Kingston University London

DTA Doctoral Training Alliance Energy

Parametric Analysis of Wind Turbine Icing in Cold Regions

Ifrah Mussa

PhD candidate in Aerospace Engineering

Supervisors: Prof. Jian Wang, Dr. Yujing Lin and Dr. Cliff Dansoh

Kingston University London, United Kingdom

Outline

- Background
- Research Objective
- Methodology
- Results
- Conclusion
- Future Work

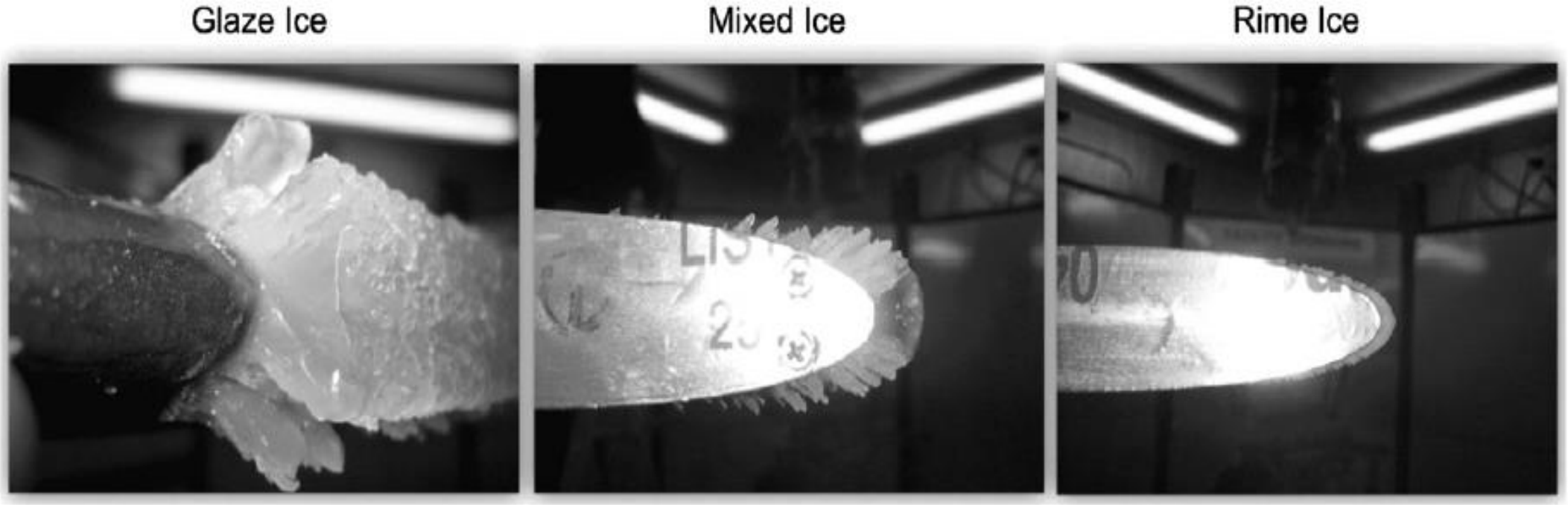
Background

- Wind turbine blade icing
  - Aerofoil shape and size
  - Twist
  - Local angle of attack
  - Flow velocity
  - Rotation
  - Icing Time

VTT Technical Research Centre of Finland (2015)

Background

- Types of ice



Three types of accreted ice on NACA 0012 aerofoil (Han et al., 2012)

Background

- Icing Parameters
  - ➢Site Dependent climatic variables:
    - Wind Speed
    - Temperatures
    - Icing Time
  - ➢Meteorological Variables:
    - Liquid Water Content (LWC)
    - Median Volumetric Diameter (MVD)
    - Humidity

Research Objective

- Effect of parameters on wind turbine icing
- Understand ice formation process
- Heat required
- Operational strategy

Methodology

- Icing Parameters
- Wind Turbine Blade
- Ice Prediction Software

Icing Parameters

- Smøla farm
  - Europe
  - Icing Data: Precipitation, Temperature
  - LWC
  - Droplet

Smøla wind farm

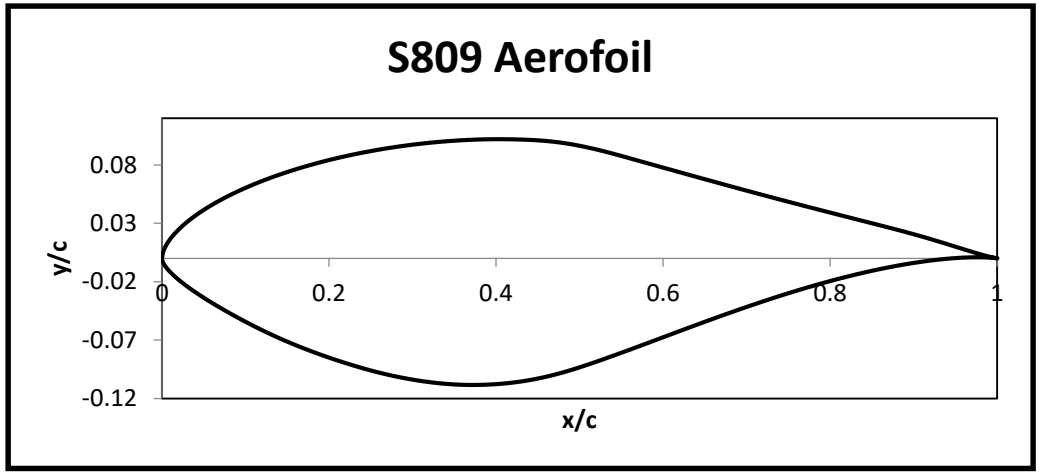
Statkraft, 2020

Icing Parameters

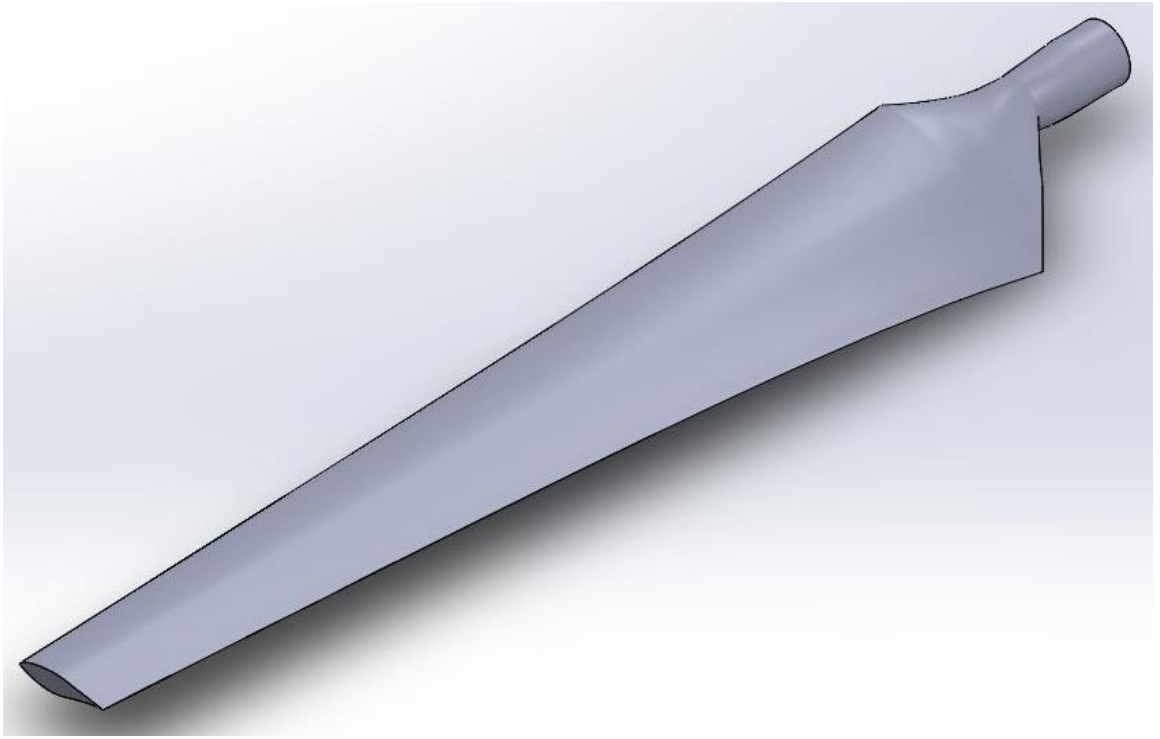
Case	Wind Speed (m/s)	Temp (°C)	LWC (g/m^3)	MVD (microns)	Time (hrs)
Reference	**13**	**-15**	**0.1**	**20**	**6**
Temp 1	13	**-7**	0.1	20	6
Temp 3	13	**-17**	0.1	20	6
LWC 1	13	-15	**0.02**	20	6
LWC 3	13	-15	**0.2**	20	6
MVD 1	13	-15	0.1	**10**	6
MVD 3	13	-15	0.1	**30**	6
Time 1	13	-15	0.1	20	**3**
Time 3	13	-15	0.1	20	**9**

