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TRANSITION PREDICTION AND IMPLEMENTATION IN RANS SOLVERS

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In the framework of laminar–turbulent flows, the prediction of transition is a demanding design issue. It has a major influence on friction drag, leading edge separation and boundary layer thickness, the latter impacting upon other key features such as shock–wave position and associated wave drag in transonic flows. Furthermore, thermal fluxes in turbulent region are at least twice higher, up to one order of magnitude, than in laminar condition affecting the thermal protection system (TPS) layout and hence the weight of the vehicle. Therefore, transition prediction is a key feature in aerodynamic analysis in order to assess properly the global performances of a vehicle in every flow regime.

The agreement between numerical and experimental results for high–lift flows, for example, is impossible without the correct prediction of transition. Likewise the extrapolation of wind tunnel results to flight scale by the use of CFD depends upon the accurate resolution of the transition phenomenon. The achievement of a reliable transition modeling capability in Navier–Stokes will therefore make a significant contribution to the efficiency of the industrial aerodynamic design process, as well as increasing confidence in the eventual design.

Nowadays, RANS code can simulate laminar–turbulent flows only imposing transition a priori, knowing it by experimental results. In the present work, based on 2–D previous developments[1, 2], a 3–D numerical procedure to impose runtime transition location in a RANS code is illustrated. The objective is to introduce a black box in a RANS solver able to compute transition location. Such tool includes a boundary layer code, a parabole code and e^N method[3] for transition prediction. The idea is to extract the pressure distribution at several wing sections after a certain number of iterations from a preliminary and partially converged flowfield and compute the boundary layer through a dedicated solver. Velocity and temperature boundary layer profiles are used to compute the linear stability through a fast and reliable method in order to identify transition location on the upper and lower side of the wing surface. In particular, the work focuses on

- an interface module which automatically manages the output of the open source CFD code OpenFOAM[4],
- the computation of the transition location,
- the implementation of such data in the RANS code.

The coupling procedure is iterated until the convergence on the transition location is achieved, then the RANS solver iterates up to its convergence criteria, as shown in the flowchart of Figure 1.

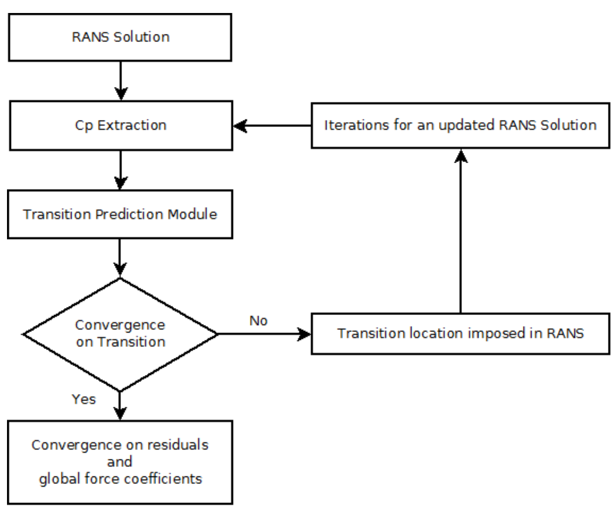

Figure 1: Flowchart of transition prediction procedure

The BLQ3D code[5] solves the boundary layer equations in conical formulation by using as input the pressure distribution along the airfoil, the geometrical parameters of the wing and the freestream flowfield data. The output are the boundary layer profiles at each chordwise station, such as streamwise and spanwise velocities, temperature and their derivatives. The transition location is predicted with the PARAB code [6] which is based on a simplified stability method called "parabole method" developed at ONERA [7, 8, 9]. In order to simulate the laminar–turbulent flowfield around 3–D bodies, like swept and tapered wings, three different transition mechanisms have been taken into account to estimate the location of the transition onset. The first mechanism is the attachment line contamination, occurring when turbulence convected along the fuselage propagates along a swept leading edge and then contaminates the wing surface. The other two mechanisms, namely Tollmienn-Schlichting (TS) and Cross flow (CF) waves, originate in a region close to the leading edge, known as the receptivity region. According to Morkovin[10], the external disturbances, such as free stream turbulence, engine noise or acoustic waves, enter the boundary layer and generate unstable waves which can trigger transition. The Poll[11] criterion is used for leading edge contamintion, Granville [12], C1 [13, 14] criteria and PARAB are used to individuate the TS and CF transition. The most conservative estimation of the transition onset given by these three mechanisms is then selected to be imposed in the RANS simulation. The proposed test case is the ONERA M6[15] wing as the experimental pressure coefficient distributions and transition location are available. Comparison with eperimental dta will be shown.

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