Special Case: Pressure Drop in Long Tunnels

In this section, we develop a set of cases to extract the implied friction factor from an FDS simulation of flow down a long tunnel (`Validation/Moody_Chart/FDS_Input_Files/tunnel_pressure_drop` series). Note that a more complete mapping of the Moody Chart is provided in the FDS Verification Guide [4], but that series uses a mean pressure gradient to force the flow, which is not a typical user case. Here we force the flow from a `VENT` and we monitor the pressure using planar averaged `DEVC`s. The tunnel section is 1.6 km (approximately one mile) with a square cross-section 10 m $\times$ 10 m. We push air from the entrance at 2 m/s and 10 m/s for sand-grain roughness heights of 0.0001 m and 0.1 m. We run two grid resolutions with uniform cells in the vertical direction corresponding to 10 and 20 cells across the tunnel height. The case matrix and friction factor results are given in Table 9.1. The target friction factor is taken from the Colebrook equation (see [22]). FDS results for the 10 and 20 resolution cases are also shown along with the max relative error as compared to the Colebrook value. The pressure profiles are shown in Fig. 9.5.

Table 9.1: Friction factors for `tunnel_pressure_drop` cases.

Case	Velocity (m/s)	Roughness (m)	f Colebrook	f FDS 10	f FDS 20	Max Rel. Error (%)
A	2	0.0001	0.011	0.011	0.011	5.2
B	2	0.1	0.038	0.037	0.039	3.5
C	10	0.0001	0.0093	0.0089	0.0085	8.8
D	10	0.1	0.038	0.037	0.039	3.2

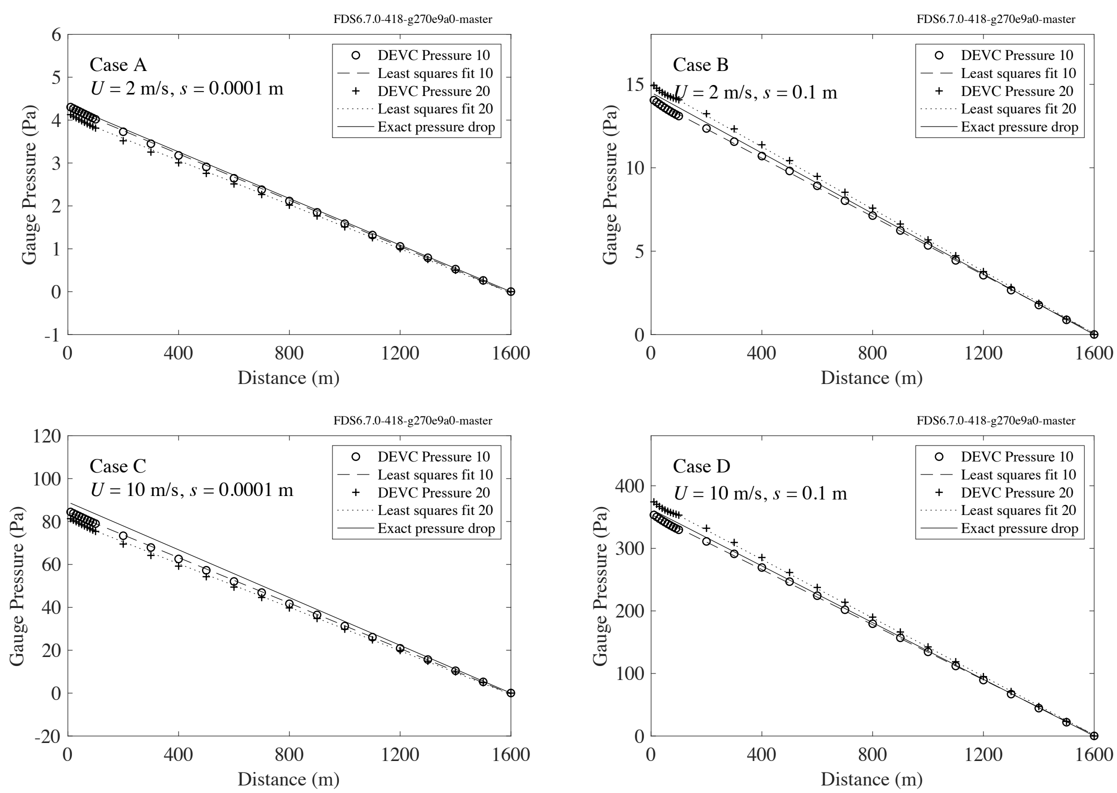

Figure 9.5: Tunnel pressure drop.

A word of caution: To achieve sensible results for tunnel cases you must take care to eliminate any mesh-to-mesh mass conservation errors and you must ensure that the time step stability criterion is never violated. For the first, you should simply use the 'GLMAT' solver. To remain stable, use CFL_VELOCITY_NORM=1, which employs a more restrictive definition of the cell velocity magnitude. Without this setting, even slight violations of the stability limits (which are precisely unknown for the Navier-Stokes equations, in general) may lead to dramatic spurious pressure oscillations.

```
&MISC CFL_VELOCITY_NORM=1/
&PRES SOLVER='GLMAT'/
```

While reasonable grid resolution is important, as you can see, the wall models in FDS are capable of giving the correct mean wall stress even at rather coarse resolution. For example, the y^+ for Case C with 10 cells is, in fact, 5000 (this is the location of the middle of the first grid cell divided by the roughness height). Note that this resolution may not be sufficient if other complexities exist and it is the user's responsibility to ensure grid convergence for their application.

Also, note that a roughness of 0.1 mm is used here only for completeness in testing the code. While this is indeed the value one finds in the literature for the roughness of concrete, a real-world tunnel may have geometric features along the walls that are unresolved by the grid and may act as roughness elements. These elements should be considered when specifying the roughness in FDS.

9.4 Parameters Related to the Background Pressure when Breaking Pressure Zones

There are two parameters on the PRES line that control iterative procedures related to the coupling of velocity and pressure. One is called RELAXATION_FACTOR and its default value is 1. When there is an error in the normal component of velocity at a solid boundary, this parameter dictates that the correction be applied in 1 time step. If its value were 0.5, the correction would be applied in 2 time steps.

A similar parameter is the PRESSURE_RELAX_TIME. It controls the rate at which the pressures in adjacent compartments are brought into equilibrium following a breach. Its default value is 1 s, meaning that equilibrium is achieved in roughly a second.