Wing Surface Roughness study and it's Effect on Turbulent Ice Accretion

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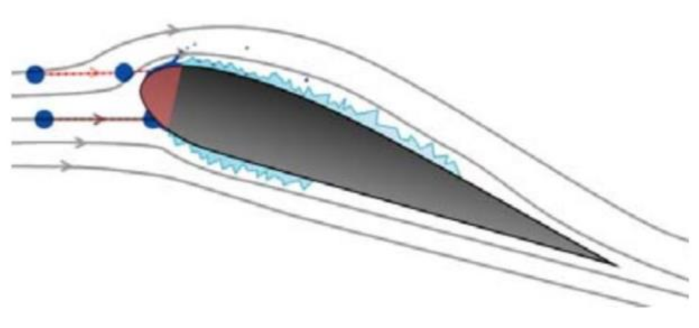
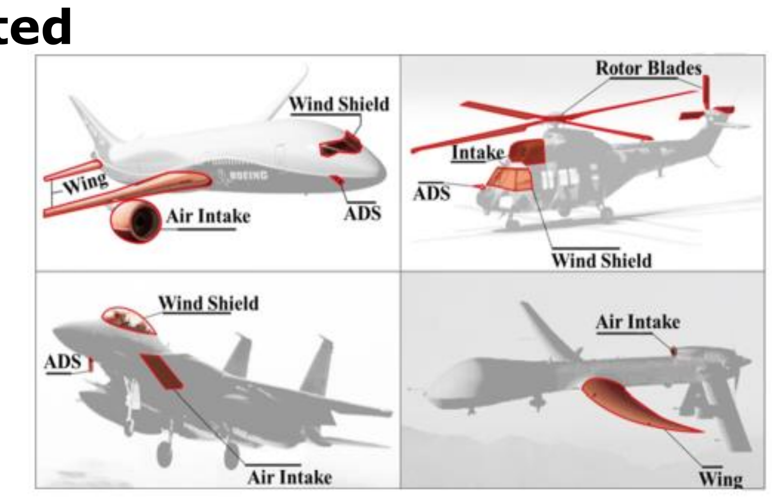
ICE ACCRETION AND ITS MARKET

The phenomenon will happen when the aircraft goes through a **low-temperature** cloud composed of moisture, the water **supercooled droplets** of the cloud may impact the aircraft surface, then it is possible that **ice accretion** happens by heat transfer and mass transfer phenomena.

- **Reduce aerodynamic performance**
- **Flight performance affected**
- **Lower control efficiency**



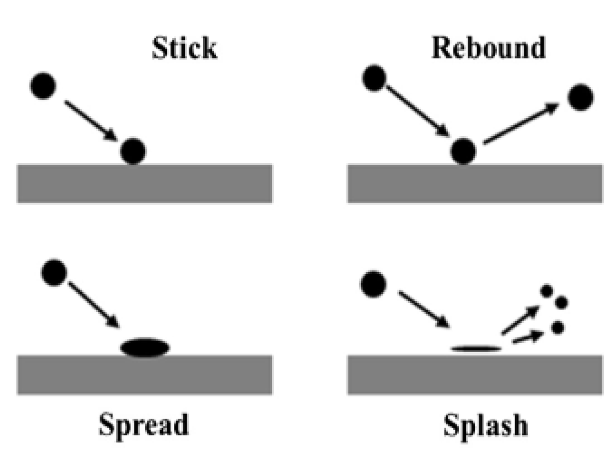
Cao, Y., & Xin, M. (2020)



Raj, et al.(2019)

Nowadays with increasing use of **aircrafts and airplanes** a very small improvement of **wings aerodynamic performance** can **save billions of dollars** and also reduce a large amount of **fossil fuel consumption** and **environment pollutants**.

