SmartAnswer – Investigations of stream-wise Rod Vortex Generators effect on noise generated by boundary layer separation on blades.

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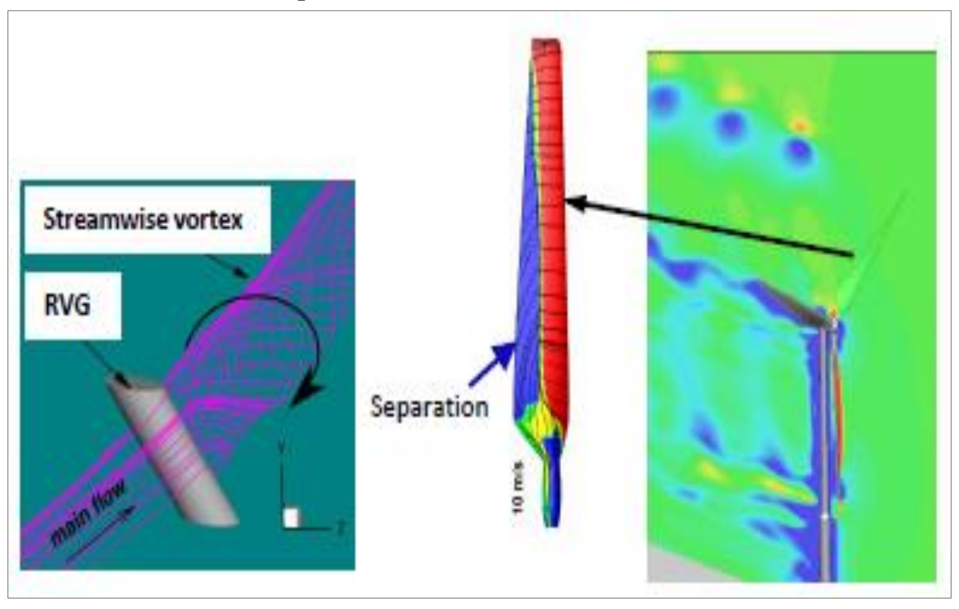
Smart Mitigation of flow-induced Acoustic Radiation and Transmission for reduced Aircraft, surface traNSport, Workplaces and wind enERgy noise

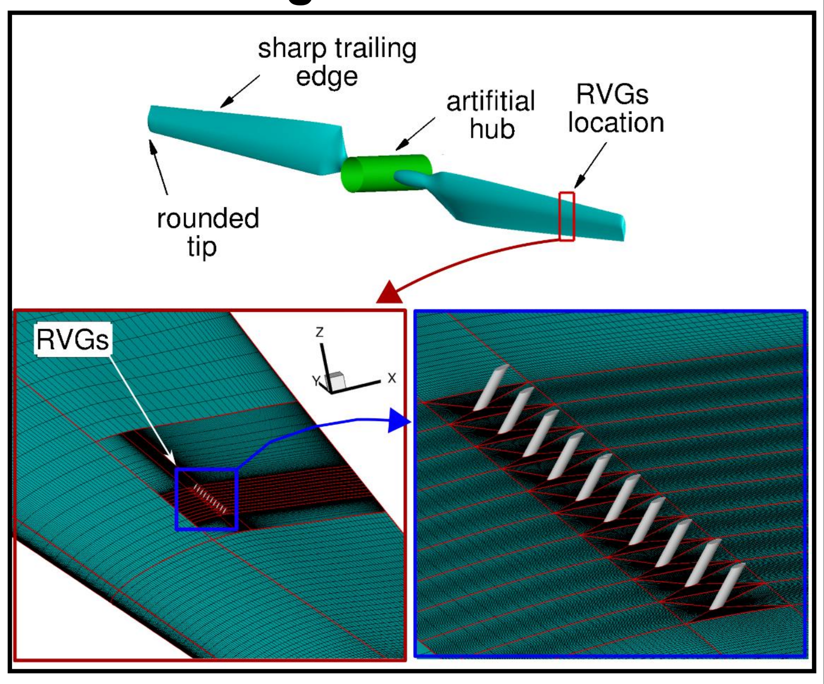
Host institution: Institute of Fluid- Flow Machinery, PAN

Partnership: The von Karman Institute for Fluid Dynamics, TU Delft

Motivation

- One of the challenges for **wind energy** is to overcome the **noise** complaint of the residents living near wind farms.
- **Trailing edge noise** has been studied intensively for **design** cases.
- **Flow separation** occurs in higher wind speed cases leading to **decreased performance** of wind turbines in **off-design** conditions.