Wind Turbine Blade

- NREL Phase VI
- S809 aerofoil
- Blade Element Momentum

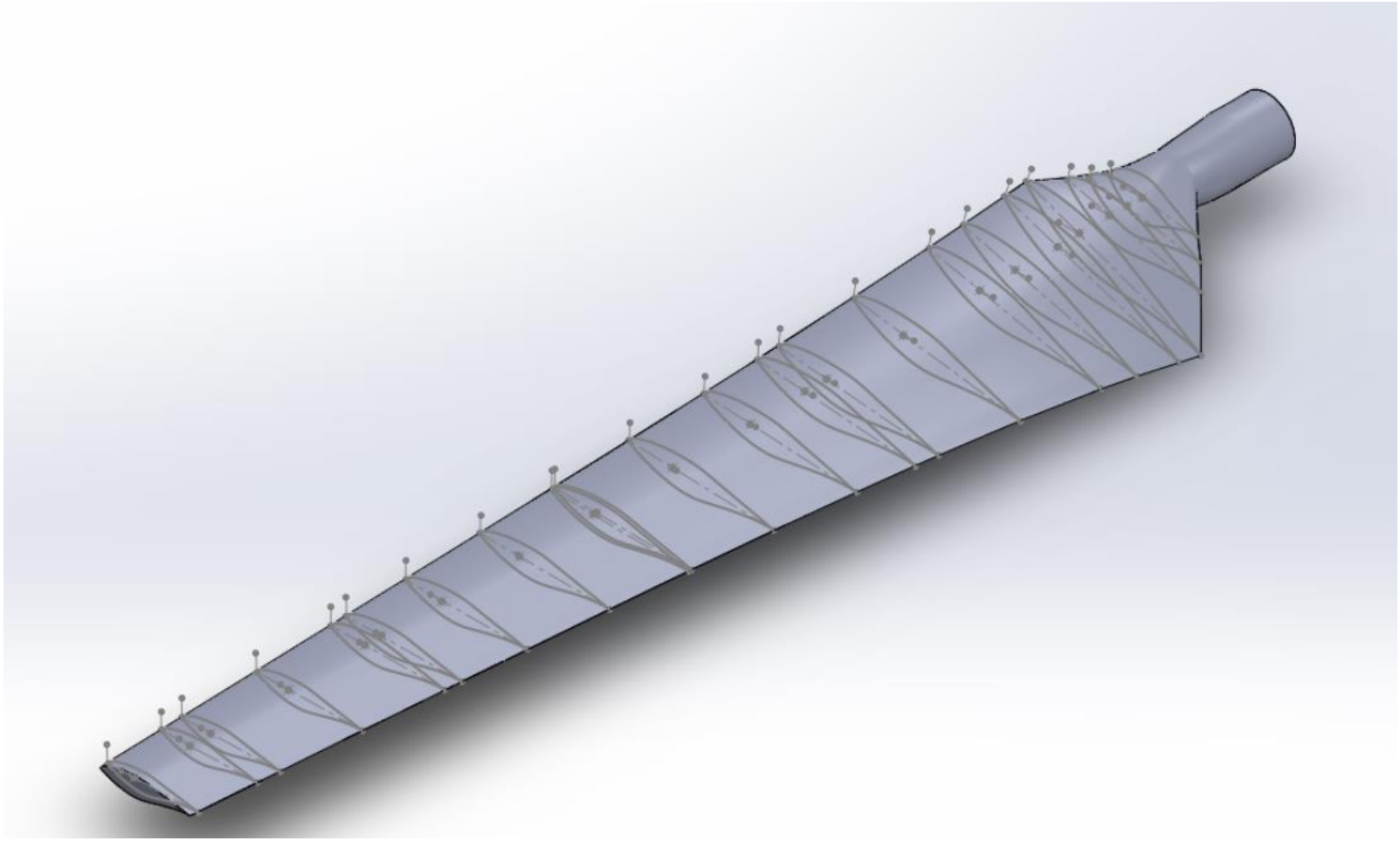


Aerofoil used for Phase VI blade



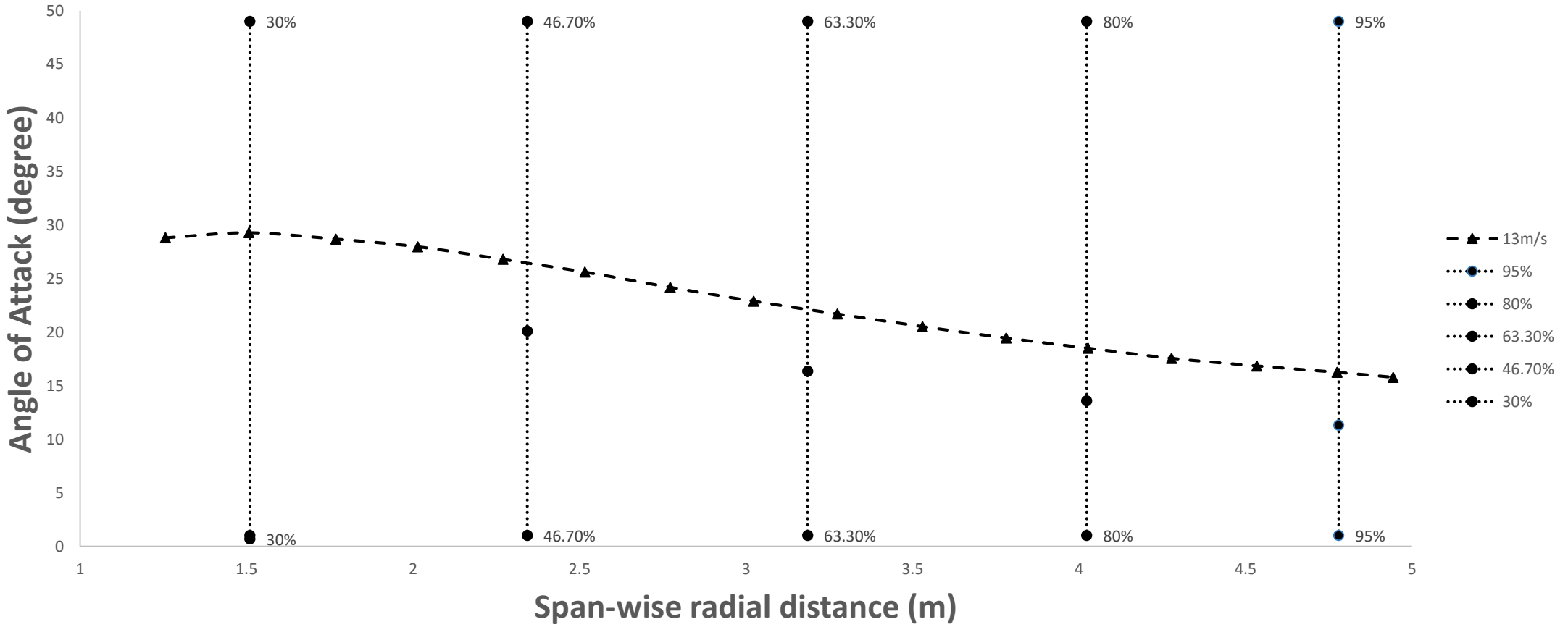
NREL Phase VI Wind Turbine Blade

Blade Element Momentum



NREL Phase VI – Blade Sections

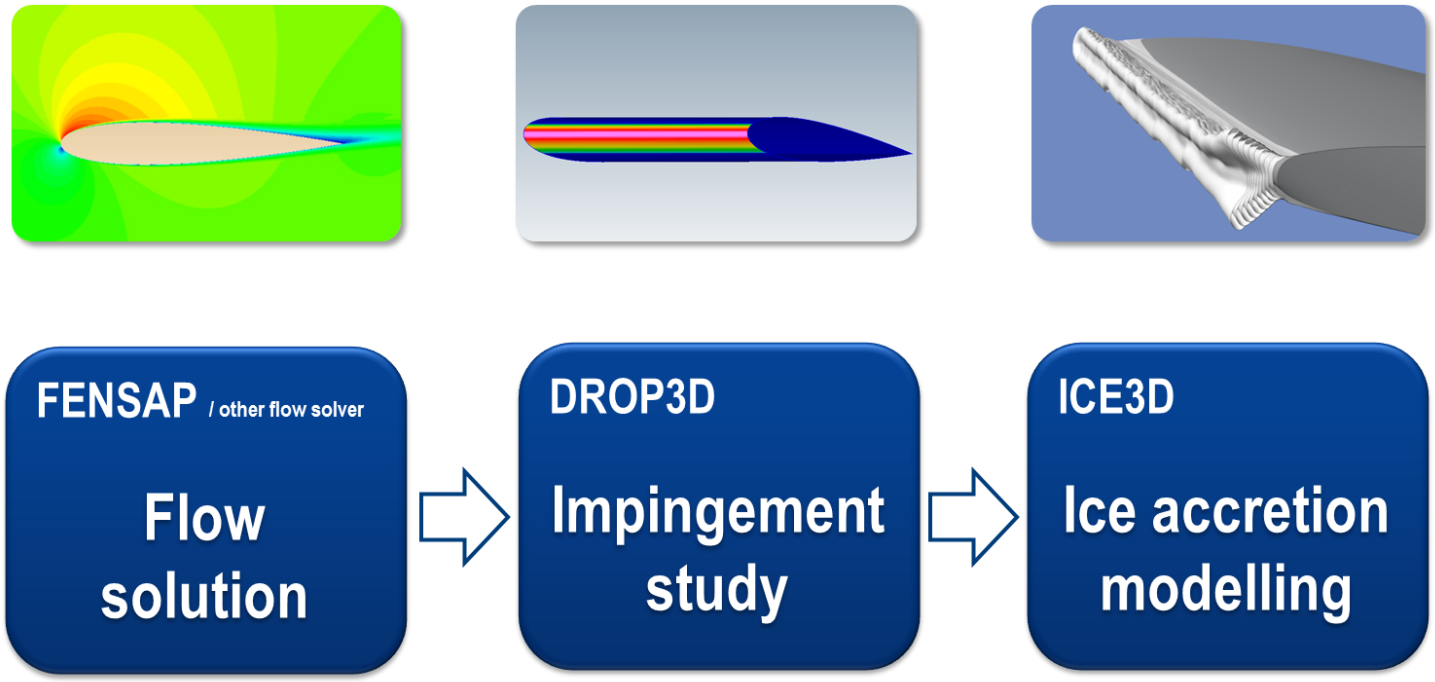
Blade Element Momentum



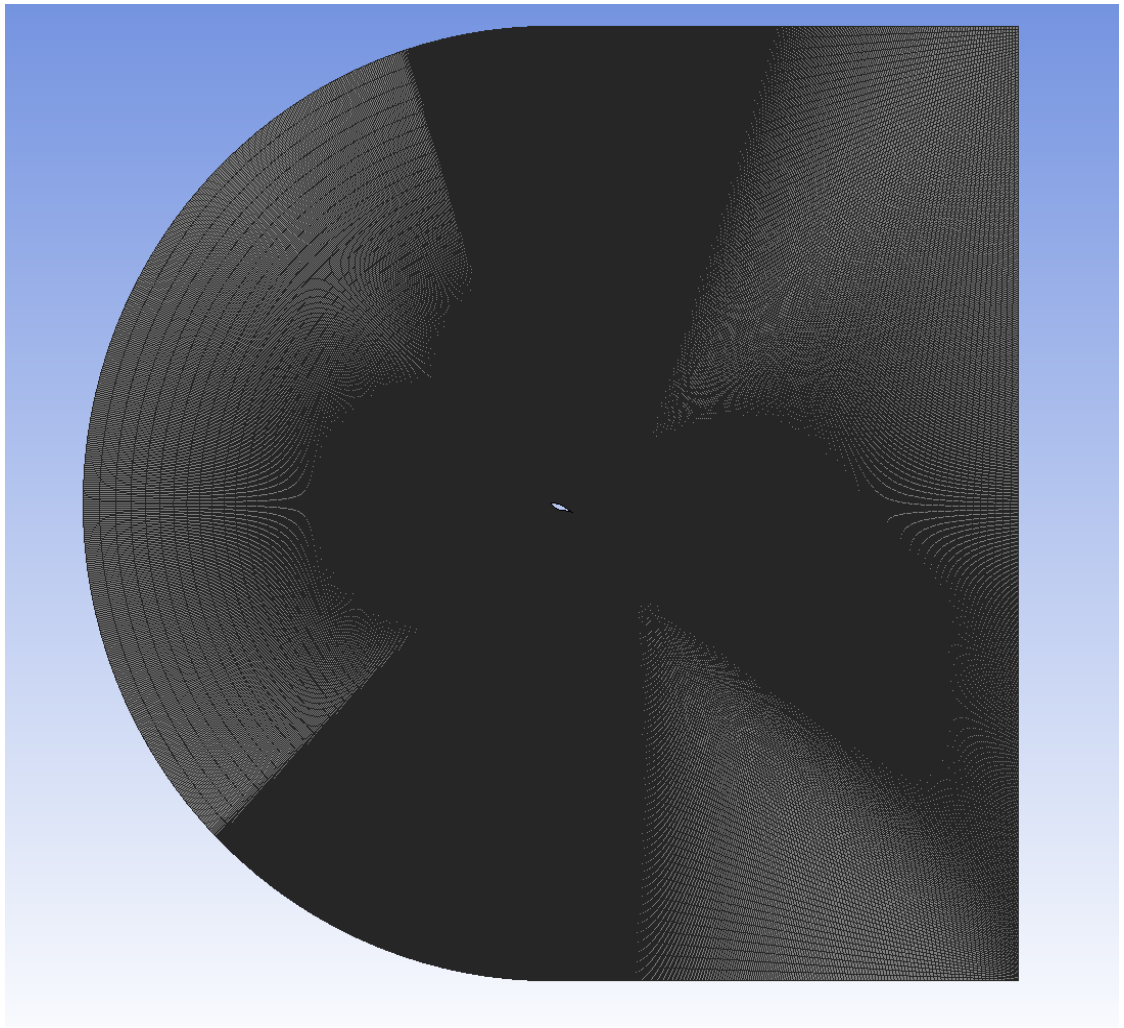
Case	Spanwise Location (%)	Chord Length (m)	Wind Speed (m/s)	Relative Velocity (m/s)	Temp (°C)	LWC (g/m^3)	MVD (microns)	Time (hrs)
Reference	**63**	**0.542**	**13**	**27**	**-15**	**0.1**	**20**	**6**
	75	**0.457**		**33**				
	95	**0.381**		**38**				
Temp 1	63	0.542	13	27	**-7**	0.1	20	6
Temp 1	75	0.457		33				
Temp 1	95	0.381		38				
Temp 3	63	0.542	13	27	**-17**	0.1	20	6
Temp 3	75	0.457		33				
Temp 3	95	0.381		38				
LWC 1	63	0.542	13	27	-15	**0.02**	20	6
