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Comment on "Local Energy Transfer and Nonlocal Interactions in Homogeneous, Isotropic Turbulence" [Phys. Fluids A2, 413 (1990)]

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COMMENT ON "LOCAL ENERGY TRANSFER AND NONLOCAL INTERACTIONS IN HOMOGENEOUS, ISOTROPIC TURBULENCE"

[PHYS. FLUIDS A2, 413 (1990)]

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ABSTRACT

It is argued that the low-Reynolds number results in the subject paper are not congruous with the data of Ling and Huang (Phys. Fluids 13, 2912 (1970)), and that the spectral transfer should be less local.

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Domaradzki and Rogallo[1] address an important question concerning the nature of the spectral transfer in turbulence: Does the transfer take place mainly between neighboring wavenumbers, or between wavenumbers that are substantially separated? In spite of the fundamental nature of this question, only a limited amount of work has appeared in the literature.

My comments have to do with the correctness of certain results in the subject paper, and with that of my results in Ref. 2. The results under question concern contributions $P(\kappa,\kappa')$ from wavenumbers κ' to the total energy transfer $T(\kappa)$ at κ, where $T(\kappa)$ was measured by Ling and Huang.[3] The authors of the subject paper believe that the results in Ref. 2 are in error because of the disagreement of those results with their own, and because the method used there does not give unique results for $P(\kappa,\kappa')$.

In reality, however, the conditions used by the writer to obtain $P(\kappa,\kappa')$ from the $T(\kappa)$ measured by Ling and Huang[3] are quite restrictive. Those conditions are[4]

$$P(\kappa,\kappa') = -P(\kappa',\kappa) \tag{1}$$

and

$$T(\kappa) = \int_0^\infty P(\kappa,\kappa')\, d\kappa'. \tag{2}$$

As will be seen, the present method,[2] in contrast to the numerical simulation of the subject paper, gives results for $P(\kappa.\kappa')$ which satisfy Eqs. (1) and (2) exactly when the empirical equation of Ling and Huang is used for $T(\kappa)$. That equation, which gives an excellent fit to Ling and Huang's data is, in dimensionless form,

$$T(\kappa) = -\frac{10}{3}\left(\kappa + \sqrt{10}\kappa^2 + 3\kappa^3 - 2\sqrt{10}\kappa^4\right)e^{-\sqrt{10}\kappa} \tag{3}$$

where κ has been scaled by setting $\left[\nu(t - t_0)\right]^{1/2} \kappa = \kappa$, T is a dimensionless transfer function, ν is the kinematic viscosity, t is the time, and t_0 is the virtual origin of the turbulence. Equation (3) is plotted in Fig. 1.

The description of the method for obtaining $P(\kappa,\kappa')$ which follows is perhaps clearer and more satisfying than that given in Ref. 2. It will be seen that, for the low Reynolds-number data,[3] $P(\kappa,\kappa')$ can be obtained by using a reasonable systematic procedure.

Terms in the expression for $P(\kappa,\kappa')$ that satisfy Eq. (1), and, through Eq. (2), can satisfy Eq. (3), are of the form

$$\text{Term} = (\kappa^m\kappa'^n - \kappa^n\kappa'^m)e^{-\sqrt{10}(\kappa+\kappa')}, \tag{4}$$

where m and n are positive intergers. Then the expression for $P(\kappa,\kappa')$ which satisfies Eqs. (1) to (4), while containing the smallest possible number of terms of the lowest possible order in κ and κ', is

$$P(\kappa,\kappa') = \frac{100}{3}\Big[\sqrt{10}\,(\kappa\kappa'^2 - \kappa^2\kappa') + 3(\kappa\kappa'^3 - \kappa^3\kappa') - 2\sqrt{10}\,(\kappa\kappa'^4 - \kappa^4\kappa')\Big]e^{-\sqrt{10}(\kappa+\kappa')} \tag{5}$$

Note that a term proportional to $\kappa - \kappa'$ is not included in Eq. (5), since that would not satisfy $T(0) = 0$, as required by Eq. (3), although it would satisfy Eq. (1).

An important consequence of Eq. (2) and the relation $P(\kappa,\kappa') = -P(\kappa'.\kappa)$ (Eq. (1)) is that if $T \propto \kappa^n$ for small κ, then $P \propto \kappa'^n$ or $P \propto \kappa^n$ for κ' or κ respectively small. In the present case this means that $T(\kappa)$ and $P(\kappa,\kappa')$ both start with the first power of κ or κ' (see Eqs. (3) and (5), or Figs. 1 and 2). This has a major effect on the shape of $P(\kappa,\kappa')$ and tends to make the bulk of the energy transfer from κ' to κ nonlocal. (See the solid curve in Fig. 2, where the peak occurs at small values of κ'/κ.) On the other hand, the shape of the curve obtained in the subject paper near $\kappa' = 0$ (dashed curve in Fig. 2) is characteristic of that of a curve which starts with a much higher power of κ' than the first. It thus appears to be not congruous with the energy transfer of Ling and Huang (Eq. (3)) and conditions (1) and (2). As a result, the dashed curve shows an energy transfer which is evidently too local (the peak of the curve lies too close to $\kappa'/\kappa = 1$). The simulation from the subject paper[1] does not seem to faithfully represent the experiment of Ling and Huang. The present representation of $P(\kappa,\kappa')$, in starting with the first power of κ', appears to represent the experiment much more closely. Thus, it appears that the original conclusion that the spectral transfer in Ling and Huang's experiment is nonlocal (the energy tends to jump between wavenumbers that are separated) still holds.

