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Direct Numerical Simulations of Flow in a Low-Pressure Compressor Cascade with Incoming Wakes

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ABSTRACT

Direct Numerical Simulations (DNS) of flow in a compressor cascade with incoming wakes were performed. The geometry was selected in accordance with experiments performed by Lothar Hilgenfeld of the University of the Armed Forces in Munich. The Reynolds number of the flow problem was $Re=138500$, based on the mean inflow velocity U_0 and the axial chord-length L, see Figure 1 (a). To resolve the flow, a 1030x640x128-point mesh was employed. The mesh, illustrated in Figure 1 (b), was optimised using experience gained in earlier DNS and LES of periodic unsteady flow in a T106 cascade [1,2], and provided an adequate resolution of both the suction side boundary layer and the pressure side boundary layer. As illustrated in Figure 1, periodic boundary conditions were employed in the y-direction for $x/L < 0$ and $x/L > 1$, while on the surface of the blade no-slip boundary conditions were prescribed. The size of the spanwise direction, where periodic boundary conditions were employed, was $l_z=0.15L$.

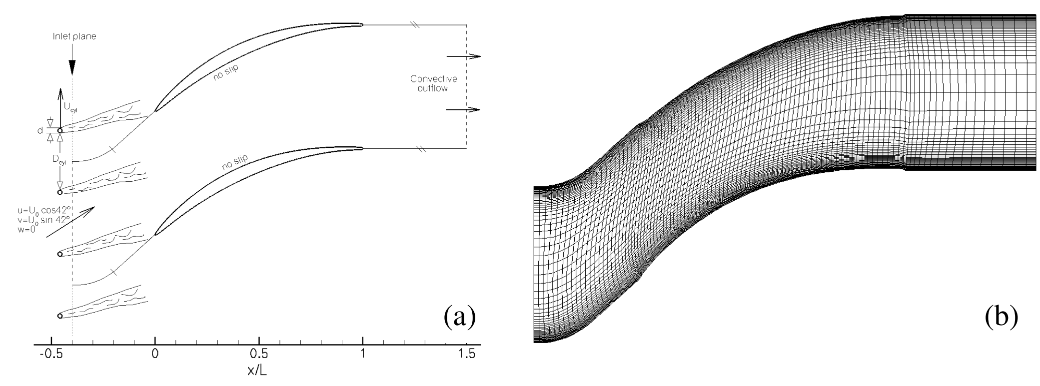

Figure 1. (a): Geometry of the flow problem,
(b): computational mesh showing every tenth gridline in the (x,y)-plane.

At the outlet plane, a convective boundary condition was prescribed, while at the inlet plane turbulent wakes were introduced which were superposed on the mean velocity field $(u,v,w)=U_0(\cos\beta,\sin\beta,0)$, where $\beta=42°$. The wake data was generated in a separate DNS of flow around a circular cylinder [1]. The data correspond to a wake generated by a cylinder of diameter $d=4mm$ moving upwards with velocity $U_{cyl}=0.30U_0$ in the plane x/L = -0.453. The distance between cylinders was chosen to be half the pitch between blades, D_{cyl} = ½P = 0.5953*L*. The axial chord length was L=203.25 mm and the period of the flow was $T=0.5953\ L/(0.30U) = 0.9922\ L/U_o$.
Two simulations - employing different intensities for the incoming wakes - have been performed. While the weak wakes in the first simulation were unable to suppress separation along the suction side of the blade, the stronger wakes in the second simulation were found to periodically trigger turbulent spots upstream of the location of separation. As these turbulent spots were convected downstream, they were found to partially suppress the separation downstream. The snapshots of the spanwise vorticity, displayed in Figure 2, clearly show the appearance of a wake-induced turbulent spot inside the boundary layer flow and its growth as it is convected downstream.

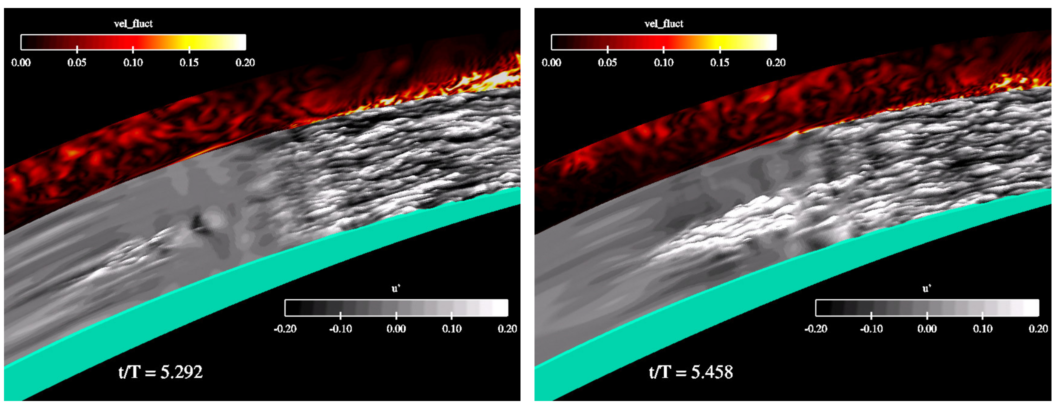

Figure 2: Snapshots showing the evolution of a wake-induced turbulent spot

The wake-induced turbulent spots spread out while they are convected downstream to finally merge in the fully turbulent region somewhat upstream of the trailing edge. In the simulation with weaker wakes, separation along the suction side is never (partially) suppressed. Instead, at all times a Kelvin-Helmholtz instability causes a quasi-periodic shedding of rolls of recirculating flow that are washed downstream by the main flow. Inside the rolls further transition to turbulence takes place.

REFERENCES

[1] J.G. Wissink, DNS of separating, low Reynolds number flow in a Turbine Cascade with incoming wakes. *Int. J. of Heat and Fluid Flow* **24** (2003), pp. 626-635.

[2] J.G. Wissink, W. Rodi and H.P. Hodson: The influence of disturbances carried by periodically incoming wakes on boundary layer separation along the suction side of a turbine blade. *Int. J. of Heat and Fluid Flow* **27** (2006), pp. 721-729.

[3] J.G. Wissink and W. Rodi, "Numerical study of the near wake of a circular cylinder", *Submitted to: Int. J. of Heat and Fluid Flow* (2008)