LWC 1	75	0.457		33				
LWC 1	95	0.381		38				
LWC 3	63	0.542	13	27	-15	**0.2**	20	6
LWC 3	75	0.457		33				
LWC 3	95	0.381		38				

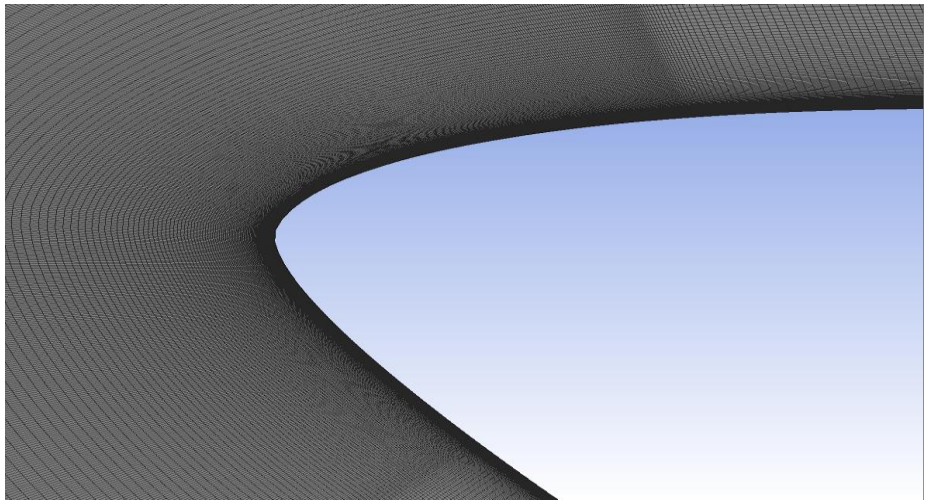
Case	Spanwise Location (%)	Chord Length (m)	Wind Speed (m/s)	Relative Velocity (m/s)	Temp (°C)	LWC (g/m^3)	MVD (microns)	Time (hrs)
Reference	**63**	**0.542**	**13**	**27**	**-15**	**0.1**	**20**	**6**
	75	**0.457**		**33**				
	95	**0.381**		**38**				
MVD 1	63	0.542	13	27	-15	0.1	**10**	6
MVD 1	75	0.457		33				
MVD 1	95	0.381		38				
MVD 3	63	0.542	13	27	-15	0.1	**30**	6
MVD 3	75	0.457		33				
MVD 3	95	0.381		38				
Time 1	63	0.542	13	27	-15	0.1	20	**3**
Time 1	75	0.457		33				
Time 1	95	0.381		38				
Time 3	63	0.542	13	27	-15	0.1	20	**9**
Time 3	75	0.457		33				
Time 3	95	0.381		38				

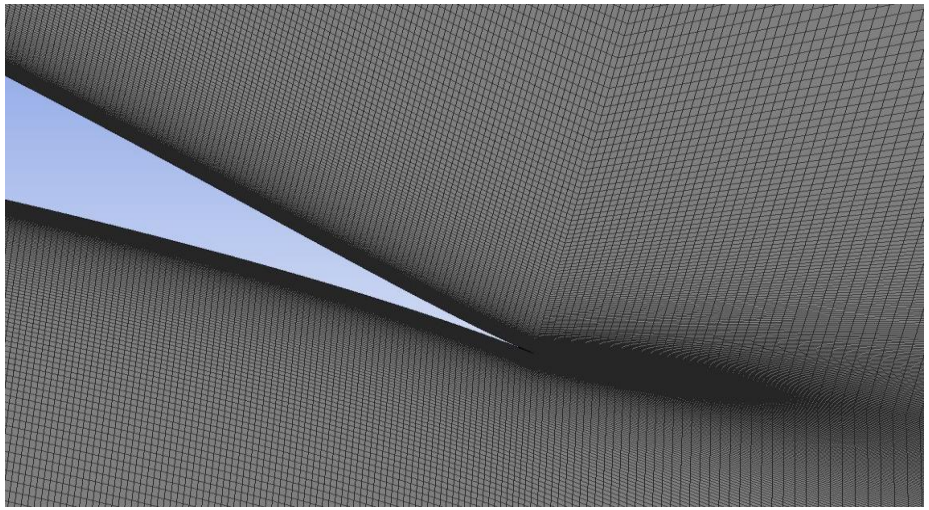
Ice Prediction Software



(EnginSoft Group, 2016)

