Aerodynamic and aeroacoustic simulation arround a NACA0018 at various angles of attack

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Introduction

Motivation of this work

- We would like to catch aerodynamic coefficient and pressure distribution over a NACA0018 at multiple angles of attack
- we would like to reproduce separation and reattachment
- In a second time we want to simulate the noise generated by the flow.

Set up

- 0° NACA0018 set up :
  - chord = 0.08[m]
  - $\rho_0 = 1.225[kg/m^3]$, $P_0 = 101300[Pa]$
  - $U_0 = 30[m/s]$
  - $Tu = 1\%$,
  - $\frac{\mu}{\mu_t} = 0.1$
  - $tref = \frac{chord}{U_0}$
  - Structured mesh non dimensional $y_w^+ = 1$ 1.4M Nodes.

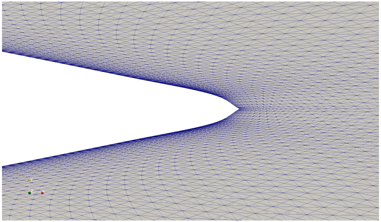


Figure – Trailing edge meshes.

Name	Mesh size	y_w^+	$\overline{C}_D$	$\overline{C}_L$
Fine mesh				
DDES $k-\varepsilon$	1.8M	1	0.018	0.02
DDES $k-R$	1.8M	1	0.015	0.02
DDES $k-\varepsilon$/DVMS	1.8M	1	0.018	0.03
DDES $k-R$/DVMS	1.8M	1	**0.015**	**0.03**
Measurements				
Du [1]			0.01	0.02
Boutilier [2]			-	0.04

Table – Coefficients aérodynamique à 0° d'incidence pour un nombre de Reynolds $1.6 \times 10^{\mathbf{5}}$.

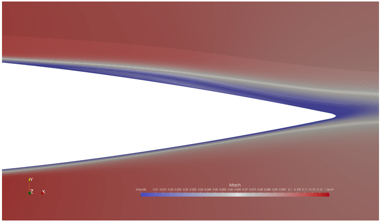


Figure – Recirculation bubble using DDES $k-\varepsilon$/DVMS.

1. **LDu2016**.
2. **Boutilier2012**

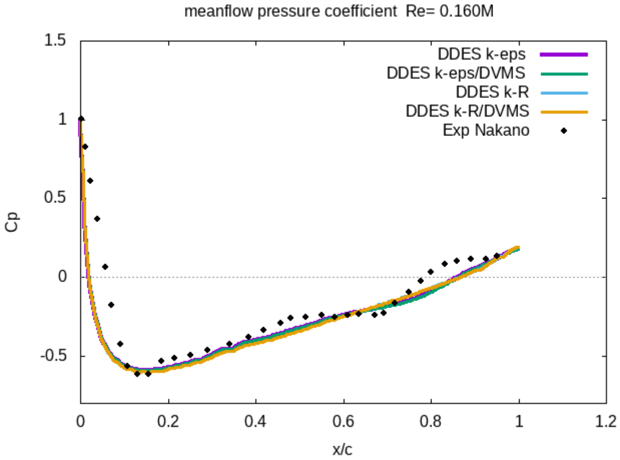


Figure – Meanflow pressure coefficient distribution over NACA0018 airfoil at 0°.

Aeroacoustic 0 AOA

- Sound Pressure Level $SPL = 10\log_{10}\left(\frac{\overline{p}^2 - \overline{p^2}}{p_{ref}^2}\right)$ $[dB]$, where $p_{ref} = 2 \times 10^{-5}[Pa]$

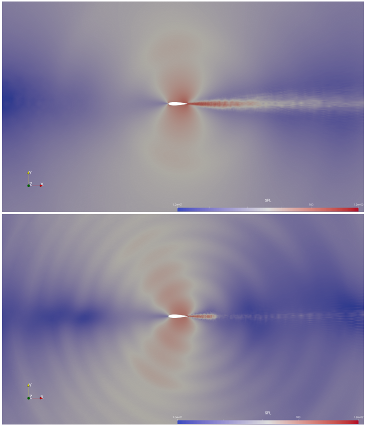


Figure – Sound pressure level in [dB], DDES/DVMS on left, DDES k-R /DVMS on right.

