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Investigating the Flow Physics within Vortex-Shockwave Interactions

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Abstract : No doubt, current CFD tools have a great many technical limitations, and active research is being done to overcome these limitations. Current areas of limitations include vortex-dominated flows, separated flows, and turbulent flows. In general, turbulent flows are unsteady solutions to the fluid dynamic equations, and instances of these solutions can be computed directly from the equations. One of the approaches commonly implemented is known as the 'direct numerical simulation', DNS. This approach requires a spatial grid that is fine enough to capture the smallest length scale of the turbulent fluid motion. This approach is called the 'Kolmogorov scale' model. It is of interest to note that the Kolmogorov scale model must be captured throughout the domain of interest and at a correspondingly small-time step. In typical problems of industrial interest, the ratio of the length scale of the domain to the Kolmogorov length scale is so great that the required grid set becomes prohibitively large. As a result, the available computational resources are usually inadequate for DNS related tasks. At this time in its development, DNS is not applicable to industrial problems. In this research, an attempt is made to develop a numerical technique that is capable of delivering DNS quality solutions at the scale required by the industry. To date, this technique has delivered preliminary results for both steady and unsteady, viscous and inviscid, compressible and incompressible, and for both high and low Reynolds number flow fields that are very accurate. Herein, it is proposed that the Integro-Differential Scheme (IDS) be applied to a set of vortex-shockwave interaction problems with the goal of investigating the nonstationary physics within the resulting interaction regions. In the proposed paper, the IDS formulation and its numerical error capability will be described. Further, the IDS will be used to solve the inviscid and viscous Burgers equation, with the goal of analyzing their solutions over a considerable length of time, thus demonstrating the unsteady capabilities of the IDS. Finally, the IDS will be used to solve a set of fluid dynamic problems related to flow that involves highly vortex interactions. Plans are to solve the following problems: the travelling wave and vortex problems over considerable lengths of time, the normal shockwave–vortex interaction problem for low supersonic conditions and the reflected oblique shock–vortex interaction problem. The IDS solutions obtained in each of these solutions will be explored further in efforts to determine the distributed density gradients and vorticity, as well as the Q-criterion. Parametric studies will be conducted to determine the effects of the Mach number on the intensity of vortex-shockwave interactions.

Keywords : vortex dominated flows, shockwave interactions, high Reynolds number, integro-differential scheme
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