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INVESTIGATION OF THE EFFECTS OF SELECTED PHYSICAL FACTORS ON WATER COLLECTION EFFICIENCY OF AN AERODYNAMIC SURFACE IN ICING PROBLEMS

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Water collection efficiency of an aerodynamic surface is a measure of the amount of water hitting the surface in two-phase flow consisting of air and water droplets. It is defined as ratio of water stream intercepted by an infinitesimally small surface element to the value of water stream far away from the surface. This quantity has high importance particularly in simulations of ice accretion, because it provides the information of the distribution of mass of water intercepted by the surface and it allows to evaluate the heat flux reaching the surface with incoming water. A method of determination of the surface distribution of this quantity for a body in external flow, using Eulerian approach, has been implemented as an extension of the commercial Fluent sover. The water droplet phase is modeled using variables and equations introduced as User-Defined Scalars and User-Defined Functions. The system of equations describing the transport of the water droplet consists of the continuity and momentum equations. It is assumed, that interactions between the phases are one-directional, i.e. the air flow influences the water droplet flow and itself is not influenced by the water droplet flow. This assumption is valid for low concentration of water phase, typical for atmospheric icing problems, and frequently used in the numerical analyses of this phenomenon. The current implementation of the method allows for investigations of two-dimensional problems, encountered frequently in aerodynamics, such as flow around airfoils. In Figure 1 a solution of droplet phase density around a NACA23012 airfoil is presented for compressible, viscous flow at angle of attack of 2.5 degrees.

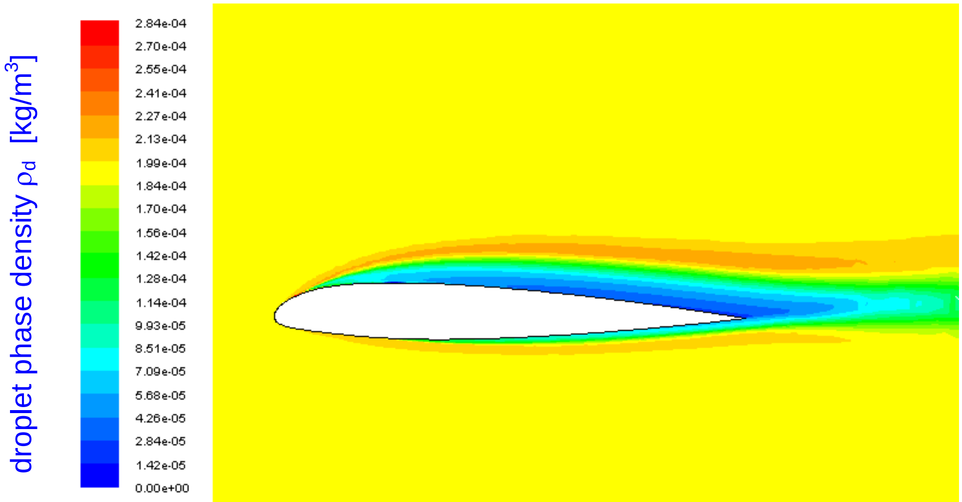

Figure 1. Contour of droplet phase density, ρ_d around NACA 23012 airfoil, at angle of attack α=2.5°.

Boundary conditions for the droplet flow have been chosen to correspond to the external flow boundary conditions being used for the computation of the aerodynamic characteristics of airfoils and three-dimensional bodies. The external border surfaces of the computational domain have been divided into two categories: pressure far field and pressure outlet. The pressure far field includes surfaces of uniform and undisturbed flow lying ahead of and on both sides of the airfoil. The air flow quantities being set there include Mach number, X and Y components of the vector of the flow direction, pressure and temperature. They allow for the determination of the values of the flow variables computed by the solver: components of flow velocity, density, pressure and temperature. The water flow variables include mass concentration and X and Y components of the droplet velocity. It is assumed that the X and Y components of the air and water droplet velocity are equal in the far field (The computational problem may be considered as body moving through two-phase fluid at rest). On the outlet surface only the pressure and temperature are set. The air flow velocities and density include disturbances caused by the airfoil and are computed by the solver. Similarly the water flow concentration and velocity components are computed up to the cell center point adjacent to the outlet surface. Their values on the outlet surface are extrapolated using gradients computed in the center of the cell.

On the airfoil surface the typical wall no-slip boundary condition is applied for the air flow. For the water flow there are two cases treated in different way: the case when water is intercepted by the surface and the case when water droplets move by the surface. In the first case, when $(\vec{U}_d \cdot \vec{n}) < 0$, $\vec{n}$ being the cell-wall normal vector, the airfoil surface is considered totally permeable for the water. The water velocity on the surface is extrapolated using gradients computed in the cell center. This is a standard procedure applied for the computation of collection efficiency for the simulation of ice accretion. The flow of water on the surface is a separate problem, being treated in the ice accretion simulation codes with the application of heat exchange and heat balancing procedure, summing heat flows in and out of the surface. This allows for the determination of the amount of water that freezes in particular location or runs away along the surface. Such procedure has not been created for the present work yet, but is planned for the future.

In the case when $(\vec{U}_d \cdot \vec{n}) > 0$ the water concentration on the surface, ρ_d is set to zero, and the components of water flow velocity are extrapolated using gradients computed at the cell center. This ensures the continuity of droplet flow variables.

It was assumed, that the droplet motion is the result of aerodynamic drag acting on them, the net effect of gravity and buoyancy forces and forces resulting from pressure grandients in the flow field.

In the proposed article impact of physical factors on a collection efficiency of an airfoil in viscous, compressible flow will be investigated. The investigated factors will include Mach number, angle of attack, droplet mean diameter, droplet phase concentration in the air.