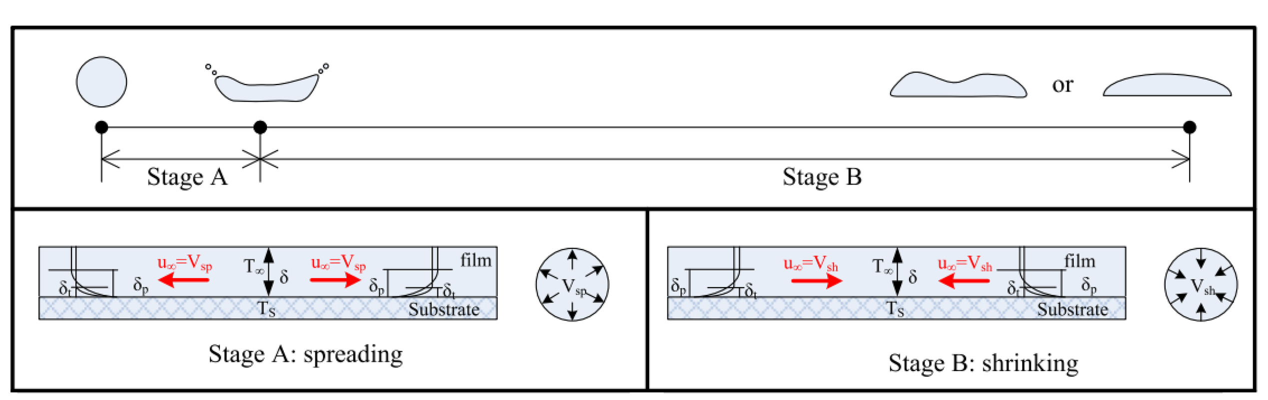
ICING THEORY



1- Different scenarios of **droplet - surface interaction**

2- Spreading of a single droplet on a **smooth surface**

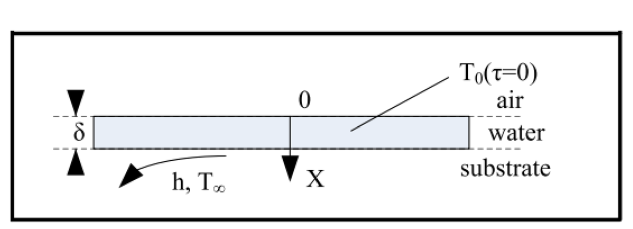
Zhang, C., & Liu, H. (2016)

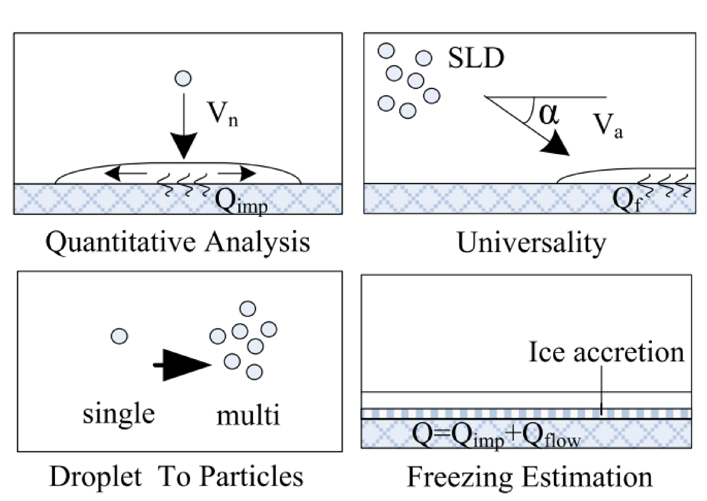


3- Neglecting **horizontal thermal exchange** phenomenon.

4- We consider the problem to be a **1-D unsteady heat transfer**.

Zhang, C., & Liu, H. (2016)





