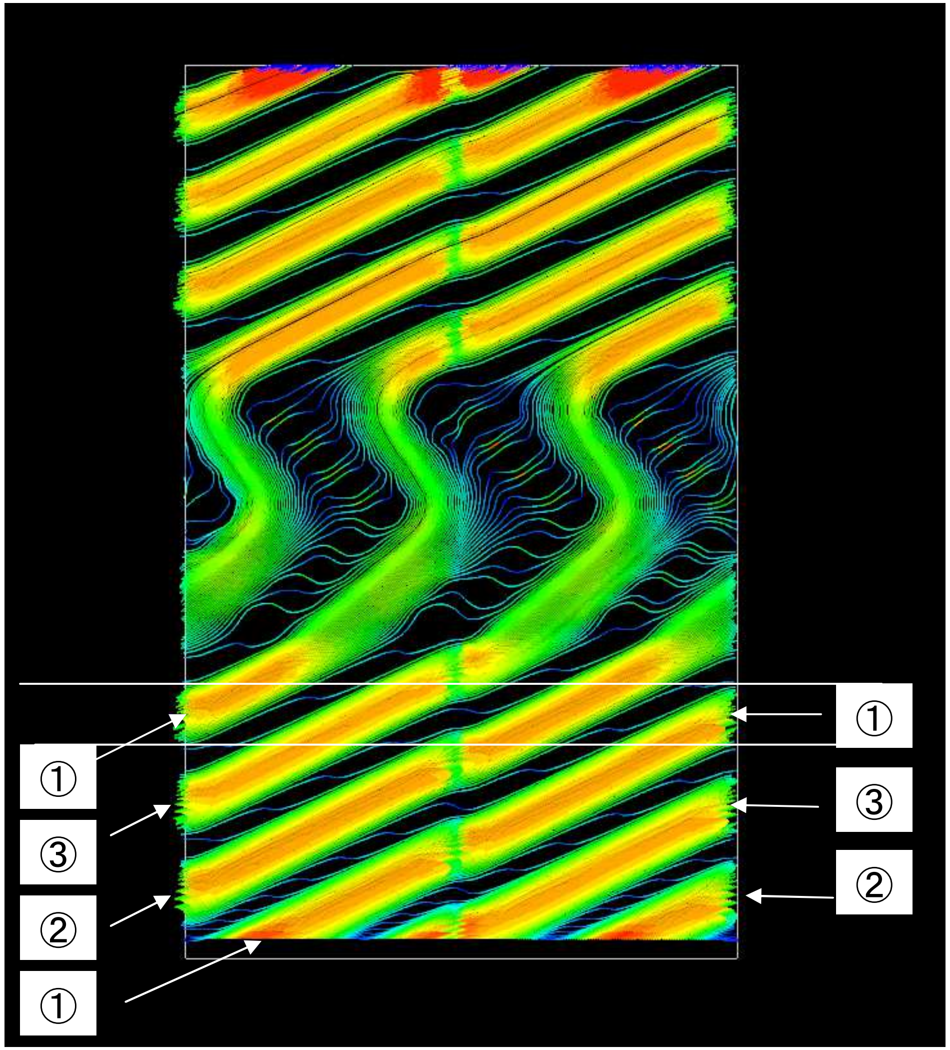
Flow vector



UV unwound model
Stream line in a snap shot information

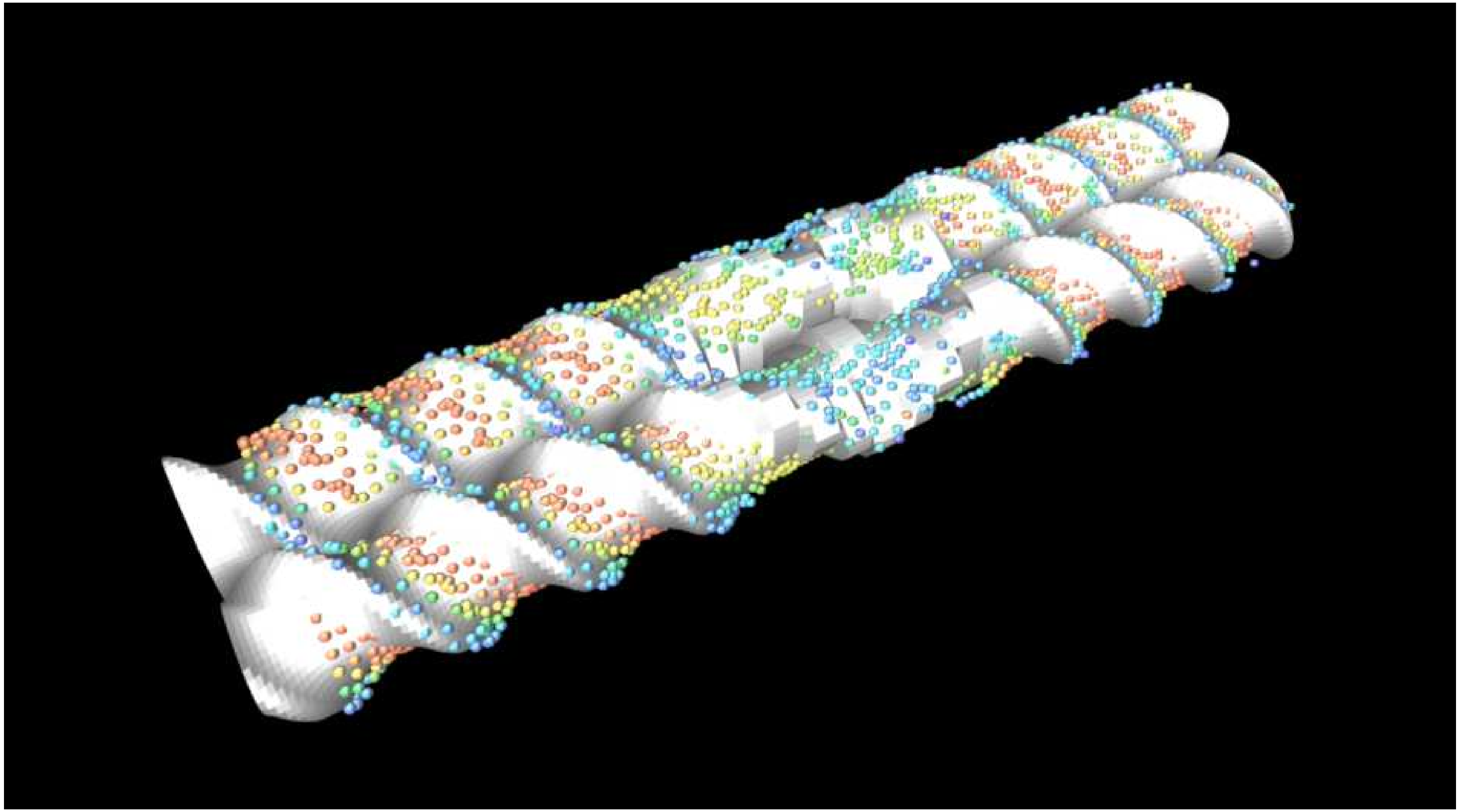
Translation of the numerical results into various models

Experimental information



Stream line information mapped on the UV unwound model

Particle path trace simulation (3D visualized information)



Animation 2: Result of the particle trace simulation in an intermeshing co-rotating twin screw extruder (3D visualized information)

