Developments in the area of mathematical modeling, code validation and new experimental platform

Dilhan M. Kalyon

Stevens Institute of Technology

Hoboken, NJ

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Developments in the area of mathematical modeling, code validation and new experimental platform

- New source code which merges extrusion with die flow seamlessly
- Ability to design with easy transition to the manufacture of the tool
- New extrusion platform with infinite flexibility

Realistic channel, GNF

$$\frac{\partial p}{\partial x} = \frac{\partial}{\partial x}\left(2\eta \frac{\partial u_x}{\partial x}\right) + \frac{\partial}{\partial y}\left[\eta\left(\frac{\partial u_x}{\partial y} + \frac{\partial u_y}{\partial x}\right)\right]$$

$$\frac{\partial p}{\partial y} = \frac{\partial}{\partial y}\left(2\eta \frac{\partial u_y}{\partial y}\right) + \frac{\partial}{\partial x}\left[\eta\left(\frac{\partial u_x}{\partial y} + \frac{\partial u_y}{\partial x}\right)\right]$$

$$\frac{dp}{dz} = \frac{\partial}{\partial x}\left(\eta \frac{\partial u_z}{\partial x}\right) + \frac{\partial}{\partial y}\left(\eta \frac{\partial u_z}{\partial y}\right)$$

For 3-D Analysis

Fluid/Solid Interface

$$\underline{n}\ \underline{\underline{T}} = (\underline{n}\underline{t}_1 : \underline{\underline{T}})\,\underline{t}_1 + (\underline{n}\underline{n} : \underline{\underline{T}})\,\underline{n} + (\underline{n}\underline{t}_2 : \underline{\underline{T}})\,\underline{t}_2$$

$$\underline{\underline{I}}_{II}\ (\underline{u} - \underline{u}_{solid}) = \beta \underline{\underline{I}}_{II}\ (\underline{n}\ \underline{\underline{T}})$$

$$\underline{\underline{I}}_{II} = \underline{\underline{I}} - \underline{n}\underline{n} = \underline{t}_1\underline{t}_1 + \underline{t}_2\underline{t}_2 + \underline{n}\underline{n} - \underline{n}\underline{n}$$

Silliman and Scriven, 1980

$$\frac{\partial u_x}{\partial x} + \frac{\partial u_y}{\partial y} + \frac{\partial u_z}{\partial z} = 0$$

$$Q - \int_D u_z dD = 0$$

$$Pe\left(u_x \frac{\partial\theta}{\partial x} + u_y \frac{\partial\theta}{\partial y} + u_z \frac{\partial\theta}{\partial z}\right) = \left(\frac{\partial^2\theta}{\partial x^2} + \frac{\partial^2\theta}{\partial y^2}\right)$$

$$+ G\eta(|\dot{\gamma}|)^2$$

$\Theta=(T-T_o)/(T_b-T_o)$

T_b (Barrel Temperature) ; T_o (Entrance Temperature)

1. **at z=0 (Entrance) $\Theta=0$**
2. **On the barrel surface $\Theta=1$**
3. **On the screw surface** $\frac{\partial\theta}{\partial \underline{n}} = 0$

Conservation of linear momentum upon application of Bubnov Galerkin:

$$\int_D \pi \, \underline{\underline{T}} \, dD - \int_{\Gamma_s} \pi (\underline{n}\underline{t} : \underline{\underline{T}}) \underline{t} \, d\Gamma_s - \int_{\Gamma_s} \pi (\underline{n}\underline{n} : \underline{\underline{T}}) \underline{n} \, d\Gamma_s = 0$$

Weighting function

Total stress tensor

Unit tangent vector

Unit normal vector

$$\underline{t} \, (\underline{u} - \underline{u}_{solid}) = \beta \underline{n}\underline{t} : \underline{\underline{T}}$$

