Comparative estimation of QGDFoam solver accuracy for inviscid flow around a cone

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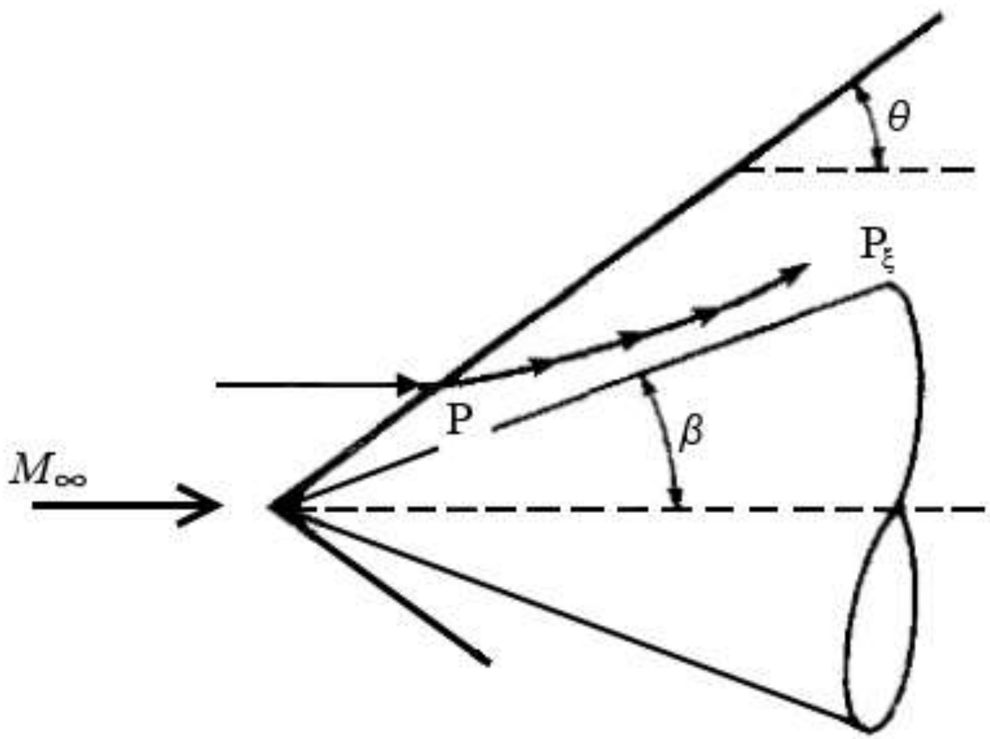
OpenFOAM

- OpenFOAM: Open Source Field Operation And Manipulation
- C++ toolbox for the development of customized numerical solvers, and pre-/post-processing utilities for the solution of continuum mechanics problems, including computational fluid dynamics (CFD)