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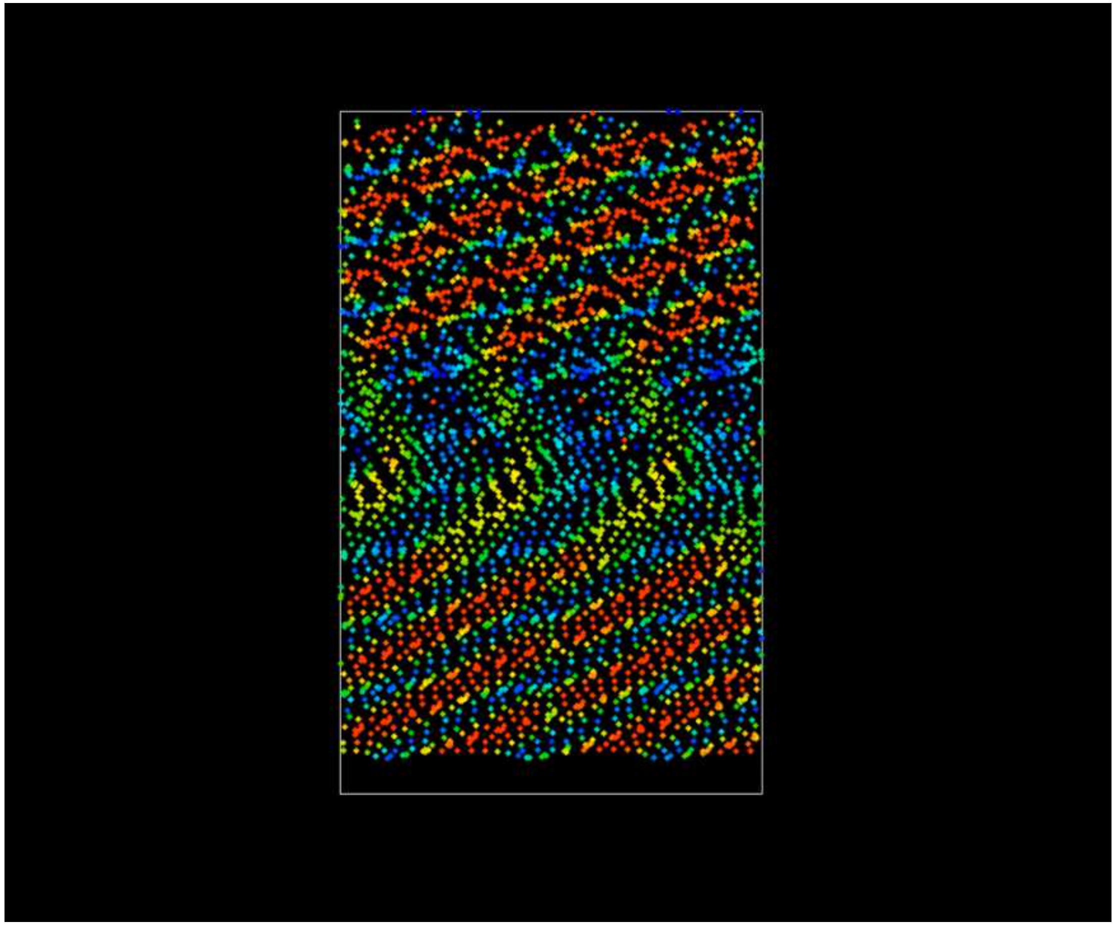
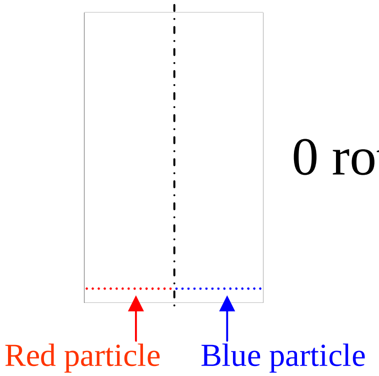
Particle path trace simulation (UV mapping information)

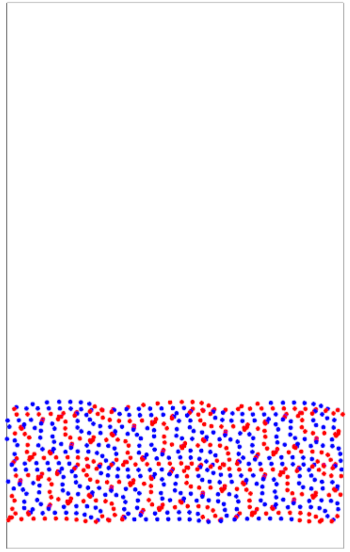


Animation 3: Result of the particle trace simulation in an intermeshing co-rotating twin screw extruder (Mapping information on the UV expanded unwound model)

