TURBICE - the Turbine Blade Icing Model, and its further development via a new interface

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Abstract

TURBICE (Turbine Blade Icing Model) is the in-house two-dimensional wind turbine blades ice accretion simulation program of VTT. Development of the program started in 1991, new features have been added throughout the time, and also some of the constituent models of the program have been modified since its introduction. The program has been verified via comparisons with the results of its counterpart programs as well as with icing wind tunnel experiments. The program has proved itself as one of the main components of wind turbine blades ice prevention systems development and design process by simulating required operating conditions in cold climate and arctic environments to estimate heating energy demands.
Recently, construction of a new programming architecture and interface for TURBICE is proposed and currently under progress, which envisions an object-oriented programming (OOP) interface using Python programming language, at the same time maintaining advantages of low-level programming languages, such as FORTRAN, by utilizing Python as code glue. By utilizing OOP approach, usability, modularity, flexibility and extendibility of the program will be enhanced to a great extent, which will also enable using the program coupled with other related simulation programs in order to get advantage of multi-physics simulations of engineering systems (i.e. fluid-structure interaction analysis of iced blades, fluid-structure-control mechanism interaction simulations).
In this poster, development phases and some technical aspects of the current TURBICE are highlighted, along with introducing the new programming interface for further development of the program.

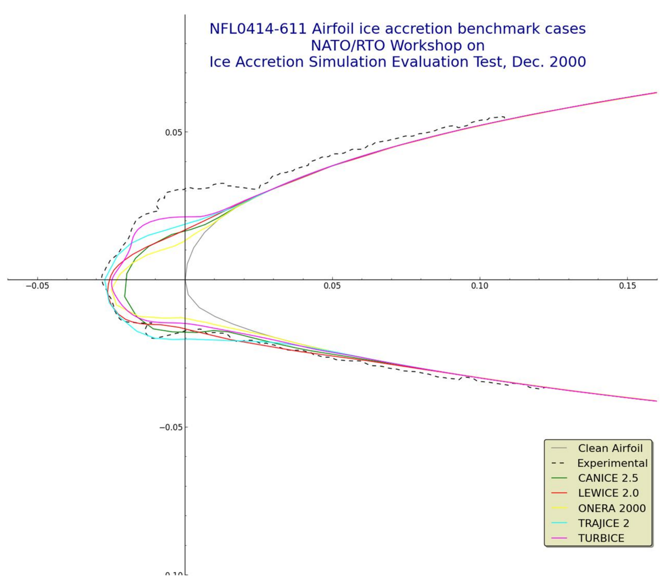
TURBICE

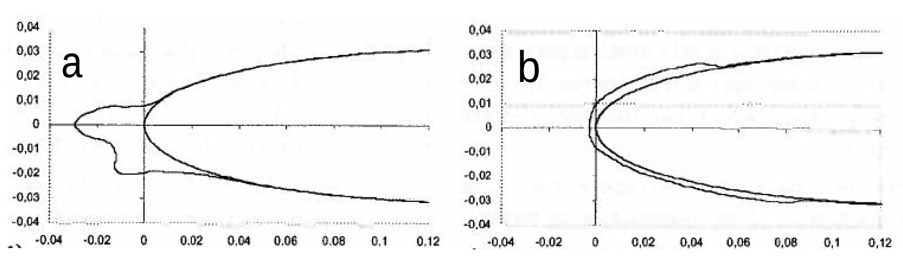
Program is based on:

- Utilizing *panel methods* for incompressible potential flow field calculations around airfoil cross-sections.
- Releasing droplets from their initial positions in front of the airfoil cross-section and calculating their trajectories by Lagrangian droplet tracking technique.
- Finding droplet impingement locations and collision efficiencies along the surface in order to simulate **ice accretion** on an operating wind turbine blade surface in a pseudo-3D setting.
- This process enables finding the **required heat amount** to prevent ice accretion on the wind turbine blades.
- The model is able to simulate both *rime* (dry) and *glaze* (wet) icing, as well as simulating an operating blade heating system.

U [m/s]	T [K]	LWC [g/m³]	MVD [μm]	Time [s]
92.54	257.60	0.33	20.0	1224.0

U [m/s]	T [C]	LWC [g/m³]	MVD [μm]	Time [m]
58.0	a) -13.9 b) -2.80	1.3	20.0	a) 7 b) 8





TURBICE simulations [3]
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Further development of the program

Further development of the program has been a continuous process and has been going on regarding various improvements and enhancements of the physical methodologies included in the program.

For example, improvement of the boundary layer methodology and its implementation is currently one of these subject areas.

