Numerical study on aerodynamics of a blade section under adverse weather conditions

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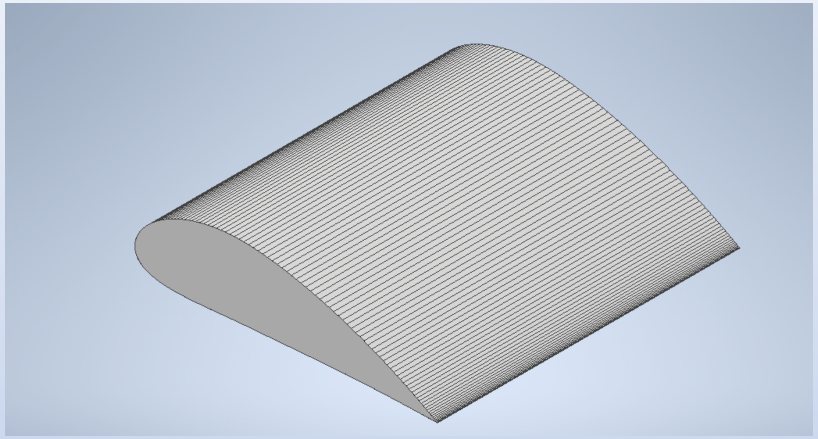
INTRODUCTION

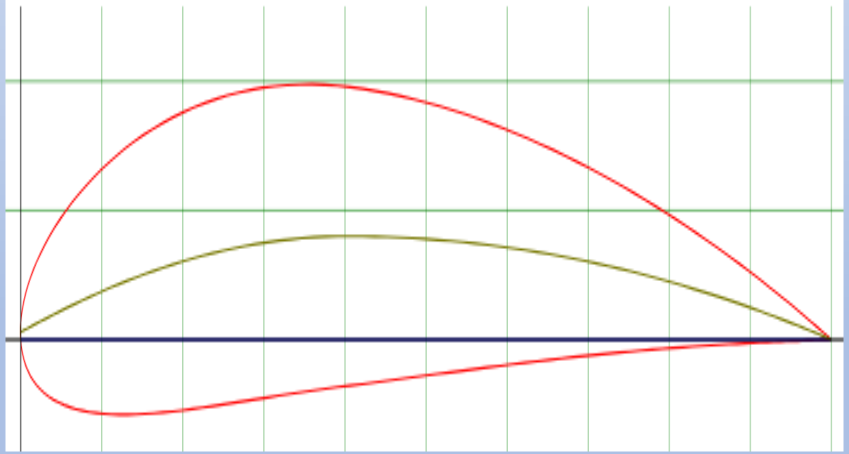
- Wind turbine icing causes - Annual power loss (estimated 5-30%), increased loads to aerodynamic deterioration.
- Aerodynamic performance degradation and ice accretion on wind turbine is affected by physical parameters (MVD, LWC etc.) and numerical parameters (number of shots, sand grain roughness etc.).
- This study determines the number of shots which can accurately predict ice accretion and reduce computational time and reveals the effects of physical parameters on rate of icing and on aerodynamic coefficients.

https://www.windpowerengieering.com/detecting-ice-on-wind-turbine-blades/

OBJECTIVES

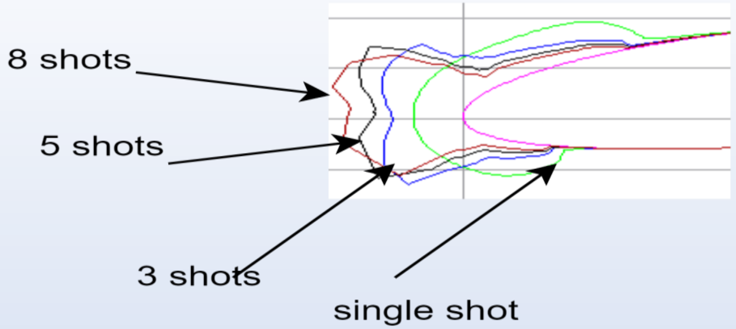
- Choosing numerical parameters (Number of accreting shots) to optimize accuracy and computational time
- Compute aerodynamic performance degradation on the wind turbine blade section with the LWC, MVD and air temperature due to icing.