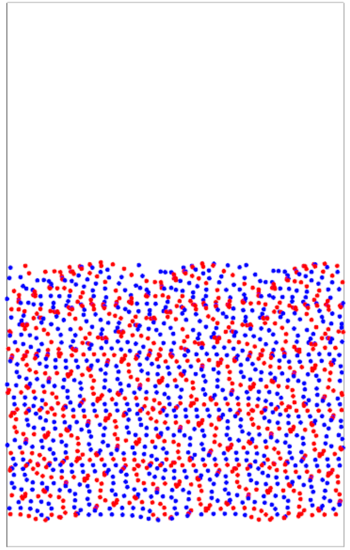
Time variation of the mixing pattern



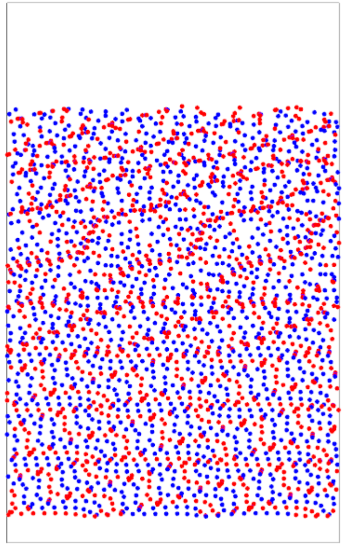
0 rot. time:0 sec



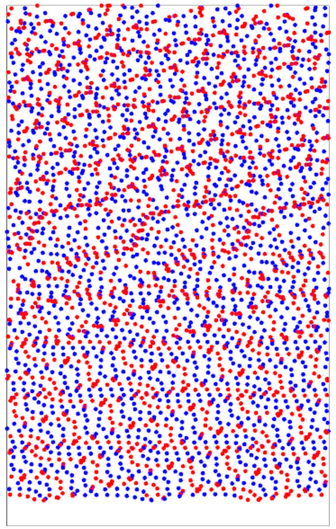
15 rot. time:9 sec



30 rot. time:18sec

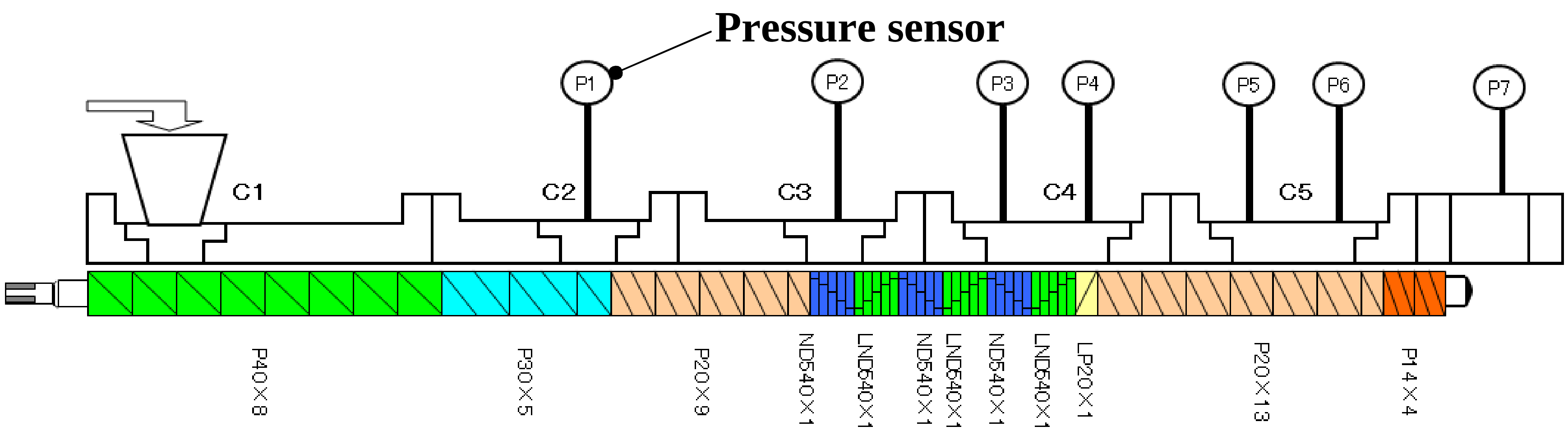


45 rot. time:27sec

