CFD Application in Polymer Processing

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ATES

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What is CFD? : Computational Fluid Dynamics

Nonlinear Partial Differantial Eqns

$$\frac{\partial}{\partial t}\int_V \rho\phi dV + \oint_A \rho\phi\vec{V}\cdot\hat{n}dA = \oint_A \Gamma\nabla\phi\cdot\hat{n}dA + \int_V S_\phi dV$$

격자 & 이산화

Algebraic Eqns

연립방정식 계산

Simulations of the flow, heat transfer, chemical reaction, etc

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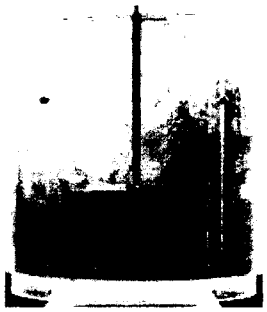
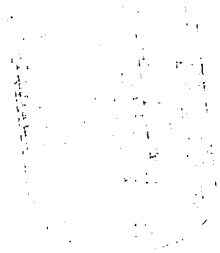
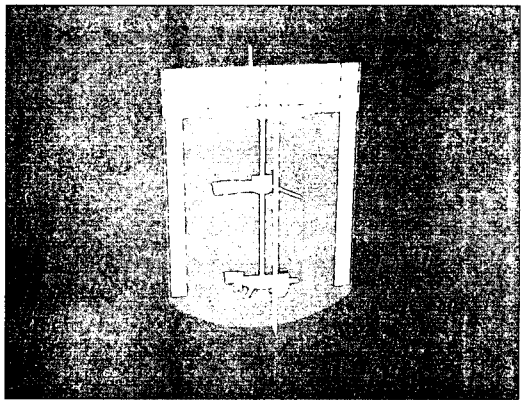


Mesh
Generation





Advantages of CFD

Low Cost

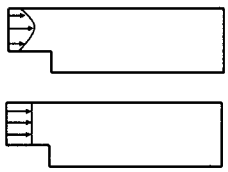
Speed

Simulate Real / Ideal Conditions

Comprehensive Information

Limitations of CFD

- Physical Models
  - Real world > Physical Model
- Numerical Errors
  - Round-off Error
  - Truncated Error
- Boundary conditions



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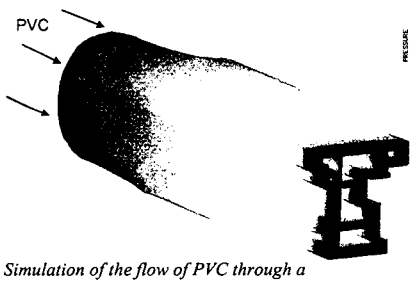
POLYFLOW : the Fluent code in Polymer Processing



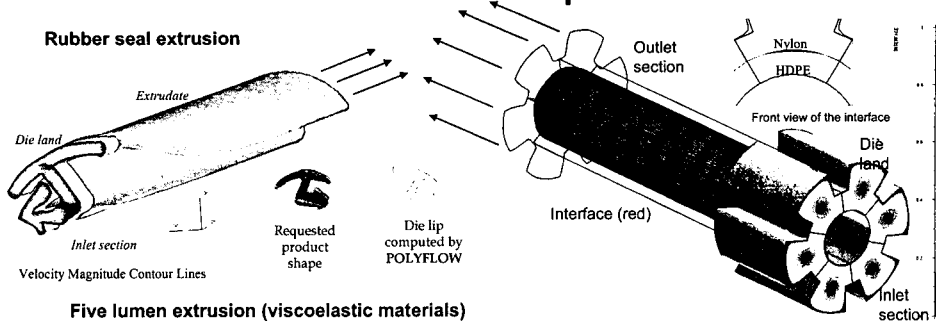
Simulation of the flow of PVC through a complex geometry die (window profile)

