Centrifugal buoyancy test case in closed cavity Ra=10^7

Test case

Compare Code_Saturne LES, ANSYS CFX LES, Hydra DNS and Semtex DNS.
2D mesh node number 159984, 101 nodes from hub to shroud, 800 nodes in tangential direction.
The max y^+ in the domain is below 0.8, wall-resolved LES.

Reference

[1] Gao, F., Chew, J.W. and Pitz, D.B., 2019. Numerical study of buoyancy-driven flow in a closed rotating annulus. GPPS-BJ-2019-0034.

[2] Bohn, D., Deuker, E., Emunds, R. and Gorzelitz, V., 1995. Experimental and theoretical investigations of heat transfer in closed gas-filled rotating annuli.

[3]

Nomenclature

$$r^* = \frac{r-a}{b-a} \qquad Nu = \frac{\bar{Q}\ln(b/a)}{2\pi d\lambda(T_b - T_a)}$$

$$T_{ave}{}^* = \frac{\bar{T}-T_a}{T_b-T_a} \qquad T_{rms}{}^* = \frac{\sqrt{\overline{T'T'}}}{T_b-T_a}$$

$$v_{\theta,rms} = \sqrt{\overline{v_\theta{}'v_\theta{}'}} = \sqrt{\overline{v_\theta v_\theta} - \overline{v_\theta}\times\overline{v_\theta}} \qquad v_{r,rms} = \sqrt{\overline{v_r{}'v_r{}'}} = \sqrt{\overline{v_r v_r} - \overline{v_r}\times\overline{v_r}}$$

Converge condition

The time-averaged data was collected in 130 revolutions after the solution converged. The energy balance was checked, which showed a good convergence.