Flow visualization on wind turbine blade with RVGs [1]

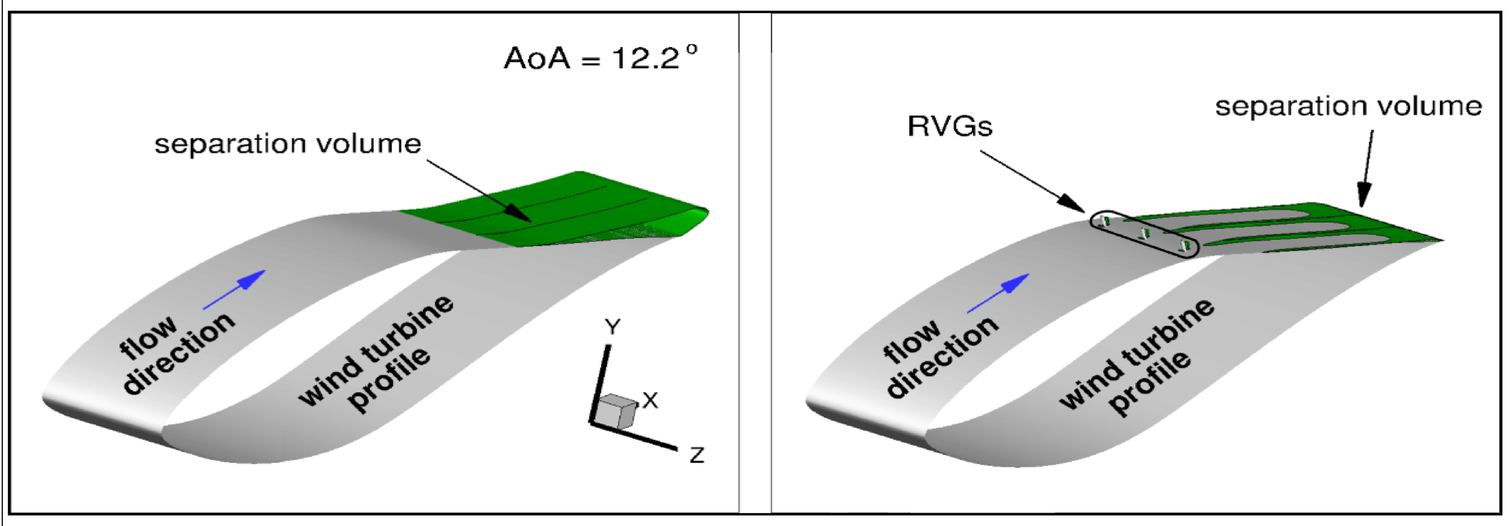
- **Rod Vortex Generators(RVGs)** are investigated to **reduce** the **flow separation.**
- **RVGs increase aerodynamic performance** of wind turbine and helicopter rotors.
- What is their **acoustic** impact? Increase or decrease noise levels?

Main Objectives

- To identify **noise sources** in the flow field for **wind turbine** blades in the **boundary layer separation** cases.
- To investigate the effect of **RVGs on noise** generated by rotor blade.

Existing Background

- Numerical investigations of **RVGs** installed on **helicopter rotor** and NREL **wind turbine** rotor show **improved aerodynamic performance.**



Performance of RVGs on profile from Suarez[1]

Methodology

- **Ffowcs Williams- Hawkings (FW-H)** acoustic analogy describes **acoustic pressure** as a sum of elementary acoustic sources such as the **monopole, dipole** and **quadrupole**.
- **Aero-acoustic code development** in **Tecplot** using macro scripting based on **linear** integral **Farassat Formulations** of **FW-H** in **time** domain.
- Acoustic investigations of **rotating bodies** such as **helicopter** rotor, **wind turbine**.
- **Experimental acoustic and flow (PIV) measurements** for wind turbine profile **DU96-W-180 reference** case and **RVGs** case (designed to control separation) in test section at **TU Delft.**

Theory: **Integral solution** of **FW-H** by Farassat as **Formulation 1A**[2]

$$4\pi p'_T(x,t) = \int_{f=0}\left[\frac{\rho_0 \dot{v}_n}{r(1-M_r)^2} + \frac{\rho_0 v_n \hat{r}_i \dot{M}_i}{r(1-M_r)^3}\right]_{ret} dS + \int_{f=0}\left[\frac{\rho_0 c v_n (M_r - M^2)}{r^2(1-M_r)^3}\right]_{ret}$$