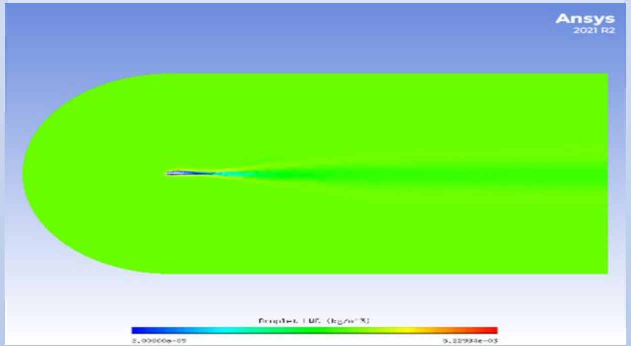


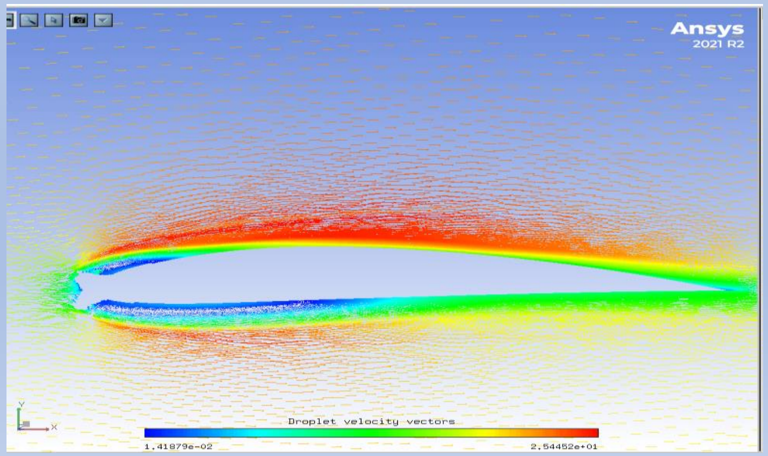
METHODOLOGY

- Numerical model
- Model: FENSAP ICE2021R2
- Geometry: NACA4412
- Parameters: Velocity -20m/s, air temperature (-5°C, -10°C and -20°C), LWC ($0.1 g/m^3$, $0.5 g/m^3$ and $1 g/m^3$), MVD (20-100µm),
- Number of shots in the numerical simulation (single shot, 3 shots, 5 shots and 8 shots)



