Department of Mechanical Engineering

ME537 Multiphase Flows. Midterm. Fall 2018

Assigned on 11-02-2018, due 11-04-2018 at 5 pm

Consider a car driving in the rain. The presence of rain (a disperse phase) changes the motion and dynamics of the air around the car, changing the equilibrium of forces and the energetics of the car. Discuss the physics of this problem, using approximations from multiphase flows:

- To first approximation, use a two-fluid approach in which there is no slip between the water and the air, and the flow around the car can be computed with the density and viscosity of the air-water mixture, as air modified by the presence of the droplets. Assume that, at typical highway speeds, the aerodynamic drag is about 80% of the total resistance and the friction at the wheels make up the remaining 20%. Calculate the increase in drag, and therefore in power consumption, as a function of precipitation (measured typically in inches per hour, that is volume of water captured per unit area of soil and per unit time; convert this into a volume fraction). For a given precipitation rate, you can establish two limiting cases: large rain drops (of the order of 2 mm in diameter) and drizzle (of the order of 100 microns).

A more detailed analysis of the flow can be broken down to the mechanics of the front, sides of the car and back:

- On the front, we have a stagnation pressure that will increase with the mass flow of drops impacting the windshield. Think about how the droplet trajectories would look like and what are the implications for forces and droplet distributions along the car.
- On the sides, the boundary layer dynamics will be influenced by the presence of the drops and will modify the drag (viscous friction) contribution. You can use the approximation of a flat plate boundary layer for the analysis of this part. How will the flow respond to large vs small droplets? How will the amount of rain influence the interaction?
- Finally, on the back, the flow is separated (except for sports cars) and the flow resembles a blunt body wake. How will the drops interact with the eddies present in this type of flows? How will the flow be changed by the droplets? What can you estimate about the contribution of the low pressure in this region to the overall drag, will it increase or decrease with rain?

Note: Remember that this an open ended question. The subsections and subquestions are just for guidance. You should only use them in as much as they are helpful to your thinking. I am looking for argumentation, not final answers.