$$\Omega \times M_{shroud} + Q_{shroud} = \Omega \times M_{hub} + Q_{hub}$$

$$M = \oiint r \times \bar{\tau}_{tangential}\, dS$$

$$Q = \oiint \bar{q}\, dS$$

Solver	Code_Saturne LES	ANSYS CFX LES
Energy balance error	0.0540%	7.64%

Results

Instantaneous field

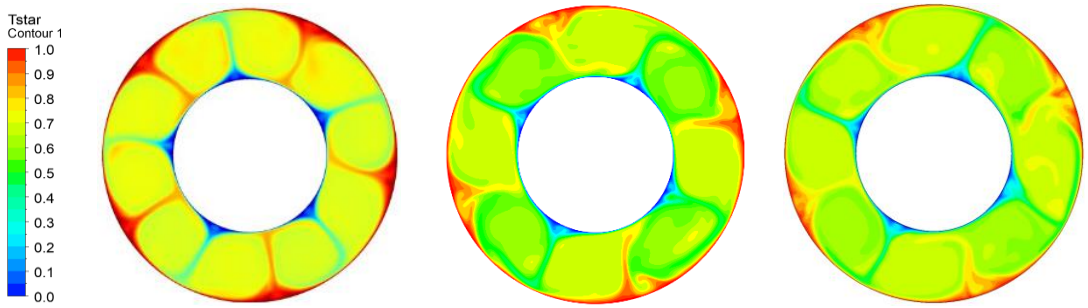

Fig 1. Instantaneous temperature contour

Shroud heat transfer

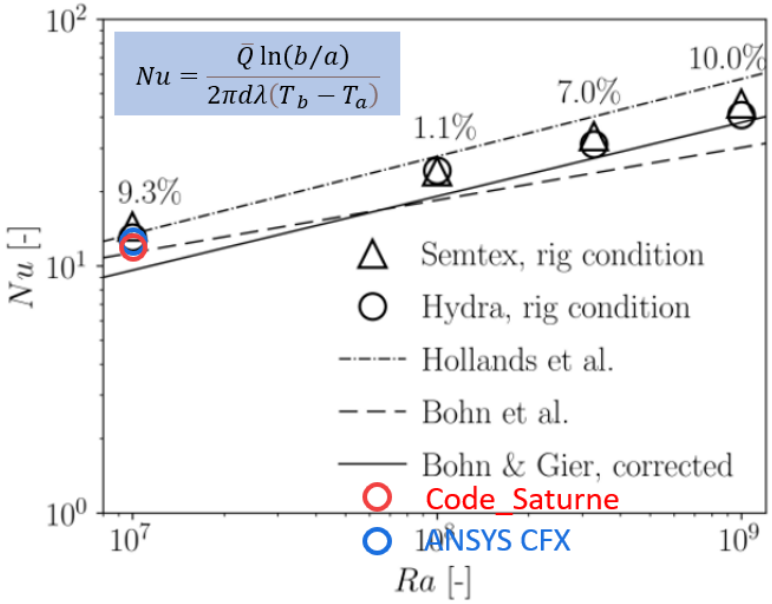

Fig 2. Time-averaged Nusselt number on shroud

Solver	Code_Saturne	ANSYS CFX	Semtex		Hydra	
2D/3D	2D	2D	2D	3D	2D	3D
Numerical method	LES	LES	DNS	DNS	DNS	LES
Compressible or not	incompressible	compressible	incompressible		compressible	

Density treatment	Ideal gas law	Ideal gas law	Boussinesq		Ideal gas law	
Nu	11.80	12.87	13.97 roughly	11.27	13.06 roughly	10.89

Thermal boundary layer (compare with Hydra and Semtex)

