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3-D Comsol Analysis Of Extruder Dies

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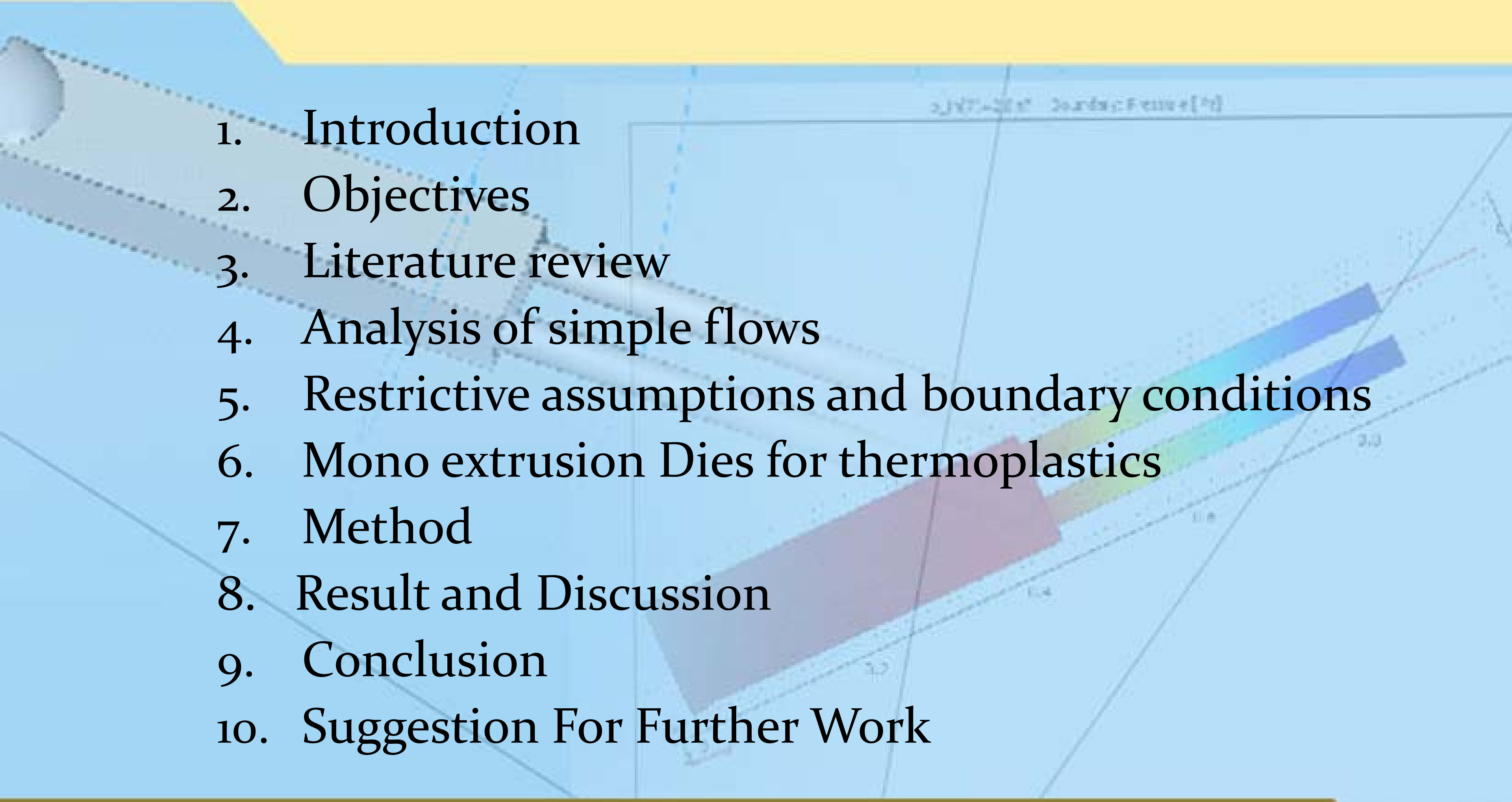
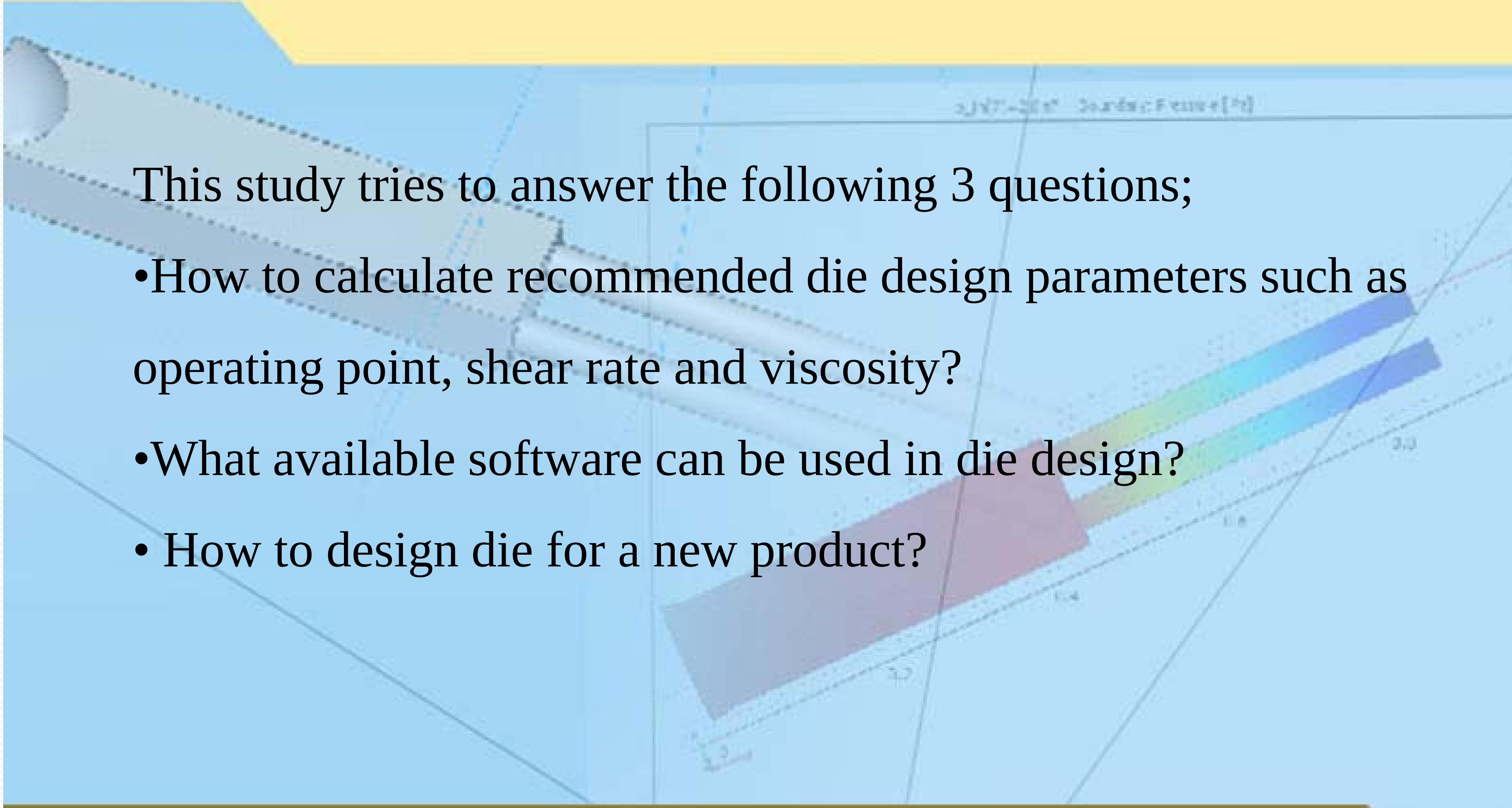
Content



1. Introduction

- The principle of polymer extrusion manufacturing process is pushing a molten polymer across a well designed extruder die which continuously shapes the melt to the desired final product.
- Design procedure of dies, unlike other parts of machine components, was considered as an art rather than science.
- The usual traditional methods of design depends on numerous trial–and error loops, mainly relying on the designer’s experience.

