Vessel pressurization

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Introduction

The purpose of this test-case is to check the ability of an Euler solver to compute a slow pressurization of a closed cavity.

1 Description of the problem.

We consider the 2D rectangular cavity of figure 1. We suppose that it is initially filled with a calorically perfect gas and in uniform conditions, with initial temperature T_I and initial pressure P_I. We inject the same gas from the bottom part of the cavity (l is the opening width). The

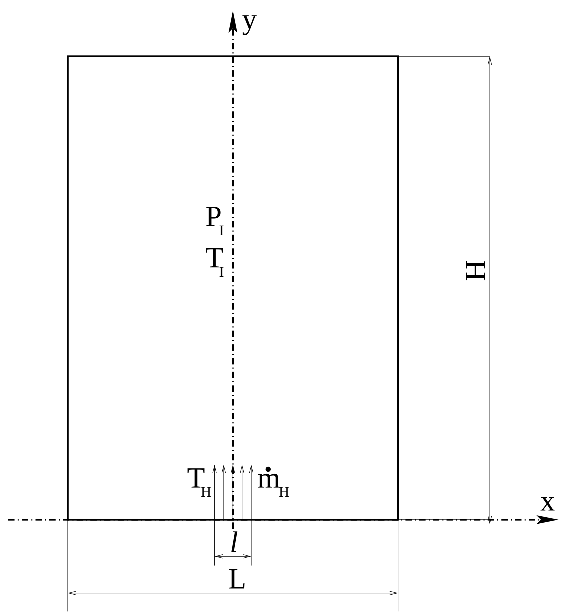

Figure 1: Rectangular cavity initially filled with air at rest. Gas is injected through the opening at the bottom.

cavity wall is supposed to be impermeable and adiabatic. The injected flow temperature is T_H; the mass flux $\dot{m}_H$ is uniform along the injection surface.

1.1 Governing equations

The governing equations are the compressible Euler equations for a calorically perfect gas.

Two cases have been considered:

- Test case T1: injection without taking into account the gravity action.
- Test case T2: injection with taking into account the gravity action.

1.3 Data

The dimension of the cavity are

$$\begin{aligned} L &= 4 \text{ m} \\ H &= 7\ m \end{aligned}$$

while the dimension of the injection opening is

$$l = 0.2\ m$$

The gas is calorically perfect, with specific heat ratio and gas constant

$$\begin{aligned} \gamma &= 1.4 \\ R &= 288 \text{ J/kg/K} \end{aligned}$$

respectively. In the case T2 we take the gravity $g = 9.81$ m/s^2.
At the beginning the gas in the cavity is at rest, at 1 bar and 300 K.
As far as the boundary conditions are concerned, we suppose that the wall is impermeable and adiabatic everywhere except at the injection opening. The injection boundary conditions are given by a mass flow and a temperature, namely

$$\begin{aligned} \dot{m}_H &= 1.0 \text{ kg/m}^2\text{/s} \\ T_H &= 600\ K \end{aligned}$$

We also suppose that the injection is parallel to the y-axis.
Note that the flow is subsonic and in low Mach number regime. Indeed, the order of magnitude of the flow velocity in the vessel is the same as in the injection region:

$$w_H = \frac{\dot{m}_H}{\rho_H} = \frac{\dot{m}_H}{P_H} R T_H$$

Since the injection pressure P_H is larger than P_I, we have that the injection velocity w_H is

$$w_H < \frac{\dot{m}_H}{P_I} R T_H \approx 1.7 \text{ m/s}$$

The sound speed is initially about $\sqrt{\gamma R T_I} = 350$ m/s in the containment and 500 m/s at the injection, i.e. much bigger than the flow speed.

2 Required results

As one can see in figure 1, the reference frame is in the center of the injection line, the x-axis is horizontal and the y-axis is vertical.

The participants are asked to produce grid and time converged results, t varying form 0 to 40 s. We are interested in:

$$t \qquad M(t)$$

where

$$M(t) = \int_{\Omega} \rho(\vec{r}, t) \; \mathrm{d}V$$

in the two columns ASCII file M_m, m being the participant letter which will be supplied.

- The maximum and the minimum of the pressure in the domain as functions of time,

$$\begin{array}{ll} t & P_{\max}(t) \\ t & P_{\min}(t) \end{array}$$

in the two columns ASCII files PMAX_m and PMIN_m.

- The maximum and the minimum of the density in the domain as functions of time,

$$\begin{array}{ll} t & \rho_{\max}(t) \\ t & \rho_{\min}(t) \end{array}$$

in the two columns ASCII files RHOMAX_m and RHOMIN_m.

- The maximum and the minimum of the components of the speed $\vec{w} = (u, v)^{\top}$ in the domain as function of time,

$$\begin{array}{ll} t & u_{\max}(t) \\ t & u_{\min}(t) \\ t & v_{\max}(t) \\ t & v_{\min}(t) \end{array}$$

in the two columns ASCII files UMAX_m, UMIN_m, VMAX_m and VMIN_m.

- The maximum and the minimum of the speed divergence $\mathrm{div}(\vec{w})$ and vorticity $\omega = \mathrm{rot}(\vec{w})$ in the domain as function of time,

$$\begin{array}{lc} t & \mathrm{div}(\vec{w})_{\max}(t) \\ t & \mathrm{div}(\vec{w})_{\min}(t) \\ t & \omega_{\max}(t) \\ t & \omega_{\min}(t) \end{array}$$

in the two columns ASCII files DIVMAX_m, DIVMIN_m, VORMAX_m and VORMIN_m.

- The evolution of the density, pressure, speed components, speed divergence and speed rotational on the vertical (symmetric) axis $x = 0$ at $t = 10$, 20, 30 s, 40 s as function of y

$$y \qquad \alpha(y)$$

in the two-columns ASCII files α_X0_β_m, where

$\alpha =$ RHO, P, U, V, DIV, VOR

$\beta = 10, 20, 30, 40$

speed divergence and speed rotational on the horizontal axis $y = H/3$ and $y = 2H/3$ at $t = 10$, 20, 30 s, 40 s as function of x

$$x \qquad \alpha(x)$$

in the two-columns ASCII files $\alpha_\gamma_\beta_$m, where

$\alpha =$ RHO, P, U, V, DIV, VOR

$\beta = 10, 20, 30, 40$

$\gamma =$ H3, 2H3

- A data file data_m containing

  type of approach, type of mesh, number of mesh points, time step

  CPU to reach the steady state, type of machine

  name

Remark. All the quantities must be expressed in the fundamental SI units.

3 Important dates.

15th April, 2004, *Intention to participate*

Send to the organizers a one-page abstract describing the numerical approach used to compute the problem solution. In return, the organizers will send to the participant her/his identification letter m ($m = A, B, C, \ldots$).

28th May, 2004, *Numerical solutions*

Send the required files to the organizers.

21st - 25th June, 2004, *Workshop*

Discussion of the numerical results during the workshop dedicated to Low Mach number flow benchmarks.