Number of shots at $1 g/m^3$ at 100µm at 120 minutes for -10°C

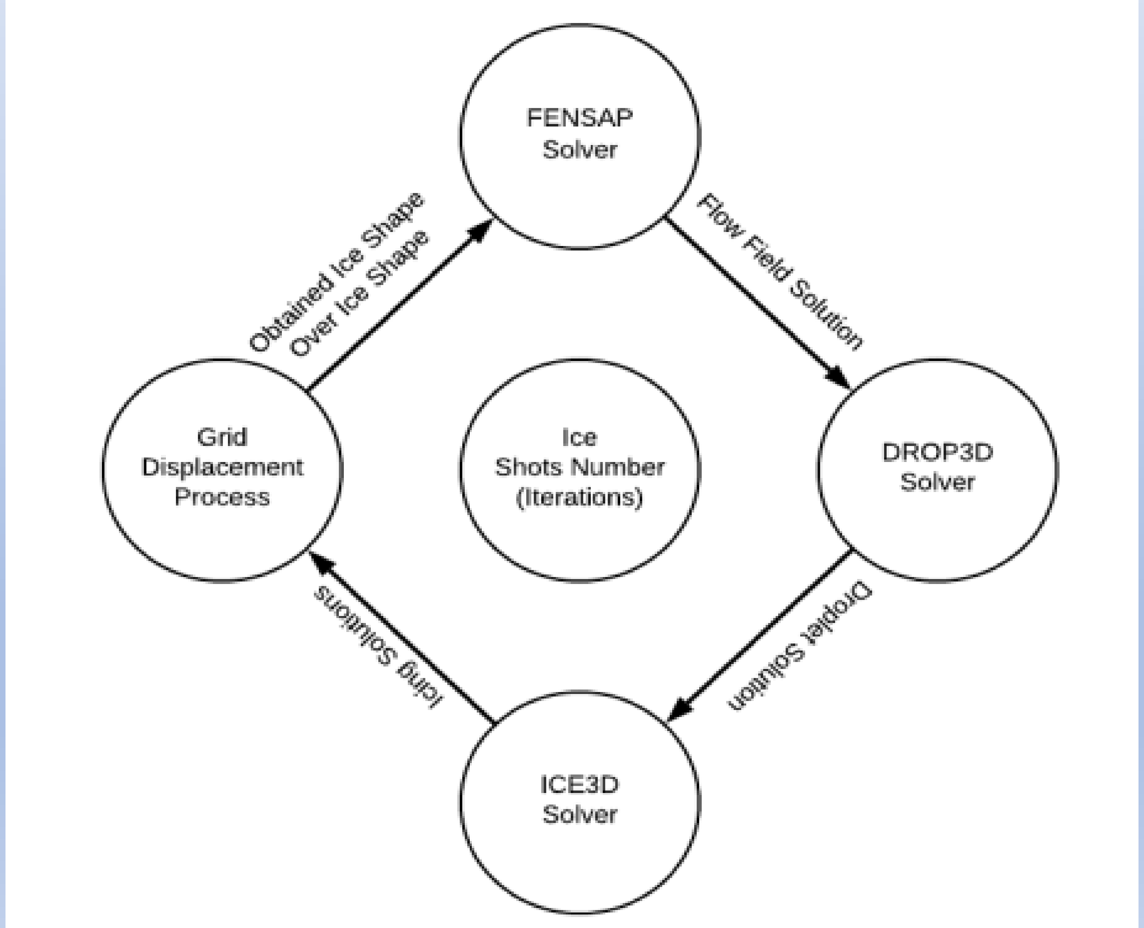




Wind turbine section icing: CFD

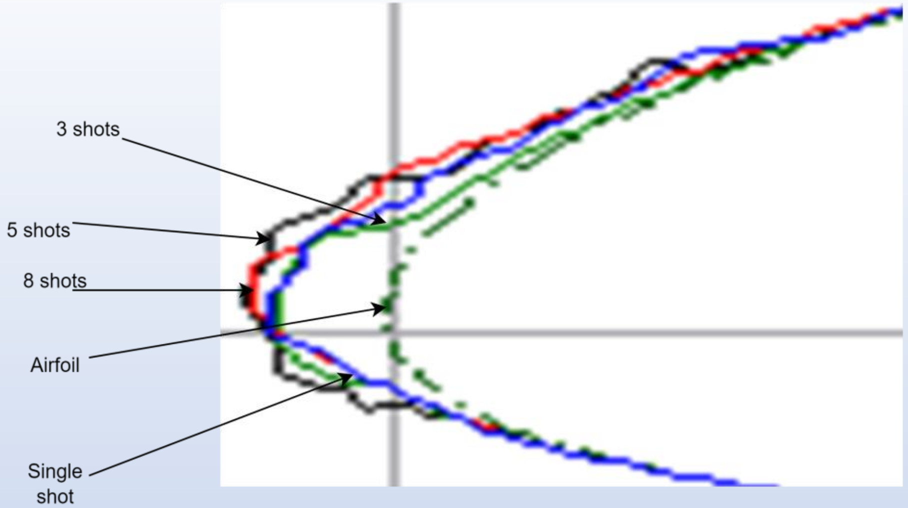
- ❑Icing occurs due to supercooled droplet impingement on the airfoil surface
- ❑Ice accretion results in
  - ➢Shape modification
  - ➢Ice roughness affecting the flow
- ❑Aerodynamic performance deterioration.

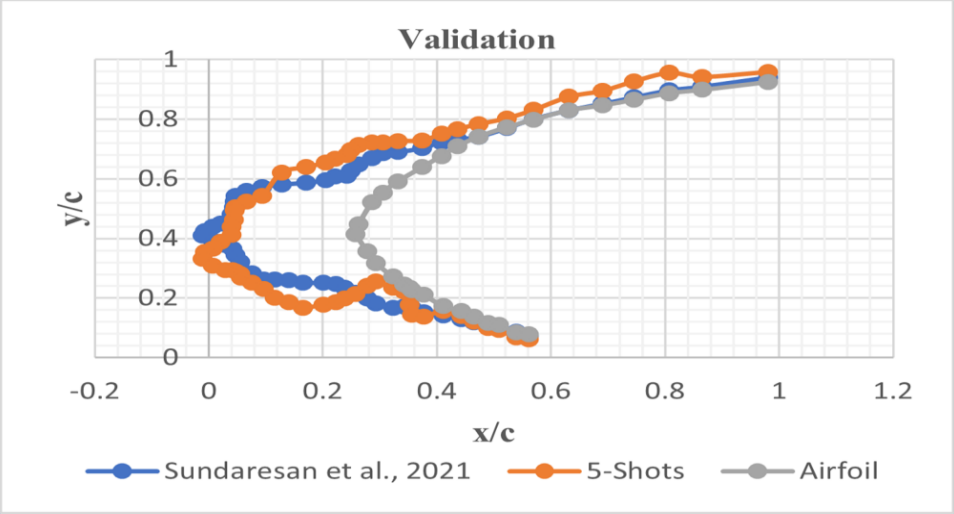
ICE Accretion simulation



Numerical model validation with experimental studies

- ❑ Model validation comparing with the experiments done with the numerical data from single shot, 3, 5 and 8 shots.
- ❑Results were in good agreement with experimental.