2.Objective



This study tries to answer the following 3 questions;

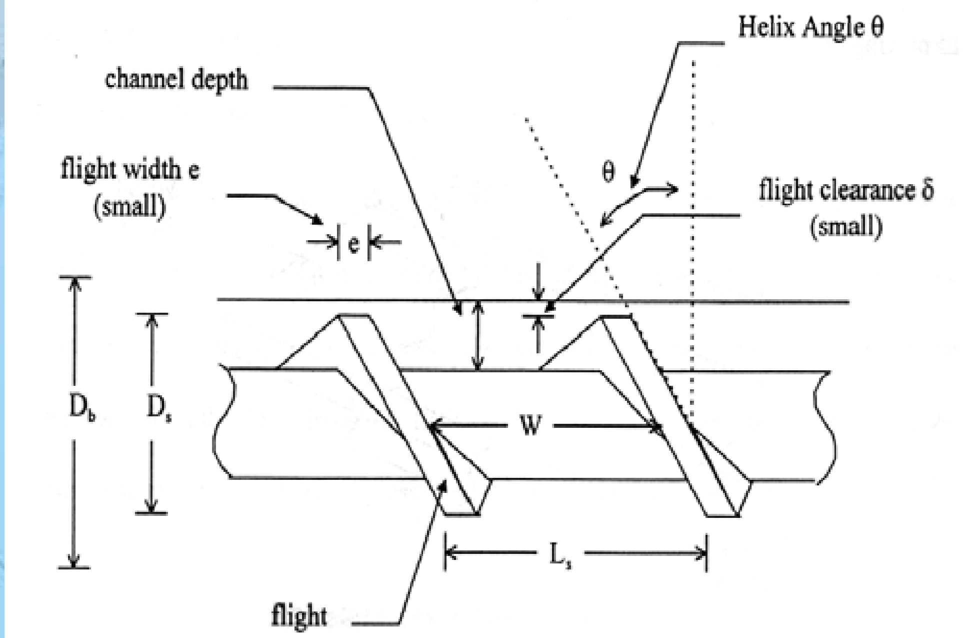
- How to calculate recommended die design parameters such as operating point, shear rate and viscosity?
- What available software can be used in die design?
- How to design die for a new product?

Q_d

3. Analysis of simple flows

1. Drag flow:

is flow between two surfaces caused by the movement of one relative to the other.



$$\text{Drag flow } (Q_d) = (1/2)\,\pi^2 D^2 N H \sin\theta\cos\theta$$

3. Analysis of simple flows(cont.)

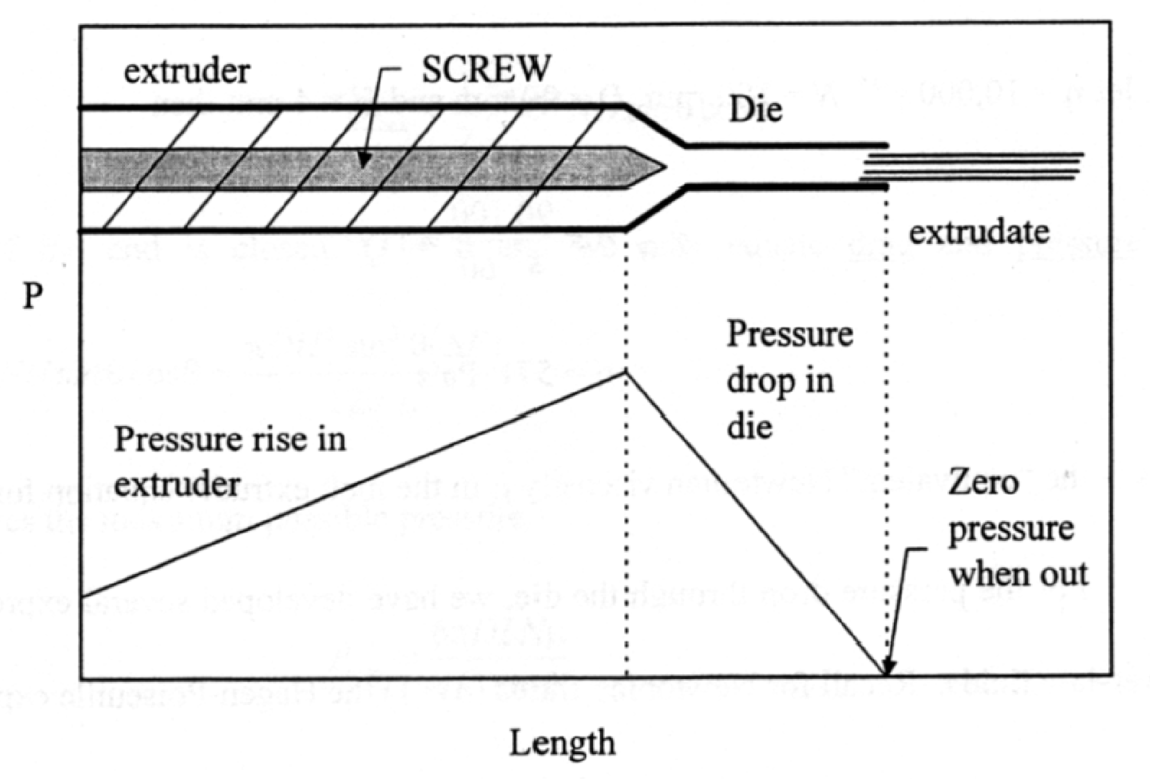
2.Pressure flow (Poiseuille flow):

In extrusion process, this is the kind of flow only noticed when the die or the head is present .It is a flow caused by a pressure difference. This flow occurs in the metering zone of the screw characterized by the back ward flow of materials

$$\boxed{Q_p = \frac{k}{\mu}\frac{\Delta P}{L}}$$

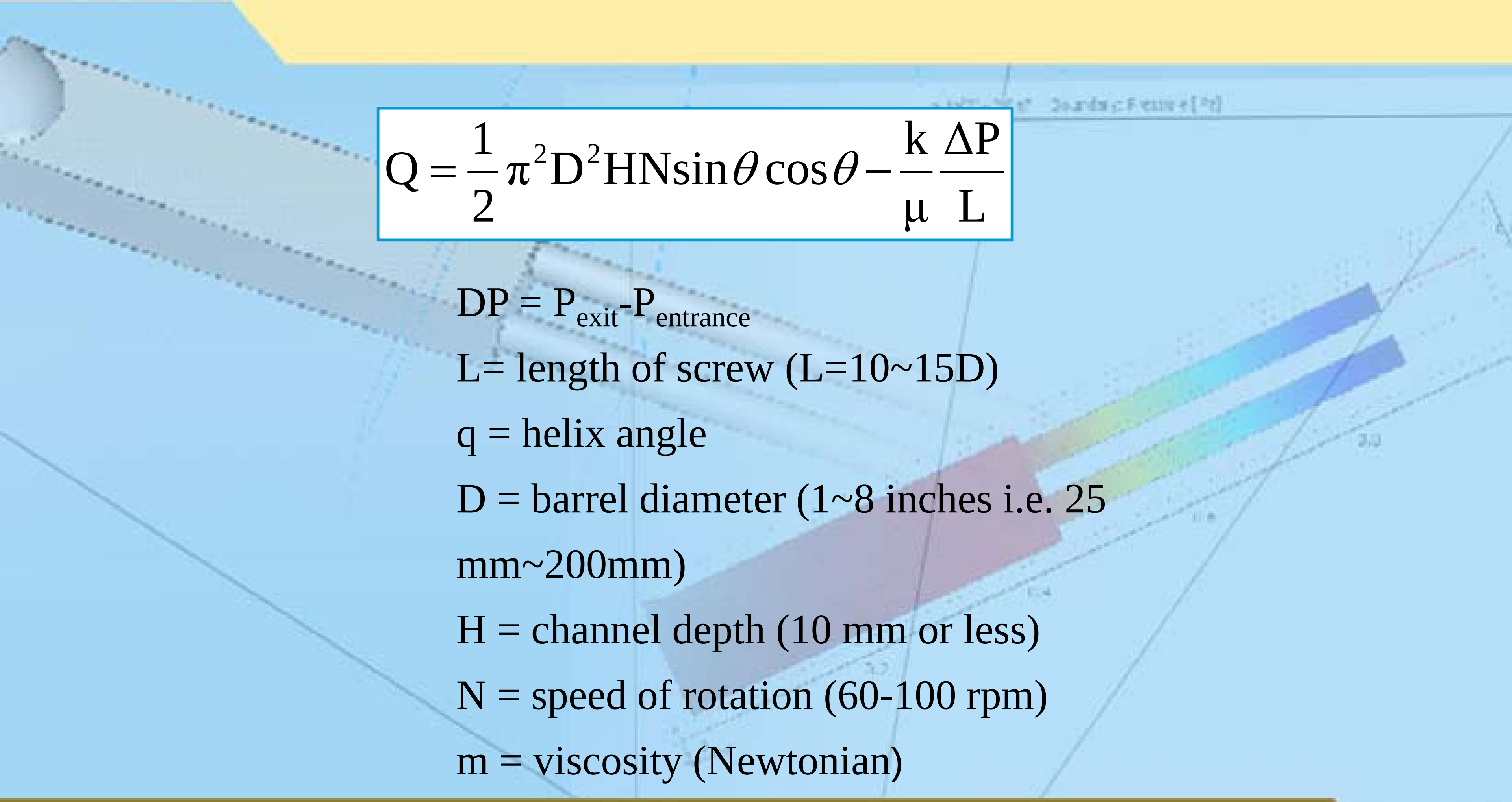
3. Analysis of simple flows(cont.)