Mixing of particles in a TSE

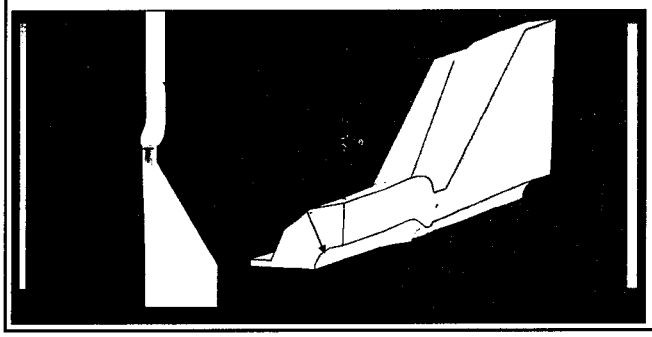
Thermoforming of a medical blister

Extrusion examples

Rubber seal extrusion



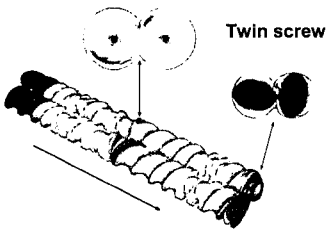
Five lumen extrusion (viscoelastic materials)

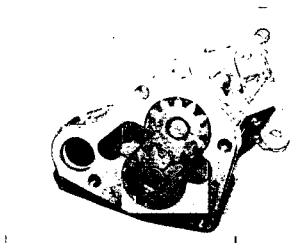


Cable coating (Coextrusion)

Screw examples

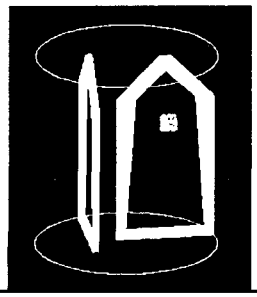
Twin screw extruder

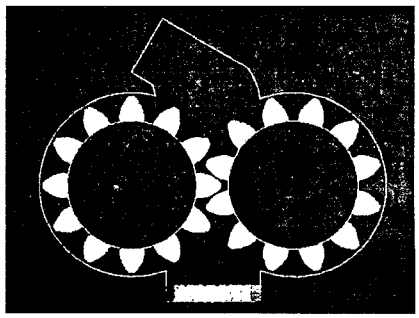




A car pump

A stirring tank





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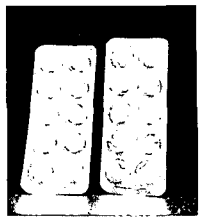
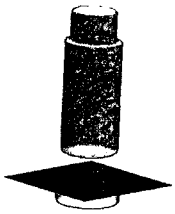
Blow molding examples

Blowmolding of a gas tank

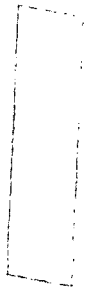
Stamping of medicine packaging





Extrusion blow molding of a one gallon bottle

Thermo-forming of a freezer



FLUENT

POLYFLOW
Grid

Time Index: 0.029999999
May 05, 2000
FLUENT/Post 1.2

POLYFLOW expertise areas

- Complex rheology and viscoelasticity
  - Generalized Newtonian models
  - Models with yield stress
  - Viscoelastic models (with extensional behaviors)
- Deforming meshes
  - swelling, contraction, blowing, extension, compression
- Contact algorithm
  - Detection of the transient non isothermal contact between moving boundary and solid wall
- Mesh superposition technique
  - Moving rigid body in a confine domain (TSE, batch mixing, etc.)

Numerical Technique

- Finite Element Technique
- We solve the 3-D equations of
  - Conservation of the mass
  - Conservation of the momentum
  - Conservation of energy
  - Constitutive equation
    - A Generalized Newtonian law modeling the shear rate dependence of the viscosity (Bird-Carreau, Cross, power law)
    - Possibly Viscoselastic differential models (PTT, GL)
    - An Arrhenius law modeling the temperature dependence of the viscosity
- In order to calculate the following variables :
  - velocity, temperature, pressure, position, residence time

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Complex rheology
Widest range of fluid models

Newtonian fluid ⇨ Constant shear viscosity, no memory effects.

Generalized Newtonian possibly with yield stress ⇨ Shear rate dependent viscosity, no memory effects.
Type : Bird-Carreau, Cross, Bingham, Hershel-Bulkley, power-law.

Viscoelastic fluid ⇨ Memory effects, normal stress differences, elongational effects

differential type : Maxwell, Oldroyd-B, Giesekus-Leonov, White-Metzner, Phan-Thien-Tanner, FENE-P, Pom-Pom

integral type : Lodge, Doi-Edwards, KBKZ, ...