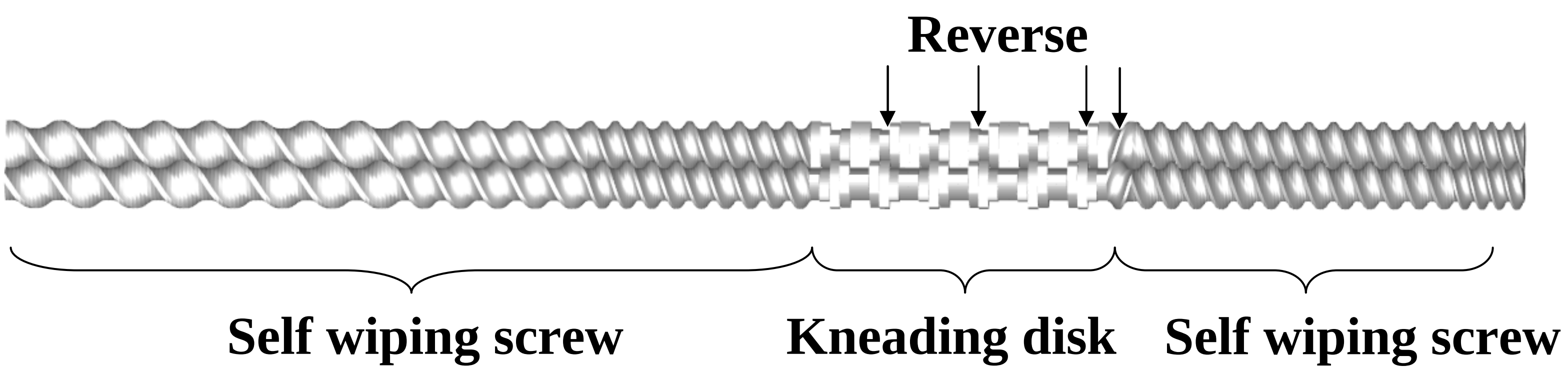


60 rot. time:36sec

□Experimental verification

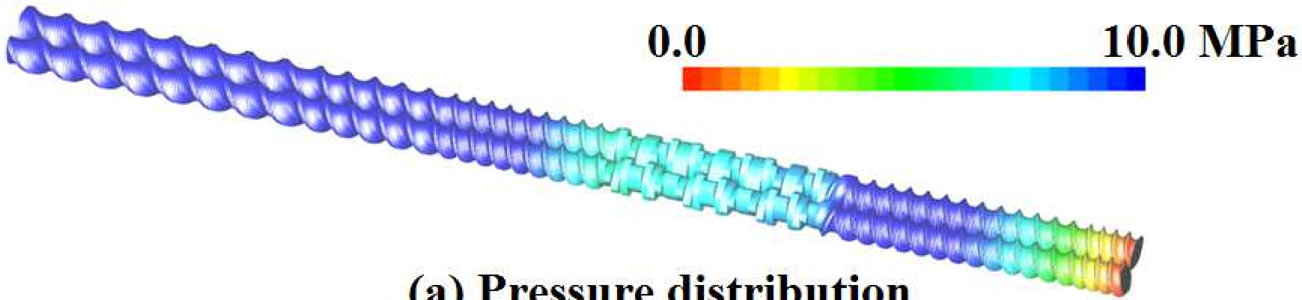


Layout of the testing machine

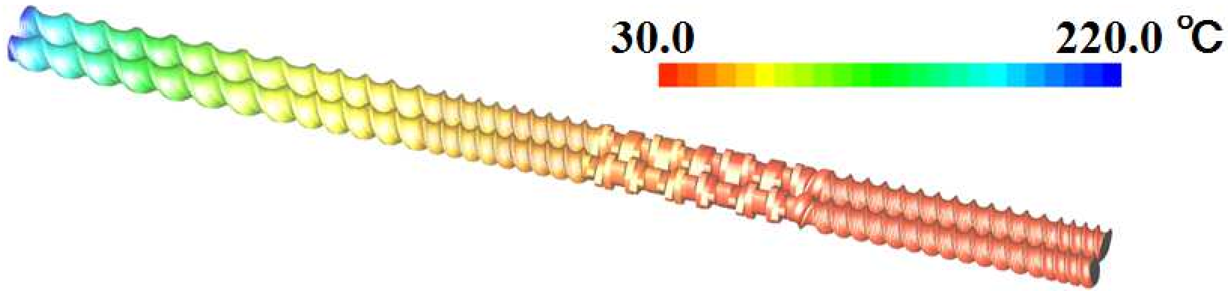


FEA model

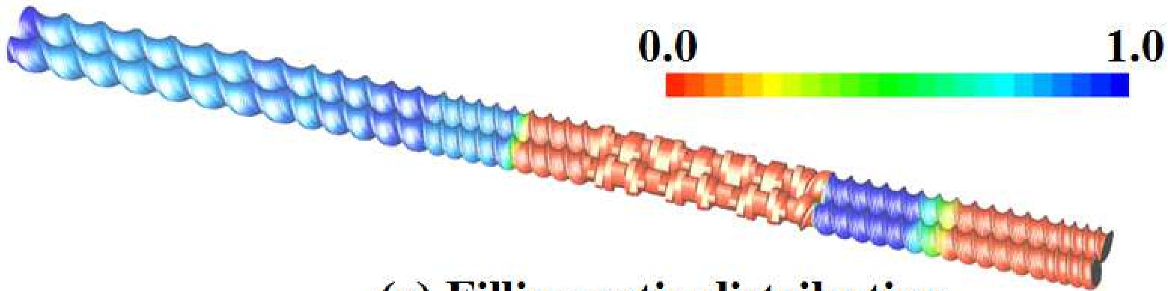
Results of the thermal flow distribution



