LES and DES of vortex breakdown in highly swirling flow

Ardalan Javadi

Supervised by: Prof. Nilsson,

Applied Mechanics/Fluid Dynamics,
Chalmers University of Technology,
Gothenburg, Sweden

2014-11-12

Dellenback Abrupt Expansion(DAE)

1. Advanced Numerical Study of DAE
   - The DAE test case and operating conditions
   - Numerical setup and computational domain
   - Results

Dellenback Abrupt Expansion(DAE)

1. Advanced Numerical Study of DAE
   - The DAE test case and operating conditions
   - Numerical setup and computational domain
   - Results

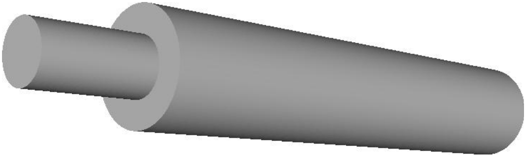
Dellenback Abrupt Expansion(DAE)

1. Advanced Numerical Study of DAE
    - The DAE test case and operating conditions
    - Numerical setup and computational domain
    - Results

Dellenback Abrupt Expansion(DAE)

1. Advanced Numerical Study of DAE
   - The DAE test case and operating conditions
   - Numerical setup and computational domain
   - Results

Test case and operating conditions

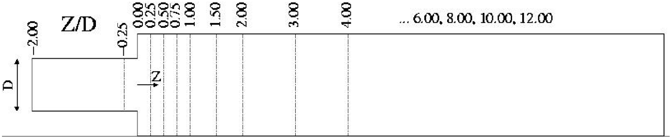


Inlet diameter	$D_{in} = 50.78mm$
Outlet diameter	$D_{out} = 98.5mm$
Expansion ratio	$D_{out} / D_{in} = 1.94$
Inlet length	$2 * D_{in}$
Outlet length	$10 * D_{in}$

Test case and operating conditions

$$Re = \frac{U_{b,in} D_{in}}{\nu} = 3.0 \times 10^4, \quad 6.0 \times 10^4, \quad 10^5$$

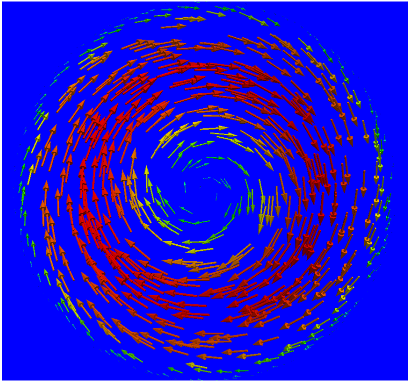
$$Sr = \frac{\int_0^{R_{in}} V_\theta V_z r^2 dr}{R_{in} \int_0^{R_{in}} V_z^2 r dr} \Big|_{z/D_{in}=-2.00} = 0.6, \quad 0.74, \quad 0.98, \quad 1.16, \quad 1.23$$



Dellenback, P.A., Metzger, D.E., Neitzel, G.P., 1988. Measurements in turbulent swirling flow through an abrupt axisymmetric expansion. AIAA J. 26 (6), 669_681.

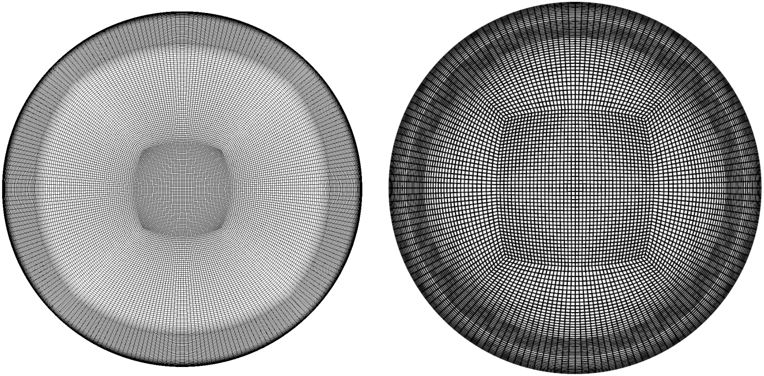
Boundary condition

Inlet steady boundary condition for velocity



ν_{sgs} is considered as constant.

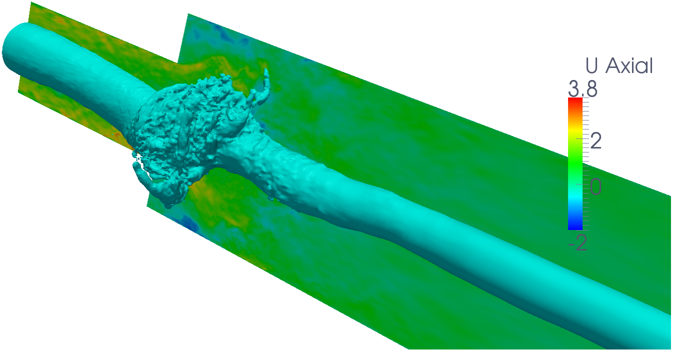
O-grid configuration



8.6×10^6 , 10.2×10^6 and 12.6×10^6 *cells*

Two O-grids and three numerical schemes (first and linear order upwind) and linear limited (TVD) are examined.