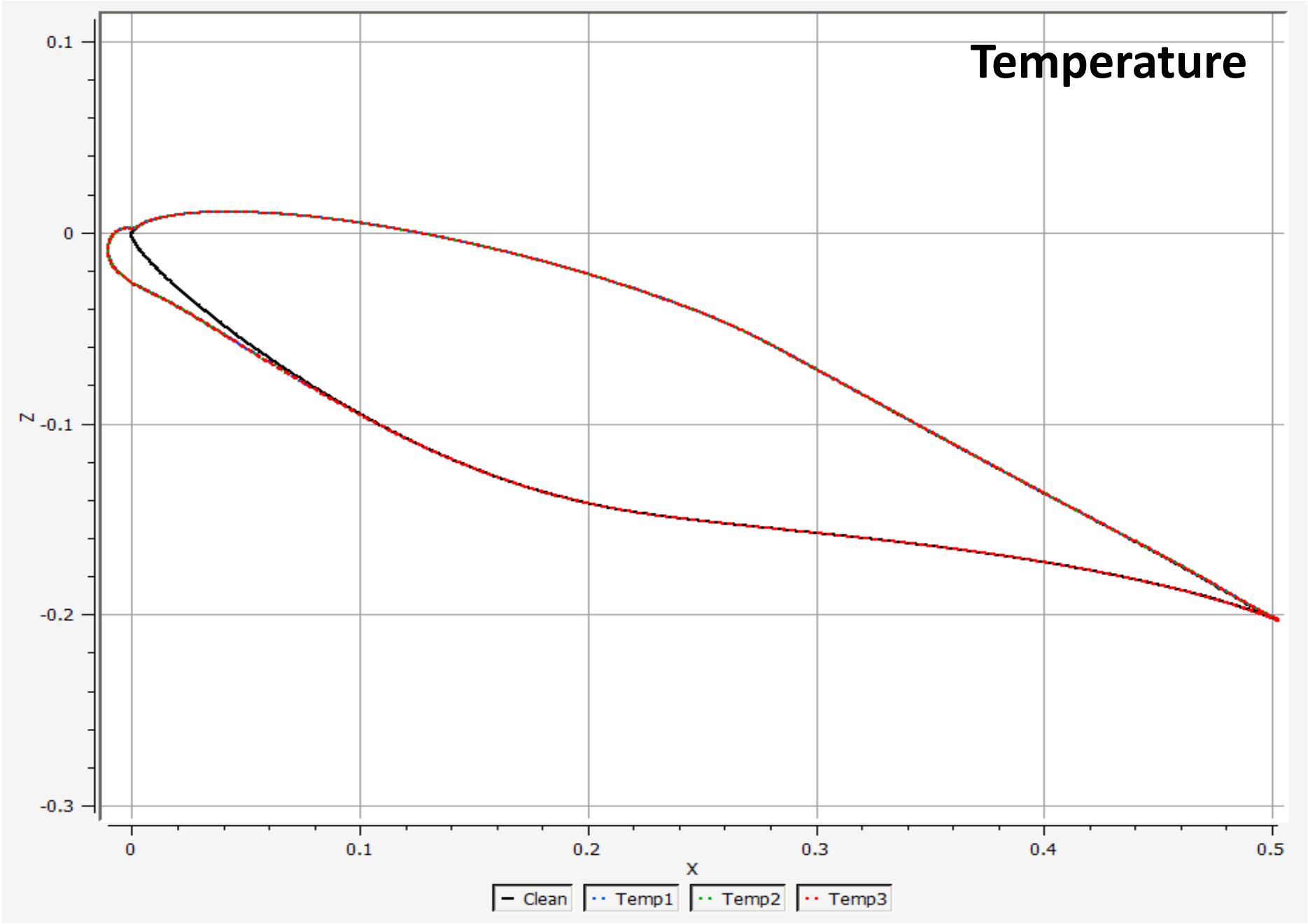




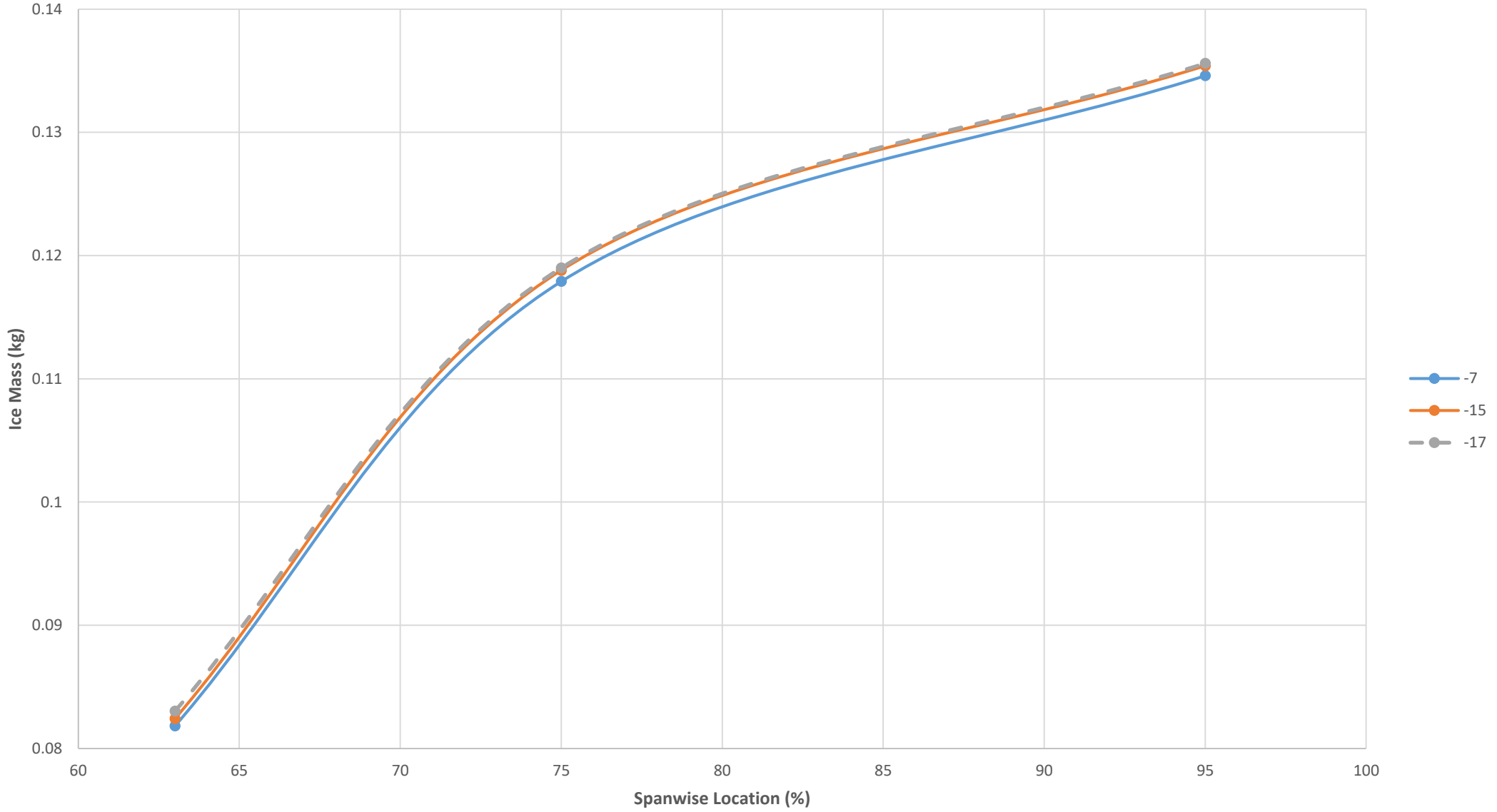


Results

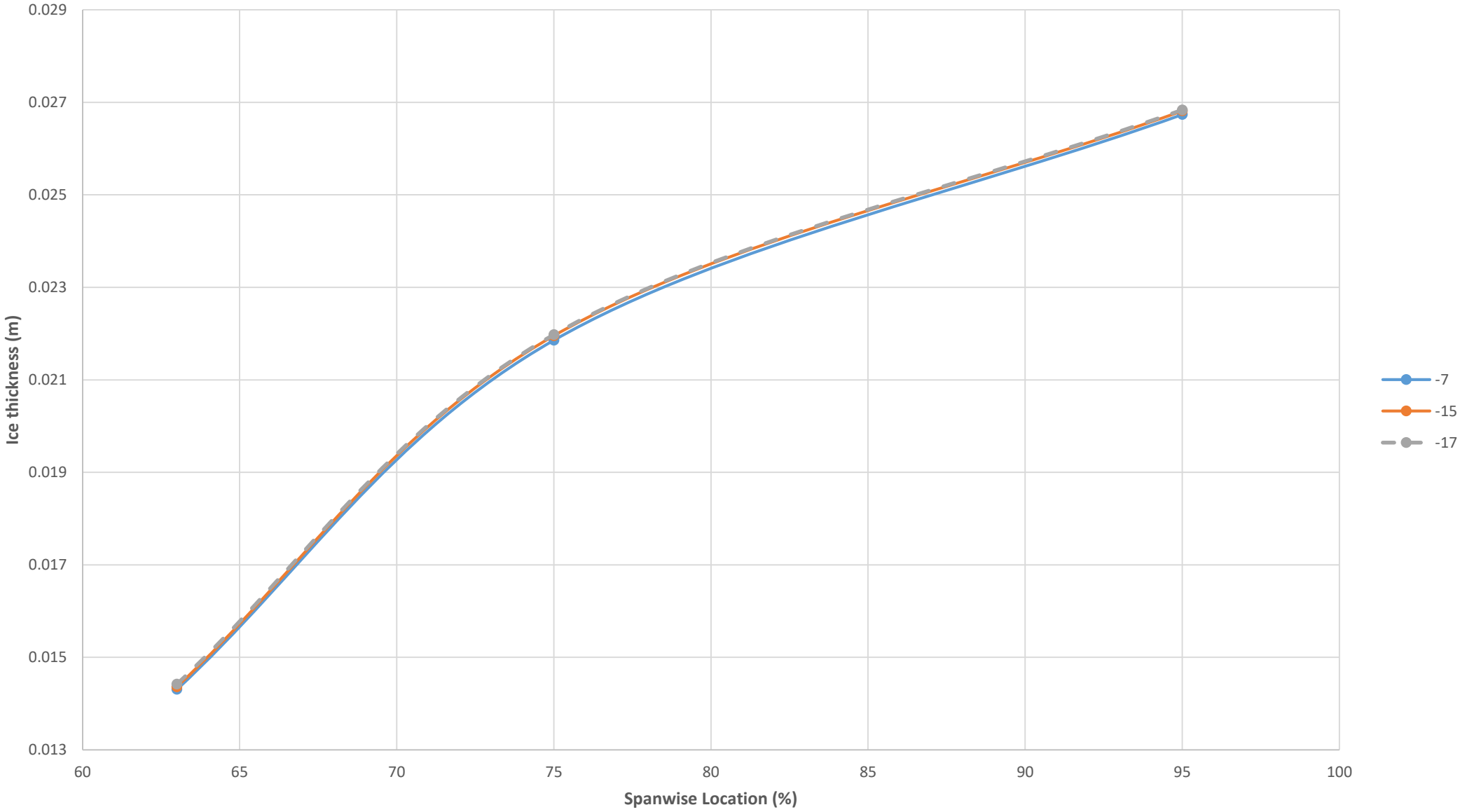
- Ice shapes – 63% span
- Ice Mass
- Ice Temperature

