INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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SHORT ABSTRACT

Low Reynolds number (*Re*) aerodynamics is important for both natural and man-made flying objects. Over the last few decades there is a growing interest in designing Micro Air Vehicles (MAVs) which are used for both civil and military applications. The small length scale and low Reynolds number ($10^4 - 5 \times 10^5$) flight regime encountered in these classes of air vehicles lead to a complex flow phenomenon. This flow complexity is mainly due to viscous effects, laminar to turbulent transition, formation of the laminar separation bubble (LSB) with turbulent reattachment, which pose a major aerodynamic challenge to designers. The phenomenon of laminar to turbulent flow transition is one of the major area which is not fully understood by the Computational Fluid Dynamics (CFD) community. However, there are different ways in CFD to predict transitional flow namely (i) empirical e^N method based on linear stability theory approach (ii) Direct Numerical Simulation (iii) Large Eddy Simulation (iv) the statistical based RANS models. The present work mainly focuses on predicting the aerodynamics and transition characteristics of airfoils and wings used in MAV application and understanding the influence of different flow and geometry parameters on the performance of these airfoils and wings. In this study, the numerical simulations for *Re* ranging from 4×10^4 to 2×10^5 are carried out using the RANS based transition models *viz.* $k_T - k_L - \omega$ and $\gamma - Re_\theta$ SST available in the in-house multi-block incompressible flow solution code 3D-PURLES (3D Pressure based Unsteady RANS LES). The RANS based transition models are chosen for this study as they are computationally less expensive with their average flow quantities being reasonably accurate and best suited as a designer approach. This report discusses, the systematic numerical study carried out to investigate the effect of geometrical parameters like camber, thickness and planforms, grid parameters, flow parameters, transition models for low *Re* Selig-Donovan (SD) airfoil series on the aerodynamic and transition characteristics for a wide range of angle of attack. The grid size, grid resolution, grid topology, farfield location and other flow parameter like spatial discretisation schemes, freestream turbulence intensity and inlet eddy viscosity ratio which control the accuracy of the flow solution code is fixed based on the sensitivity study carried out at Re = 6×10^4 for SD7003 airfoil. The aerodynamic performance parameters (stall angle, lift coefficient and drag coefficient) and transition characteristics (transition onset, separation point, reattachment point and length of the LSB) are validated against the available measurement data. This comparative study indicated that the transition and aerodynamic features of the low *Re* SD7003 airfoil was predicted better by the $\gamma - Re_\theta$ SST transition model when compared to the $k_T - k_L - \omega$ transition model. The $\gamma - Re_\theta$ SST model because of its better performance was used for all the other simulations for different airfoils and wings carried out in this work. Based on the study carried out to understand the influence of the airfoil camber and thickness in the low *Re* regime it was inferred that increasing the airfoil camber significantly improved the performance of the airfoil whereas the increasing the thickness did not bring in any significant improvement in the performance of the airfoil. It was observed from this study that increasing the *Re* form 6×10^4 to 2×10^5 enhanced the aerodynamic performance whereas the transition features were not significantly effected. The numerical simulation past the non-dimensionalized SD7003 rectangular wing using the $\gamma - Re_\theta$ SST transition model is also discussed in detail. In this study, the effect of the different wing semi aspect ratio (sAR) of 0.25, 0.5 & 1 in the low *Re* regime at $Re = 6 \times 10^4$ is carried out to predict and understand its influence on the aerodynamic and transition characteristics. This study showed that wing with lowest semi aspect ratio of 0.25 is most suited for MAV application as its performance was better in terms of having lower drag, higher maximum lift coefficient, delayed stall angle, negative pitching moment slope and having a larger laminar region as compared to other two wing planforms with higher semi aspect ratio. It was further noted from this study that increasing the *Re* from 4×10^4 to 1.5×10^5 did not bring a considerable change in the aerodynamic and transition features of the SD7003 rectangular wing with 0.25 semi aspect ratio.