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VOF-based concentration-gradient-driven mass transfer model for water evaporation

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The evaporation of water can be easily observed in daily life. However, unlike its occurrence, it is not straightforward to accurately resolve the problem and to predict the corresponding evaporation rate, since evaporation is a rather complex multi-physical mass-transfer process occurring at the free surface between two phases — water and air, where a number of factors are involved [1]. Nevertheless, it is crucial to accurately estimate the evaporation rate at the given conditions in many industrial fields such as the prediction of local corrosion effects in automotive applications. Therefore, a robust numerical method is essential to resolve the evaporation phenomenon.

A new mass transfer model for evaporation phenomena below the boiling point at the water-air interface is implemented in a VOF-based solver, or the icoReactingMultiphaseInterfoam. Thereby, it is assumed that the main driving force of the liquid mass transferred into vapor is diffusion driven by the normal-directional vapor concentration gradient in the air phase close to the free water surface [2]. It is also assumed that the cells completely filled with liquid have saturated vapor concentration whereas within the cells lying at the phase interface, thus $0 < \alpha < 1$, the vapor concentration gradient can be calculated [3]. The vapor is then further transferred into the cells completely filled with air phase, where each cell has its own vapor mass fraction, and eventually diffused or moved away by forced convection. Thus, the air phase can also have predefined ambient relative humidity in the air phase cells and at the boundaries, in terms of vapor mass fraction, which is necessary to correctly predict the evaporation rate.

The simulation results are validated based on a series of experiments measuring the water evaporation rate with a relatively simple water vessel geometry. In the experiments, controllable conditions that strongly influence the evaporation rate such as air temperature, relative humidity, and air flow rate are varied. The measured evaporation rates are then compared with the results of the VOF-based two-phase simulation with the newly implemented evaporation model. The validation results are reasonably acceptable and promising.

REFERENCES

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