

Modeling of Humidification in Comsol Multiphysics 4.4

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Abstract: Humidification is a complex phenomenon including multiphase flow along with heat and mass transfer. Further the presence of discontinuous phase in the form of water droplets poses even greater a challenge.

In the following study Comsol Multiphysics 4.4 was used to simulate evaporation of water droplets in a stream of heated air. This was a precursor to the modeling of a humidifier, which is used to humidify the air supplied to fuel cell stack. Since the percentage of water droplets was relative low, particle tracing method was used for the simulation. Source terms were added to model evaporation of water droplets due to the heat transfer from surrounding air. However Comsol solves particle tracing in Lagrangian frame and particle variables cannot be passed to air phase, which is solved in Eulerian frame, and vice versa. To circumvent this, a system of PDE's was defined. To remove the limitation on the overall time step of the simulation due to the source term in the energy equation, it was assumed that particle evaporation has no effect on the air temperature. Motion of water droplets in a heated air stream, across a straight channel along with evaporation was modeled and the motion of generated water vapor was tracked. Generated water vapor eventually converged to a parabolic profile as expected for a laminar flow through channel. The rate of evaporation increased with increase in temperature of inlet air while for the range of particle diameters studied it varied to lesser degree. Both, lower and higher velocities of inlet air were found to dampen the rate of evaporation. There is an optimum velocity for maximum evaporation based on the inlet air temperature, channel dimensions etc.

Keywords: Humidification, Comsol.

1. Introduction

Humidifiers have become key components in a variety of applications ranging from air conditioning to fuel cells. Most often humidifiers rely upon evaporation of water droplets which presents a complex heat and mass transfer

problem. Hence it is desirable to model the humidification process through Computational Fluid Dynamics (CFD) to gain an insight into aspects like efficiency of evaporation, distribution of evaporated vapor etc. In this study we model the humidification of air in a straight channel flow due to the evaporation of water drops introduced at one end. The simulation domain is given in Fig. 1. As with all problems involving heat and mass transfer convergence requires critical solver settings. Although the application is pretty common and there would be lot of CFD studies in the area, the authors have not referred to any of those since the underlying physics is well defined. Only the expression for rate of mass transfer at the surface of the droplet is taken from [1,2].

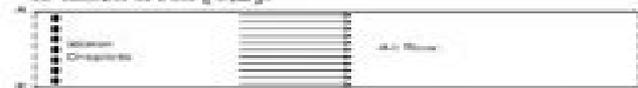


Figure 1. Simulation domain used in the study.

Effect of inlet air temperature, inlet air velocity and the diameter of inserted particles was studied. Along with, the rate of evaporation for laminar flow as compared to turbulent flow was studied. Although, the contours of water vapor concentration represent physical trends; they need to be validated with experiments.

2. Governing equations

The air flow is governed by the Navier Stokes equations. However source terms must be added to the continuity and the energy equations due to the evaporation of water droplets. It is assumed that the presence and evaporation of water droplets has no significant effect on the momentum of air.

The continuity equation is given as:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho u) = \Gamma(T_p) \dot{m} \quad (1)$$

Momentum conservation and Energy conservation respectively are:

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