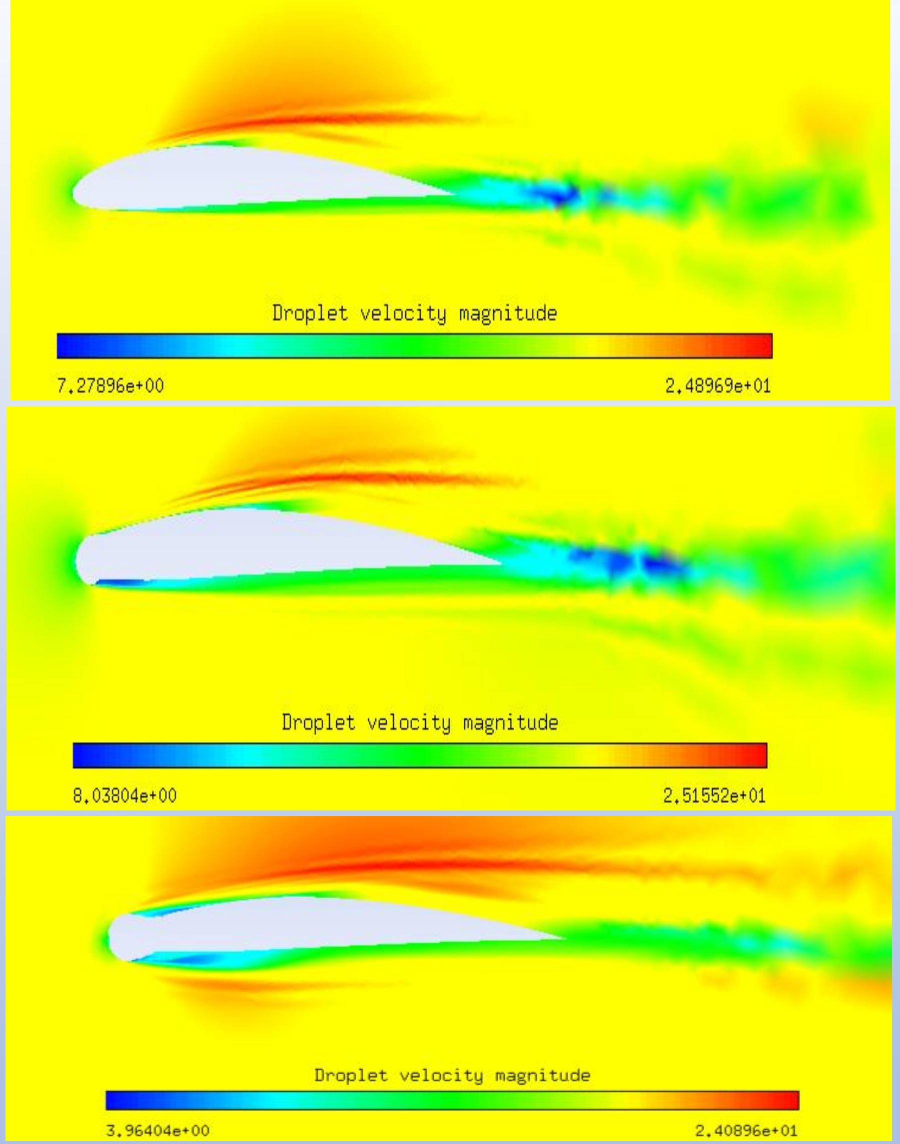




Numerical studies on FENSAP ICE 2021 R2 comparison with experimental data from low-speed subsonic wind tunnel facility University (Sundaresan et al., 2021) for 77m/s, 20μm, 0.6g/m^3 and 16.9minutes

RESULTS:
Flow distribution

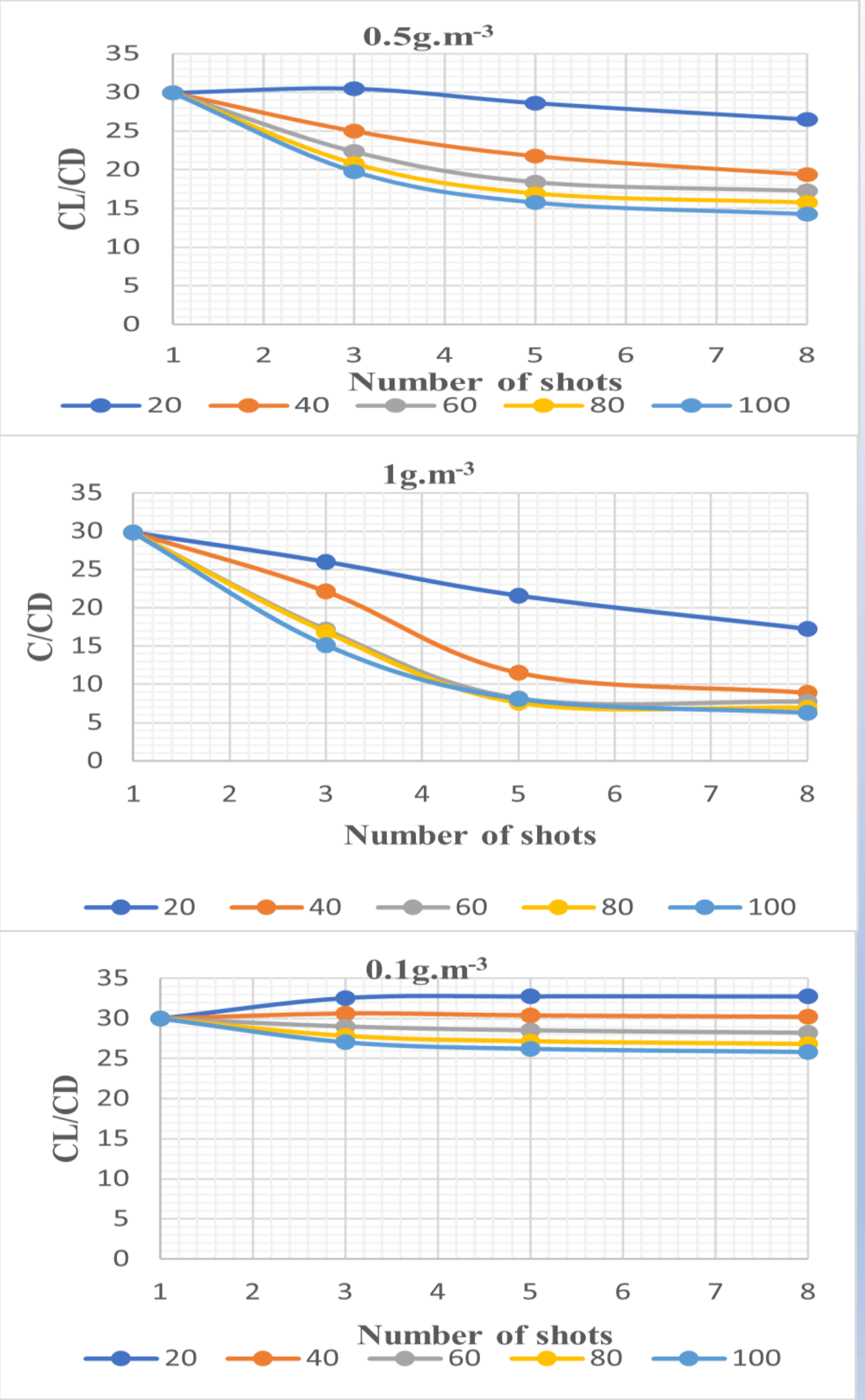
- Single-shot: uniform shape is formed.
- The horn structures started developing with successive shots, affecting the flow field, heat fluxes, and collection efficiency due to transient changes from ice accumulation.