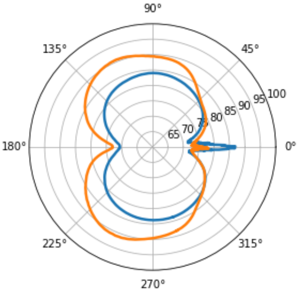
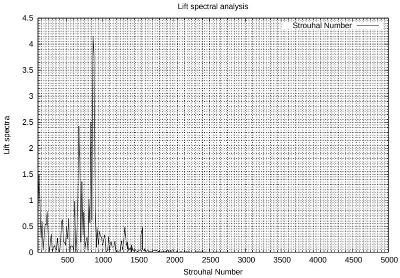


Figure – Directivity graph of SPL, along r=5.

- Spectrum analysis : Experimental data given by Nakano 2000[Hz] for $0^\circ - 6^\circ$ AOA.



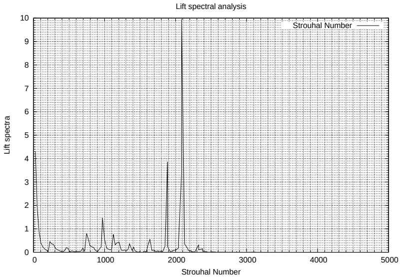


Figure – Spectrum Analysis of the lift coefficient fluctuation, DDES $k-\varepsilon$/DVMS on left, DDES $k-R$/DVMS on right.

Set up

- NACA0018 6° set up :
  - chord = 0.08[m]
  - AOA = 6°
  - $\rho_0 = 1.225[kg/m^3]$, $P_0 = 101300[Pa]$
  - $U_0 = 30[m/s]$
  - $Tu = 1\%$,
  - $\frac{\mu}{\mu_t} = 0.01$
  - $tref = \frac{chord}{U_0}$
  - Unstructured mesh non dimensional $y_w^+ = 1$ 1.4M Nodes.

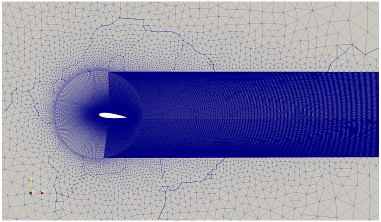


Figure – Trailing edge meshes.

Name	Mesh size	y_w^+	$\overline{C}_D$	$\overline{C}_L$
Fine mesh				
DDES $k-\varepsilon$	1.4M	1	0.02	0.47
DDES $k-R$	1.4M	1	0.02	0.52
DDES $k-\varepsilon$/DVMS	1.4M	1	0.03	0.57
DDES $k-R$/DVMS	1.4M	1	0.02	0.53
Measurements				
Du [3]			0.03	0.65
Boutilier [4]			-	0.71

Table – Bulk coefficient of the flow around a circular cylinder at Reynolds number 1M, $\overline{C}_D$ holds for the mean drag coefficient, $\overline{C}_L$ is the root mean square of lift time fluctuation.

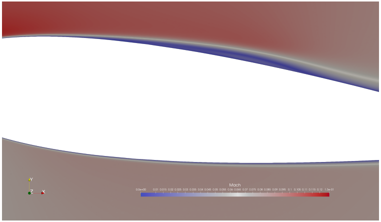


Figure – Recirculation bubble using DDES $k-\varepsilon$/DVMS.