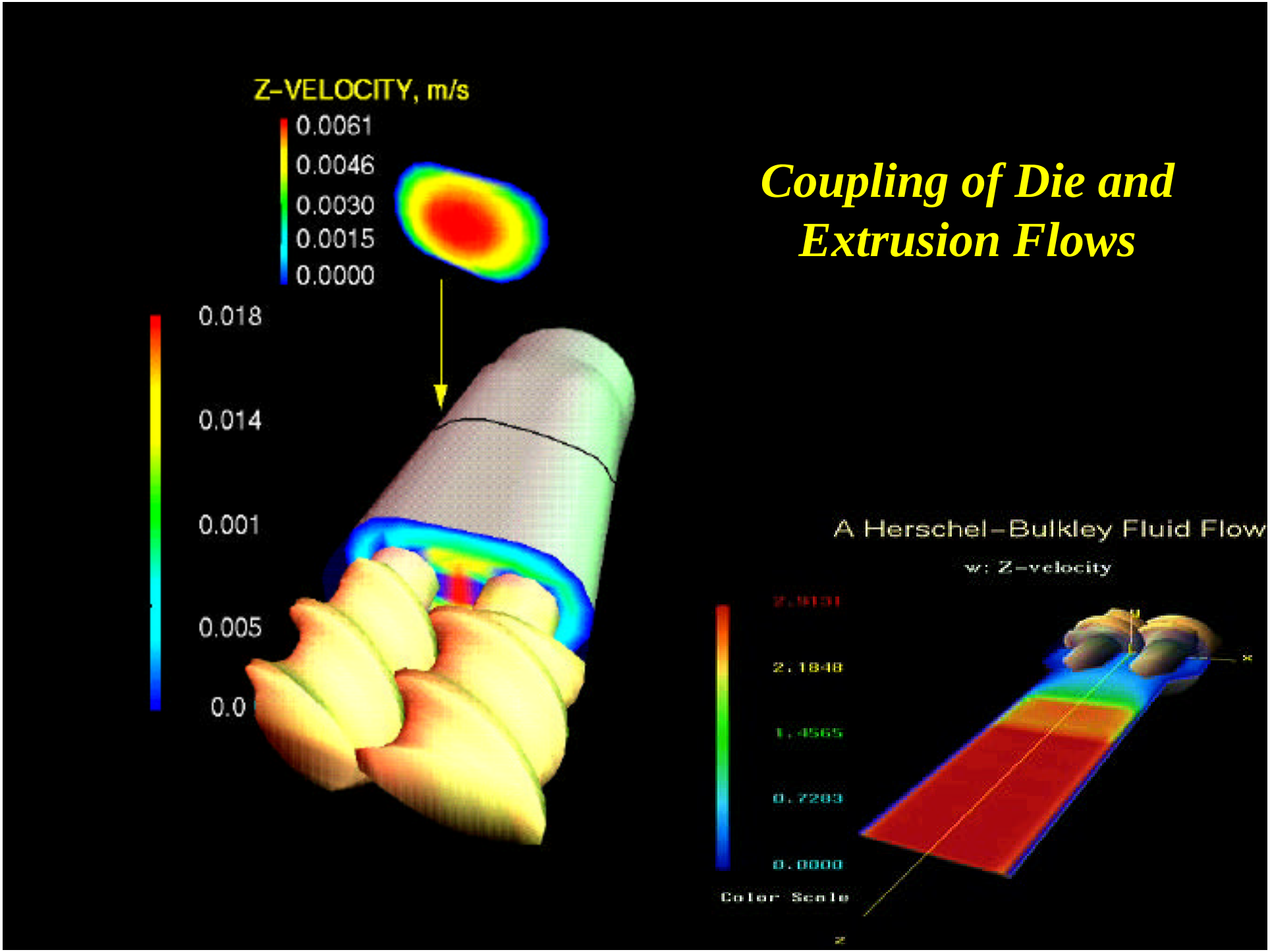
Wall slip

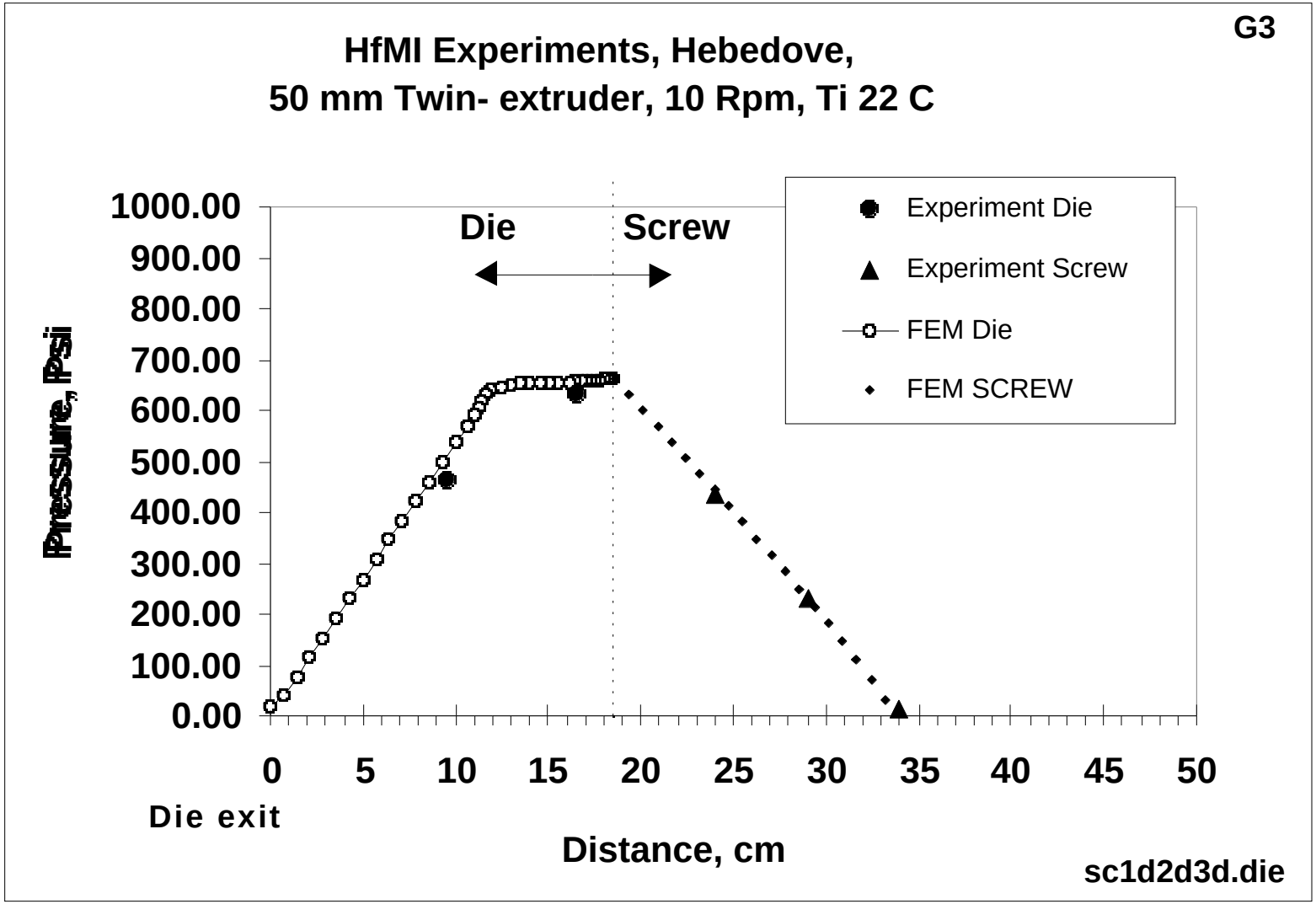
Navier's slip coefficient

$$\underline{n} \, (\underline{u} - \underline{u}_{solid}) = 0$$

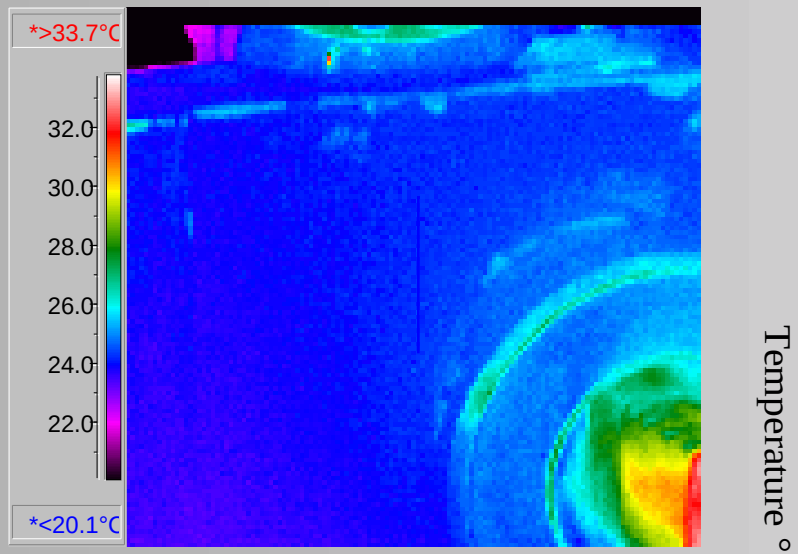
No material exchange

Coupling of Die and Extrusion Flows



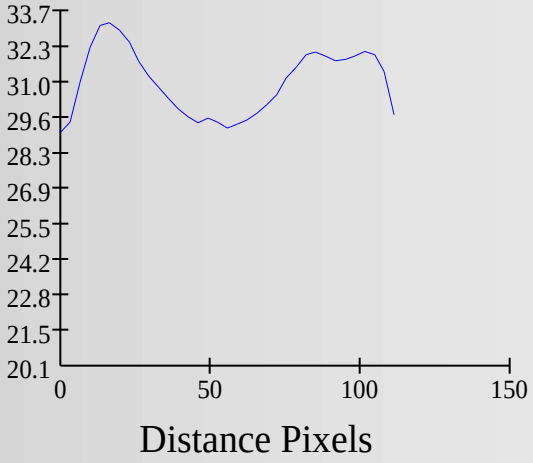

G3
HfMI Experiments, Hebedove,
50 mm Twin- extruder, 10 Rpm, Ti 22 C
Pressure, Psi
1000.00
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
Die
Screw
Experiment Die
Experiment Screw
FEM Die
FEM SCREW
0
5
10
15
20
25
30
35
40
45
50
Die exit
Distance, cm
sc1d2d3d.die

