The objective of this proposal is to extend this method in 3d and to couple this approach with compressible laminar flows using linear continuous finite elements. The potential of the proposed approach has been demonstrated in 2d for representation of the moving solids. Adaptive mesh deformation enables to refine the mesh at the fluid-solid interface. The initial work conducted in the FP7 STORM European project [1, 2], has led to the development of a method allowing to compute ice block trajectories. The problem to be solved is a coupled problem since the airflow is modified by the motion of the ice block. In-flight icing is an important problem for aviation safety. In addition to performance degradation due to ice accretion on the wings, icing can cause vibration or pumping of the engine, engine's extinction, or even permanent degradation when blades are broken as a result of ice block detachment. These problems must be anticipated from the design phase of the aircraft. These simulations involve combining very different skills including mathematical analysis, digitalization, linear algebra and high-performance computing (HPC). This is a considerable challenge that must in particular exploit the tremendous advances in computational architectures.

Scientific Research context:

Simulating, optimising, and controlling these systems in a robust manner is far from being a simple task, especially in a real life. There is still a large number of open scientific challenges. These are related to the intrinsic nature of these flows necessitating:

- an appropriate PDE formulation taking into account the physics relevant to the engineering applications while remaining computationally affordable in an operational context
- efficient adaptive discretizations allowing to optimize the computational effort, while providing a sharp and accurate resolution of the physics
- a certification step quantifying the uncertainty in engineering outputs due to all modelling choices, both physical, and mathematical (continuous and discrete)

To develop a robust and accurate model means to be able to quantify and control the effects of the choices made in each of the above steps. The development of robust models tailoreed to the applications mentione above is the objective of CARDAMOM.

Scientific priorities: Modeling and Simulation

In-flight icing is an important problem for aviation safety. In addition to performance degradation due to ice accretion on the wings, icing can cause vibration or pumping of the engine, engine's extinction, or even permanent degradation when blades are broken as a result of ice block detachment. These problems must be anticipated from the design phase of the aircraft. With the introduction of new, more stringent regulations and the use of new materials, manufacturers would like to have reliable numerical simulation tools available during the design and certification phase.

This is one of the most strategic research topics in the CARDAMOM team.

The goal of this work will be to continue the development of an efficient high fidelity numerical method allowing to compute ice block trajectories. The problem to be solved is a coupled problem since the airflow is modified by the motion of the ice block.

The initial work conducted in the FP7 STORM European project [1, 2], has led to the development of adaptive tools for the prediction of ice blocks shed into the air flow. These tools involve an immersed boundary method applied on unstructured adaptive meshes, and coupled with a level-set representation of the moving solids. Adaptive mesh deformation enables to refine the mesh at the fluid-solid interface. The potential of the proposed approach has been demonstrated in 2d for compressible laminar flows using linear continuous finite elements.

The objective of this proposal is to extend this method in 3d and to couple this approach with...
complex physical models/modules (turbulence models, ice accretion modules, etc). To be able to perform 3d simulations in a reasonable computational time, all the tools have to run in parallel. In particular, the adaptive mesh deformation should be couple in parallel with the immersed boundary method.

**Assignment**

The milestones of the project are the following:

1. Development of an unsteady scheme for 3d penalized laminar Navier-Stokes equations
2. Parallel coupling of the mesh deformation tool with the previous
3. Benchmarking on three dimensional tests involving complex geometries
4. Development of Spallart Allmaras turbulence model
5. Coupling of these tools with this turbulence model

The development will be done in an object oriented parallel C++ platform (Aerosol) allowing both continuous and discontinuous finite element computations on general hybrid meshes.

**Main activities**

**Keywords:** CFD, immersed boundary methods, finite elements, unsteady mesh adaptation, fluid solid interaction

**References:**


**Skills**

Scientific programming, and in particular very high proficiency with object oriented programming in C++; numerical analysis, and in particular finite element methods; basic notions of fluid mechanics

**Benefits package**

- Subsidised catering service
- Partially-reimbursed public transport

**Remuneration**

2653€ / month (before taxes)