(a) Pressure distribution



(b) Temperature distribution



(c) Filling ratio distribution

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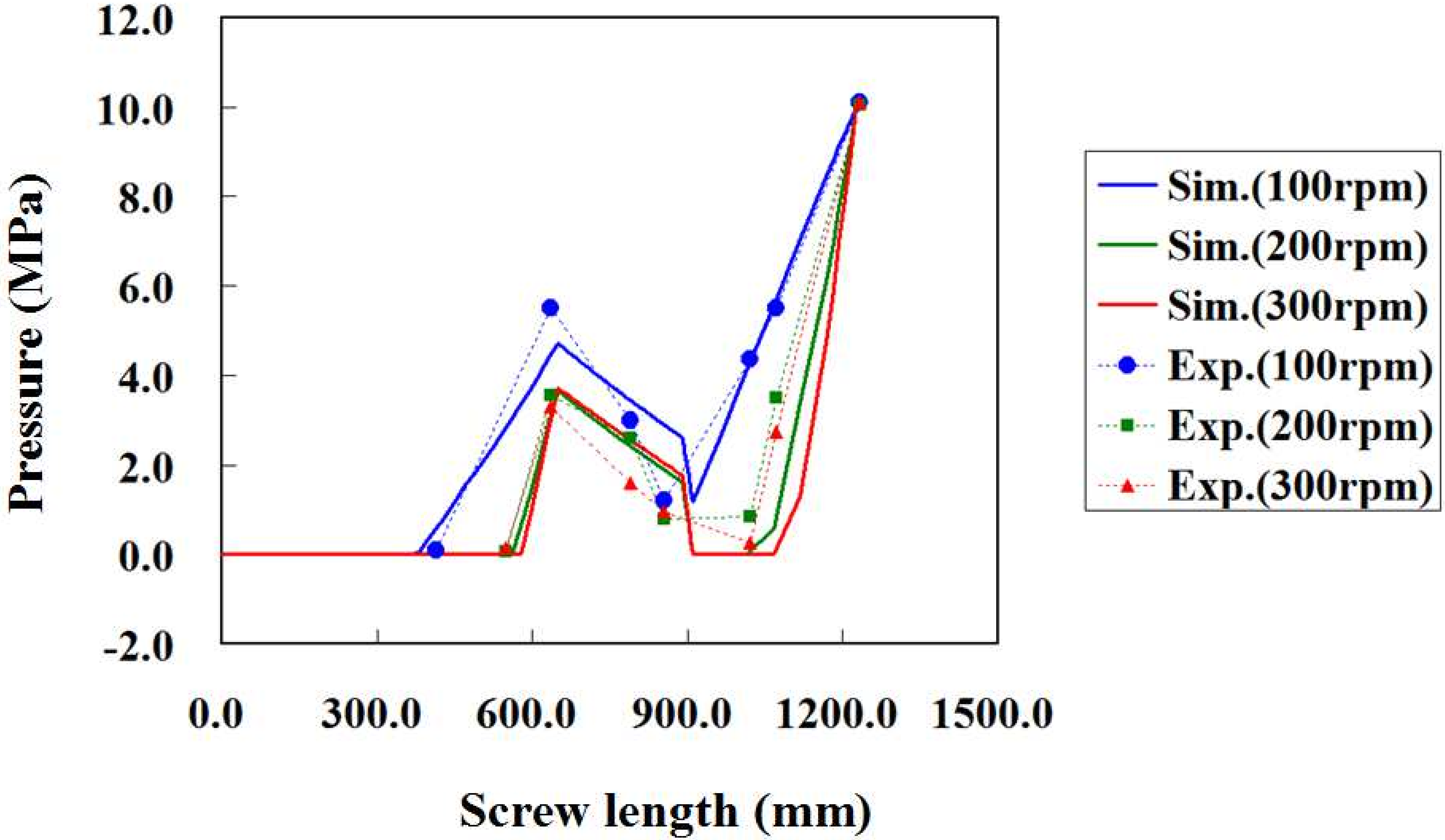
Experimental verification of the predicted pressure



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□Conclusions

成果：

・一般化Hele-Shaw流れの定式化及びメッシュ生成技術を併用することで二軸スクリュ押出機の効率的な解析法を構築した。

・実験検証解析を通じて解析結果の妥当性を検討した。

今後の課題：

・パーティルトレース機能の改良（滞留時間分布、混合効率、動的溶融可塑化モデル）

・検証解析の継続

・異方向噛合型スクリュ、コニカルタイプ等への用途展開

謝　辞

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