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翼伞弧面下反角、翼型和前缘切口对翼伞气动性能的影响

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Effects of Arc-anhedral Angle, Airfoil and Leading Edge Cut on Parafoil Aerodynamic Performance

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摘要 为了研究翼伞弧面下反角、翼型和前缘切口对翼伞气动性能的影响,对带气室的、展弦比为3的不同特征几何参数翼伞模型的流场进行了三维、定常数值模拟。运用有限体积法对三维坐标系下不可压雷诺时均Navier-Stokes (RANS)方程进行了直接求解,采用剪切应力输运(SST)k-ω两方程湍流模型对湍流进行模拟。数值模拟得出的原始翼伞的气动性能参数与试验数据在总趋势上符合很好,不同几何参数翼伞模型计算结果表明:翼伞弧面下反角越大,升力及诱导阻力越小,升阻比变化不大;前缘半径、厚度小的翼伞翼型,阻力更小,升阻比大;前缘切口对翼伞影响区域限于前缘附近,压力分布同干净翼类似,降低了其失速迎角,对升力影响不大,但明显增大阻力。该数值方法可为进一步研究更多不同几何参数的翼伞模型提供参考。

关键词： 翼伞 弧面下反角 前缘切口 气动性能 数值模拟 广义升力线理论

Abstract： To study the effects of the arc-anhedral angle, airfoil and leading edge cut of a parafoil on its aerodynamic performance, 3D steady flow field of parafoils with cells, an aspect ratio of 3, and characteristic geometric parameters is numerically simulated by using computational fluid dynamics (CFD) technique. The incompressible Reynolds-average Navier-Stokes (RANS) equations in a 3D coordinate system is solved by using the finite volume method. A k-ω shear stress transport (SST) two-equation turbulent model is also applied to simulate the turbulence. Numerical simulation results of the aerodynamic performance of the original model show good agreement with the tunnel experimental data. The results indicate that the arc-anhedral angle can obviously decrease the lift and induced drag of a parafoil, but the lift-drag ratio changes little. The model with a smaller leading edge radius and thickness of parafoil achieves larger lift-drag ratio. The leading edge cut has little effect on lift and its effect on the flow field is only confined to the region near the leading edge, making the pressure distribution of this model similar to the baseline airfoil. Meanwhile, the leading edge cut decreases the stall angle of attack and obviously increases drag. This paper can provide reference for further studies on parafoil aerodynamic performance with different geometric parameters.

Keywords： parafoil arc-anhedral angle leading edge cut aerodynamic performance numerical simulation generalized lifting-line theory

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