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Center for Turbulence Research
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II. Turbulence physics group

Numerical simulation of turbulence has proven to be a powerful tool in studying the physics of turbulence. There are three papers in this group, each illustrating how numerical simulations are being used for this purpose. Lopez and Bulbeck analyzed an existing database to investigate vortex breakdown in a mixing layer. Orlandi, Homsy, and Azaiez reported preliminary results from modeling the effect of viscoelasticity on flow structures. The last paper by Reuss and Cheng was an attempt to develop new experimental techniques for characterizing vortices in a complex flow by exploring different approaches in a much simpler flow situation. Some highlights as well as critiques of these reports are given below:

Lopez and Bulbeck studied vortex breakdown in a time-developing plane mixing layer by analyzing the database obtained by Moser and Rogers. Vortex breakdown in large-scale flows has been observed frequently, from which much of our knowledge of vortex breakdown is derived. There exists some evidence that such breakdown may also occur in smaller scales over a wide range of flows and that vortex breakdown may play a role in characterizing a length scale for vortical structures in turbulent flows. The objective of this paper was to investigate whether vortex breakdown occurs in the rib vortices in the plane mixing layer, where a previous study indicated a rapid change in the local topology. If vortex breakdown were found here, they postulated that it would also exist in other turbulent flows. Using the criteria developed by Brown and Lopez for breakdown of an isolated vortex, i.e., the sudden acceleration of the axial flow and the helix angle of the velocity vector being larger than that of the vorticity vector, they found evidence that the rib vortex downstream of the mid-braid plane began vortex breakdown. There was no evidence, however, of sudden core expansion or intense mixing, phenomena nominally associated with large-scale vortex breakdown flows. There were some discussions during the final presentation of the Summer Program as to whether what they observed here in the temporally developing mixing layer could be regarded as a true vortex breakdown.

Orlandi *et al.* performed numerical simulations of a two-dimensional mixing layer and the interaction of vortex dipole with a wall in order to investigate the effect of viscoelastic fluids on flow structures. Three different viscoelastic models were used to account for the viscoelasticity. For some models, however, they could not obtain a converged solution. In the case of mixing layer, they found that the viscoelasticity enhanced the formation of small scales, which produced intense gradients in the braid region of the mixing layer. These intense gradients led to a faster and more intense roll-up of the layer. This is contrary to the linear stability analysis by Azaiez and Homsy, who showed that viscoelasticity reduced the instability of the flow. The second part of the paper concerned with the effect of viscoelasticity on vortex dipole impinging on a wall, a model of streamwise vortices in a turbulent boundary layer. They considered both free-slip and no-slip walls but found that the effect of the viscoelasticity for both cases was small. The results presented in this paper appear to be preliminary and they should be interpreted as such. As the authors pointed out, further numerical studies as well as experimental verifications are deemed necessary to validate the present result.

Reuss and Cheng explored different methods for characterizing vortex structures by examining a turbulent flow field obtained from a simulation of turbulent channel. The senior author has been conducting experiments to investigate vortex structures that influence flame wrinkling in reciprocating internal combustion engine, and the objective of this project was to develop an experimentally suitable technique for identifying the turbulence properties associated with these structures. They applied two-dimensional spatial filtering to the instantaneous flow field to separate different scales present in the flow field. As expected, they were able to identify vortical structures which were not apparent from the unfiltered field, but the results were highly dependent on the filter size used. They proceeded to use a conditional-averaging procedure in which the detection was based on the local peak vorticity. They presented results obtained from this procedure as representative of the coherent parts of the flow field. It should be pointed, however, that these results might also depend on the threshold value used for the detection and, to a lesser extent, on how the alignment for the averaging process was conducted. I might add that in the past other investigators have used an iterative procedure using a correlation technique to minimize this problem.

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