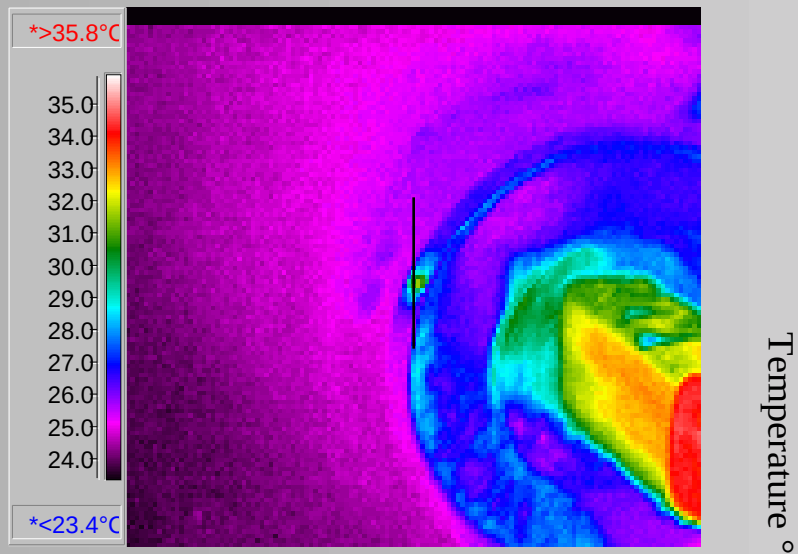
TEMPERATURE DISTRIBUTIONS WITHIN EXTRUDATES



Temperature °C

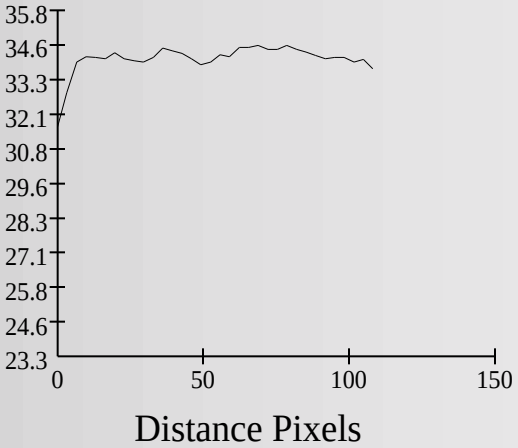
NON-UNIFORM DISTRIBUTION





Temperature °C

UNIFORM DISTRIBUTION



Ability to move fast from design with FEM to the manufactured tool

- Partnership of SIT with MPR Inc of Hoboken and Shear Tool Inc. of Saginaw, MI
- Through use of e-transfer of files; seamless transfer from AutoCad to numeric controlled machining
- Special capabilities in coating.

New Experimental Station

- Shear roll milling
- Single screw extruder
- Twin screw extruder
- Co and counter
- Tangential and fully-intermeshing
- Variable L/D, splittable and segmented simultaneously
- Integrated rheometers and x-ray diffraction

SIT Contributors 1986-2001

(alphabetical listing)

1.Ab initio, Polymerization, Dissolution, Crystallization:

- Akbulut, Cao, Chiou, Ermler, Gokce, Rege, Kovenklioglu.

2. Rheology:

- Allende, Aral, N. Boz, Cesmebasi, Chen, Czerwonka, Gevgilili, Gogos, Kucukpinar, S. Patel, Suwardie, Tong, Tsenoglu, Yaras, Yilmazer, D. Yu & J. Yu, Zjakic.

3. Sensor/Device Development:

Garrow, Gokturk, Karuv, Knapp.

4. Simulation:

- Du, Gotsis, Ji, Lawal, Railkar, Wang.

5. Microstructure Analysis, Interfaces, Ultimate Properties:

- Bayramli, Bhakuni, Birinci, Fiske, Han, Lao, Libera, Lim, Sun, Swaminathan, Tan, Wagner, Yao, Yazici.

6. Experimental processing studies:

- I. Boz, Dey, Garrow, Guy, Jacob, Sangani, Yaras.

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