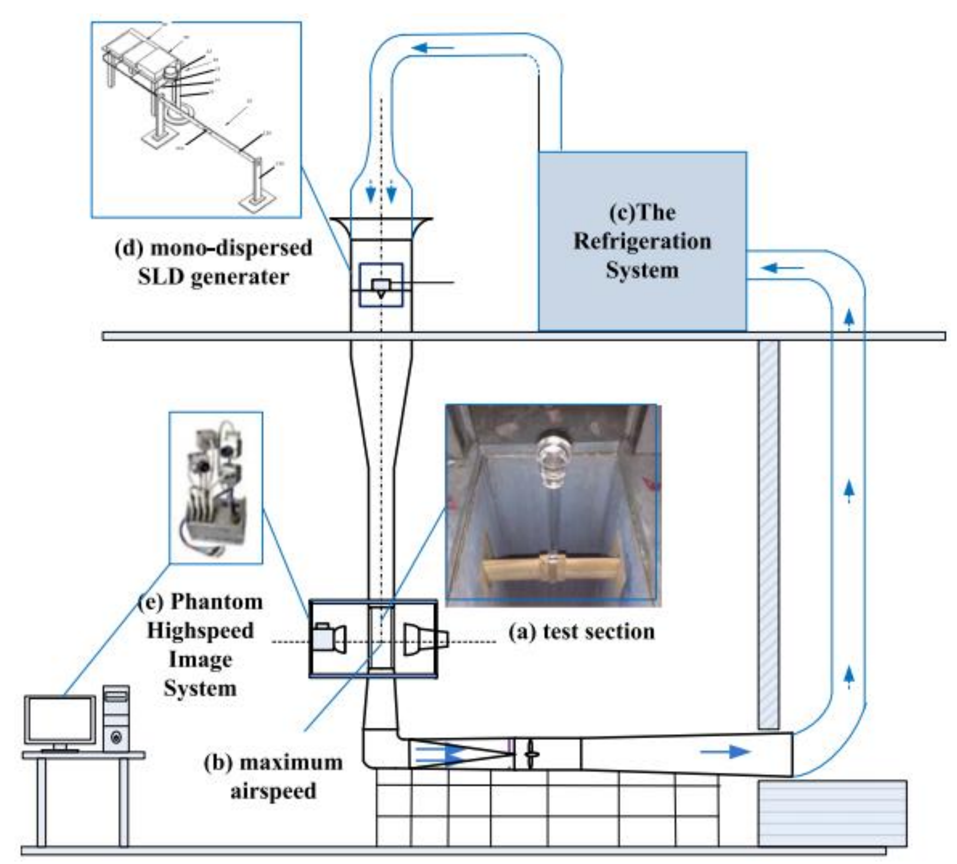
$$\frac{\partial T}{\partial \tau} = \frac{\lambda}{\rho c}\frac{\partial^2 T}{\partial x^2}(0 < x < \delta, \tau > 0)$$

OBJECTIVES

A better **prediction of turbulent heat transfer** and by taking into account the **effect of surface roughness** during droplet impact we can have:

- **Have cleaner environment and save a lot of money.**
- **Less aircraft accidents and provide safer flight.**
- **increase the performance of aircraft and airplane**.

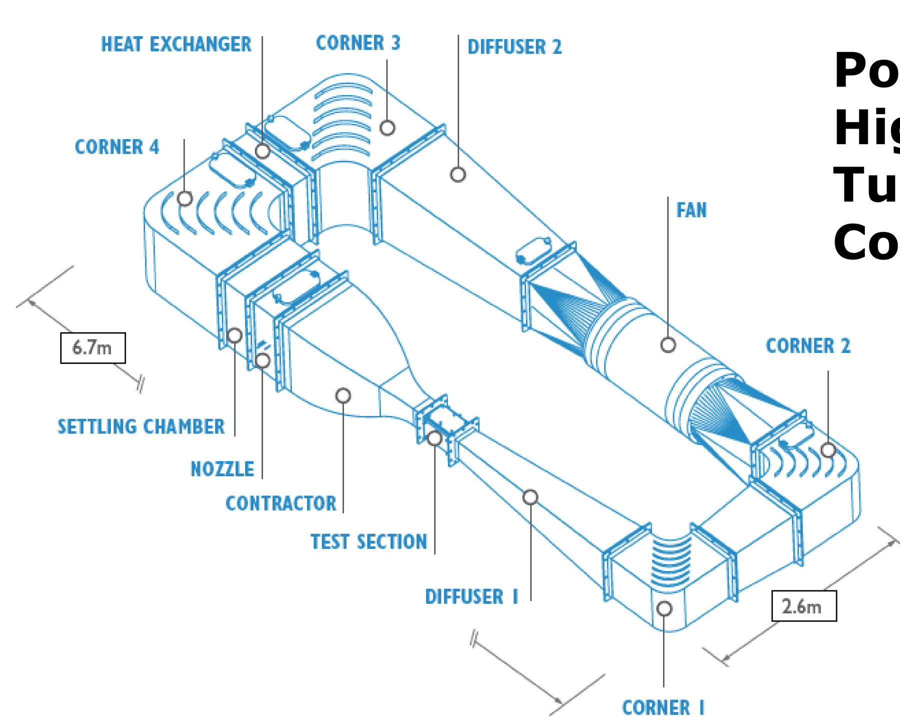
METHODOLOGY



Example of an experimental setup

Shanghai01 Icing Wind Tunnel (SH01 IWT)