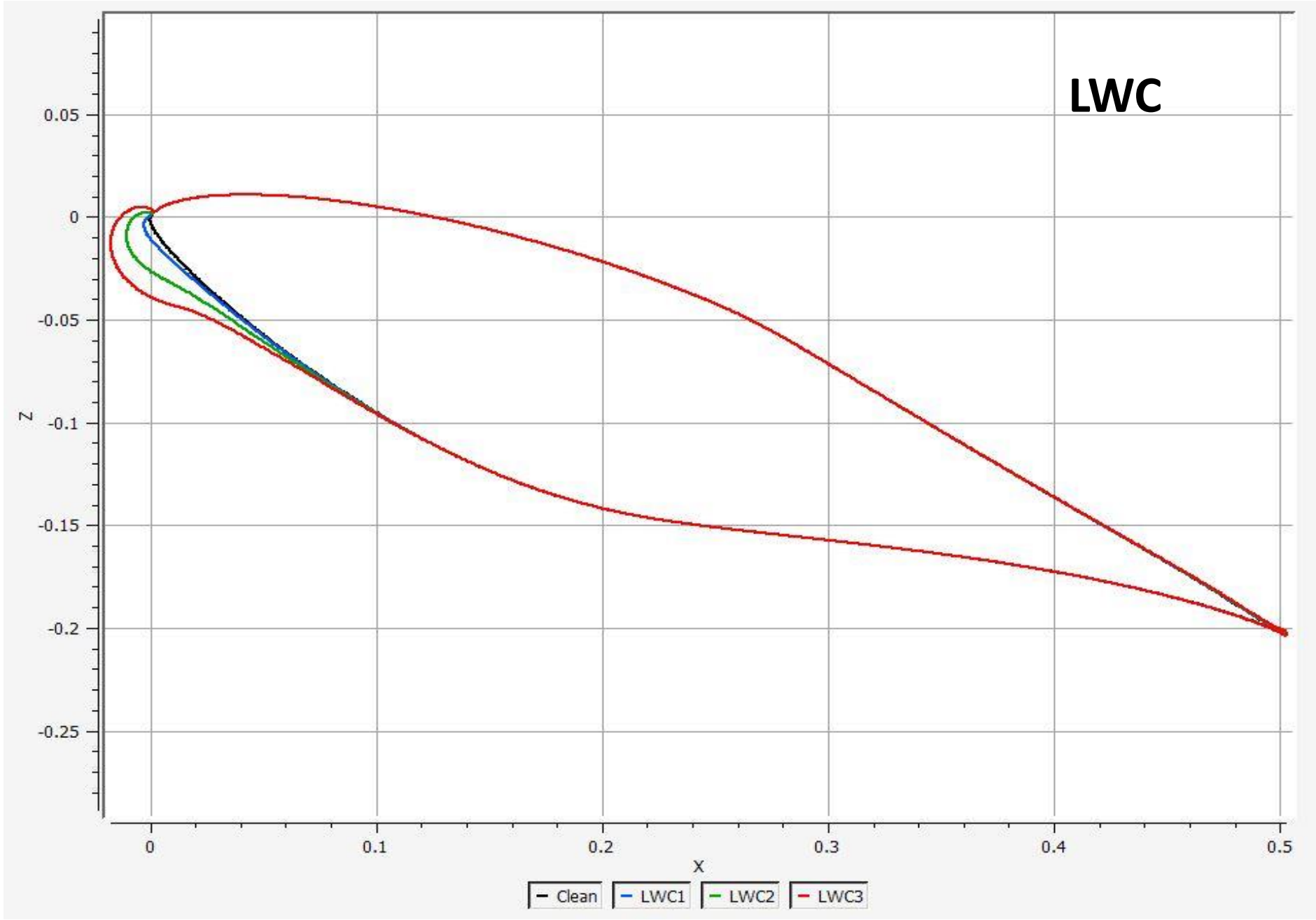

Temperature
0.1
0
-0.1
-0.2
-0.3
Z
0
0.1
0.2
0.3
0.4
0.5
X
Clean
Temp1
Temp2
Temp3

