On the Generation of Packets of Hairpins In Shear Flows

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ABSTRACT

In the present work we follow the breakdown of pairs of counter-rotating vortices (CVP) and the consequence formation of packets of hairpins in uniform shear flows. We employ a recent developed method which is capable of following (numerically) the evolution of finite-amplitude localized vortical disturbances embedded in shear flows. The solution is carried out using Lagrangian variables in Fourier space which is convenient and enables fast computations on a regular PC. Streamwise variation of the CVP is required to generate concentrated spanwise vorticity which together with the lift-up by the induced velocity and shear of the base flow generates packets of hairpins. This scenario, obtained 'synthetically' with minimal simple elements seems to be universal and may explain similar observations both in fully developed wall-bounded shear flows as well as in wall-bounded transitional shear flows. This work has been motivated by our previous observation, based on experimental, numerical and theoretical results, that the formation and characteristics associated with the structure of a single hairpin, evolved from a dipole vortex, are very similar to the structures of those composing packets of hairpins in turbulent and transitional shear flows.

The similarity of the coherent structures naturally occurring in different fully developed boundary turbulent hear flows as well as in transitional flows and free shear layers suggests the existence of a basic mechanism responsible for the formation of these structures, under various base flow conditions. The common elements for all such flows are the *shear of the base flow* and the presence of a *localized vortical disturbance*. Recently, combining experimental, numerical and theoretical efforts, it was demonstrated (e.g. (1)) that a simple model, which takes into account only the interaction between a localized vortical disturbance and a laminar shear base flow, is capable of reproducing the generation process and characteristics of the coherent structures. In this article we follow the minimal sequence of events required for the generation of packets of hairpins due to the breakup of synthetic pair of CVP superimposed on a uniform base shear flow.

For this purpose we employ our recent developed method (2) which is capable of following (numerically) the evolution of finite-amplitude localized vortical disturbances embedded in shear flows. The solution is carried out using Lagrangian variables in Fourier space which is convenient and enables fast computations on a regular PC. Streamwise variation of the CVP is required to generate concentrated spanwise vorticity which together with the lift-up by the induced velocity and shear of the base flow generates packets of hairpins. This scenario, obtained 'synthetically' with minimal simple elements seems to be universal and may explain similar observations both in fully developed wall-bounded shear flows as well as in wall-bounded transitional shear flows.

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