Pressure distribution of flow in extruder



$$Q=Q_d-Q_P$$

3. Analysis of simple flows(cont.)



$$Q = \frac{1}{2}\pi^2 D^2 H N \sin\theta \cos\theta - \frac{k}{\mu}\frac{\Delta P}{L}$$

DP = P_{exit}-$P_{entrance}$

L= length of screw (L=10~15D)

q = helix angle

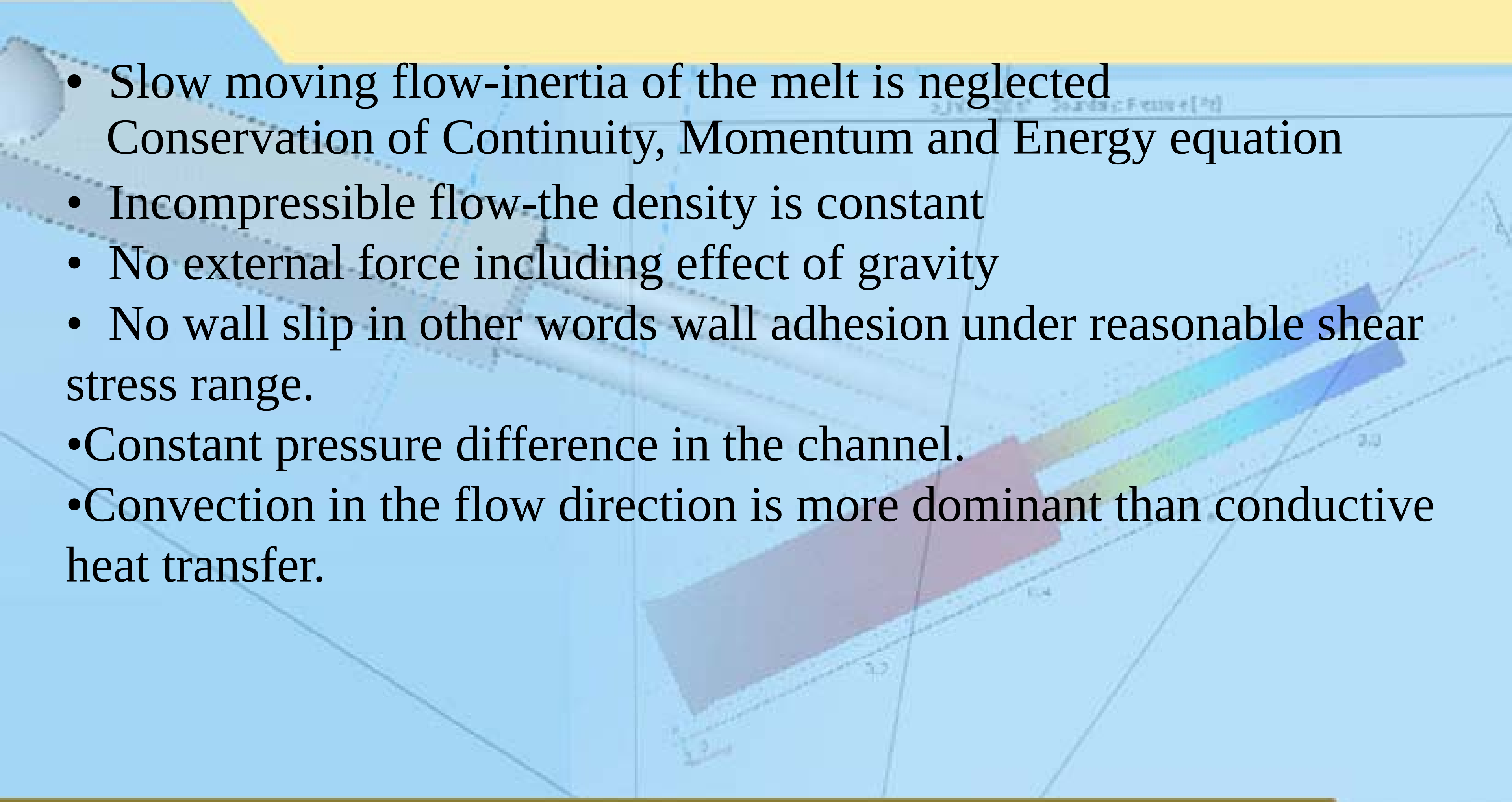
D = barrel diameter (1~8 inches i.e. 25 mm~200mm)

H = channel depth (10 mm or less)

N = speed of rotation (60-100 rpm)

m = viscosity (Newtonian)

4. Restrictive assumptions and boundary conditions



- Slow moving flow-inertia of the melt is neglected
  Conservation of Continuity, Momentum and Energy equation
- Incompressible flow-the density is constant
- No external force including effect of gravity
- No wall slip in other words wall adhesion under reasonable shear stress range.
- Constant pressure difference in the channel.
- Convection in the flow direction is more dominant than conductive heat transfer.

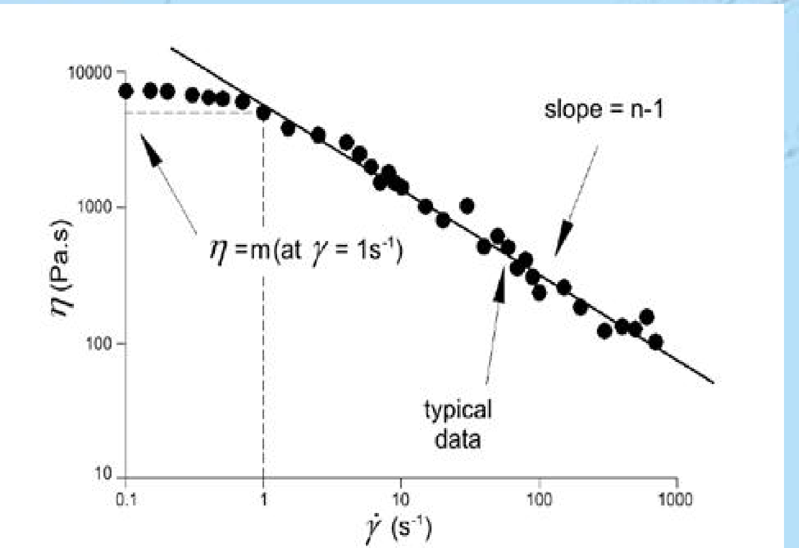
Mathematical description of Psedoplastic

- **Carreau-Yasuda Law :**

$$\eta = \eta_\propto + \left(\eta_0 - \eta_\propto\right)\left[1 + \left(\lambda\dot{\gamma}\right)^a\right]^{\frac{n-1}{a}}$$

