Best Practice Guidelines for the DLR *TAU* Code

Turbulence and Transition Models

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Best Practice Guidelines for Turbulence Models

Best Practice Guidelines for Transition Models

- **Transition Prescription (Transition Fixing) - 1**
  - **Transition locations which are known *a priori* can be taken into account in a *TAU* computation.**
  - **Transition prescription is based on transition point coordinates; on a 3d configuration they form polygonial lines.**
  - **The prescribed transition points must be located near the surface of the geometry. They can be located a little bit above or a little bit below the surface. They can also be located directly on the surface.**

Best Practice Guidelines for Transition Models

- Transition Prescription (Transition Fixing) - 2
  - The following configurations can be handled:
    - Single element airfoils or other simple 2d configurations
    - Multi element airfoils or other more complicated 2d configurations
    - Single element wings or other simple 3d configurations
    - Multi element wings or other more complicated 3d configurations
    - Fuselages or nacelles
    - Combinations of wings, fuselages and nacelles

Best Practice Guidelines for Transition Models

- Transition Prescription (Transition Fixing) - 3
  - Prescription of the following data
    - 2d, single element: $(x,y,z)_u^T$ for upper side
      $(x,y,z)_l^T$ for lower side
    - 2d, multi element: $(x_i,y_i,z_i)_u^T$ and $(x_i,y_i,z_i)_l^T$ for each element i
    - 3d, single element (wing): polygonial line L_u^T for upper side
      polygonial line L_l^T for lower side
    - 3d, multi element (wing): $L_{i,u}^T$ and $L_{i,l}^T$ for each element i
    - 3d, fuselage: L^T around the fuselage
    - 3d, nacelle: around the nacelle, L_i^T inside & L_o^Toutside

Best Practice Guidelines for Transition Models

- Transition Prescription (Transition Fixing) - 4
  - You should use two *different* boundary markers for the upper and lower sides. Only then you can also use transition prediction. The boundary markers are an attribute of the computational grid and have to be taken into account during the grid generation process.
  - Transition prescription is a prerequisite for transition prediction. Without transition prescription you can not apply transition prediction.

Best Practice Guidelines for Transition Models

- **Transition Prescription (Transition Fixing) - 5**
  - **Around the surface contours, laminar zones are created automatically. The extent of the laminar zones perpendicular to the wall, d_{lam}, have to be specified by the user. The laminar zone must be large enough, so that the complete laminar boundary layer is contained inside the zone.**
  - **Estimation of d_{lam}:**
    - **single element: in doubt, as large as possible**
    - **multi element: not to large, in order to prevent artificial turbulence destruction through unnaturally large laminar zones**
    - **$d_{lam} = 2 \times \delta_{lam,max}$**

$\delta_{lam,max}$: maximum laminar boundary layer thickness, to be estimated using flate plate boundary layer theory and the chord length of the airfoil element or wing section

Best Practice Guidelines for Transition Models

- Transition Prescription (Transition Fixing) - 6
  - Before you start the computation, check the correctness (shape, extent) of the laminar zones.
  - Produce a contour plot using a graphical tool (e.g. Tecplot).
  - Depict the wall distance of all points in the computational grid. The wall distance values of grid points located inside laminar zones have a negative algebraic sign as marker for a laminar point.
  - Value range for the depiction: 0 to 0.00001
  - Number of contour levels: 2

Best Practice Guidelines for Transition Models

- **Transition Prediction - 1**
  - If transition prediction is used, the use of transition prescription is a prerequisite.
  - Transition prediction starts with the grid generation: You *must* use two *different* boundary markers for the upper and lower sides of e.g. an airfoil. The boundary markers are an attribute of the computational grid and have to be taken into account during the grid generation process.
  - If you want to use the TAU internal computation of the laminar boundary layers you must have enough grid points in the direction perpendicular to wall:
    - for TS instabilities → at least 48 (2d flows)
    - for CF instabilities → at least 128 (3d flows)

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- **Transition Prediction - 2**
  - **These number of points must be distributed inside the structured part of a hybrid grid in the vicinity of the wall. The wall normal extent of the structured part should be as large as the maximum *turbulent* boundary layer thickness which could occur.**
  - **For transition in attached flow regions, the laminar boundary layer code COCO should be used to calculate the laminar boundary layers**

    → `Boundary layer data mode: 1.`

    COCO can be used for airfoil configurations and high aspect ratio wing configurations, *not* for fuselages and nacelles.
  - **For transition in laminar separation bubbles, the TAU internal computation of the laminar boundary layers *must* be used**

    → `Boundary layer data mode: 0`

Best Practice Guidelines for Transition Models

- **Transition Prediction - 3**
  - **Start a computation with transition using initial transition points located very far downstream, e.g. at the trailing edge.**
  - **Use a pre-prediction phase with a about**
    - **500 RANS cycles for simple configurations (attached flow expected)**
    - **1000 RANS cycles for complicated configurations (laminar separation bubble expected)**
  - **Use a pre-prediction interval of 20 RANS cycles.**
  - **Use laminar separation points from the RANS solution as transition points →** `Pre-prediction mode: 2`

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- Transition Prediction - 4
  - Use a prediction phase with a about
    - 20% of the RANS cycles expected for convergence of the RANS computation when attached flow is expected.
    - 50% of the RANS cycles expected for convergence of the RANS computation when a laminar separation bubble is expected.
  - Use a prediction interval of
    - 100 RANS cycles with laminar BL code COCO
    - 100 to 250 RANS cycles with TAU internal BL computation and attached flow
    - 250 to 1000 RANS cycles with TAU internal BL computation and laminar separation bubbles

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- **Transition Prediction - 5**
  - **Use an underrelaxation factor of at least 0.5 → only 50% of the currently new predicted transition location are taken into account.**
  - **The maximum value of the underrelaxation factor is about 0.8 → only 20% of the currently new predicted transition location are taken into account.**
  - **The parameter `Maximum delta for transition` bounds the shift of the transition point between two consecutive iteration steps. Use the value**
    - **0.5 with laminar BL code COCO**
    - **0.2 with TAU internal BL computation and attached flow**
    - **0.1 with TAU internal BL computation and laminar separation bubbles**