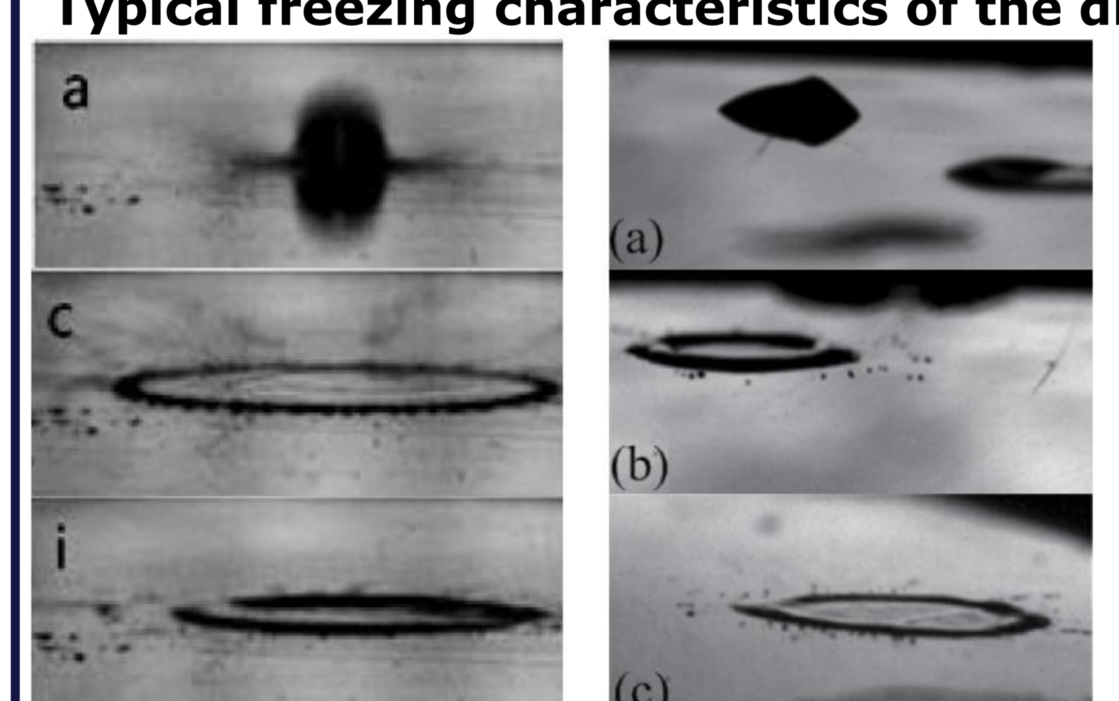
Zhang, C., & Liu, H. (2016)
Raj, L. P., Lee, J. W., & Myong, R. S. (2019)



Possible place:
High Speed Icing Wind Tunnel installed at **Concordia University**