Temperature

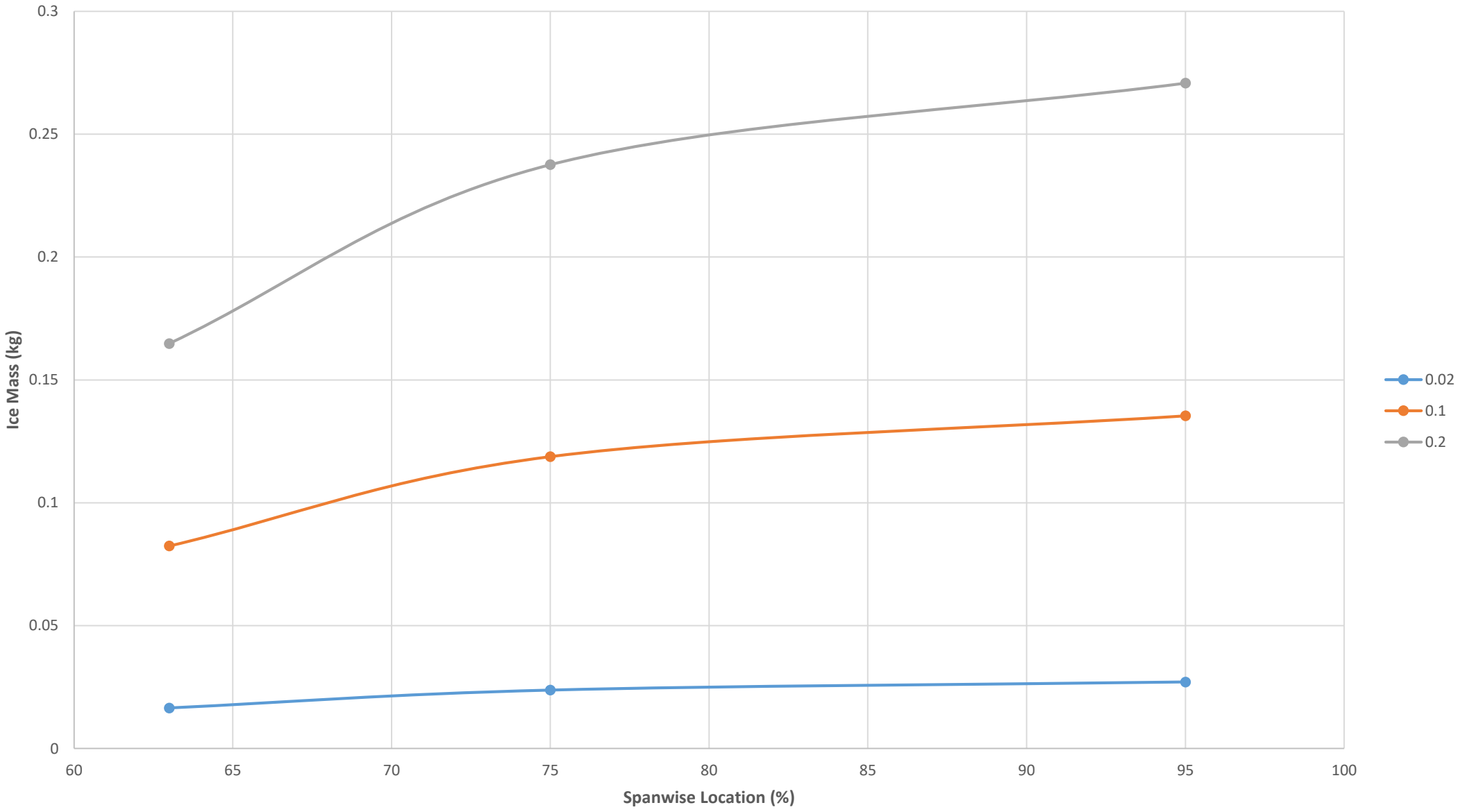


Temperature

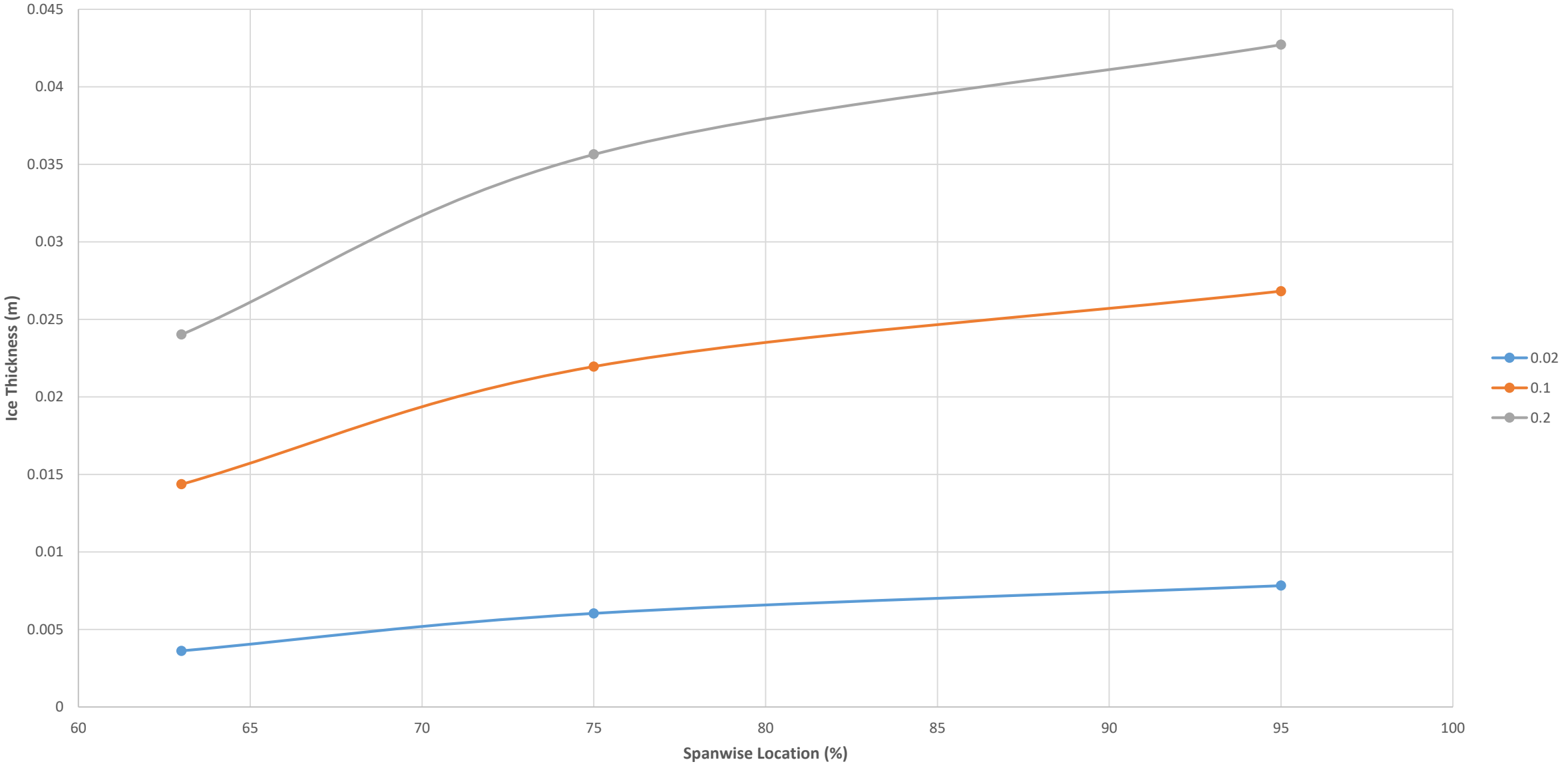


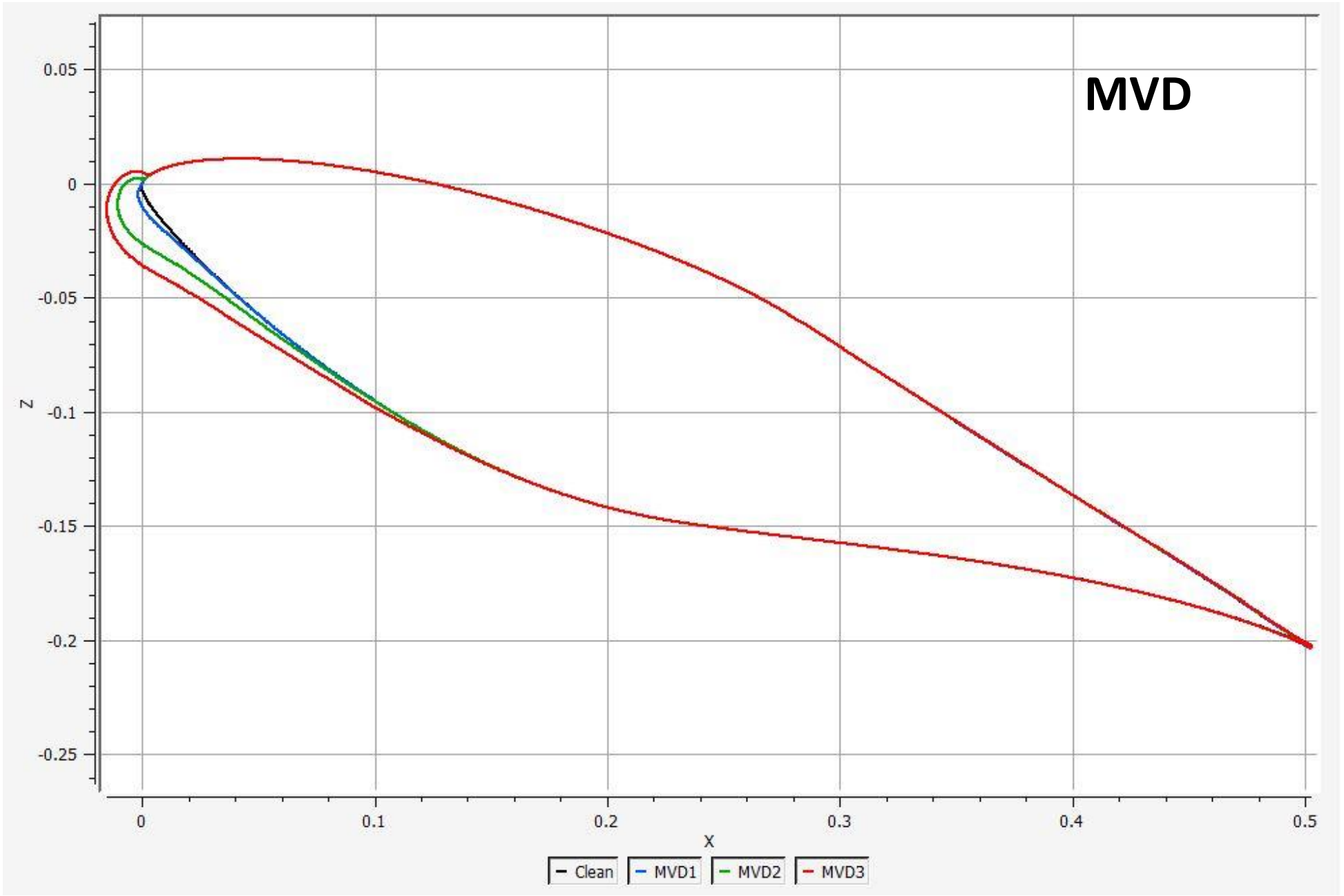

LWC
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
Z
0
0.1
0.2
0.3
0.4
0.5
X
Clean
LWC1
LWC2
LWC3

