A DATA-DRIVEN PROACTIVE MESH REFINEMENT FRAMEWORK FOR COMPUTATIONAL FLUID DYNAMICS SIMULATIONS IN CONVERGING-DIVERGING NOZZLES

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ABSTRACT

In most computational fluid dynamics (CFD) simulations, an adaptive mesh refinement (AMR) technique, which refines the critical areas where solution accuracy is predicted to be low, is frequently used. However, for complex CFD simulations such as large-scale Navier-Stokes equations, determining a solution during the AMR process is computationally expensive and slow. Therefore, if we could preemptively and accurately predict the appropriate mesh density for the analysis target before performing CFD simulations, we expect that both the accuracy and efficiency of CFD simulations significantly improve. In this study, we assume a CFD simulation based on the Navier-Stokes equation where a shock occurs inside a jet ejected through a converging-diverging (CD) nozzle. This is considered as a difficult problem because the shock wave patterns inside the jet significantly vary according to the nozzle expansion ratio, which is the ratio between the nozzle throat and the nozzle exit inside the CD nozzle, and accordingly, the critical areas that require mesh refinement also significantly vary. We propose a data-driven proactive mesh refinement framework that learns the shock locations and corresponding optimal mesh refinement level in each element inside the jet with respect to various CD nozzle geometries and expansion ratios. Then, the proposed neural network accurately predicts the optimal mesh refinement level and finally produces high-quality refined meshes under a given CD nozzle geometry and expansion ratio condition.

Keywords: adaptive mesh refinement, computational fluid dynamics, converging-diverging nozzles

ACKNOWLEDGMENT

This work was supported in part by the National Research Foundation of Korea (NRF) Grant funded by the Korea Government (MSIT) under Grant NRF-2020R1A2C1007917. This work was also supported in part by the National Research Foundation of Korea (NRF) Grant funded by the Korea Government (MSIT) under Grant NRF-2022R1A4A5034121.