Thickness near –field term; Thickness far –field term

$$4\pi p'_L(x,t) = \int_{f=0}\left[\frac{\dot{p}\cos\theta}{cr(1-M_r)^2} + \frac{\hat{r}_i \dot{M}_i p\cos\theta}{cr(1-M_r)^3}\right]_{ret} dS + \int_{f=0}\left[\frac{p(\cos\theta - M_i n_i)}{r^2(1-M_r)^2} + \frac{(M_r - M^2)p\cos\theta}{r^2(1-M_r)^3}\right]_{ret} dS$$

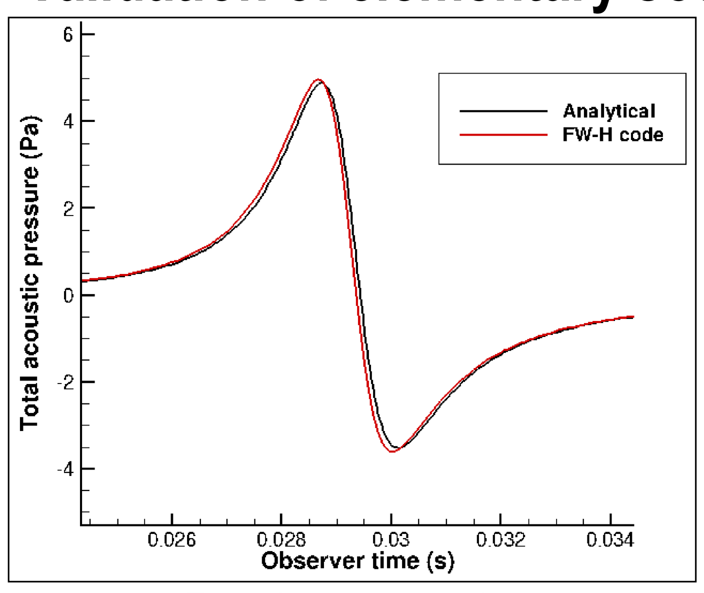
Loading near –field term; Loading far –field term

Analysis:

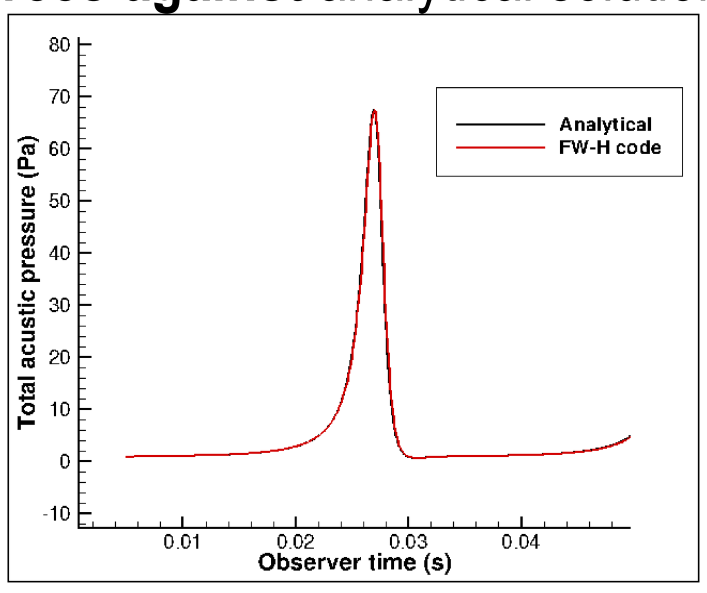
- **Validation** → **Stationary : Monopole/Thickness** and **Dipole/loading**; **Rotating : Monopole, Dipole, source - sink pair**
- **Helicopter rotor** case – experimental and other numerical results available(**thickness term** dominant).
- **Wind turbine blade** with and without **RVGs**(**loading term** dominant).

Results

- **Validation of elementary sources against** analytical solutions[3]