- **Power Law Model:**

$$\eta = m(\dot{\gamma})^{n-1}$$

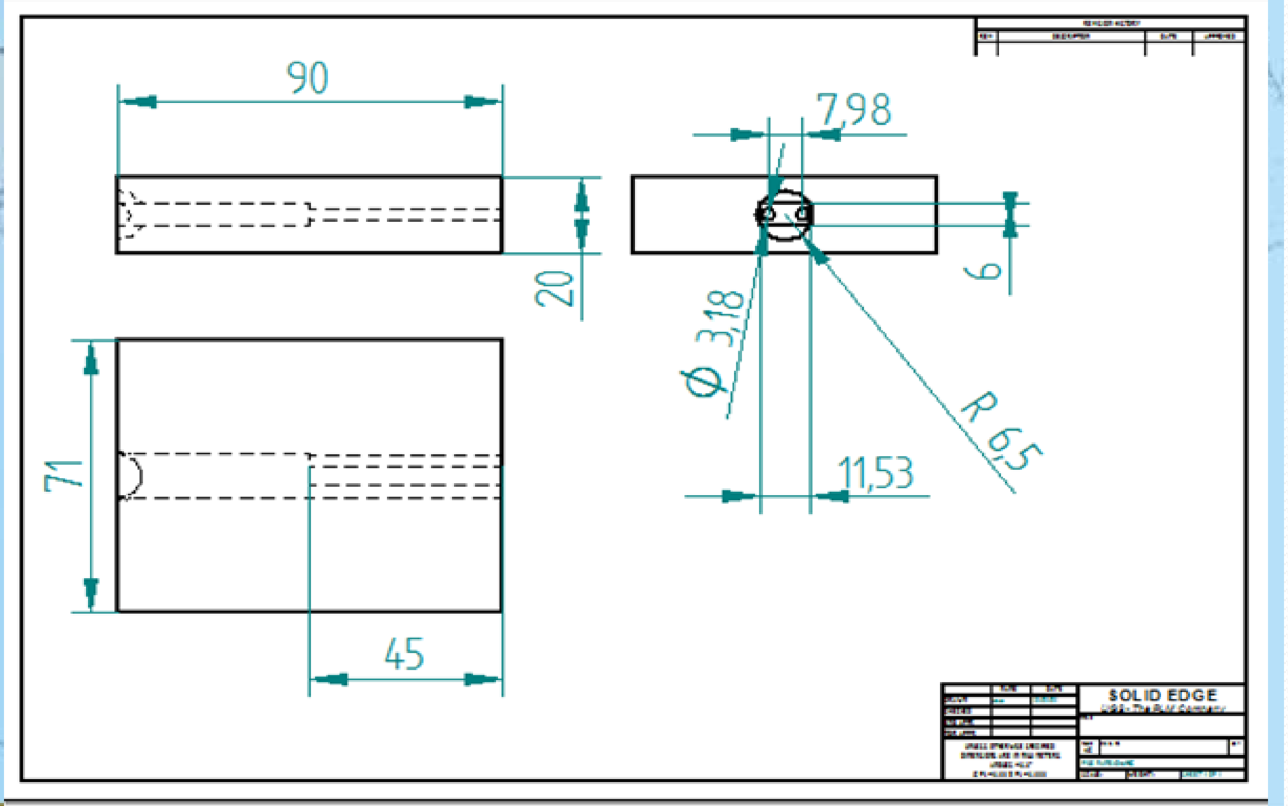


Zero shear rate viscosity, η_0 A=1437.4 pa*.
Infinite shear rate viscosity, η_∞ = 0 Pa-s
Natural time, λ = 0.902
Transition Parameter, a = 0.585
Exponent, n = 0.29
Density, ρ = 930Kg/m^3
Specific Heat, c_p = 1200 J/Kg-K
Thermal Conductivity, k = 0.12307 W/m-K
Coefficient of thermal expansion, β = 0.5e-5 m/m-K

6.Method (cont.)

Engineering drawing of the die in Arcada

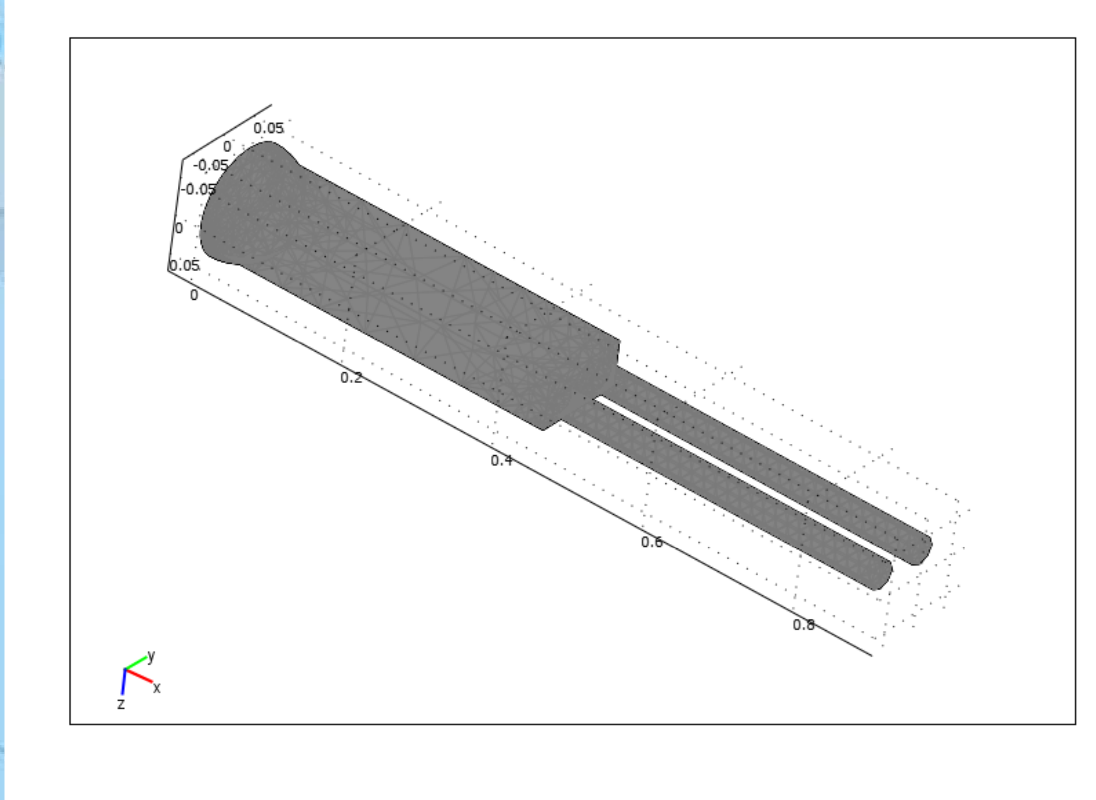
Solid edge
Bolean feature
Stl. file



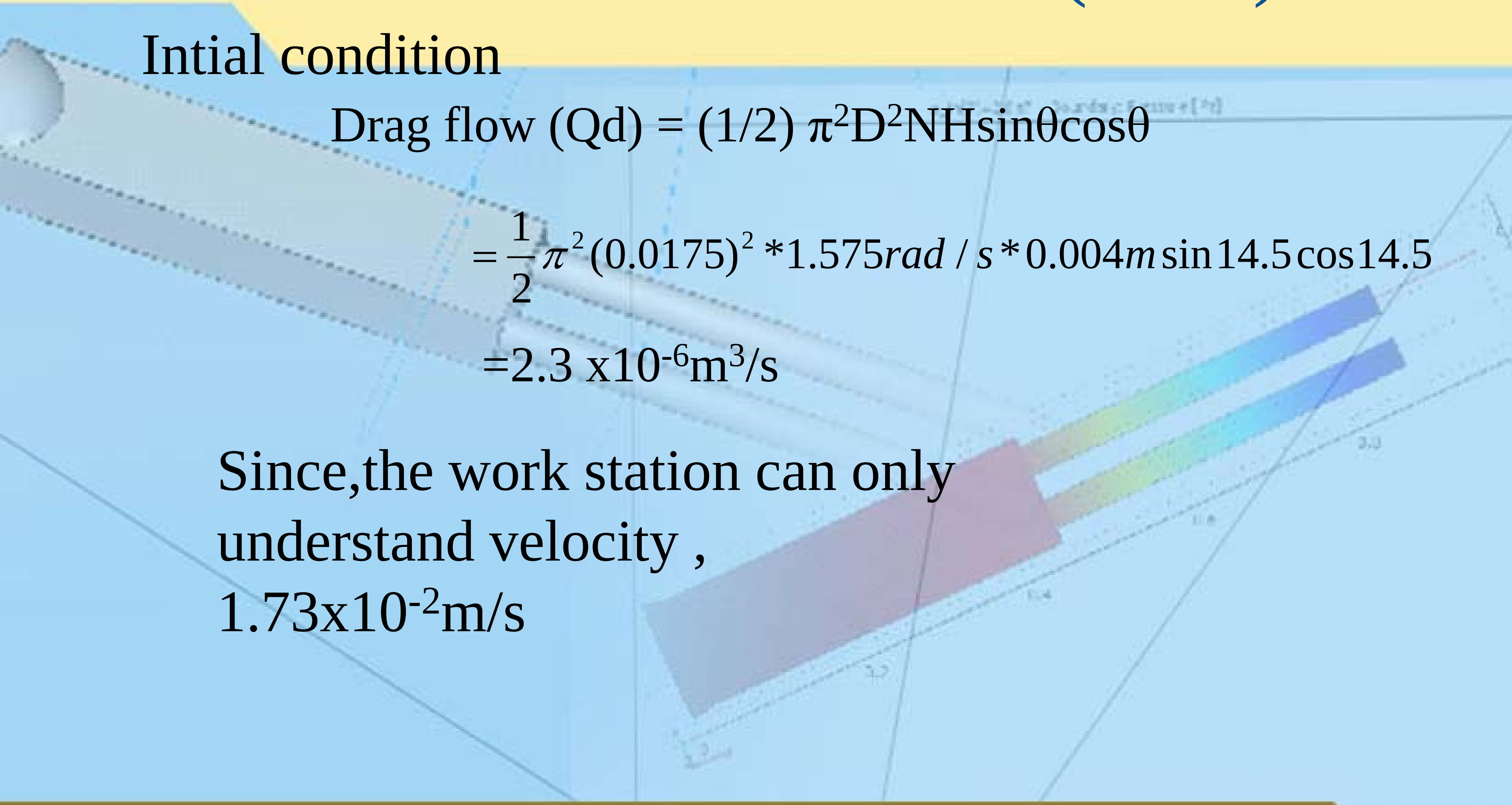
6.Method (cont.)

