High-Fidelity CFD Verification Workshop 2024:
Sajben Transonic Diffuser

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The original version of the Sajben diffuser is ill-posed at the inlet where an inflow condition meets a no-slip wall. The Sajben diffuser problem has been modified with a slip condition at the inlet to circumvent this issue. Participants should use this version of the problem.

Steady, viscous, transonic flow: Sajben transonic diffuser

The second test problem is viscous flow through the Sajben transonic diffuser. The problem features fully turbulent flow, a normal shock, and shock-induced flow separation. It is intended to assess the ability of CFD methods to handle these features in a relatively simple two-dimensional geometry.

A. Geometry and Meshes

The Sajben diffuser geometry described in Bogar et al. [1] is modified with a slip wall region at the inlet (Figure 1). The profile of the upper wall, for $x \in [-5.44h, 8.65h]$, is

$$y(x) = \begin{cases} 1.4h & -5.44h \leq x < \ell_c \\ y_c(x) & \ell_c \leq x < 0 \\ y_d(x) & 0 \leq x < \ell_d \\ 1.5h & \ell_d < x \leq 8.65h, \end{cases}$$
(1)

where

$$y_c(x) = \frac{\alpha_c \cosh \zeta_c(x)}{(\alpha_c - 1) + \cosh \zeta_c(x)}, \qquad y_d(x) \frac{\alpha_d \cosh \zeta_d(x)}{(\alpha_d - 1) + \cosh \zeta_d(x)}$$
(2)

and

$$\zeta_c(x) = \frac{C_1(x/\ell_c)(1 + C_2(x/\ell_c))^{C_3}}{(1 - x/\ell_c)^{C_4}}, \qquad \zeta_d(x) = \frac{D_1(x/\ell)_d}{(1 - x/\ell_d)^{D_4}},$$
(3)

with parameters $\alpha_c = 1.4114$, $\ell_c = -2.598h$s, $C_1 = 0.81$, $C_2 = 1.0$, $C_3 = 0.5$, $C_4 = 0.6$, $\alpha_d = 1.5$, $\ell_d = 7.216h$, $D_1 = 2.25$, $D_4 = 0.6$, and $h = 44$mm.

B. Governing equations

The compressible Navier-Stokes equations should be simulated using the perfect gas assumption (e.g. single species, constant specific heat) and Sutherland's Law for viscosity. The flow should be simulated both without a turbulence model and with the negative Spalart-Allmaras turbulence model [2]. The flow conditions are shown in Table 1. The inflow and outflow boundaries can use the condition that is most appropriate for the flow solver used. The viscous wall boundary condition is an adiabatic, no-slip condition.

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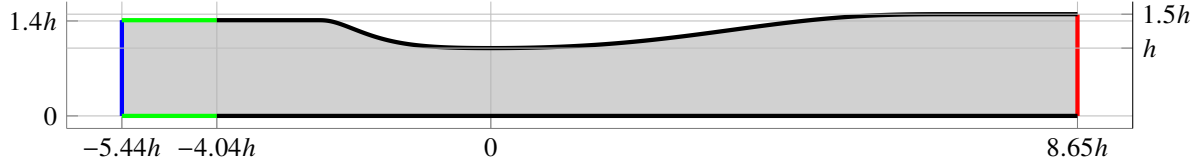
Fig. 1   Geometry of Sajben diffuser. Boundary conditions: subsonic inflow (——), slip wall (——), viscous wall (——), and subsonic outflow (——).

Table 1   Flow conditions for Sajben diffuser problem

Specific heat ratio, γ	1.4
Mach Number, M_∞	0.4
Inlet total pressure	19.58 psi
Inlet total temperature	278 K
Outlet static pressure	14.10 psi
Freestream Reynolds Number, Re_∞	7.0×10^5 m^{-1}
Prandtl Number, Pr	0.71

C. Mandatory campaign

All participants will simulate this flow on a sequence of discretizations. For each mesh and turbulence model, participants should report the x-directed force integrated over the top and bottom walls, the flow separation location, and the static pressure profile along the top and bottom walls. Furthermore, a succinct description of the numerical method used should be provided as well as algorithmic details (e.g., how is the flow initialized, if/how is adaptation incorporated). Finally, the nonlinear residual convergence and work units should be reported.

References

[1] Bogar, T. J., Sajben, M., and Kroutil, J. C., "Characteristic frequencies of transonic diffuser flow oscillations," *AIAA Journal*, Vol. 21, No. 9, 1983, pp. 1232–1240. doi: 10.2514/3.8234.

[2] Allmaras, S., and Johnson, F., "Modifications and clarifications for the implementation of the Spalart-Allmaras turbulence model," *Seventh International Conference on Computational Fluid Dynamics (ICCFD7)*, Vol. 1902, 2012.