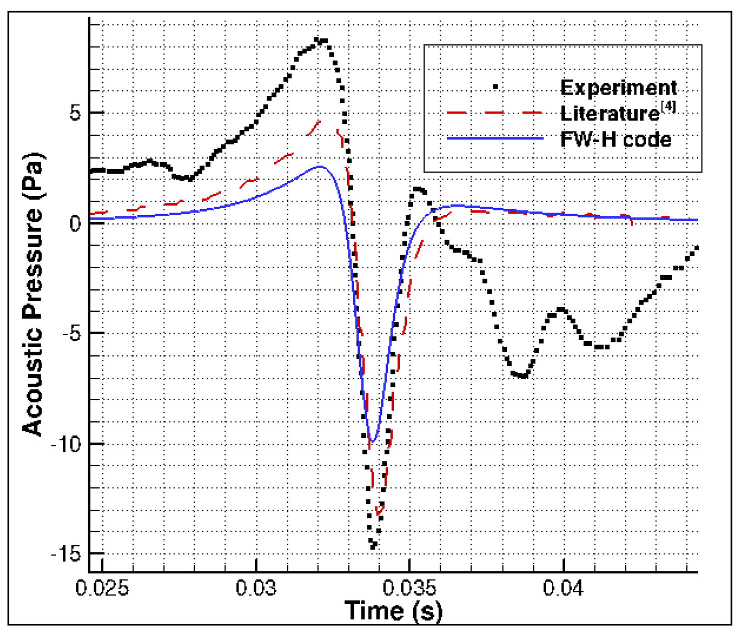
Rotating monopole



Rotating dipole

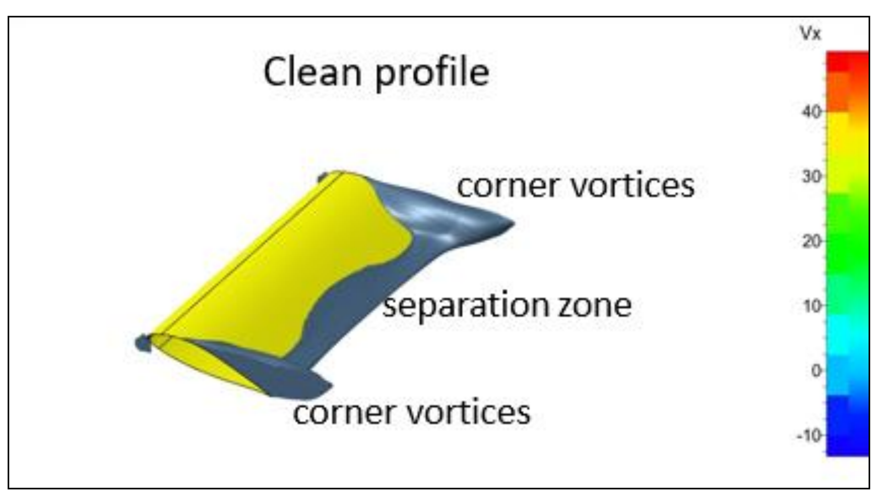
Good agreement with analytical solutions

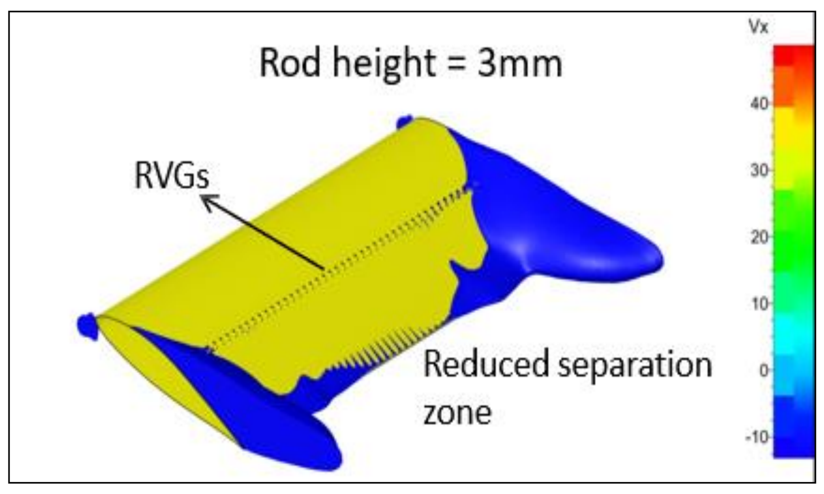
- **Helicopter results**: Acoustic signal from code against experimental data and numerical acoustic model for 1/7 scale model helicopter by **Sargent**[4] at M_T **= 0.661**, hover mode.



Good trends. *Under-prediction of peak amplitude under analysis.*

- **Design** of **RVGs** for **DU96-W-180** profile for an anechoic vertical open-jet wind tunnel at TU Delft[5]





DU96-W-180 profile, full 3D simulation at flow velocity = 30 m/s, AoA = 13°

Future Work

- **Steady** and **unsteady** pressure data of **NREL Phase VI** rotor is under acoustic analysis using the developed **aero-acoustic code**.
- **Secondment at TU Delft : experimental acoustic** and **flow** measurements for **DU96-W-180** with/without RVGs.

References

[1] Suarez, et al, *Wind Energy, 21:1202-1215, 2018.*
[2] Farassat, F., *NASA TM-214853*, 2007.
[3] Rienstra, S. W. et al, *IWDE92-06, 2001.*
[4] Sargent, D. C. et al, *Jou. of Aircraft, 2014.*
[5] Carpio, A. R. et al, *Jou. of Sound and Vibration, 2018.*

MARIE CURIE ACTIONS

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