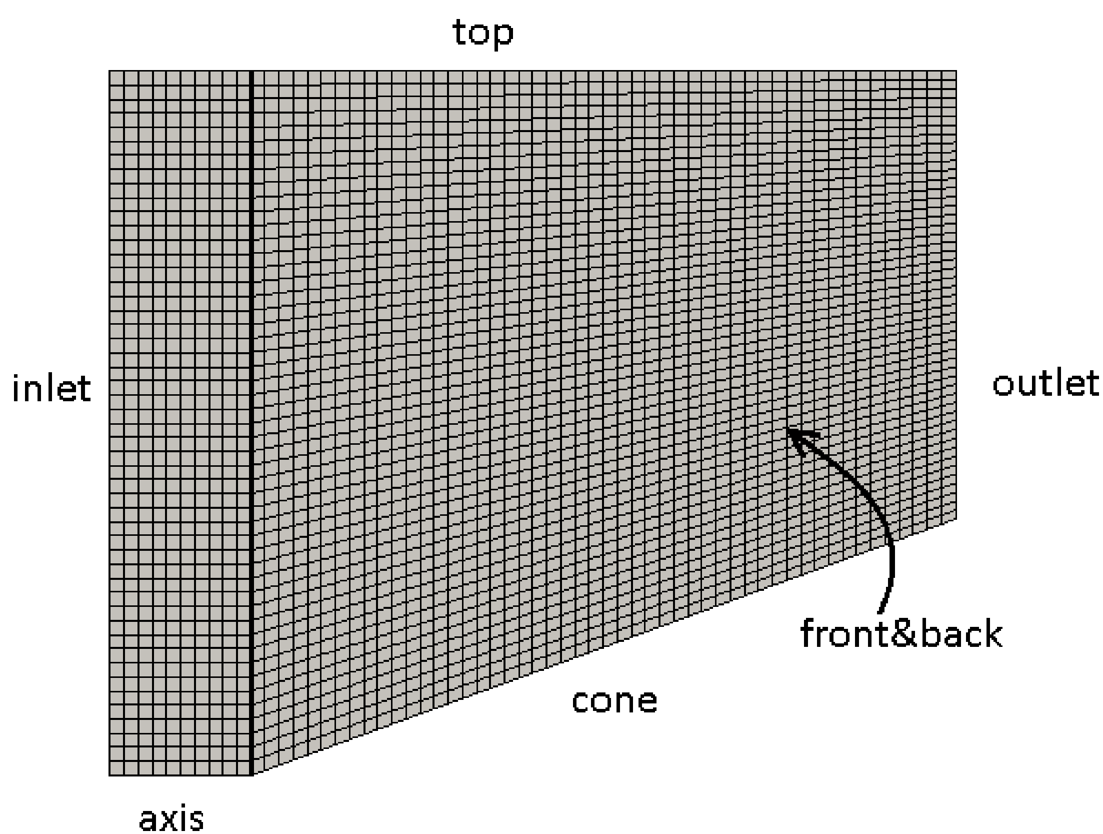
Solvers

- rhoCentralFoam (central-upwind scheme of Kurganov and Tadmor)
- sonicFoam (PIMPLE algorithm — combination PISO and SIMPLE algorithms)
- pisoCentralFoam (hybrid implementation)
- QGDFoam (quasi-gas dynamic equation)