Meshed part of the flow domain

Imported
Meshed



6.Method (cont.)



Intial condition

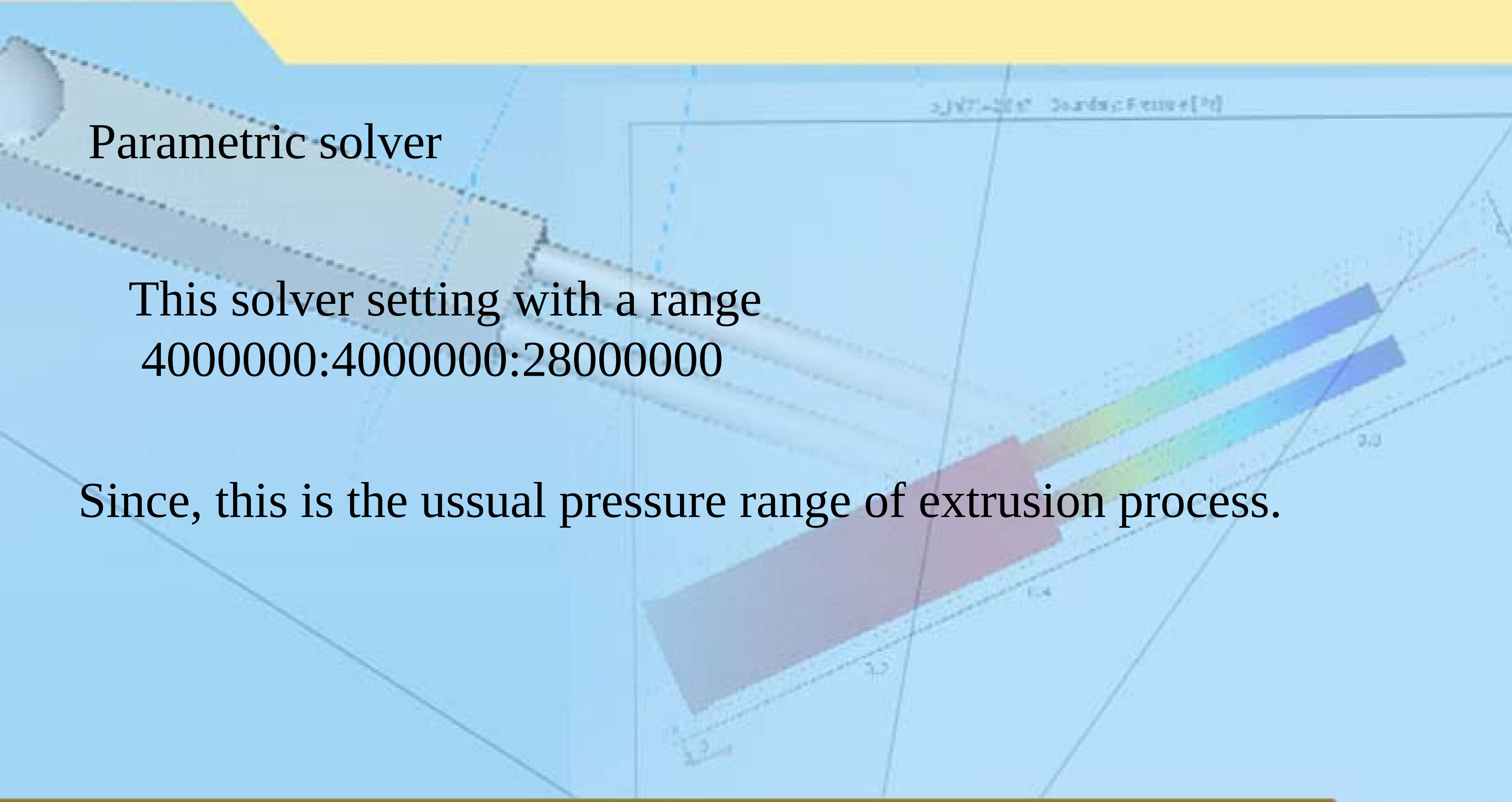
Drag flow (Qd) = (1/2) $\pi^2 D^2 N H \sin\theta \cos\theta$

$$= \frac{1}{2}\pi^2(0.0175)^2 * 1.575\,rad/s * 0.004\,m \sin 14.5 \cos 14.5$$

$=2.3 \times 10^{-6} m^3/s$

Since,the work station can only understand velocity , 1.73×10^{-2}m/s

6.Method (cont.)