3. LDu2016.

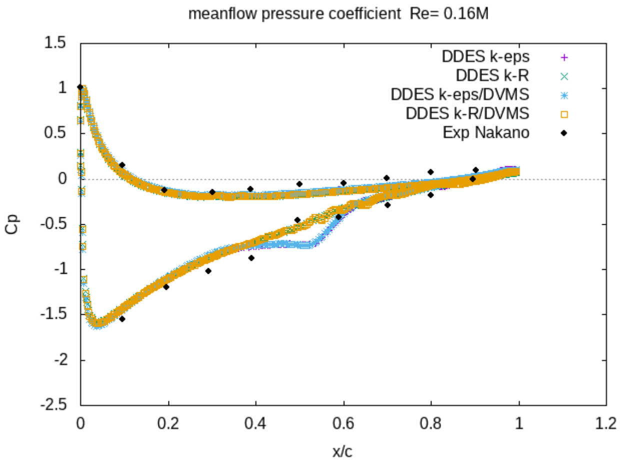


Figure – Meanflow pressure coefficient distribution arround body airfoil at 6° incidence.

Aeroacoustic 6 AOA

- Sound Pressure Level $SPL = 10\log_{10}\left(\frac{\overline{p^2} - \overline{p}^2}{p_{ref}^2}\right)$ $[dB]$, where $p_{ref} = 2 \times 10^{-5}[Pa]$

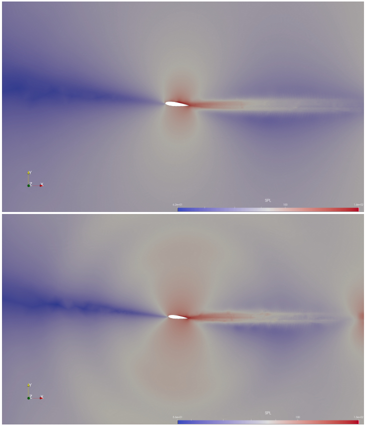


Figure – Sound pressure level in [dB], DDES/DVMS on left, DDES k-R /DVMS on right.

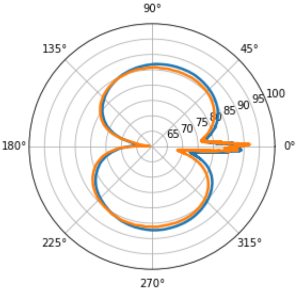


Figure – Directivity graph of SPL, along r=5.

- Spectrum analysis : Experimental data given by Nakano 2000[Hz] for $0 - 6^{\circ}$ AOA.

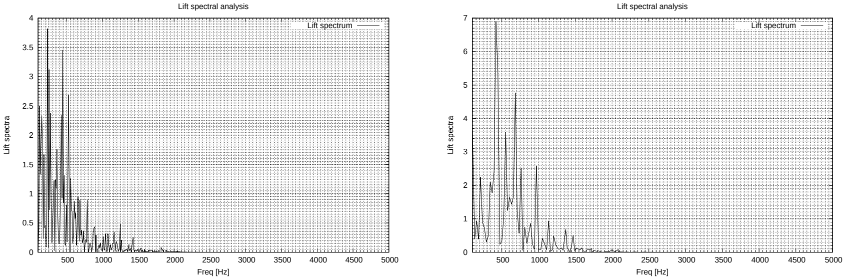


Figure – Spectrum Analysis of the lift coefficient fluctuation, DDES $k - \varepsilon$/DVMS on left, DDES $k - R$/DVMS on right.

Set up

- NACA0018 15° set up :
  - chord = 0.08[m]
  - AOA = 15°
  - $\rho_0 = 1.225[kg/m^3], P_0 = 101300[Pa]$
  - $U_0 = 30[m/s]$
  - $Tu = 1\%$,
  - $\frac{\mu}{\mu_t} = 0.01$
  - $tref = \frac{chord}{U_0}$
  - Unstructured mesh non dimensional $y_w^+ = 1$, 1.4M Nodes.

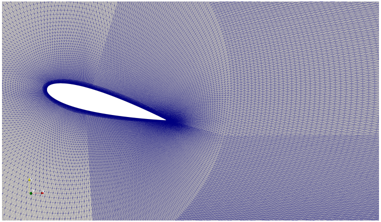


Figure – Trailing edge meshes.