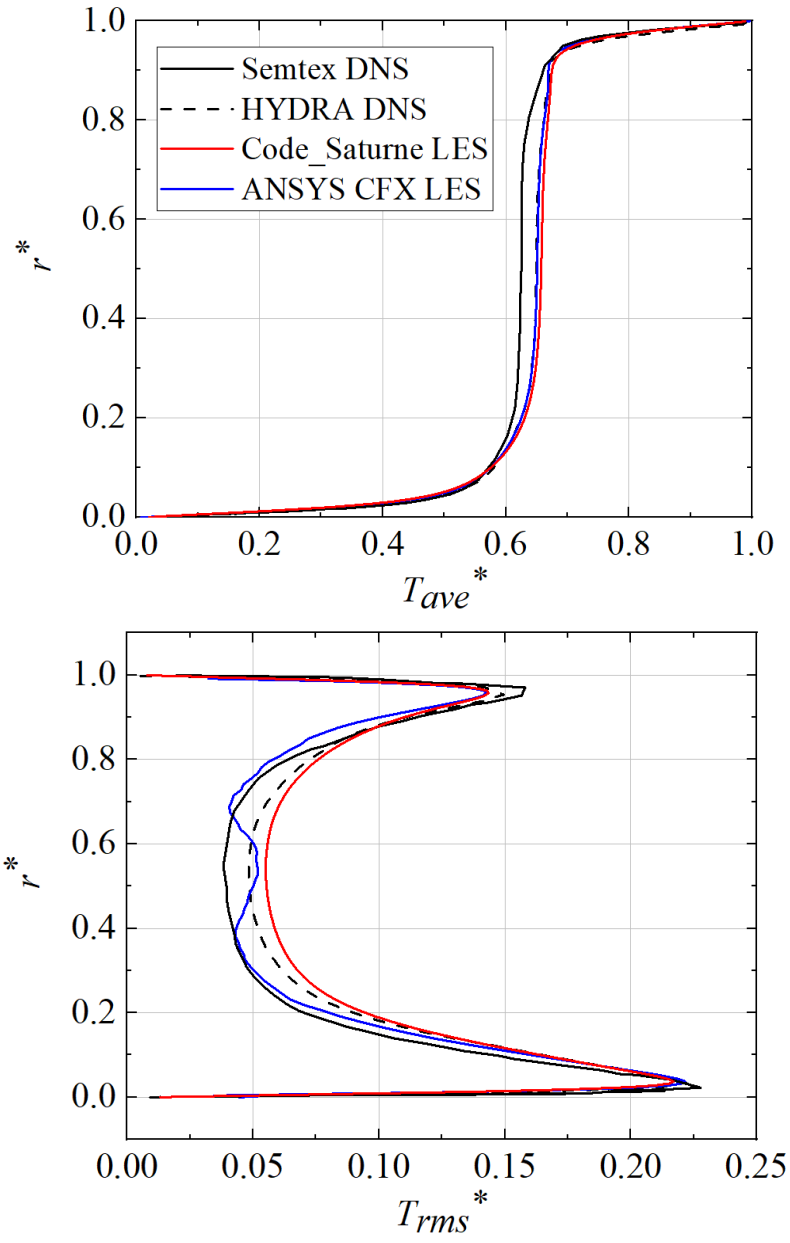

Fig 3. First and second order statistic of temperature

Kinematic boundary layer (compare with Hydra)

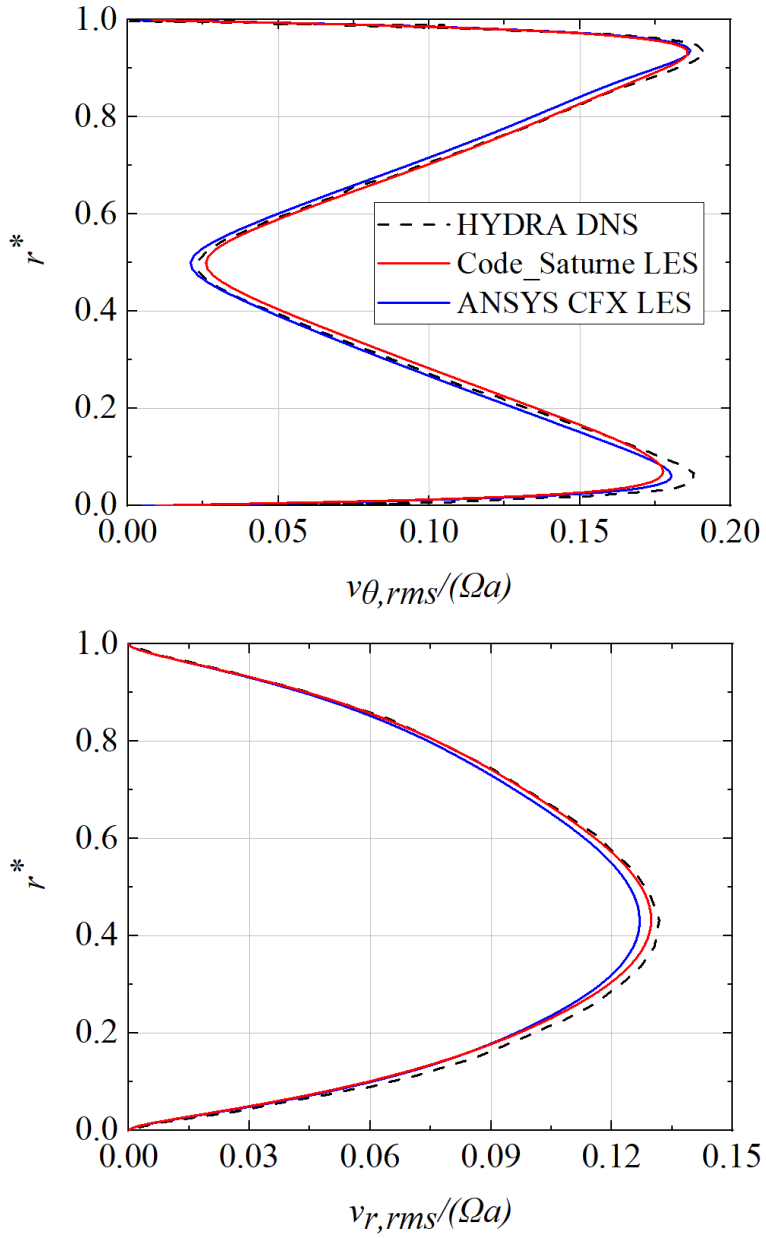

Fig 4. Second order statistic of tangential and radial velocity