Flow scheme



Computational field geometry

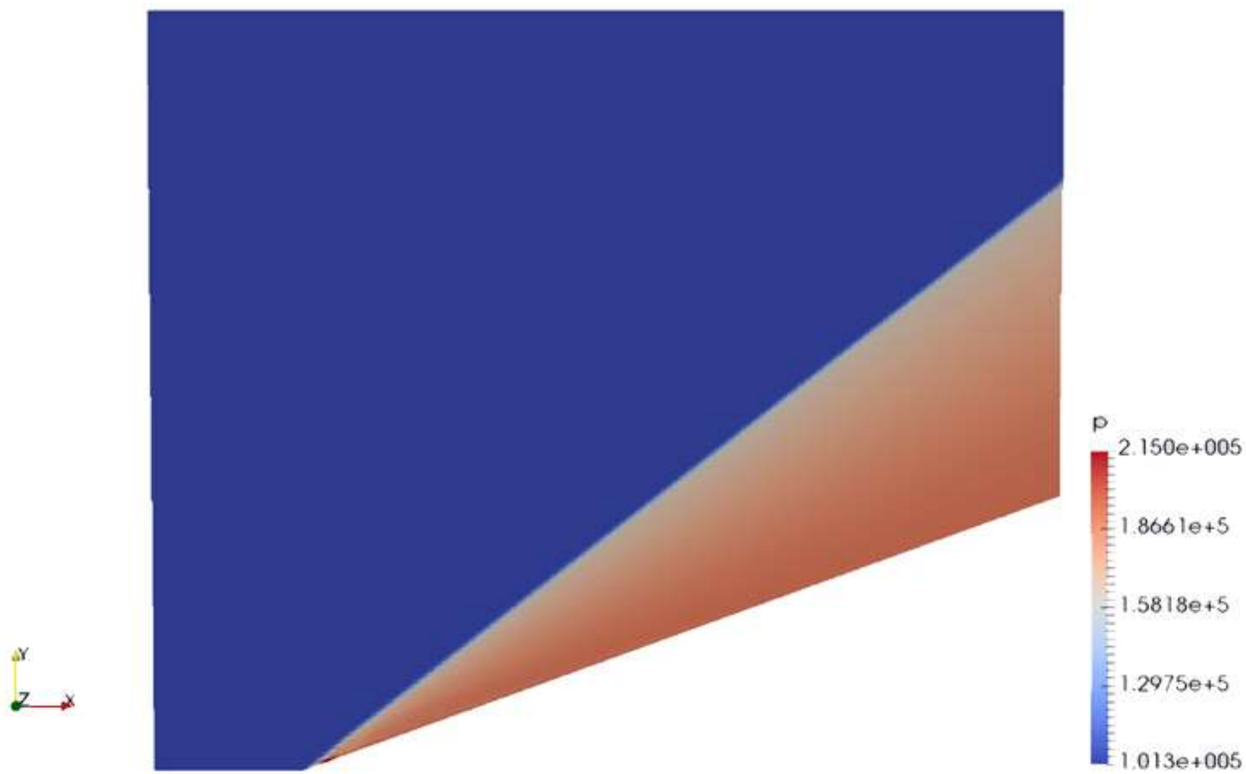


Initial and boundary conditions

	P	T	U
inlet	101325	300	(694.5 – 2430.75, 0, 0)
outlet	zeroGradient	zeroGradient	zeroGradient
axis	empty	empty	empty
top	zeroGradient	zeroGradient	zeroGradient
cone	zeroGradient	zeroGradient	slip
front&back	wedge	wedge	wedge

Thermophysical properties		
Gas	Molar weight	Cp
Air	28.96	1004

Pressure field for steady flow, M=2



QGDFoam solver

QGDFoam uses a quasi-gas dynamic system of gas dynamics equations. We need smoothing parameter α for dissipation control.

We used parameter $\alpha = 0.1$, unless otherwise stated.

Solvers comparison

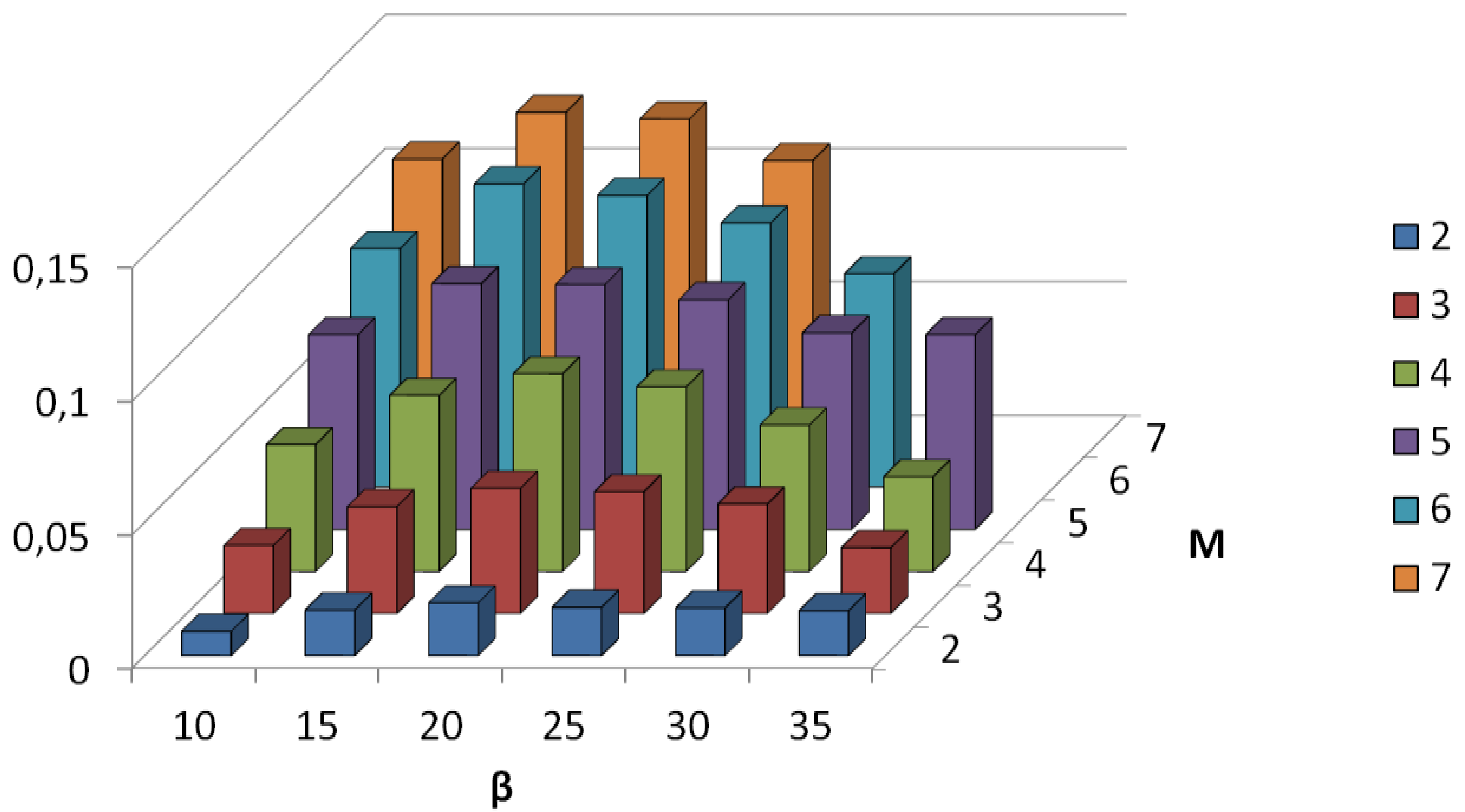
We used an analog of the L_2 norm:

$$\sqrt{\sum_m \left| y_m - y_m^{exact} \right|^2 V_m} \Bigg/ \sqrt{\sum_m \left| y_m^{exact} \right|^2 V_m}$$

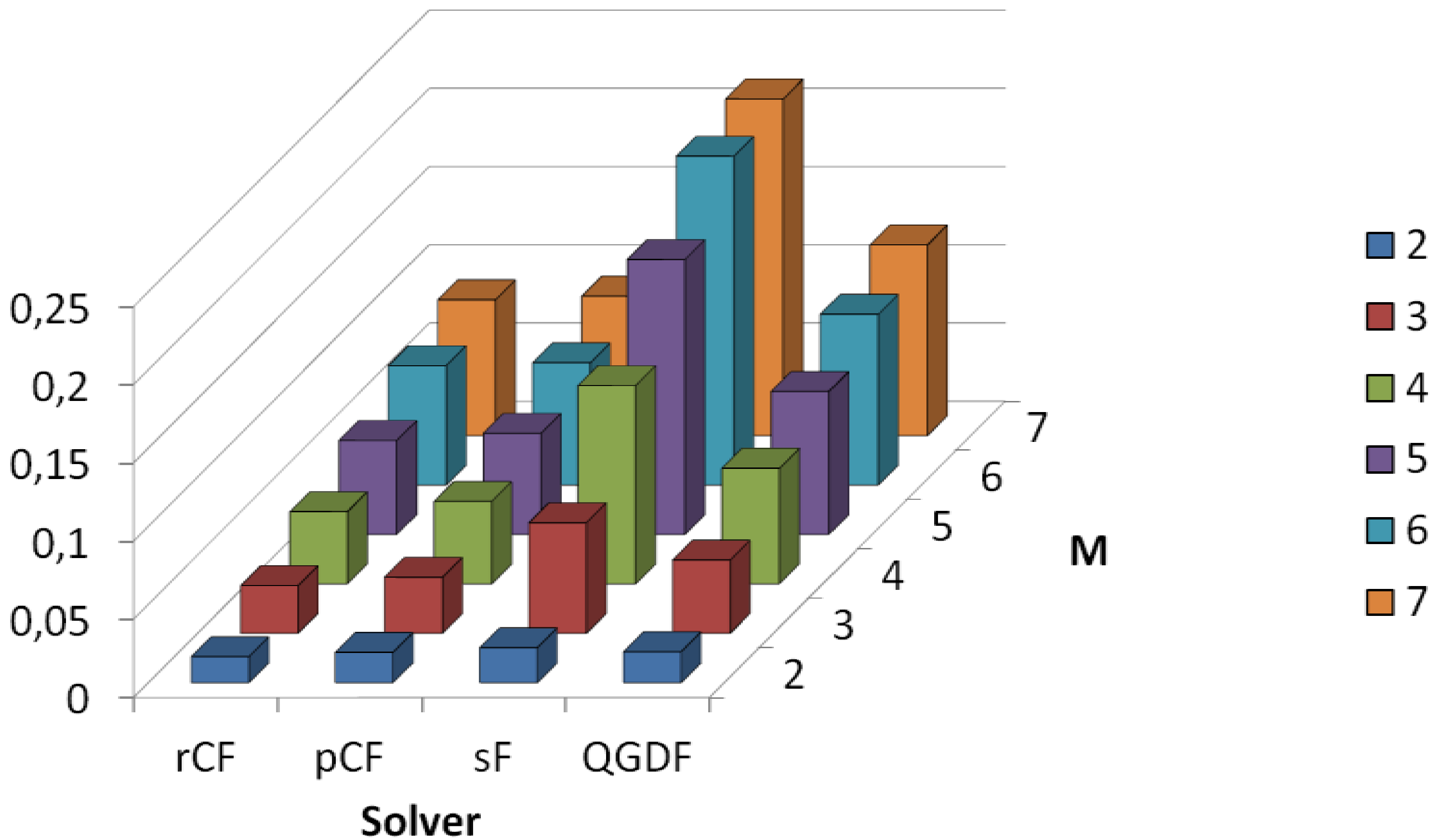
y_m is the pressure p in the cell, V_m is the cell volume for the cone half-angle β = 10–35 ° in steps of 5° and the Mach numbers M = 2–7.
The values y_m^{exact} are obtained by interpolation table values of (Babenko et al., 1964).