Effect of icing on airflow over the iced airfoil for 36 mins, 108 mins, and 180 minutes at 1g/m^3 at –20^{o}C (5 shots)

Effect of number of shots on icing and aerodynamic performance degradation

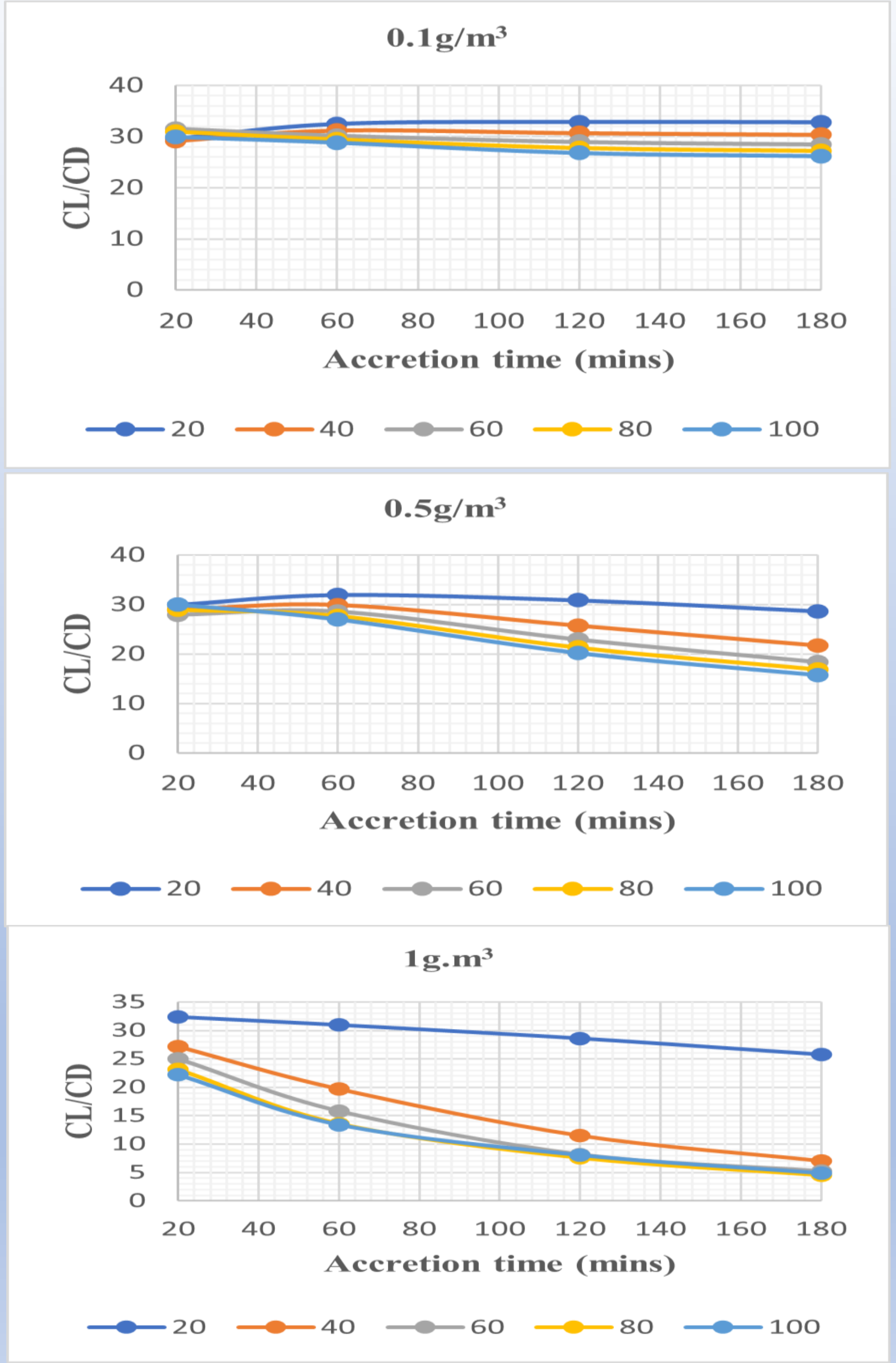
- ➢Increasing the number of shots above five doesn't guarantee the further accuracy in ice accretion and aerodynamic performance.
- ➢This could guide in determining the minimal number of shots which reduces the computational time.