RESULTS

Typical freezing characteristics of the droplets

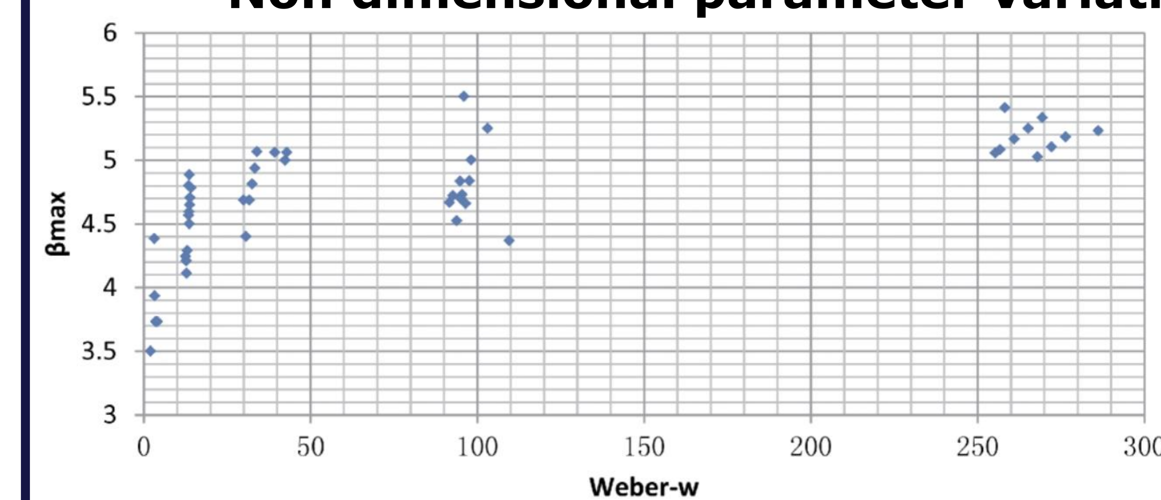


Analyzing and justifying the experimental data in a **physical way** which makes sense and help to come up with some simple additional **correlations** between the nondirectional parameters.

Zhang, C., & Liu, H. (2016)

RESULTS (CONT'D)

Non dimensional parameter variation

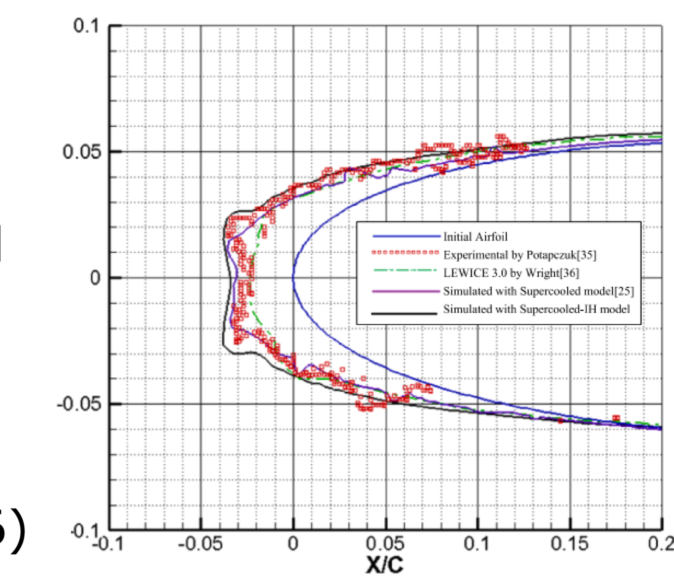


Zhang, C., & Liu, H. (2016)

Correlation of improved heat transfer coefficient

$$h = \frac{Nu \cdot \lambda}{\left(\frac{d_{max}}{2}\right)} = \frac{0.664 \cdot Re_n^{0.5} \cdot Pr^{1/3}}{d_{max}} = \frac{0.664(\rho \cdot V_{sh})^{0.5} \cdot Pr^{1/3}}{(\mu \cdot d_{max})^{0.5}}.$$

Comparing experimental and numerical results



Zhang, C., & Liu, H. (2016)

CONCLUSIONS

- There are still a large amount of **differences** between the **experimental and numerical results** of ice accretion.
- ice accretion demands to be studied in **more details** for having better predictions.
- **Turbulence and surface roughness** could have the **potential for improving** the predictions of heat transfer and phase change in this kind of flow.
- **Small improvement** in prediction of the ice shape can have a **huge amount** of **environmental** and **economical benefits.**

NOMENCLATURE

- c: Specific heat capacity
- d_{final}: Final diameter of substrate
- d_{max}: Maximum diameter of substrate
- d_0: Initial diameter of substrate
- h: Heat transfer coefficient
- Nu: Nusselt number
- Re: Reynolds number
- Pr: Prandtl number
- T: Time
- x: perpendicular dimension
- V: Velocity
- β_{real}: Real spread rate
- β_{max}: Maximum spread rate
- ρ: Density
- δ: Water thickness
- λ: Thermal conductivity
- τ: Droplet spreading time
- μ: Viscosity

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