II. Present working problems and perspective

1. Methods

| Basic equations: $\nabla \cdot u = 0$, $\rho(u_t + u \cdot \nabla u) = -\nabla p + \nabla \cdot (\mu \nabla)u$ |
| Boundary conditions: $[u]^2_1 \cdot n = 0$, $[u]^2_1 \cdot t = 0$, $\partial f/\partial t + u \cdot \nabla f = 0$ |

\[
\begin{align*}
    n \cdot T n &= \sigma \kappa, \\
    t \cdot T n &= -t \cdot \nabla \sigma, \\
    (T &= -pI + \mu D)
\end{align*}
\]

- Long wave approx.
- Discrete vortex method
- Level-Set method

- Reduced evolution eqs.
- Induced vortex eq., Circulation eq.
- NS eq. (CSFmodel), Advection eq.

Previous topics:
- Breakup phenomena of a liquid sheet with surrounding gas placed between rigid walls,
- Encapsulation of a gas-cored liquid jet,
- Breakup phenomena of a viscous compound jet
Examples: Encapsulation in a compound liquid jet

- Long wave expansion

Core: \( u_1 = u_1^{(0)} + r^2 u_1^{(2)} + \cdots \), \( p_1 = \cdots \)

Annular:
\[
\begin{align*}
    u_2 &= u_2^{(0)} + u_2^{(1)} (r - R) + u_2^{(2)} (r - R)^2 + \cdots , \\
    v_2 &= \cdots , \quad p_2 = \cdots
\end{align*}
\]

- Evolution eqs.:
\[
\begin{align*}
    \frac{\partial b}{\partial t} &= -\frac{\partial (bu_2)}{\partial z} - bv_2/R, \quad \frac{\partial R}{\partial t} = v_2 - u_2 \frac{\partial R}{\partial z}, \\
    \frac{\partial u_1}{\partial t} &= -u_1 \frac{\partial u_1}{\partial z} - (1/\rho) \frac{\partial p_1}{\partial z}, \\
    \frac{\partial u_2}{\partial t} &= -u_2 \frac{\partial u_2}{\partial z} - \frac{\partial P}{\partial z} + (\Delta P/b) \frac{\partial R}{\partial z}, \\
    \frac{\partial v_2}{\partial t} &= -u_2 \frac{\partial v_2}{\partial z} - \Delta P/b, \\
    A_1 \frac{\partial^2 p_1}{\partial z^2} + A_2 \frac{\partial p_1}{\partial z} + A_3 p_1 + A_4 &= 0.
\end{align*}
\]
• Breakup phenomena when sinusoidal disturbances are applied at the nozzle exit:

(i) influence of $W_b$ ($\sigma = 1, \rho = 0.001$: (a)$W_b=26.9$, (b)$W_b=500$)

(ii) influence of $\sigma$ ($\rho = 1$, (a)$\sigma = 0.1$, (b)$\sigma = 2.7$)
Kendall (1986)

\[ D = 7 \text{ mm}, \quad v_l = 100 \text{ cm/s} \]

- producing periods and sizes of liquid shells are determined by the most unstable disturbances
• influence of non-Newtonian viscosity (Re=10)

(a) $n = 0.2$ (pseudo-plastic)

(b) $n = 1$ (Newtonian)

(c) $n = 1.8$ (Dilatant)
2. Present working problems and perspective

(i) Breakup of a jet in the region of absolute instability (dripping mode)

Convective (jetting) and absolute (dripping) instabilities

Breakup in jetting mode

A new method of producing uniform drops and capsules is to be developed.
(ii) Numerical investigations of breakup behavior in jets and sheets

Level-set method

Discrete vortex method

Numerical solutions are to be compared with analytical results using long wave approximations or weakly nonlinear perturbations.
(iii) Breakup of a planar sheet for three-dimensional disturbances

- Experiments

- breakup model

Viscous and Marangoni effects on the breakup are to be investigated.
Marangoni effects due to solute concentration (solutocapillary phenomena )

Langmuir isotherm:

\[
\sigma = \sigma_0 + (RT\Gamma_\infty) \ln(1 - \Gamma/\Gamma_\infty),
\]

adsorption-desorption:

\[
J = (KC - \Gamma)/\tau,
\]

Influence of adsorption and desorption is additionally considered.
The analysis can be extended to the compound jet where the surfactants exist on both inner and outer interfaces.
(v) Breakup behavior of a jet in a static electric field:

Formation mechanism of microdrops and capsules and the application to materials with low dielectric constants are to be investigated.