Babenko, K.I., Voskresnskii, G.P., Lyubimov A.N. and Rusanov V.V.
Three dimensional flows of an ideal gas past smooth bodies, Izdat. Nauka, Moscow, 1964

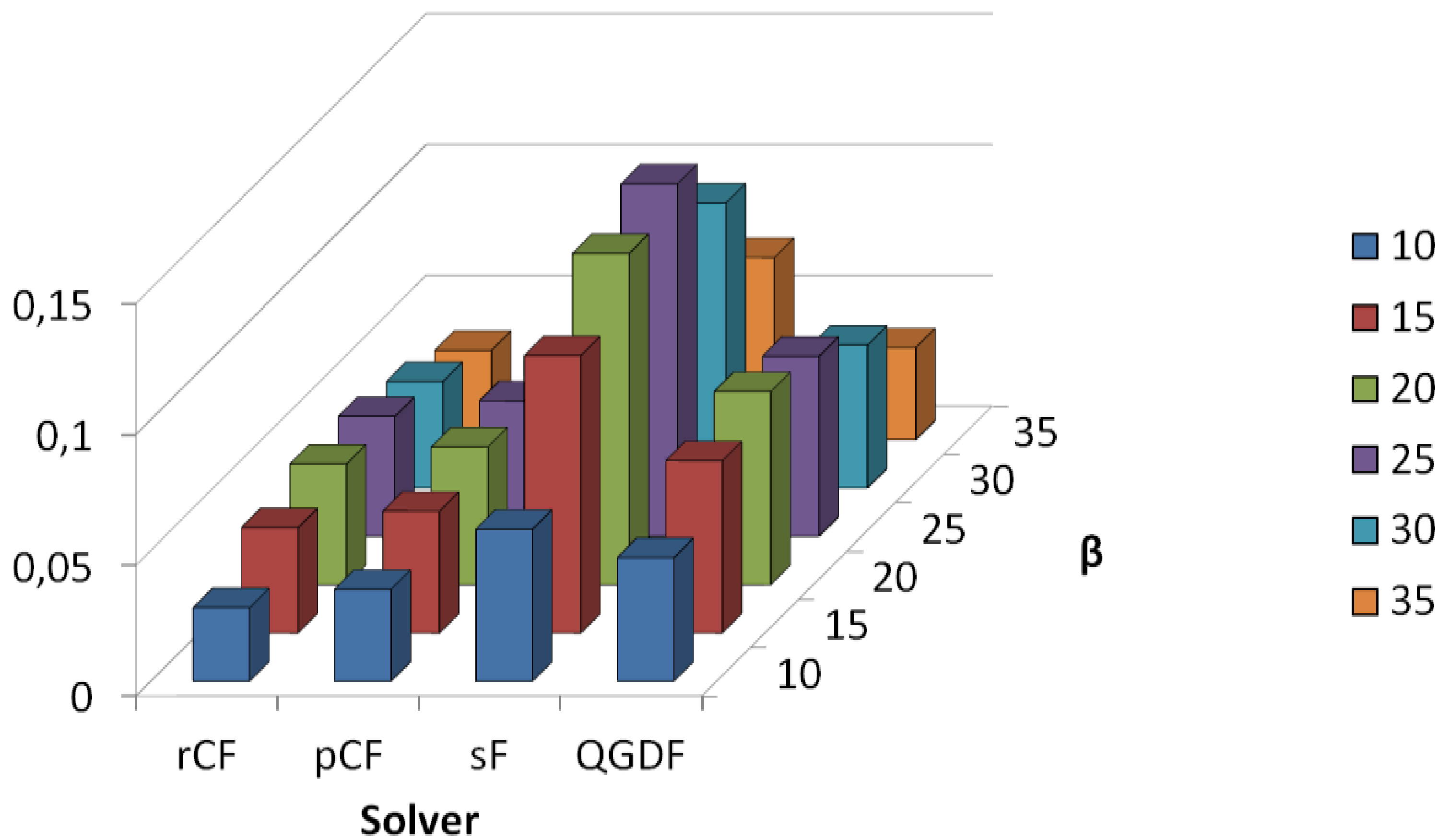
Results: pressure error for QGDFoam α=0.1



