Transition Modeling in FLOWer — Transition Prescription and Prediction

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Summary. This paper summarizes the developments of transition prescription and transition prediction techniques which were implemented into the DLR Reynolds-averaged Navier-Stokes (RANS) solver FLOWer in the framework of the DLR projects MEGAFLOW and MEGAFLOW II and the German research project MEGAFLOW. The very basic transition handling functionalities which FLOWer provided before the projects started were generalized in order to prescribe arbitrary transition lines on very complex aircraft geometries with different components, such as wings, fuselages or nacelles. A number of transition prediction methods were incorporated into the code and an infrastructure was built up in order to handle the underlying transition prediction strategy which results in an iteration process within the solution process of the RANS equations. Finally, physical models for the modeling of transitional flow were implemented and tested.

3.1 Introduction

The modeling of laminar-turbulent transition in Reynolds-averaged Navier-Stokes (RANS) solvers is a necessary requirement for the computation of flows over airfoils and wings in the aerospace industry, as it is not possible to obtain quantitatively correct results if the laminar-turbulent transition is not taken into account.

A laminar-turbulent transition modeling consists of three major parts, the transition prescription, the transition prediction and the physical modeling of transitional flow. The transition prediction determines the transition locations on the surface of the configuration. The transition prescription applies the determined transition locations in the flow solver and thus brings the information from the transition prediction into the solution process of the RANS equations. The physical modeling of transitional flow is a means to improve the quality of the computational results on the one hand and to stabilize the iteration process of the transition locations on the other hand.

In this paper, results obtained with the RANS flow solver FLOWer, [1], of the German Aerospace Center (DLR) are presented. FLOWer is a 3-
dimensional, compressible RANS code for steady or unsteady flow problems and uses structured body-fitted multi-block meshes. The code is based on a finite volume method and a cell-vertex or a cell-centered spatial discretization scheme and uses an explicit Runge-Kutta time integration scheme with multi-grid acceleration. The influence of turbulence is taken into account by eddy viscosity turbulence models according to the Boussinesq approximation. All computational results shown in this paper were obtained with the cell-vertex discretization scheme.

The development of the transition prescription technique and the implementation of a coupling structure, which connects the flow solver to transition prediction methods has been partly realized in the German research project MEGAFLOW, [2].

\section{3.2 Transition Prescription}

The transition prescription technique in FLOWer can be applied in a general way to arbitrary, 3-dimensional geometric configurations and uses known transition locations, which have been determined previously, e.g. by experiments or separate calculations. A transition prescription technique is a necessary condition for transition prediction.

In general, a complex configuration consists of several components, each having an individual set of transition points. The transition points usually define a transition line on a part of the surface of the configuration, e.g. a wing or the fuselage of an aircraft. A single component of the configuration can have more than one transition line, e.g. a nacelle of a jet engine (outer surface of nacelle and inlet part) or a flap downstream of an engine with its jet blowing on the flap. The transition lines are curves in space bounded to the surface of the configuration. The shape of the surface of the configuration is arbitrary and, generally, the configuration itself is 3-dimensional.

Basically, the transition prescription technique splits the computational domain into laminar and turbulent flow regions. Its functioning is based on three steps, first the division of the surfaces of the configuration into laminar and turbulent regions, then the division of the field apart from the surfaces into laminar and turbulent regions and finally the different treatment of computational grid points in the laminar and turbulent regions during the solution process of the RANS equations.

\subsection{3.2.1 Transition Setting on Surfaces}

The boundary between a laminar and a turbulent flow region on the surface of the configuration is defined by a prescribed transition line usually in form of an oriented polygonal line defined by a definite, well-ordered sequence of transition points given in surface coordinates. The transition line must be mapped into the surface grid of the configuration, so that all surface grid