Liquid Water Content

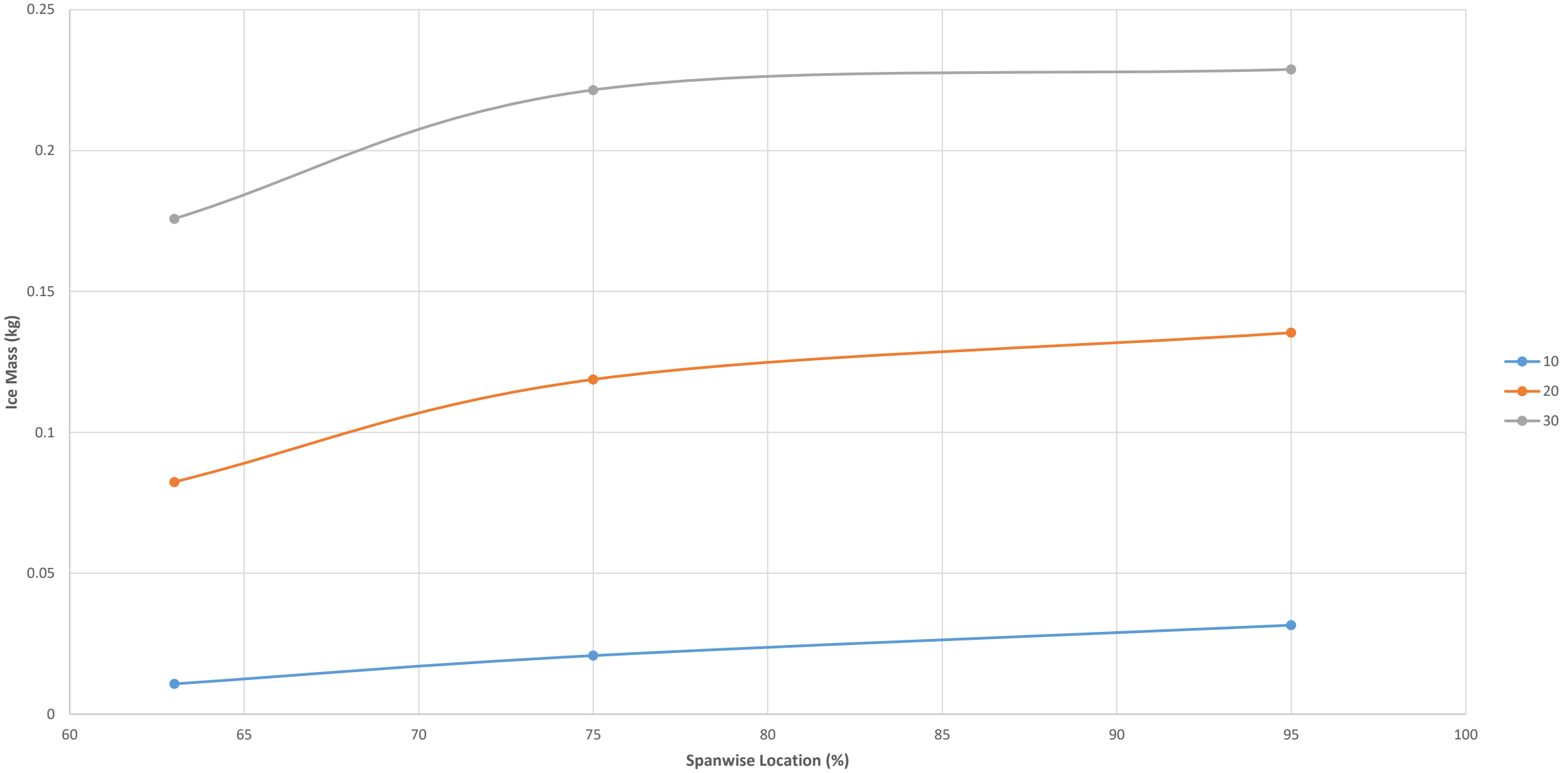


Liquid Water Content

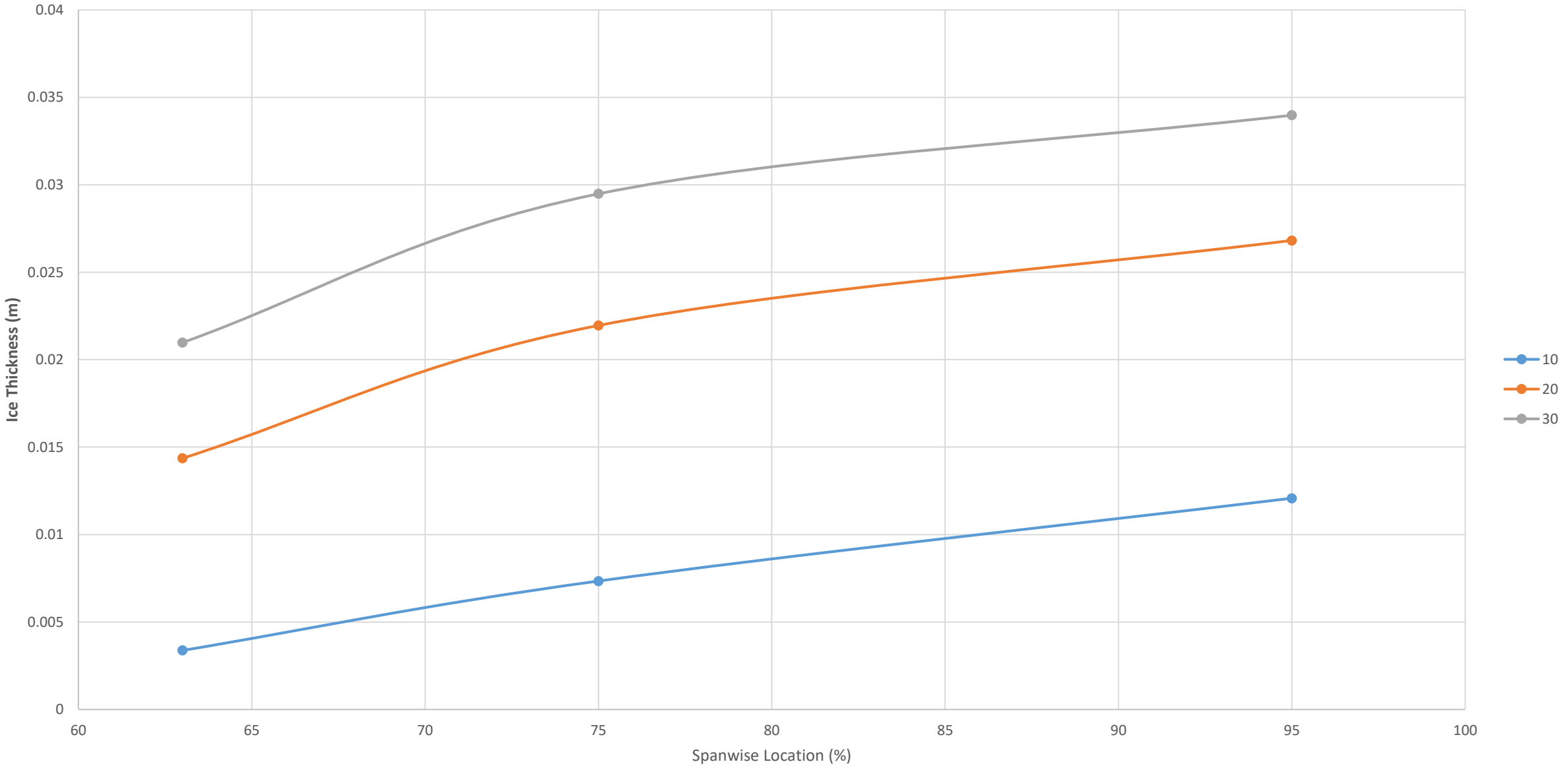


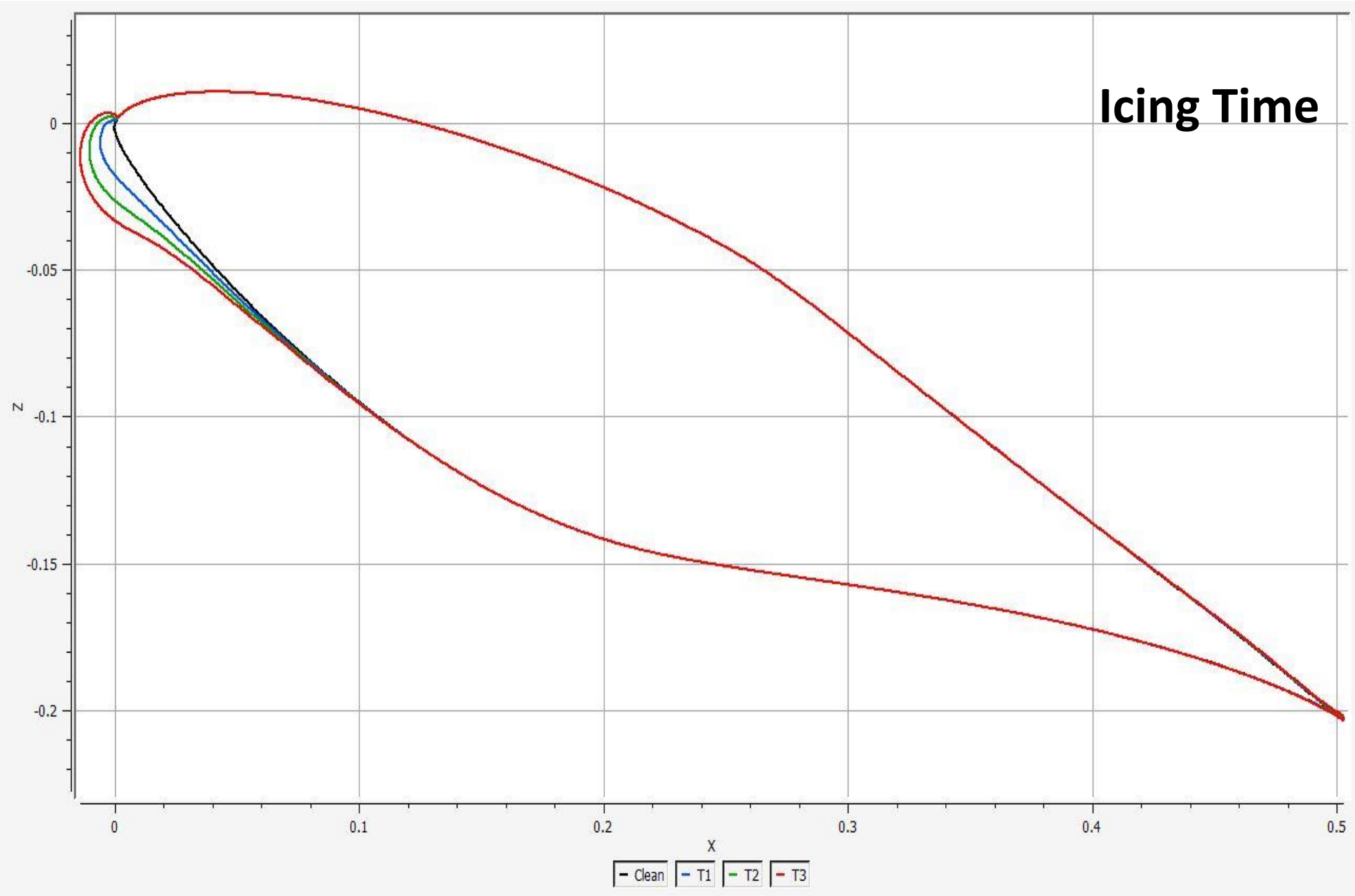

MVD
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
Z
0
0.1
0.2
0.3
0.4
0.5
X
Clean
MVD1
MVD2
MVD3

