Detailed Experimental Measurements of Turbulence Model Constants

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Experimental data at small Atwood numbers ($A_t = 0.04$) from the Rayleigh-Taylor (RT) mix experiment has been used to perform model constant evaluations. As a key hydrodynamic process during inertial confinement fusion (ICF) implosion, our studies of RT mixing directly impact fundamental understanding of the flow physics, and aid in validation of predictive engineering models for ICF target design and energy deposition. We consider the primary momentum transport flux $<\rho' v'>$, for which a model representation is to use the gradient diffusion hypothesis [1] as:

$$< \rho' v' > = -\frac{\nu_t}{\sigma_t}\frac{\partial \rho}{\partial y} = -\frac{C_\mu k^{1/2} \ell_m}{\sigma_t}\frac{\partial \rho}{\partial y} \qquad (1)$$

where ν_t is the turbulent viscosity and the active scalar turbulent Prandtl number, σ_t, takes a value of 0.7 [2]. The primary transport in small A_t experiments is associated with the largest structures and these are of size h_b ($= h_s$ at small A_t), thus we take the integral length scale l_m as h_b. Figure 1 shows that the measured density profile is reasonably linear across the mix and thus, the density gradient $\partial\rho/\partial y = \Delta\rho/2h_b$ (the factor 2 arises because h_b is the half mixing width). Our velocity measurements [3] at the centerline indicate that $u'^2 = w'^2 = 0.3 v'^2$ so the turbulence kinetic energy ($k = 0.5 < u'^2 + v'^2 + w'^2>$) is given by $k = 0.8 v'^2$. Figure 2 plots the collapse of the centerline RMS vertical velocity (v') to obtain a measured centerline α_{CL} of 0.07. Since v' can be related to the mix width by [4]:

$$v' = \frac{dh_b}{dt} = 2\alpha_{CL} A_t g t = 2\alpha_{CL} A_t g \frac{x}{U_m} \qquad (2)$$

the centerline turbulence kinetic energy is given by $k = 0.8(2\alpha_{CL} A_t g x/U)^2$. Substitution into (1) gives the following expression for the measurement of C_μ:

$$C_\mu = -\frac{< \rho' v' > \sigma_t}{\Delta\rho\sqrt{0.8}\left(A_t g \frac{x}{U}\right)\alpha_{CL}} \; . \qquad (3)$$

Figure 3 plots measured values of $\rho' v' > / (\Delta\rho(A_t g x/U))$ that at late time $\tau = \frac{x}{U_m}\left(\frac{A_t g}{H}\right)^{1/2} = 1.986$) reach a value of –0.024, giving a corresponding value for C_μ of 0.288. A typical value quoted in the literature for C_μ is 0.09 [5]; however, this lower value corresponds to turbulent shear flows and flow situations where the rate of turbulence kinetic energy production and dissipation are balanced [1]. The present buoyancy-driven flow has a global $PE_{released}$ /*Dissipation* of ~2.0 which is far from a balanced case. Measured C_μ at the centerline for the different downstream locations are given in Table 1. It is seen that the value of C_μ remains approximately constant at various downstream locations and is independent of the Reynolds number of the developing flow.

TABLE 1. Turbulence modeling constant ($C\mu$) at different times (τ).

τ	$\frac{<\rho'v'>}{\Delta\rho(Agt)}$	α_{CL}	C_μ
0.567	-0.0482	0.12169	0.3098
0.851	-0.03812	0.09268	0.3219
1.135	0.02878	0.07709	0.2922
1.418	-0.02634	0.06743	0.3057
1.702	-0.02444	0.06741	0.2838
1.986	-0.02397	0.06520	0.2877
2.213	-0.02363	0.06583	0.2809

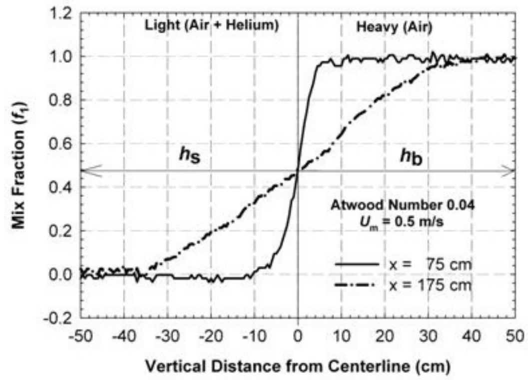

Fig. 1.
Mixture fraction profiles from the experimental run at small A_t (= 0.04).

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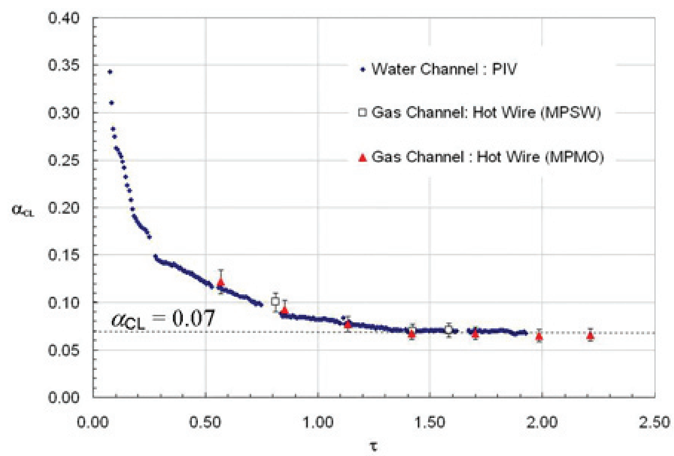

Fig. 2.
Centerline measurements of velocity RMS at small A_t (= 0.04).

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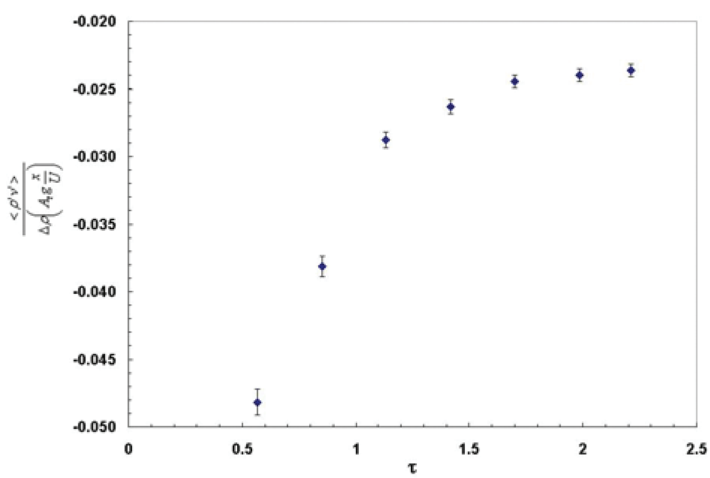

Fig. 3.
Evolution of <ρ′v′> (primary transport term) for A_t = 0.04.