One another important physical phenomenon when considering wind turbine operations in cold and arctic climates is the **increased loading** of the wind turbine blades due to high density of cold air and the loads induced by accreted ice which leads to undesirable consequences such as:

- Load imbalance ➡ excessive vibration ➡ increased fatigue loading ➡ reduced life-time of the wind turbine parts

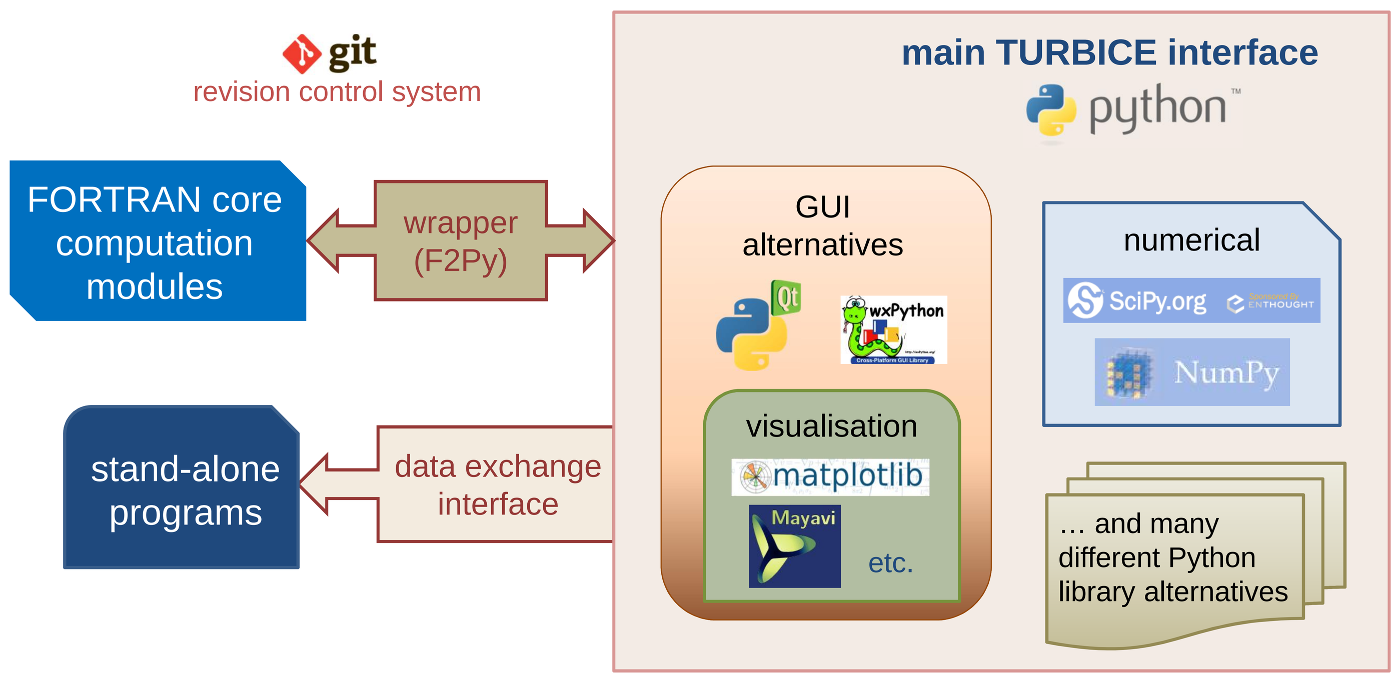
Furthermore, some other undesirable effects are:

- Change of the aerodynamic shape therefore the performance of the wind turbine blade ➡ overall performance degradation
- Ice shedding ➡ operation safety risks

In order to better understand and simulate the physical environment, *ice accretion research coupled to a structural analysis simulation* is of high importance. Considering the wind turbine operations these types of multi-physics simulations are known as **fluid-structure interaction** and **fluid-structure-control mechanism interaction** simulations. One of the promising alternatives to conduct such simulations is by coupling these isolated fluid, structural, control mechanism environments in various interaction levels (i.e. loose or tight coupling). Another would be to provide a unified physics and, therefore, a unified set of governing equations.

A new programming interface

The need for multi-disciplinary computations brings a requirement to have at least a software based infrastructure which is capable to orchestrate different programs that are usually produced as stand-alone programs on their specific subjects and fields.
In this regard, due to its high-level, general-purpose and object-oriented characteristics, *Python* is a promising alternative which could allow construction of such high-level infrastructures in several integration levels.
Owing to its clean and easier to write/read syntax as well as large number of various specific purpose libraries that are usually freely available, Python is also a viable alternative to C++ [1].
For instance, by using Python one could either develop a code management environment for data exchange between stand-alone programs by I/O files or memory handling [2], or by using wrappers (as a code glue) around native source codes to import them as libraries and modules inside the programming interface in order to get advantage of their low-level fast run-time properties.



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Topic #2: Ice management and optimization of low-temperature adaptations

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