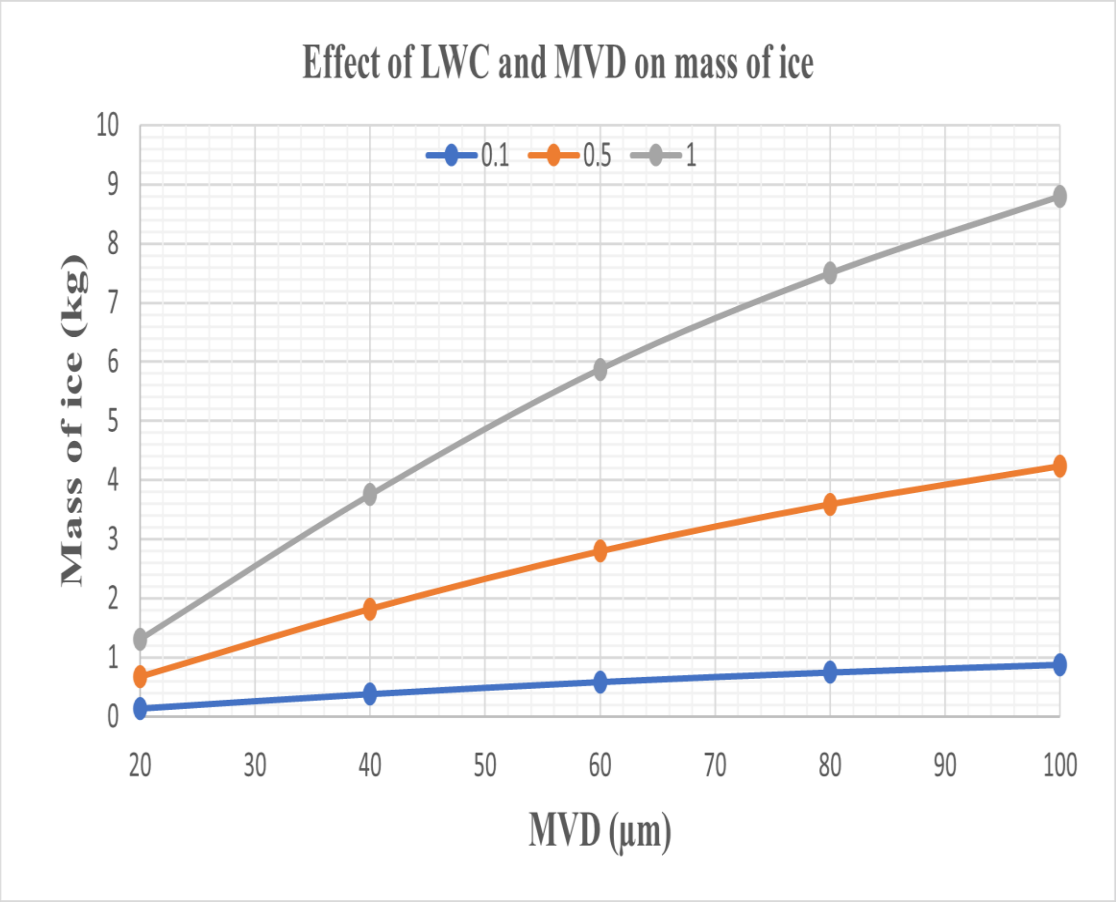
Effect of the number of shots on aerodynamic performance degradation for 180 mins at $1 g/m^3$ at -10˚C.

Effects of aerodynamic performance with accretion time (mins): LWC and MVD

- Performance affected by ice shape, roughness and ice accumulation rate
- Higher LWC and MVD increases ice mass rate leading to severe icing, rougher and irregular ice shape degrading the performance.



