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LETTERS TO THE EDITORS

COMMENT ON TRANSPORT PHENOMENA IN FREE TURBULENT FLOWS

IN THE calculation of the ratio of distortion coefficients to account for the anisotropy of large scale motion in wake flow, the above paper relies entirely upon the analogy between the drag on a solid spheroid and that on a fluid entity. This degree of sophistication surely demands a much fuller description of the assumed flow conditions around the entity than has yet been given in either the paper presenting the basic analysis [1], the authors' rejoinder [3] to my earlier comments [2], or the above work [4].

In [3], it is explained that the effect of small entity migration is to increase the effective viscosity acting on the "energy containing entity" (without apparently forming a turbulent boundary layer) and that this provides a description of the process of "inertial interaction". Thus it seems that the motion of the large entities should be analogous to that of a solid sphere in the range of Reynolds number N_R^+, based on molecular viscosity, between 1 and 10^5. This is compatible with the estimate of $N_R^+ \sim 400$ in [2], and is entirely reasonable.

However Tyldesley and Silver's description of this motion [1] involves using Stokes' equation for the drag force with the substitution of an effective viscosity, due to small entity migration, for the molecular viscosity. Their justification [3] for this is that "the appropriate Reynolds number of the large entities" is much smaller than my estimate, implying that the pattern of mean-flow streamlines about the fluid entity is the symmetrical one for which Stokes' equation applies, because of (and, it may be remarked, in spite of) the small entity migration. This argument is dubious because it neglects the modification to the streamline pattern which is a consequence of inertial interaction, it neglects the presence of a boundary layer dominated by molecular viscosity, and it ignores the possibility of separation. It is these very effects which prevent the analogy between heat and momentum transfer from spheres, shown in [2], from persisting for Reynolds numbers greater than unity.

It may well be objected that the above interpretation of the fluid entity model is not "fluid" enough—that knowledge of the precise nature of an entity's progress through the surrounding medium is not necessary—but such considerations must be discussed if the model is to be used to predict the variation of turbulent Prandtl number with Reynolds number, as in [1], or the effects of anisotropy as in [4]. In view of the interesting results already published [1, 4] and the good agreement with wave-number analyses which has apparently been found [3], it is to be hoped that the objections to the model cited in this letter may eventually be overcome by some modification.

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REJOINDER TO TRANSPORT PHENOMENA IN FREE TURBULENT FLOWS

LAWN is not entirely correct in his assertion that the above paper relies "entirely upon the analogy between the drag on a solid spheroid and that on a fluid entity". The results for solid spheroids have been used in the analysis only because the comparisons between scalar and vector diffusion for such bodies are likely to be representative of the corresponding comparisons for fluid entities and more particularly the effect of aspect ratio is likely to be similar for more general shapes. The use of spheroids is not in any way indicative of misplaced sophistication.

At the other extreme the use of the simple relationships for vector and scalar transport to the entity is not a gross simplification. Stokes' equation for momentum transport can be used since the situation being considered initially is low Reynolds number flows where the significant contribution to the transport processes is from the small scale fluctuations. In the extreme, which is what is being considered at this point, the entity Reynolds numbers *are* small and Stokes' equation may be taken to be a reasonably accurate representation of what is taking place.

At higher entity Reynolds numbers the Stokes' equation using molecular viscosity would be invalid as Lawn [1] has demonstrated; but the situation considered by Lawn of a fluid entity with a laminar sublayer and turbulent boundary layer is not representative of what is taking place. There can be no laminar sublayer round any large scale piece of fluid in a turbulent flow since its boundaries are continually being crossed by smaller scale fluid motions or entities. If, however, one chooses to assign an effective viscosity to the average effect of the small scale motions then Stokes' equation can be used providing the molecular viscosity is replaced by this effective viscosity. Under these conditions the *mean* flow streamlines *are* symmetrical for the large scale entity and the effective Reynolds numbers are small.

Reasonably precise knowledge of the expected interaction between an entity and its surroundings *is* necessary for accurate prediction using the entity model of a turbulent fluid. Justification of the interaction assumed in Tyldesley and Silver [2] and Tyldesley [3], is, however, most satisfactorily obtained by making a lengthy analysis in the wavenumber field as has been made by Tyldesley [4]. It is interesting that in that paper predictions of relaxation phenomena are made and the results for stress relaxation agree favourably with those recently obtained from an analysis in the wavenumber field. In heat and mass transfer, predictions are made using the entity model which as yet have not been able to be made by any other means and it is apparent that the entity model provides a most powerful tool for the analysis of turbulent transport with reasonable mathematical simplicity.

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