# RAPID DISTORTION THEORY ANALYSIS OF TIME-DEPENDENT HOMOGENEOUS SHEAR

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An important problem of current interest is the extension of Reynolds-averaged Navier-Stokes modeling to statistically non-stationary turbulent flows. This has been motivated by the need to accurately predict turbulent flows with imposed forcing for flow control. An important example is the parameterization of the effect of forcing by synthetic jets embedded along the surface of an airfoil wing. RANS models are ordinarily calibrated for and applied to statistically stationary, or equilibrium flows. Whether for stationary or non-stationary flows, the problem of RANS modeling is to find appropriate closures for the unknown correlations appearing in dynamical equations governing turbulence, for example the pressure-strain tensor in the Reynolds stress transport equation. In the case of stationary turbulence at equilibrium, such closures have been established for certain benchmark, mainly homogeneous, flows. In order to extend the range of applicability of RANS modeling to non-stationary turbulence, it is important to study simple flows with time-dependent forcing, such as time-dependent homogeneous shear. While time-dependent homogeneous shear cannot be driven by a pressure gradient, which is irrotational, it could in principle be generated by a position and time-dependent body force. In any case, it provides a valuable theoretical laboratory for studying the influence of time-dependent forcing on turbulent fluctuations.

Little detailed knowledge of the dynamic interactions occuring over the whole spectral range of turbulence that is subject to mean flow forcing is available for use as a calibration tool. Issues associated with forcing frequency and phase, as well as amplitude, have not been studied parametrically. Direct numerical simulation (DNS) of non-stationary, homogeneous flows would be optimal, but the parameter range is large, so a complete numerical study without some a priori knowledge of the dynamic interactions may be costly in both computer resources and time. In the study reported here, a Rapid Distortion Theory (RDT) approach is used to delimit the parameter range where the most significant effects of mean flow forcing can be analyzed.

Extending previous work [1], the RDT equations, including viscous effects, are solved analytically for homogeneous shear with arbitrary time-dependence. Assuming initially isotropic turbulence with energy spectrum used in Reference [1], the correlations appearing in the Reynolds stress and dissipation rate equations are computed as functions of time through integration over wave vector space. The cases of sinusoidal, and steady plus sinusoidal forcing are studied for a variety of frequencies, phases, and amplitudes. This study lays the groundwork for future DNS investigations of time-dependent homogeneous shear.

**References**

[1] W. D. Thacker, C. E. Grosch, and T. B. Gatski, "Modeling the Dynamics of Ensemble-Averaged Linear Disturbances in Homogeneous Shear Flow," *Flow, Turbulence and Combustion* **63**, 39-58, 1999.

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