

On the Mixing in Hypersonic Laminar Transpiration Cooling

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Abstract

Transpiration Cooling remains a promising technology for protecting hypersonic vehicles against heat and oxidation. One of the central problems in implementing this reusable technology on hypersonic vehicles is the understanding of the mixing mechanism between the boundary-layer gas and the coolant in both laminar and turbulent flows, as well as on and downstream of the injector. The prediction of the of this mixing provides the amount of the coolant that is required to carry inside the vehicle for a given mission, which directly helps design the vehicle. In this article, I propose an analytical model that describes the fundamental mixing mechanism both on top of the porous injector and downstream thereof. The analytical model is derived based on one-dimensional diffusion model. Along with the derivation, I discuss in detail the limitations of the model and why the assumptions made in the model are valid for a hypersonic flow. The model is validated against experimental results in the literature. I show that the model successfully predict the shape and quantity coolant concentration.

Keywords: Hypersonics, laminar, boundary layer, mixing, transpiration cooling

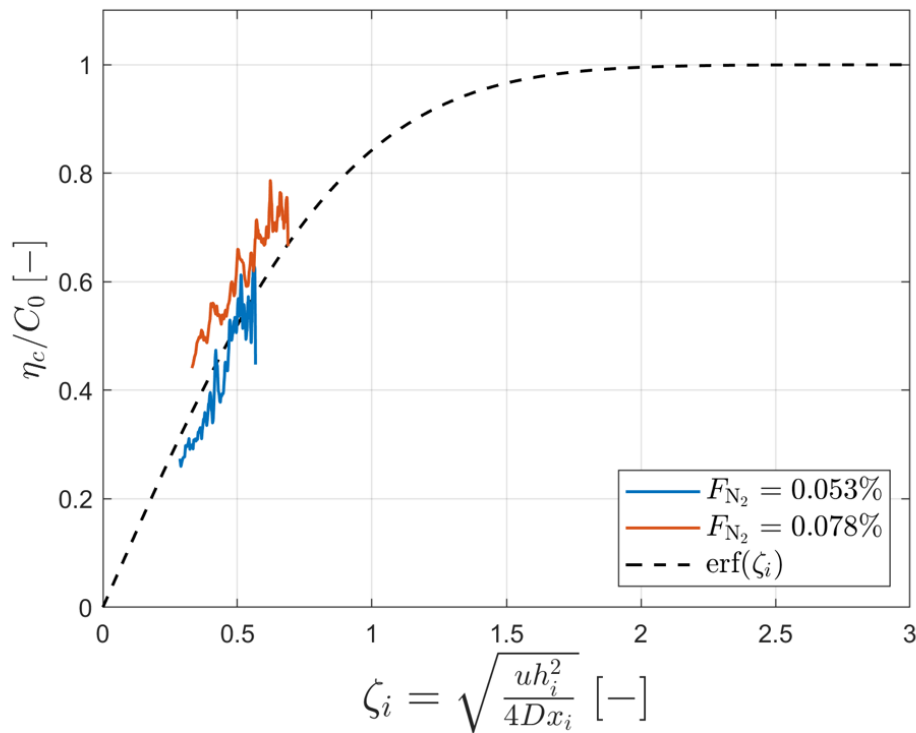


Figure 1. Normalised concentration effectiveness over the porous injector versus driving parameter for nitrogen injection. Solid lines represent experimental data; dashed line denotes the analytical model.

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