High Reynolds and Mach numbers post-shock turbulence

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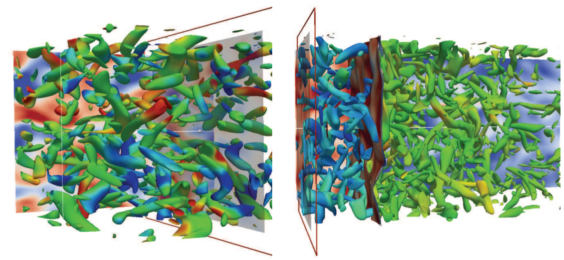
In a recent shock-resolved Direct Numerical Simulations (DNS) study of the shock-turbulence interaction [2], we have shown that, when there is a large scale separation between turbulence scales and shock width and the upstream turbulence is weak, the interaction can be described by the Linear Interaction Approximation (LIA). The results reconcile a long time open question about the role of LIA and establish LIA as a reliable prediction tool for turbulence-shock interaction problems. In a follow-up paper [1], we have used this approach to investigate the dependence of post-shock turbulence on the shock Mach number, M_s, at Reynolds and M_s values outside the reach of either DNS or typical laboratory experiments.

Background and Motivation

The interaction of a shock wave with quasi-vortical isotropic turbulence (IT) represents a basic problem for studying some of the phenomena associated with high speed flows, such as hypersonic flight, supersonic combustion and Inertial Confinement Fusion (ICF). DNS of shock waves interacting with turbulence are restricted to low Reynolds numbers, *Re*, due to the extremely large meshes required to resolve both the turbulence and the shock. Experimental realizations of this problem are also very challenging, due to problems with controlling the shock wave and the small time and length scales involved in the measurements especially close to the shock front. Thus, high *Re* / high M_s post-shock turbulence data are simply non-existent.

Description/Impact

Using LIA to alleviate the need to resolve the shock, DNS post-shock data can be generated at much higher Reynolds numbers than previously possible. In order to do this, we have also extended LIA to calculate full 3-D turbulent fields. In Ref. [1], such results with Taylor Reynolds number approximately 180 are used to investigate the changes in the vortical structure as a function of the shock Mach number, up to $M_s = 10$.



Simulations set-up. Data generated in separate IT simulations are fed through the inlet of a shock tube with a stationary shock inside.

It is shown that, as M_s increases, the shock interaction induces a tendency towards a local axisymmetric state perpendicular to the shock front, which has a profound influence on the vortex-stretching mechanism and divergence of the Lamb vector and, ultimately, on the flow evolution away from the shock. In addition, the results were also used to calibrate the BHR turbulence model [3], again at Mach numbers outside the reach of either experiment or DNS.

Acknowledgements

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References

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