Test Problem #3

A TWO-DIMENSIONAL SHEAR MIXING

The main purpose of this problem is to compare the results obtained from 2D Direct Numerical Simulation. The problem considers mixing of two miscible fluids by shear instability.

The fluids are almost incompressible. Hence the problem can be run either on an incompressible or a compressible code.

The initial geometry

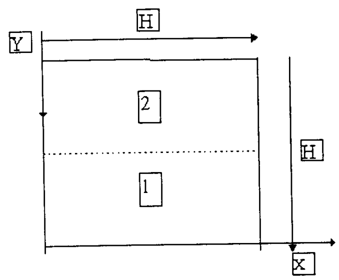

Fig.3. Initial geometry

The computational domain consists of a square with size H:

$$0 < X < H.$$
$$-\frac{H}{2} < y < \frac{H}{2}$$

For the unperturbed problem:

$$\rho = \begin{cases} \rho_1 & y < 0 \\ \rho_2 & y > 0 \end{cases}$$
$$P = P_0,$$
$$u_x = \begin{cases} u_1 & y < 0 \\ u_2 & y > 0 \end{cases}$$
$$u_y = 0.$$

The values chosen for the parameters are:

$$H = 1$$
$$\rho_1 = 1$$

$u_1 = 2$
$u_2 = -2$
$P_0 = 10^3$
$\rho_2 = 1$

Mesh

The problem is chosen so that it can be run on a relatively small mesh (200^2). Coarser or finer meshes would also be considered.

Equation of state

If a compressible simulation is being used then the equation of state for both fluids is

$P = (\gamma - 1)\rho e, \quad \gamma = 1.4$

where ρ = density,
e = specific internal energy.

Initial perturbation

Initial perturbation is set as random normal velocity distribution on the interface. The distribution formula of density perturbation is

$$\delta u_y = \text{sign}(c-0.5)\delta\ ,$$

where c is random ($0 < c < 1$), $\delta = 0.2$.

Below the program of generating random c value is appended. When calculating a cycle on cells it is necessary to address this program and to receive the c value. This program will give the same set of random numbers.

Boundary conditions

Reflective boundary conditions are assigned at $y = \pm 1/2H$. Periodic boundary conditions are assigned in the x directions.

Output required

Mass fraction of fluid 2 (f_2) is used below.

The following output is then proposed. Each item can be conveniently displayed on a single viewgraph.

1. Width of mixing zone L versus t.
   L= distance between the points where $\bar{f}_2 = 0.05$ and $\bar{f}_2 = 0.95$.
   The overbar denotes the y - line average.
   Suggested size of graph - 7 × 7 cm.
2. For $t = t_1, t_2$ $\bar{u}_x(y)$.

The moments t_i are found from conditions $L(t_1) = 0.25H, L(t_2) = 0.5H$

Suggested size of graph - 7×7 cm.

3 For $t = t_1, t_2$ $\bar{\rho}(y)$ if $\rho_1 \neq \rho_2$

The moments t_i are found from conditions $L(t_1) = 0.25H, L(t_2) = 0.5H$

Suggested size of each graph - 7×7 cm.

4. $t = t_1, t_2$

2D view of isoline $f_2 = 0.5$.

Suggested size of each graph - 10×10 cm