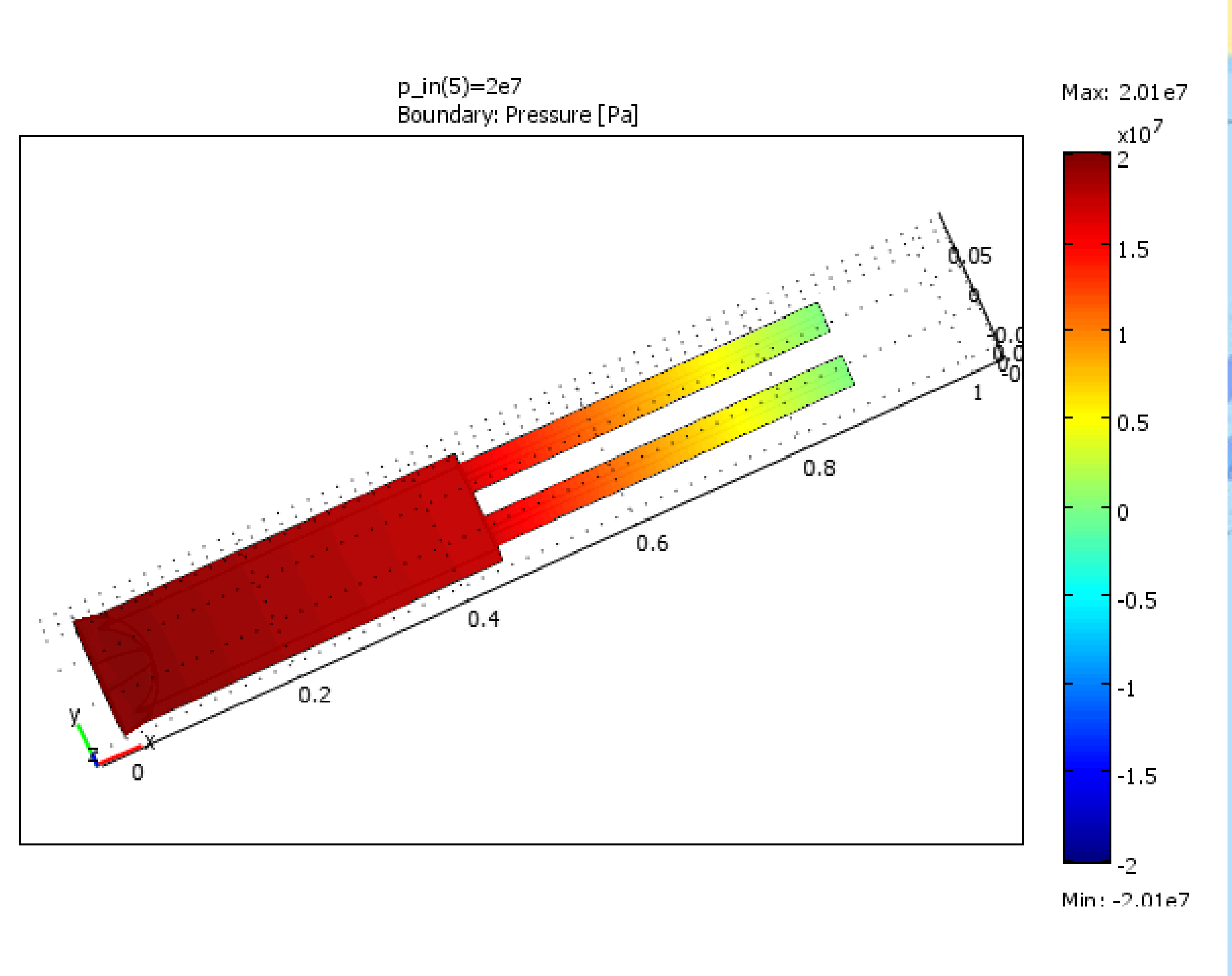


Parametric solver

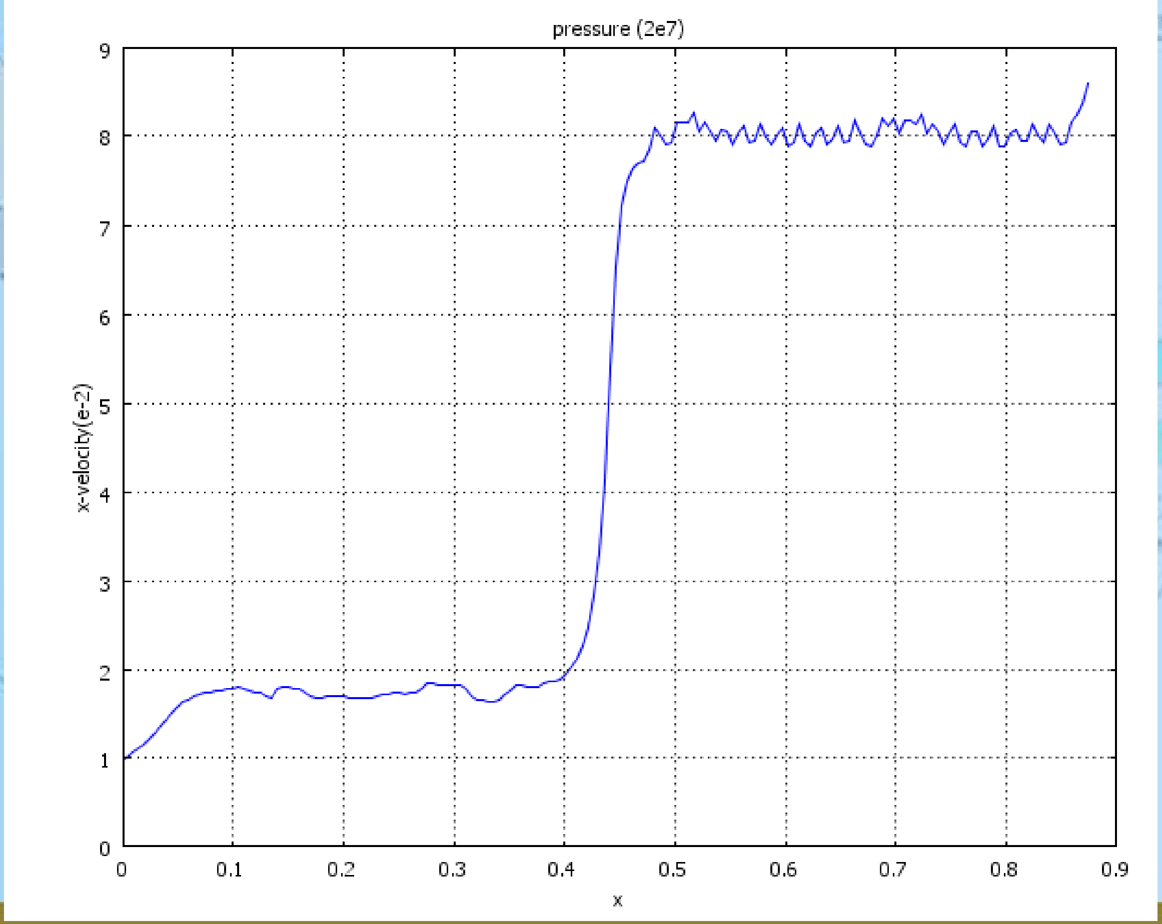
This solver setting with a range 4000000:4000000:28000000

Since, this is the ussual pressure range of extrusion process.

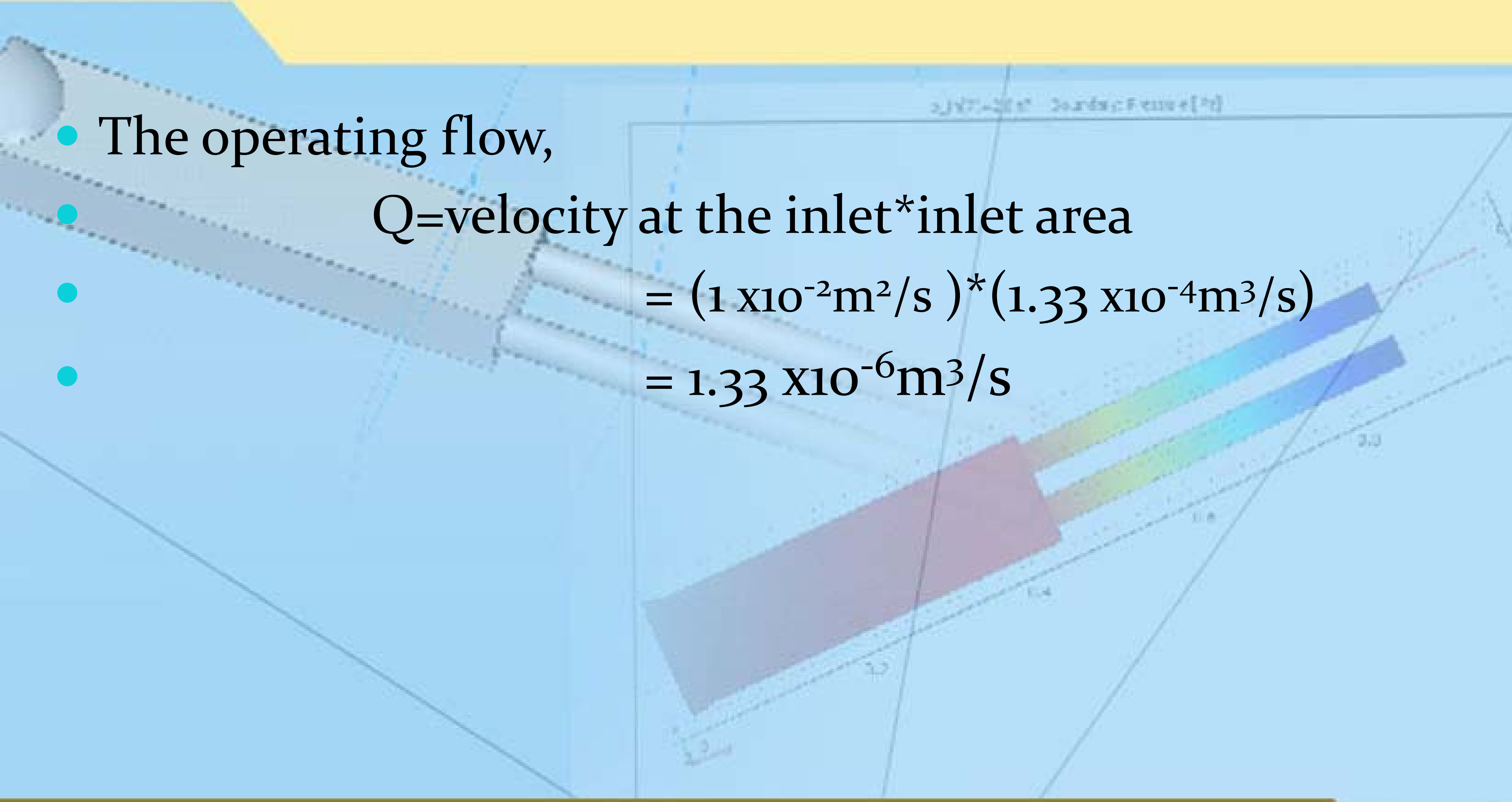
8.Result and Discussion



8.Result and Discussion(cont.)

