Abstract

The thesis deals with the meshless methods based on generalized finite difference procedure operating on the mere distribution of points. The work per se focuses on maturing the meshless LSFD-U solver as a standard industrial tool for Aerospace CFD.

One of the purported advantages of this class of methods as opposed to finite-volume methods is that they can considerably ease the need for generating grids. This aspect has been truly exploited in this thesis by projecting the meshless LSFD-U solver as a Cartesian grid methodology. The point distribution required by the LSFD-U solver is obtained from Cartesian grids. The Cartesian grid with its immense potential for process automation and the LSFD-U method with its ability to discretize the conservation equations on any arbitrary point distribution, form a natural pair for solving complex engineering problems in an automated process. The thesis presents a number of complex configurations of industrial relevance where the point distribution for the meshless solver are obtained from Cartesian grids in short turn-around times and without any human intervention. The grid convergence of the 3D inviscid solver is also established on a sequence of Cartesian point distributions.

The automation capability is one of the key requirements for solving multi-body dynamics, moving body and optimization problems. The CFD process on such problems primarily involves repetitive grid generation. Any need for human intervention and expertise in the CFD process seriously hampers the overall performance and productivity. The meshless LSFD-U solver offers complete automation in the CFD process regardless of the complexity in the configurations. This aspect has been demonstrated in this thesis by predicting the store trajectory using quasi-steady simulations. In order to understand these results better, the work has also been extended to include the viscous effects in the trajectory prediction (although within a finite volume framework) and the sensitivities of the 6-DOF model integration. An automated CFD process to determine the optimal flap location has also been included in the demonstrations.

Mesh adaptivity is one of the important areas of focus in a CFD work-flow for obtaining high resolution CFD solutions. Adopting such methodology for the meshless LSFD-U solver is attempted in this thesis work. A residual-based grid adaptive strategy in which an estimate of the local truncation error is used to define length scales for adequately resolving the flow in a given region is developed in the context of the LSFD-U solver. An attempt has been made to evolve an automated termination of the grid adaptation, which establishes the efficacy of the proposed adaptive strategy. For the flows with discontinuities, a hybrid strategy is employed in which the smooth flow regions are adapted using the $\Re$-parameter and the limiter operational regions are adapted using the divergence of velocity based indicator.

A critical milestone for the success of the meshless methods is their ability to simulate turbulent flows by the way of solving RANS equations using highly anisotropic point distribution. The LSFD-U RANS solver makes use of a wall resolved hybrid Cartesian grid for the viscous turbulent flow computations. The Spalart-Allmaras turbulence model implementation within the meshless framework is discussed in detail. A combination of high aspect ratio grids (in a finite volume parlance) exhibiting grid folding, which is common in domains with wall slope discontinuity, results in loss in accuracy and robustness of the meshless solver. In order to handle such issues, we have proposed a point adaptive strategy which detects such regions with grid folding and improves the grid quality by introducing points along the rays exhibiting grid folding. The 2D LSFD-U RANS solver is validated for complex high lift cases. The work also includes some attempts towards achieving a successful 3D LSFD-U RANS solver.