Median Volume Diameter

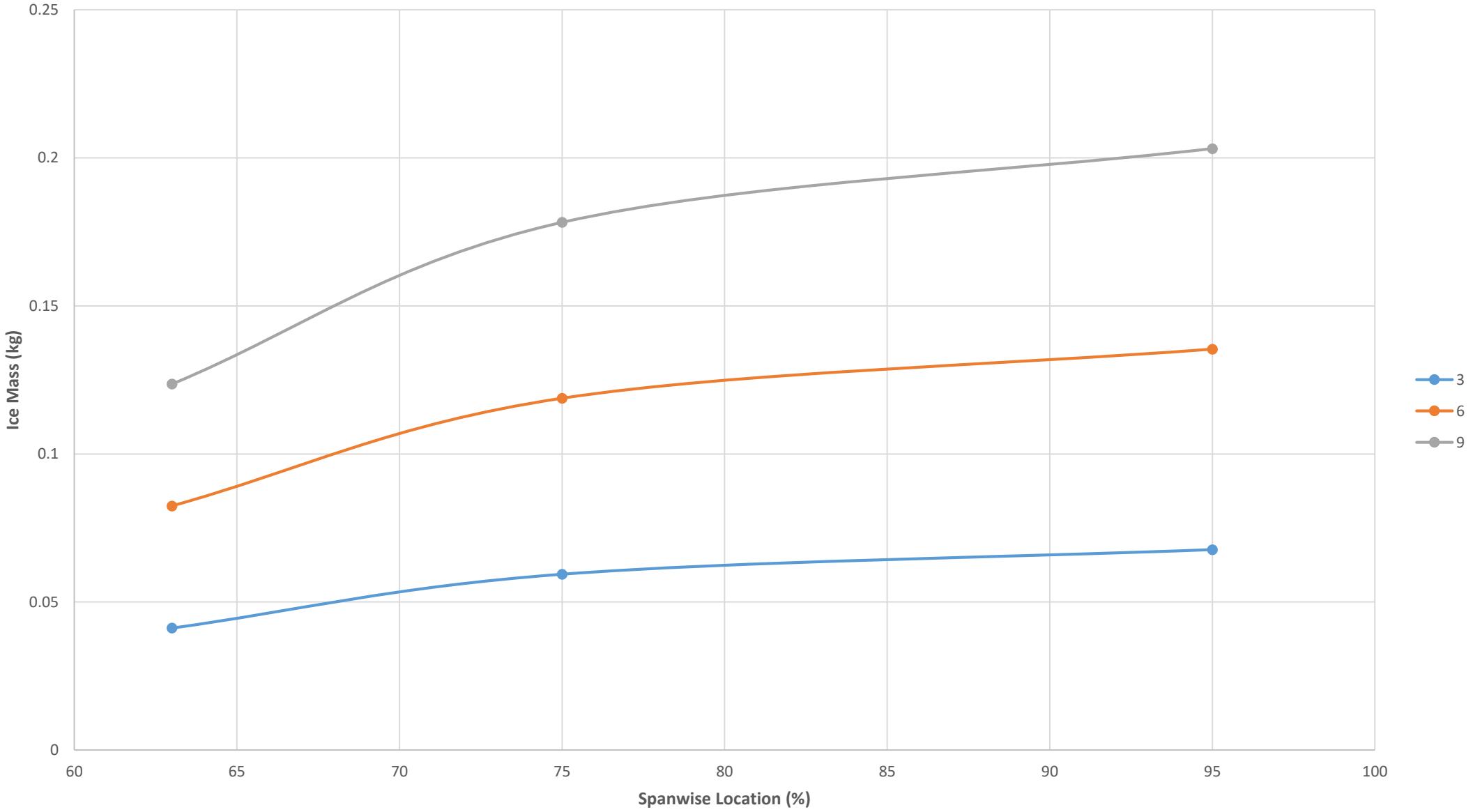


Median Volume Diameter

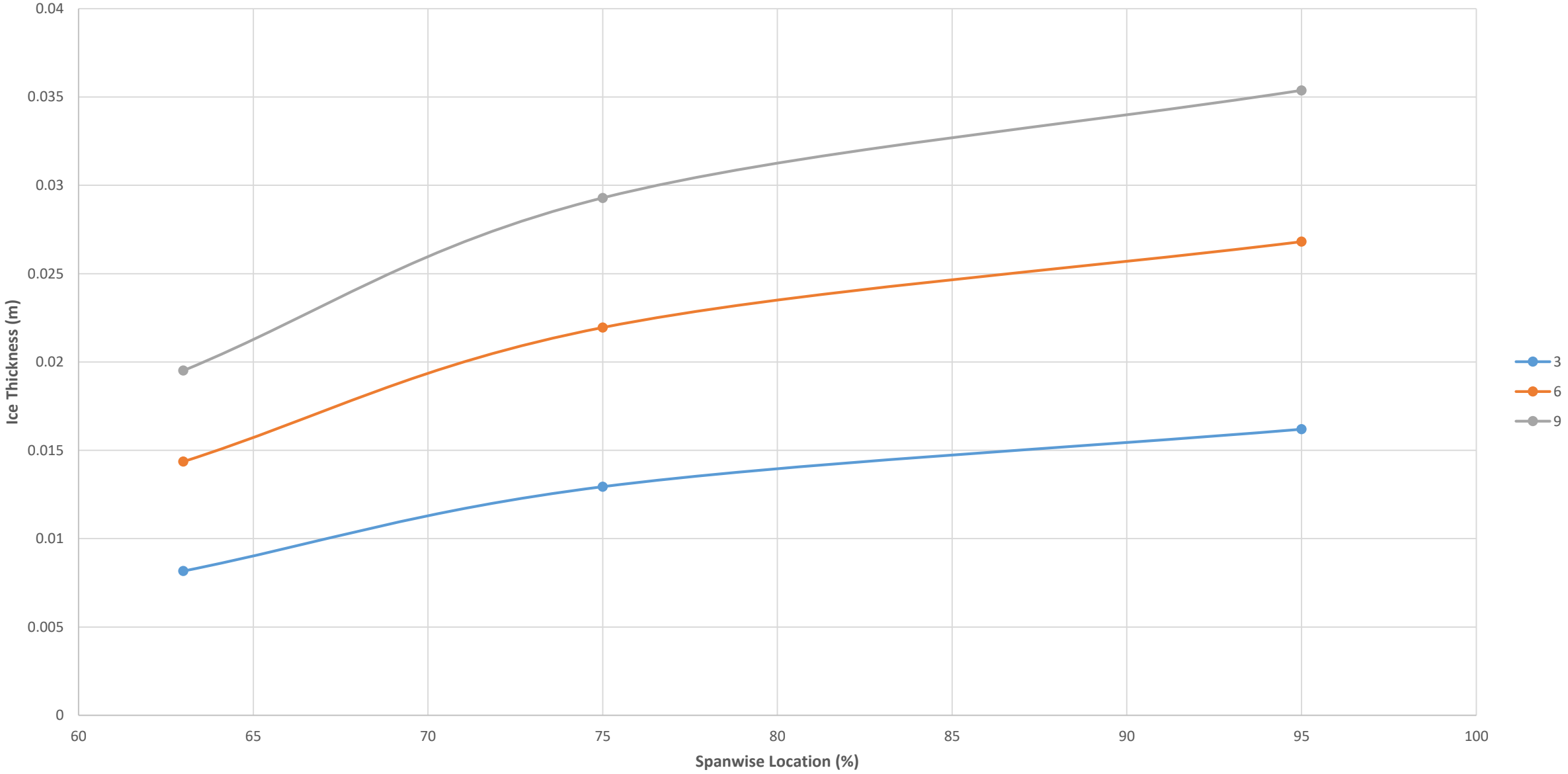


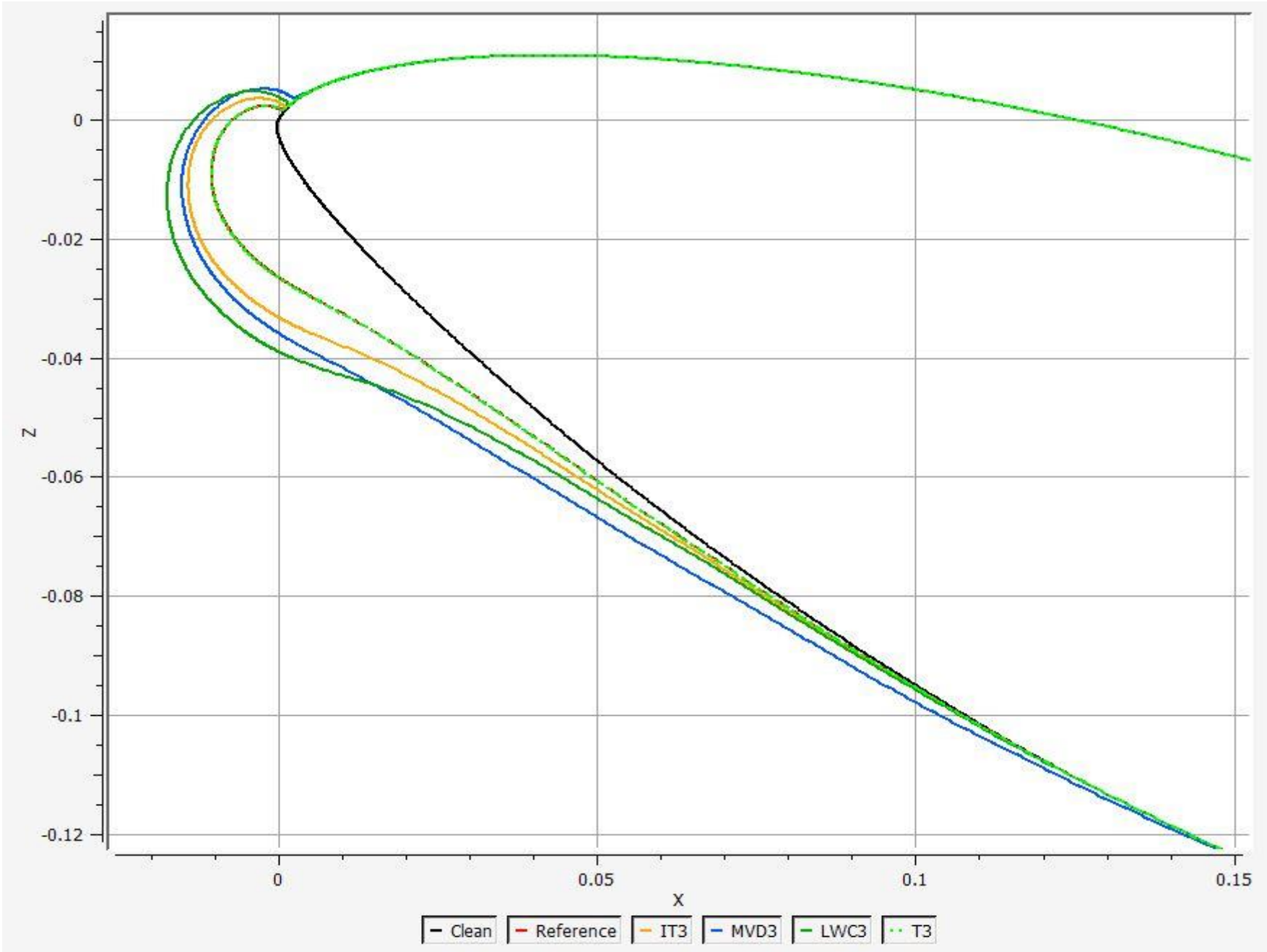

Icing Time
0
-0.05
-0.1
-0.15
-0.2
Z
0
0.1
0.2
0.3
0.4
0.5
X
Clean
T1
T2
T3

Icing Time


0.25
0.2
0.15
0.1
0.05
0
Ice Mass (kg)
60
65
70
75
80
85
90
95
100
Spanwise Location (%)
3
6
9

Icing Time


0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Ice Thickness (m)
60
65
70
75
80
85
90
95
100
Spanwise Location (%)
3
6
9


0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
Z
0
0.05
0.1
0.15
X
Clean
Reference
IT3
MVD3
LWC3
T3

Conclusion

- Parametric analysis is important
- BEM
- Ice mass, thickness and location are more important than ice shape
- LWC and MVD
- Effective ice preventing system for outer section of the blade

Future Work

- Full study with detailed results coming out by April 2020
- Offer an effective ice prevention system
- Operational strategy
- Criteria to compare ice

Acknowledgement

- Supervisory team
- MEng Group Project Students – Alin Sonny, Muram Abbadi and Sherrahman Zaman

References

- Han, Y., Palacios, J., and Schmitz, S. “Scaled Ice Accretion Experiments on a Rotating Wind Turbine Blade.” *Journal of Wind Engineering and Industrial Aerodynamics*, Vol. 109, 2012, pp. 55–67. doi:10.1016/j.jweia.2012.06.001.
- Statkraft (Online): https://www.statkraft.com/media/press-releases/Press-releases-archive/2011/smola-wind-farm-reopen-to-the-general-public/
- Engin Soft (Online): https://www.slideshare.net/mosenecchio/deicing-on-wind-mill-generators