Hessisches Kompetenzzentrum
für Hochleistungsrechnen

Aeroacoustics Simulation Using Partially-Averaged-Navier-Stokes Around the Ahmed Body



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Introduction

Aeroacoustics is a critical research field that studies sound generated by turbulent flows interacting with solid structures like aircraft and cars. As the demand for quieter vehicles increases and noise pollution's impact on human well-being becomes clearer, there's a need for precise methods to predict and reduce aerodynamic noise. Computational Aeroacoustics (CAA) combines theory and computation to address these challenges. CAA relies on Computational Fluid Dynamics (CFD) to analyze fluid flow and its acoustic effects. To capture flow dynamics and acoustics accurately, especially in turbulent scenarios, it's crucial to use reliable CFD approaches. Reynolds-Averaged Navier-Stokes (RANS) and Large Eddy Simulation (LES) are commonly used for simulating turbulence, but each has limitations in accuracy and efficiency. To overcome these limitations, researchers have developed hybrid LES/RANS methods like Partially-Averaged Navier-Stokes (PANS), aiming for a balance between computational cost and accuracy. This research focuses onassessing the SSV-PANS method, a specific PANS variant, by comparing it to Large Eddy Simulation in terms of accuracy and computational efficiency. By dissecting fluid variables into hydrodynamic and compressible perturbation equations, the study analyzes airflow around an Ahmed body, a well-known benchmark case in Computational Fluid Dynamics (CFD). Through these analyses, the research advances our understanding of CAA methods, especially the SSV-PANS method, contributing to quieter vehicles, reduced noise emissions, and optimized vehicle designs. This promotes effective noise pollution reduction and healthier, more sustainable communities.

Methods

This research employed the SSV-PANS method alongside Large Eddy Simulation (LES) to predict aeroacoustic phenomena for an Ahmed body. The study utilized a hydrodynamic/acoustic splitting approach to assess the SSV-PANS method's accuracy in simulating the hydrodynamic and aeroacoustic behaviors of a slanted-back Ahmed body. The computational setup involved the FASTEST solver, the SIMPLE algorithm, and a second-order implicit method, with a CFL number maintained below 1. High-resolution grids, including coarse (14.5 million CVs for SSV-PANS), medium (25 million CVs for SSV-PANS), and fine (48 million CVs for LES) grids, are employed to represent the flow near the Ahmed body accurately. A frozen fluid approach was applied to reduce the number of time steps needed for fluid flow simulations in computing acoustic fields. The findings indicated that the SSV-PANS method demonstrated favorable accuracy in modeling the hydrodynamic field and generating sound sources when compared to experimental and LES outcomes.

Results

The SSV-PANS method's performance in aeroacoustics, particularly its application to the Ahmed body, is comprehensively evaluated. SSV-PANS simulations consistently

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replicate airflow patterns around the Ahmed body, closely matching experimental and LES results at a Reynolds number of 768,000. Streamline and velocity vector profiles across the Ahmed body slant, reinforce these findings. The study explores aeroacoustic analysis, with a focus on near-field acoustic sources and mid-field observations at $11.2L$ from the flow direction. It demonstrates that the SSV-PANS method can predict acoustic sources accurately, comparable to LES, especially when appropriate control volumes (CVs) are chosen. The analysis of the acoustic field around the Ahmed body reveals differences in peak locations and Sound Pressure Level (SPL) values between simulations with 14.5 million CVs and LES predictions, indicating limitations in capturing intricate acoustic features. In contrast, simulations with 25 million CVs show significant improvements, including precise peak location predictions and close alignment of SPL values with LES results. The selection of control volumes is crucial for achieving accurate flow-acoustic representation, with higher CV counts improving accuracy and reliability while maintaining computational efficiency. Importantly, the study highlights the computational efficiency of the SSV- PANS method compared to LES, making it an attractive choice for simulating turbulent flows with aeroacoustic applications

Discussion

This study emphasizes the importance of understanding sound-related aspects in aerodynamic systems, utilizing the SSV-PANS method to effectively address complex flow dynamics around the Ahmed body, as demonstrated with FASTEST software. Through meticulous comparisons of experimental data and Large Eddy Simulation (LES) results in benchmark scenarios, the reliability of the SSV-PANS method is firmly established, particularly with refined grid resolutions enhancing sound accuracy prediction around the Ahmed body. With its computational efficiency and precise representation of flow patterns and sound sources, the SSV-PANS method emerges as a promising tool for comprehensive simulations in both aerodynamics and aeroacoustics, offering insights that advance noise reduction strategies and engineering design optimization in industries spanning transportation, energy, and aerospace.

Publications

Moosavifard, A; Schäfer, M. Assessing the Aeroacoustic Performance of the SSV-PANS Method for Slanted Back Ahmed Body., 93rd Annual Meeting of GAMM, Dresden, Germany, 30 may - 2 June (2023)

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