The aerodynamic performance degradation with MVD (µm) for the -10°C for 0.1g/m^3, 0.5g/m^3, and 1g/m^3 for five shots, respectively, with accretion time (mins).



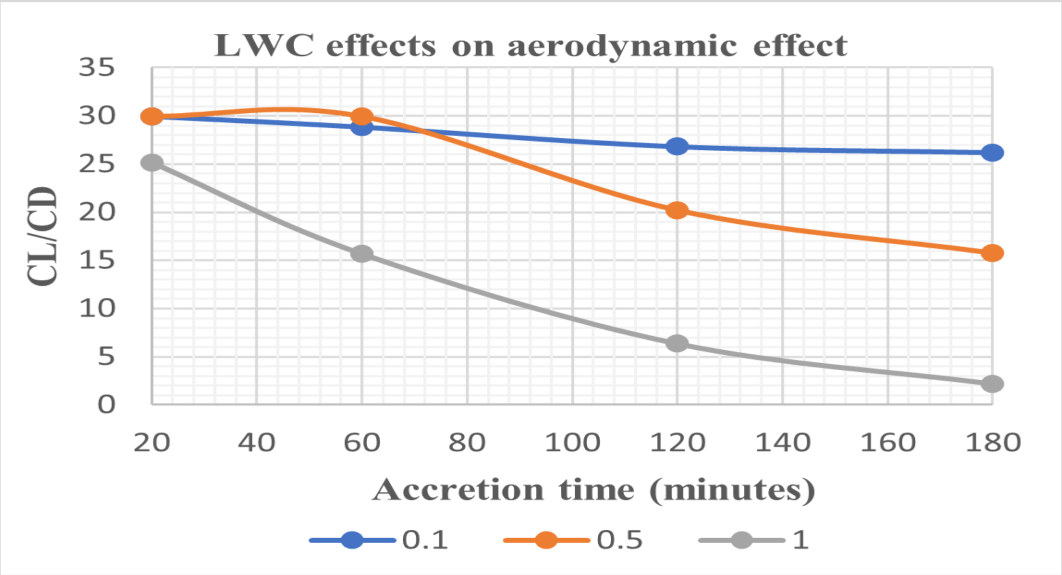
Effect of MVD and LWC and the impact on mass (kg) of ice at -10°C for 120 minutes accretion time (mins) at five shots

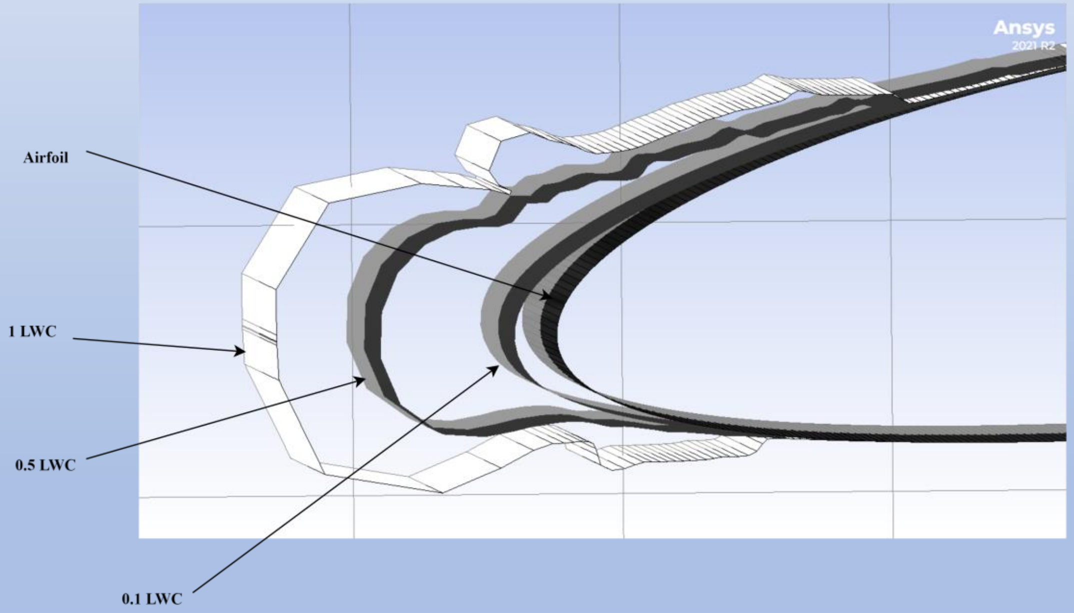
Relationship between MVD, LWC and ice mass.

- The relationship between MVD and ice mass is closely linear.
- **An increase in LWC will increase the amount of ice that forms on the blade surface for either glaze ice or rime ice, while an increase of MVD will expand the adhesion surface between ice and blade**

Effect of LWC on aerodynamic performance degradation

- Aerodynamic performance on the surface was studied.
- $0.1 g/m^3$ had minimal effect in the CL/CD
- $1 g/m^3$ – due to ice shape affecting the flow considerably.