Results: pressure error for cone half-angle β=20°



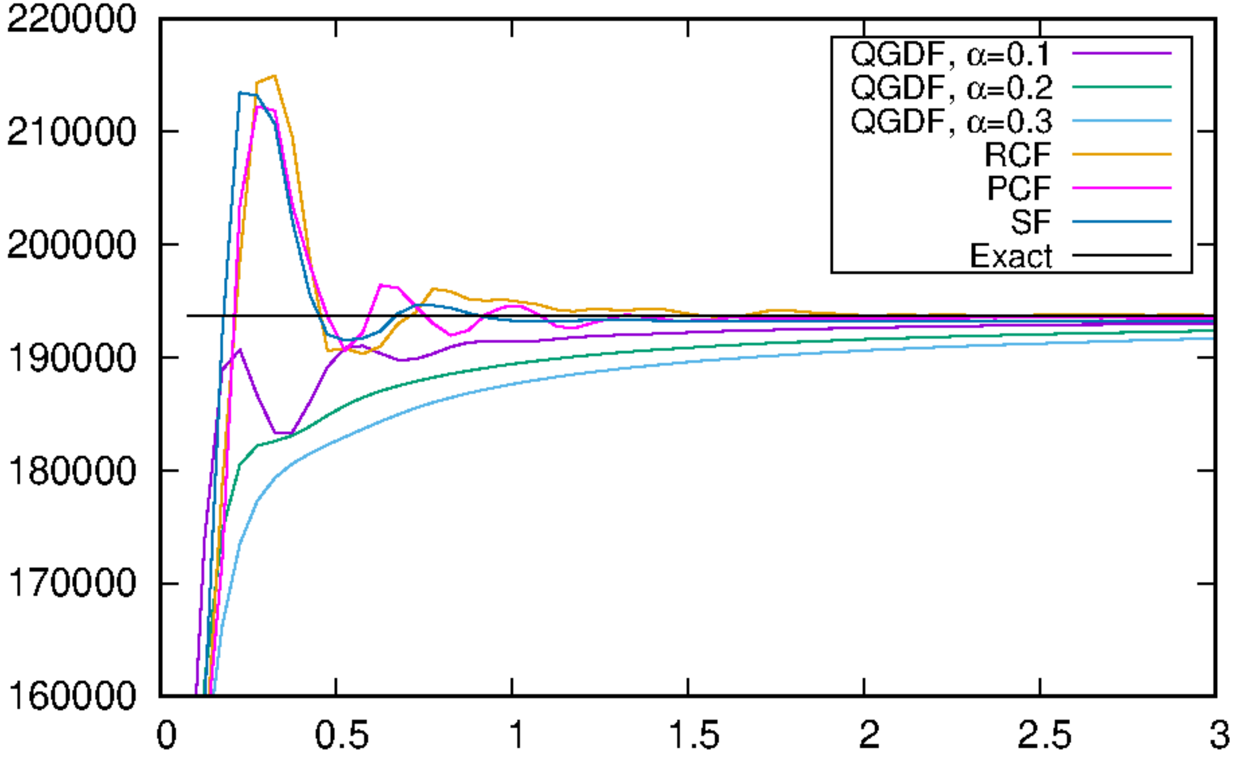
Results: pressure error for Mach number M=4



Pressure error, cone half-angle β=20°

Mach number	**QGDF $\alpha = 0.1$**	**QGDF $\alpha = 0.2$**	**QGDF $\alpha = 0.3$**
2	**0.019721**	0.024177	0.029465
3	0.046782	**0.040795**	0.045105
4	0.073927	**0.059385**	0.060644
5	0.091478	0.071973	**0.071549**
6	0.109155	0.086195	**0.083939**
7	0.122003	0.097197	**0.093897**

Pressure distribution along the cone



M=2, half-angle β = 20°

Bondarev et al. (Scientific Visualization, 2013)
Bondarev, Galaktionov (Int. Journal of Modeling, Simulation and Scientific Computing, 2013)
Bondarev, Galaktionov (Programming and Computer Software, 2015)

That’s all!

Questions?

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