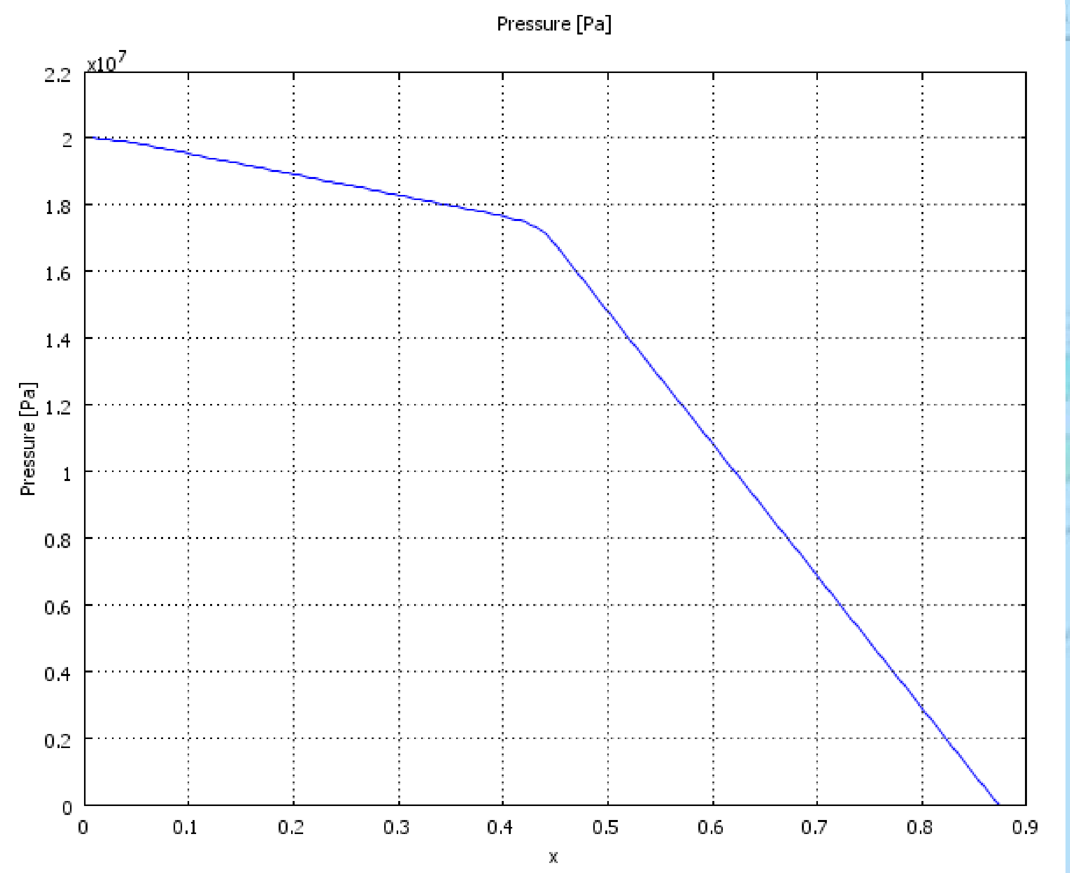


8.Result and Discussion(cont.)



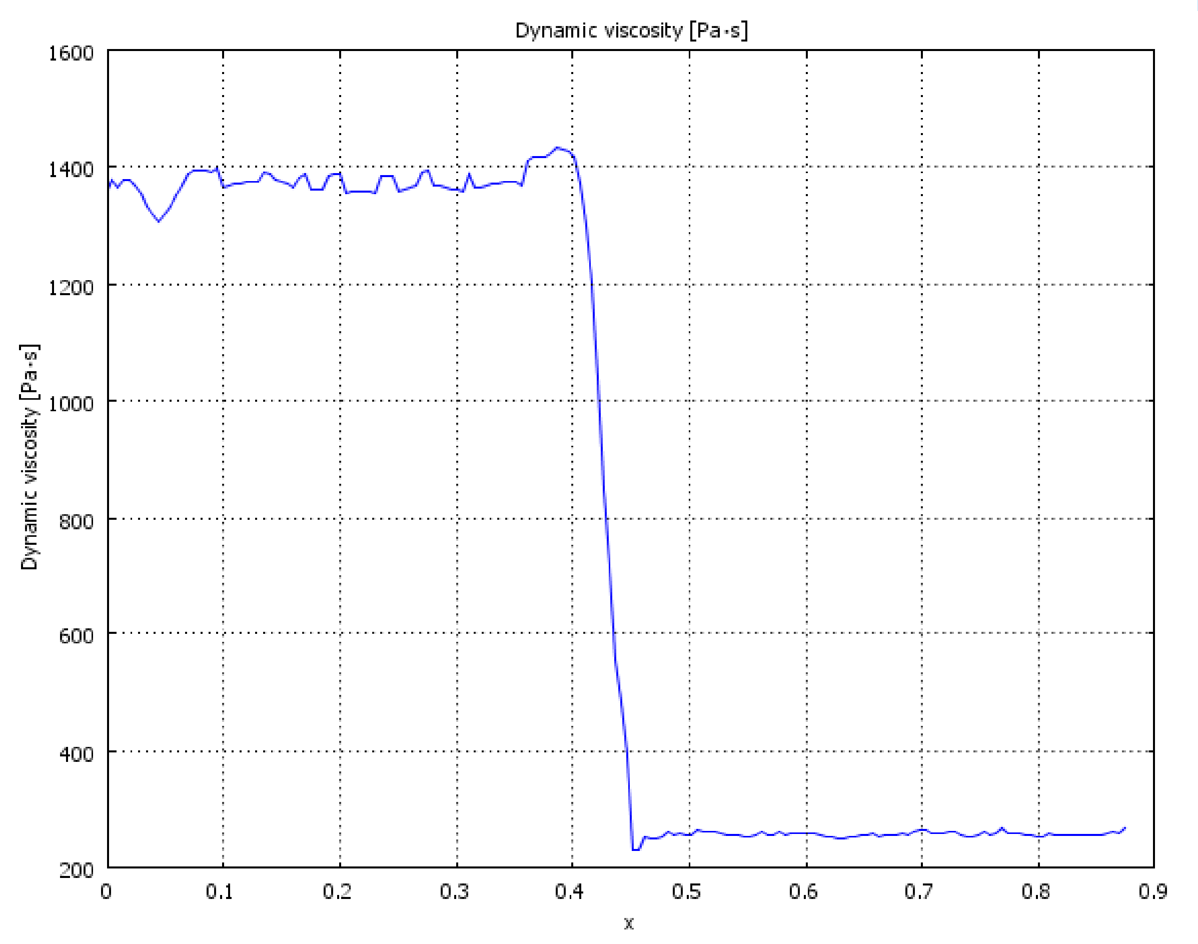
- The operating flow,
- Q=velocity at the inlet*inlet area
- $= (1\ x10^{-2}m^2/s\ )*(1.33\ x10^{-4}m^3/s)$
- $= 1.33\ x10^{-6}m^3/s$

8.Result and Discussion(cont.)



