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Turbulent Dispersion of Film Coolant in a Turbine Vane Cascade[1]

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Gas turbine engines operate at peak temperatures in excess of the material limits because the high pressure turbine nozzles and buckets are film cooled. The nozzle vanes of the first stage turbine use the most cooling air because they are exposed directly to the high temperature combustor exhaust. Existing turbine analysis assumes a uniform temperature at the rotor inlet. However, the coolant does not mix completely with the mainstream flow before impinging on the turbine rotor, and the coolant streaks create variations in temperature along the leading edge of the downstream turbine blades. 3D velocity and concentration measurements are made using magnetic resonance (MR) imaging techniques to study turbulent mixing in a realistic film-cooled nozzle vane cascade. A scalar mixing analogy for thermal diffusion is used in which a chemical contaminant plays the role of temperature. In a typical experiment, the mainstream flow is water and the film coolant is a copper sulfate solution. The concentration of copper sulfate measured anywhere in the flow is a surrogate for normalized temperature. The turbulent scalar diffusivity in the scalar transport equation can be estimated from the MR data and used to improve computational fluid dynamics models.

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