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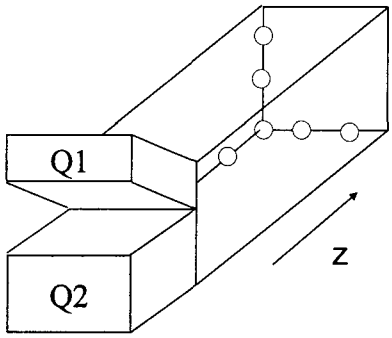
Coextrusion of a viscoelastic polymer in a square channel

analysis of secondary flow



low density polyethylene

one fluid, but two pigmentations

2D 1/2 channel flow simulation

viscoelastic model :
Giesekus, 5 relaxation times

EVSS numerical technique

Q2 / Q1 = 4

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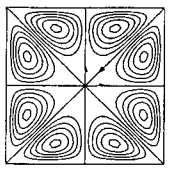
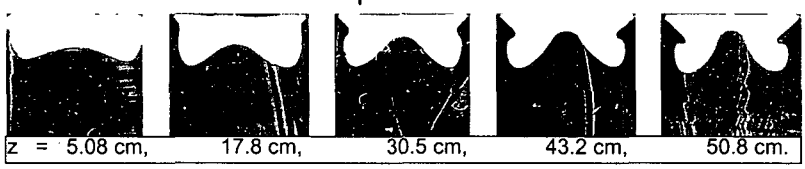
Coextrusion of a viscoelastic polymer in a square channel



Slicing at various Z-sections :

numerical

experimental



z = 5.08 cm, 17.8 cm, 30.5 cm, 43.2 cm, 50.8 cm.

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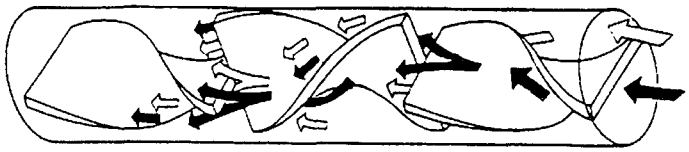
Kenics mixer

- The flow domain :



- Two coloured fluids (clay) injected at the entry
- Evolution of the concentration field from entry to exit
- Excellent agreement with experimental results

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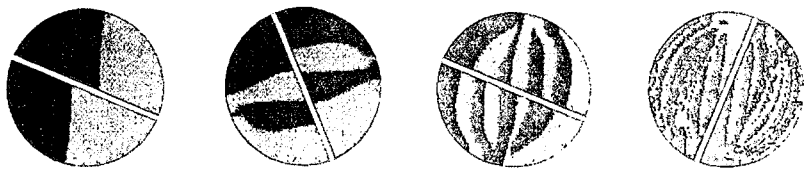
Kenics mixer

experimental

numerical



after 1 blade **after 2 blades** **after 4 blades** **(exit)**

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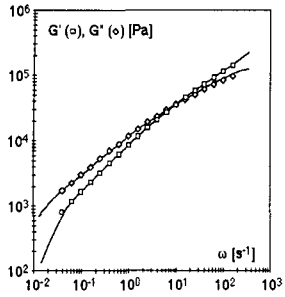
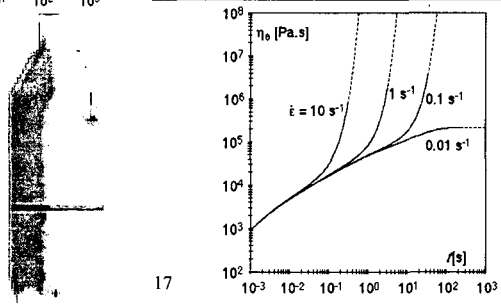
Blow Molding of a milk bottle Validation with Dow Chemical



Spectrum with 6 modes

k	$\lambda_k[s]$	$\eta_k[Pa.s]$
1	0.002688	592
2	0.01593	1059
3	0.08661	3009
4	0.4837	6665
5	2.773	12448
6	20.20	33027

LLDPE material



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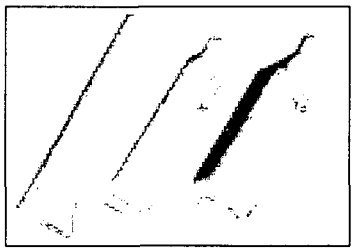
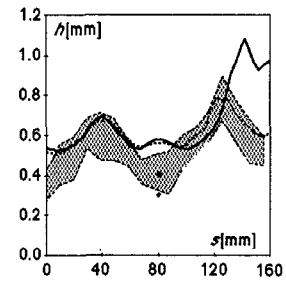
Blow Molding of a milk bottle Validation with Dow Chemical

Initial configuration



t = 0.0 s t = 0.35 s t = 0.9 s

h = 0.31 mm



Extrusion blowmolding of a HDPE milk bottle. The thickness calculated by Polyflow has been compared with experimental data measured along the black line.

