World Academy of Science, Engineering and Technology
International Journal of Aerospace and Mechanical Engineering
Vol:15, No:08, 2021

Study on the Geometric Similarity in Computational Fluid Dynamics Calculation and the Requirement of Surface Mesh Quality

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Abstract : At present, airfoil parameters are still designed and optimized according to the scale of conventional aircraft, and there are still some slight deviations in terms of scale differences. However, insufficient parameters or poor surface mesh quality is likely to occur if these small deviations are embedded in a future civil aircraft with a size that is quite different from conventional aircraft, such as a blended-wing-body (BWB) aircraft with future potential, resulting in large deviations in geometric similarity in computational fluid dynamics (CFD) simulations. To avoid this situation, the study on the CFD calculation on the geometric similarity of airfoil parameters and the quality of the surface mesh is conducted to obtain the ability of different parameterization methods applied on different airfoil scales. The research objects are three airfoil scales, including the wing root and wingtip of conventional civil aircraft and the wing root of the giant hybrid wing, used by three parameterization methods to compare the calculation differences between different sizes of airfoils. In this study, the constants including NACA 0012, a Reynolds number of 10 million, an angle of attack of zero, a C-grid for meshing, and the k-epsilon (k-ε) turbulence model are used. The experimental variables include three airfoil parameterization methods: point cloud method, B-spline curve method, and class function/shape function transformation (CST) method. The airfoil dimensions are set to 3.98 meters, 17.67 meters, and 48 meters, respectively. In addition, this study also uses different numbers of edge meshing and the same bias factor in the CFD simulation. Studies have shown that with the change of airfoil scales, different parameterization methods, the number of control points, and the meshing number of divisions should be used to improve the accuracy of the aerodynamic performance of the wing. When the airfoil ratio increases, the most basic point cloud parameterization method will require more and larger data to support the accuracy of the airfoil's aerodynamic performance, which will face the severe test of insufficient computer capacity. On the other hand, when using the B-spline curve method, average number of control points and meshing number of divisions should be set appropriately to obtain higher accuracy; however, the quantitative balance cannot be directly defined, but the decisions should be made repeatedly by adding and subtracting. Lastly, when using the CST method, it is found that limited control points are enough to accurately parameterize the larger-sized wing; a higher degree of accuracy and stability can be obtained by using a lower-performance computer.

Keywords : airfoil, computational fluid dynamics, geometric similarity, surface mesh quality
Conference Title : ICFMFA 2021 : International Conference on Fluid Mechanics and Flow Analysis
Conference Location : Kuala Lumpur, Malaysia
Conference Dates : August 23-24, 2021