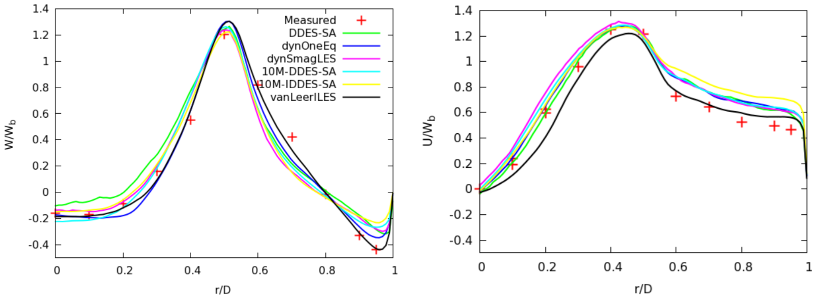
General flow configuration



Iso-surface of pressure $Re = 10^5, \quad Sr = 1.23$

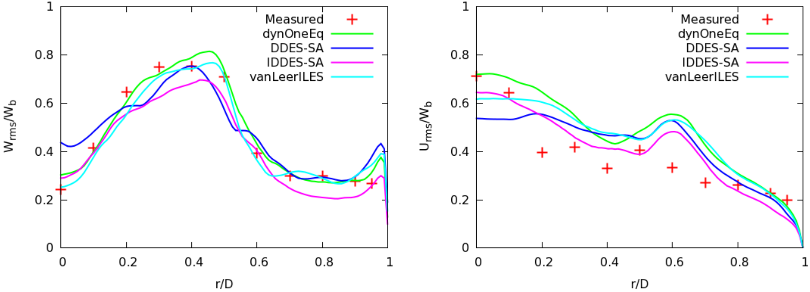
16 equidistant frames with Δt= 0.002 sec

Comparison of mean velocity



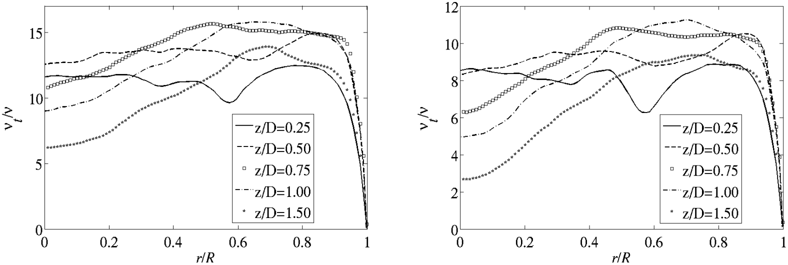
$$Re = 10^5, \quad Sr = 1.23, \quad \Delta t = 2 \times 10^{-5}, \quad Max \quad CFL = 1.3, \text{left:} \quad \overline{U}, \text{right:} \quad \overline{W}$$

Comparison of velocity rms



$Re = 10^5, \quad Sr = 1.23$, left: $\sqrt{\overline{u'^2}}$, right: $\sqrt{\overline{w'^2}}$

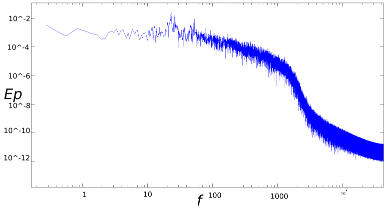
Comparison of energy spectrum

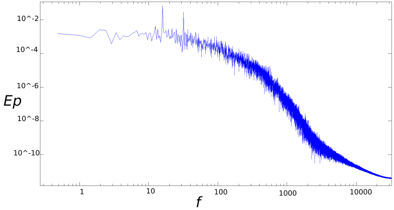


SAS viscosity ratio, ν_t/ν

left: $Re = 10^5, \quad Sr = 1.23$ right: $Re : 6.0 \times 10^4, \quad Sr = 1.16$

Comparison of energy spectrum





Energy spectrum left:

$Re = 10^5, \quad Sr = 1.23$ right: $Re : 6.0 \times 10^4, \quad Sr = 1.16$

Conclusion

Conclusion

- Comprehensive understanding of vortex breakdown is achieved.

Conclusion

- Comprehensive understanding of vortex breakdown is achieved.
- Hybrid RANS-LES is robust for swirling flows.

Conclusion

- Comprehensive understanding of vortex breakdown is achieved.
- Hybrid RANS-LES is robust for swirling flows.
- SAS captures more detailed coherent structures than LES with a coarse resolution.

Reference

- Ardalan Javadi, Håkan Nilsson, 2014, LES and DES of Strongly Swirling Turbulent Flow through a Suddenly Expanding Circular Pipe, Computers & Fluids, doi:http://dx.doi.org/10.1016/j.compfluid. 2014.11.014
- Ardalan Javadi, Håkan Nilsson, 2014, A comparative study of scale-adaptive and large-eddy simulations of highly swirling turbulent flow through an abrupt expansion, 27th IAHR Symposium on Hydraulic Machinery and Systems, Montreal, Canada

Acknowledgments

VATTENFALL
Statkraft
Fortum
Jämtkraft
e.on
Jönköping Energi
Umeå Energi
Kraft
MälarEnergi
ENERGI
HOLMEN ENERGI
LINDE ENERGI AB
SVC
SVENSKT VATTENKRAFTCENTRUM
SWECO
SveMin
ANDRITZ Hydro
STATOIL
VG Power
WSP
LULEÅ TEKNISKA UNIVERSITET
CHALMERS
KTH
UPPSALA UNIVERSITET
Energimyndigheten
SVENSKA KRAFTNÄT
ELFORSK