Name	Mesh size	y_w^+	$\overline{C}_D$	$\overline{C}_L$
Fine mesh				
DDES $k-\varepsilon$	1.4M	1	0.22	1.02
DDES $k-R$	1.4M	1	0.25	0.77
DDES $k-\varepsilon$/DVMS	1.4M	1	0.21	0.99
DDES $k-R$/DVMS	1.4M	1	0.26	0.73
Measurements				
Du et al [5]			0.20	0.50
Boutilier [6]			-	0.51

Table – Bulk coefficient of the flow around a circular cylinder at Reynolds number 1M, $\overline{C}_D$ holds for the mean drag coefficient, $\overline{C}_L$ is the root mean square of lift time fluctuation.

5. **LDu2016**.
6. **Boutilier2012**.

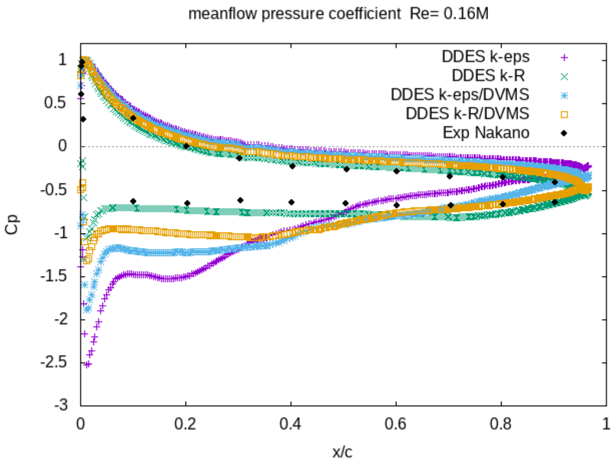


Figure – Meanflow pressure coefficient arround body airfoil.

Aeroacoustic 15 AOA

- Sound Pressure Level $SPL = 10\log_{10}\left(\frac{\overline{p}^2-\overline{p^2}}{p_{ref}^2}\right)$ $[dB]$, where $p_{ref} = 2 \times 10^{-5} [Pa]$

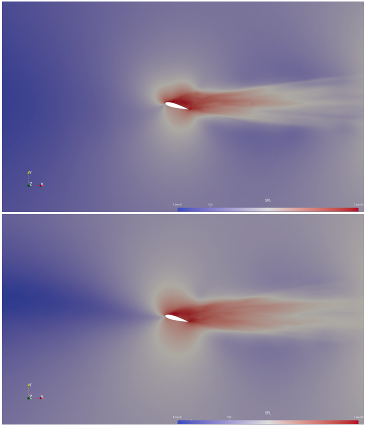


Figure – Sound pressure level in [dB], DDES/DVMS on left, DDES k-R /DVMS on right.

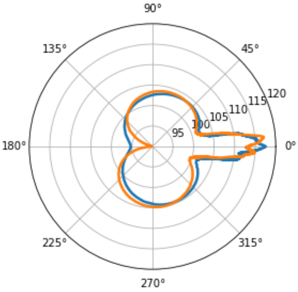


Figure – Directivity graph of SPL, along r=5.

- Spectrum analysis : Experimental data given by Nakano there is no hight frequency tonal peak at 15° AOA.

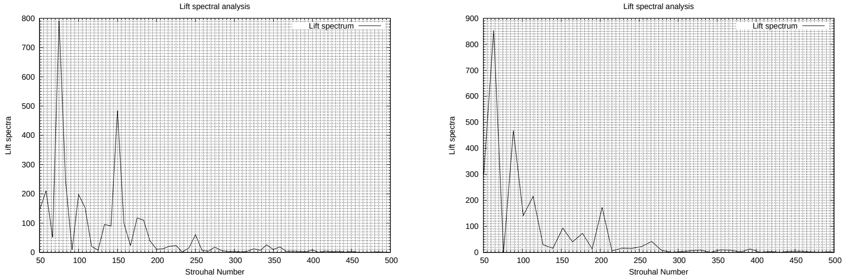


Figure – Spectrum Analysis of the lift coefficient fluctuation, DDES $k-\varepsilon$/DVMS on left, DDES $k-R$/DVMS on right.