As further evidence of the importance of the power of κ' with which $P(\kappa,\kappa')$ starts, in determining the localness of the spectral transfer, we note that in Ref. 5, where a different method is used to determine $P(\kappa,\kappa')$, and where P starts with a power of κ' much higher than the first, the transfer is more local (closer to that in the subject paper). However, when $P(\kappa,\kappa')$ was assumed to start with the first power of κ', as in the experiment of Ling and Huang, the transfer was, as expected, less local, and closer to that given by Eq. (5).

As a final note it might be pointed out that the spectral transfer must always be somewhat nonlocal because of the condition that $P = 0$ for $\kappa'/\kappa = 1$. That condition follows from Eq. (1) by letting $\kappa' = \kappa$. Thus the descrepency between the results of Domaradzki and Rogallo[1] and the present results[2] is one of degree, rather than a qualitative difference.

REFERENCES

[1]J.A. Domaradzki and R.S. Rogallo, Phys. Fluids A2, 413 (1990).

[2]R.G. Deissler, Appl. Sci. Res. 34, 379 (1978).

[3]S.C. Ling and T.T. Huang, Phys. Fluids, 13, 2912 (1970).

[4]G.K. Batchelor, The Theory of Homogeneous Turbulence (Cambridge University Press, New York, 1953.

[5]R.G. Deissler, Phys. Fluids, 1, 111 (1958).

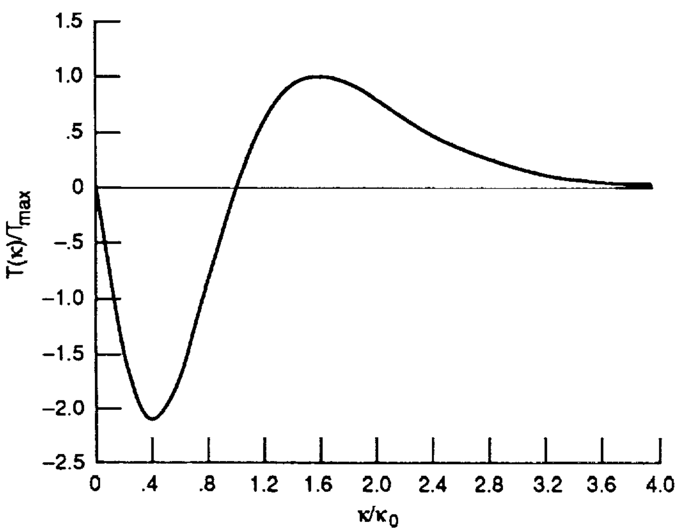

Figure 1.—Experimental energy transfer spectrum from Ling and Huang[3] (Eq. (3)) for low and moderate Reynolds numbers (R_λ is between 3 and 30). κ_0 is the wave number where $T(\kappa) = 0$ ($[\nu (t - t_0)]^{1/2} \kappa_0 = 1.0758$).

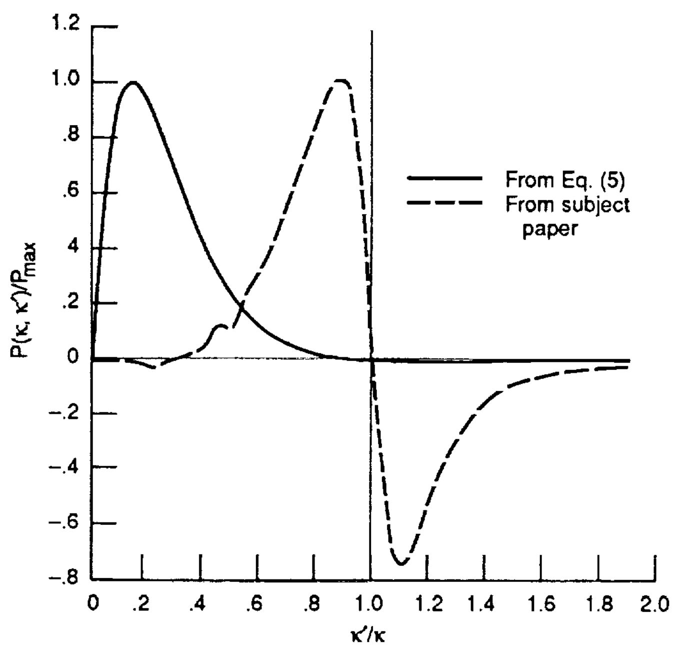

Figure 2.—Calculated contributions $P(\kappa, \kappa')$ to net energy transfer T at κ/κ_0 in figure 1 = 2.2.

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16. Abstract

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