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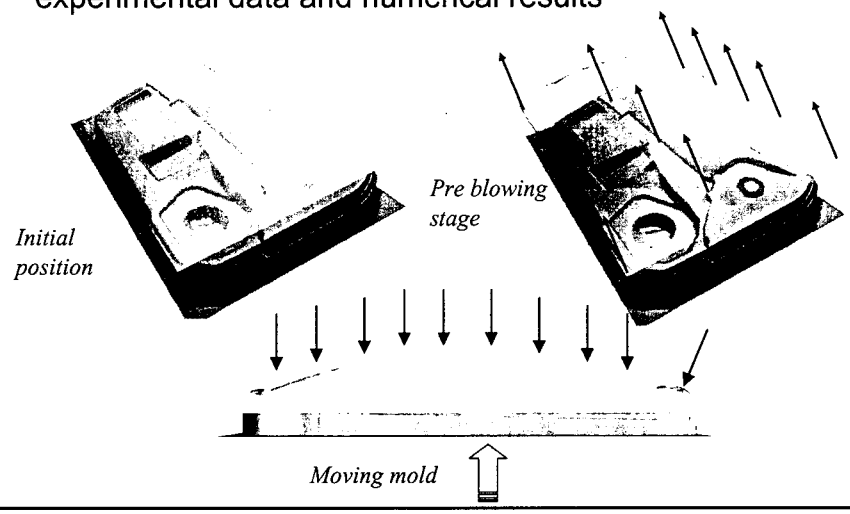
thermoforming of an car in door panel

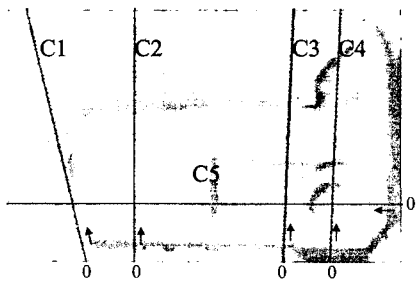
- The result shows the good agreement between experimental data and numerical results



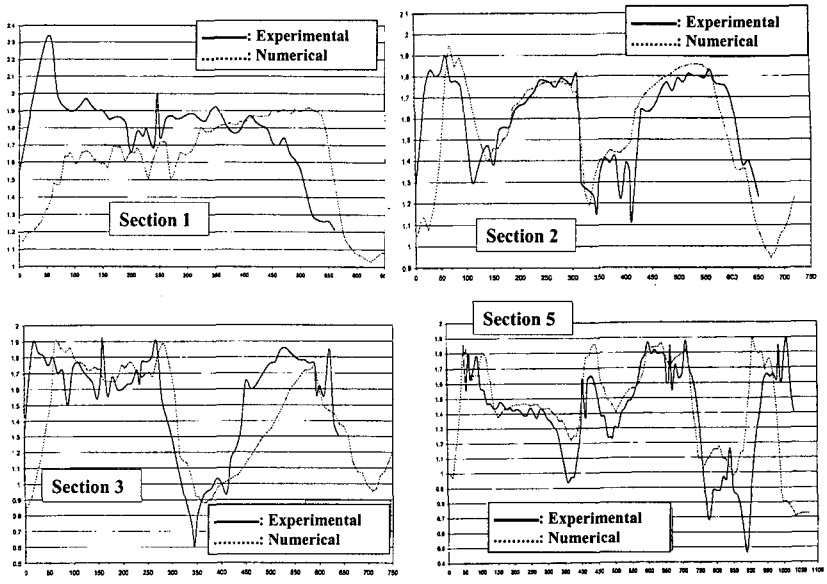
thermoforming of an car in door panel

Thickness distribution across the blown sheet.

Cross sections along which experimental data are available.



Comparison with experimental data



Conclusions

- **POLYFLOW** has proven many times its ability to simulate complex industrial problems.
- Many companies worldwide are already taking advantage of the actual benefit brought by **POLYFLOW**.
- The goal of the CFD is to be as close as possible to the process and NOT educating people to complex numerical analysis technique
- COST ARE CUT and QUALITY IS IMPROVED !

Thank you for your attention.