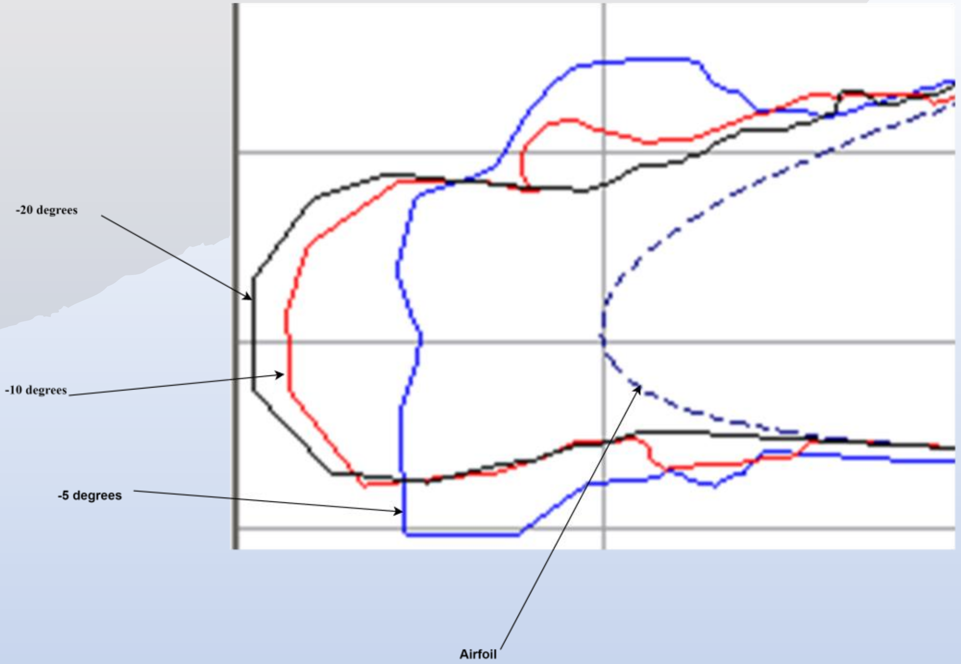


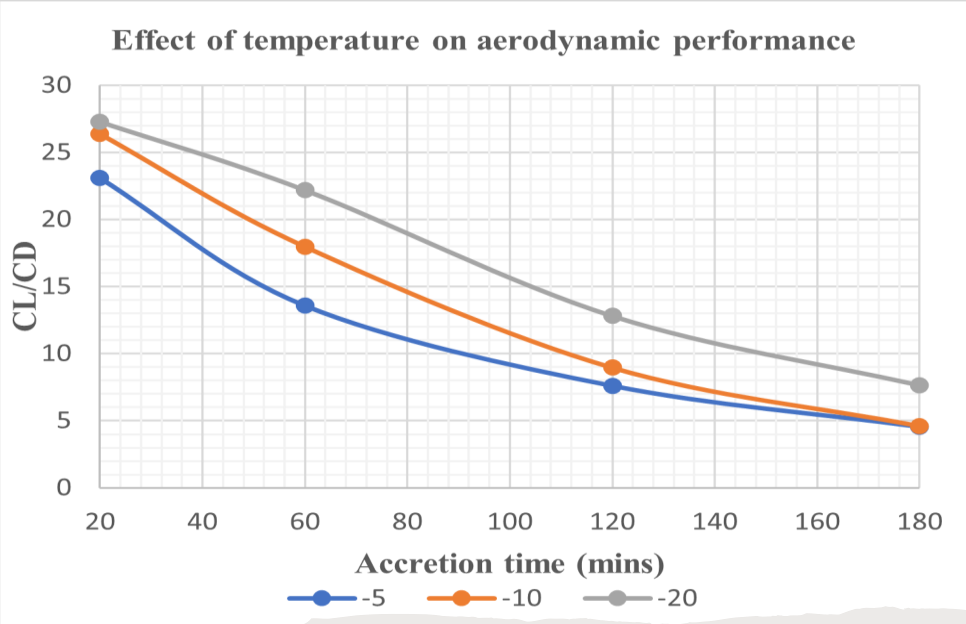


LWC effects on aerodynamic effect for -10°C with 180 minutes accretion time at 100 µm for 5 shots

Effect of Temperature on aerodynamic performance

- The increase in temperature reduces aerodynamic performance on iced blade.
- At -20°C, droplets freeze immediately upon impact on the stagnation point; rime ice
- At -5°C, there is runback of unfrozen water on the surface: glaze ice





Effect of air temperature (°) on aerodynamics for five shots for 80µm for 1g/m^3

CONCLUSION

- From the validation, numerical results had good agreement with experimental for 5 shots.
- Mass of ice increases linearly with increase in MVD and LWC
- Decrease in temperature increases the aerodynamics performance: rime (light), glaze (heavy).
- Ice geometries caused decrease in lift and increase in drag

References

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