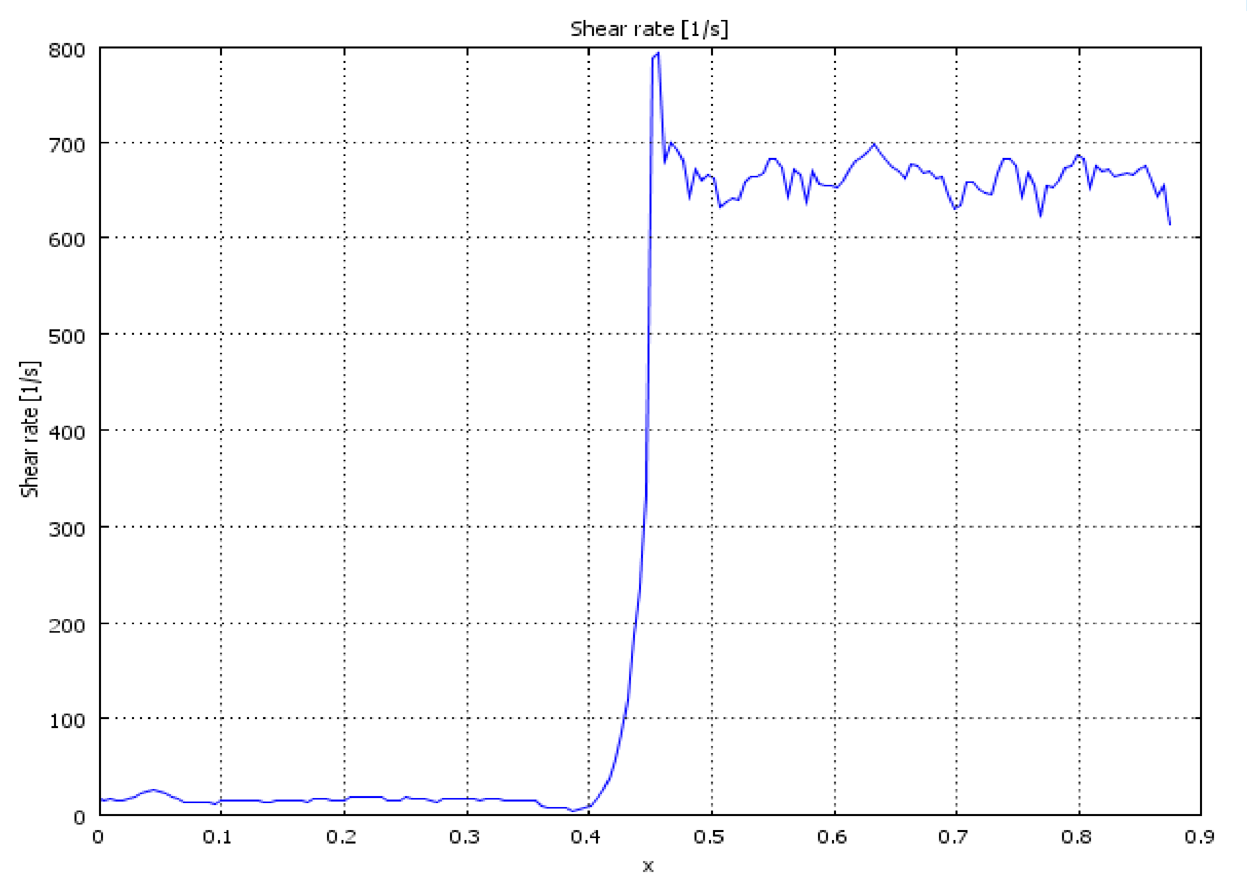
8.Result and Discussion(cont.)

Dynamic viscosity



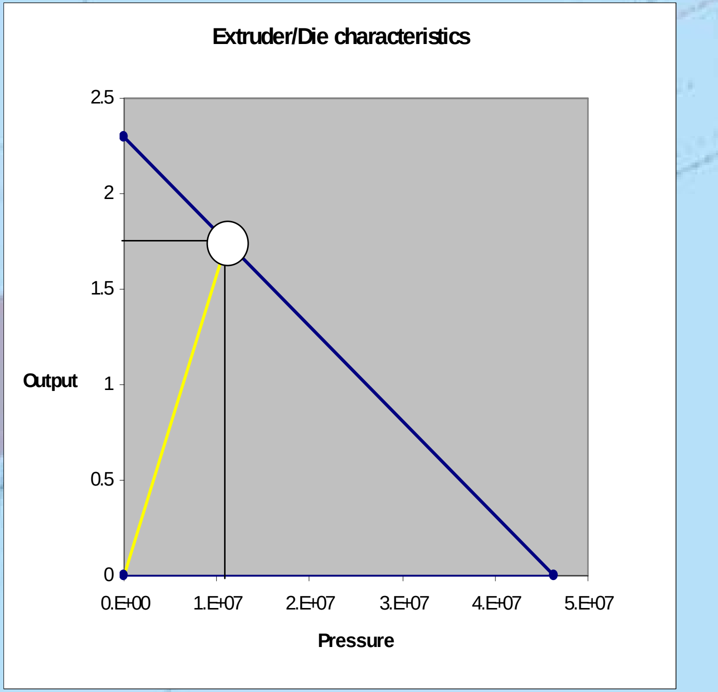
8.Result and Discussion(cont.)

Shear rate curve as the melt flows.



8.Result and Discussion(cont.)

Average operating point of the extruder and die was found to be (1.75 x$10^{-6}$$m^3$/s, 11MPa) at 15 rpm. The mass flow rate at the operating point is 4.7 kg/hr at 15 rpm.

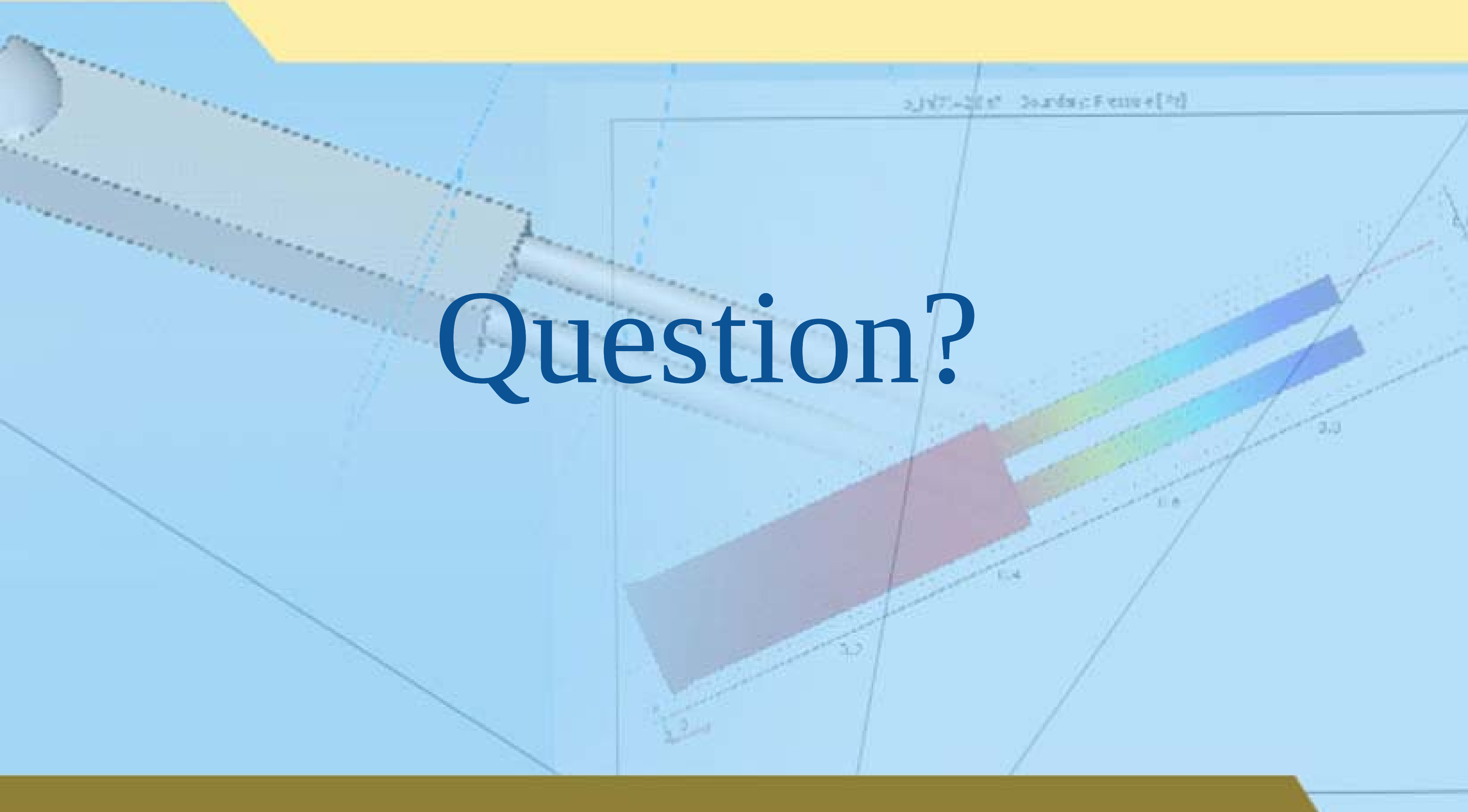


9. Findings

- Thus the operating point pressure for the given die were found to be 20MPa and the corresponding output was 1.33 x10^{-6}m^{3}/s .
- The simulated flow rate of 1.33 x10^{-6}m^{3}/s compares well to the theoretical value of 1.75 x10^{-6}m^{3}/s.
- This methodology can also be applied to design new profile dies and melt flow channels for runners in injection moulding process.

10. Suggestion for Further Work

- It would be very important to have true zero shear viscosity values for most common polymers at a reasonable operating temperature .This could be accomplished using a method called capillary rheometry.
- The K value of the die geometry, in this study was found to be high. Which indicates proper optimization could lead to a decreased resistance of the die.
- The procedures of this study can be used in the design of a new or improved profile die which reduces backflow.



Question?

3-D COMSOL

analisis of extruder" dies

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