**UNIVERSITY OF PATRAS**

**DEPARTMENT OF MECHANICAL ENGINEERING & AERONAUTICS**

**DIVISION OF ENERGY, AERONAUTICS & ENVIRONMENT**

**LABORATORY OF APPLIED THERMODYNAMICS**


TITLE:

# COMPUTATIONAL INVESTIGATION OF SECONDARY FLOW IN LINEAR TURBINE CASCADE


**THEODOROS ANTONOPOULOS**

**1026627**

**Supervisor: KONSTANTINOS SOUFLAS, Assistant Professor**

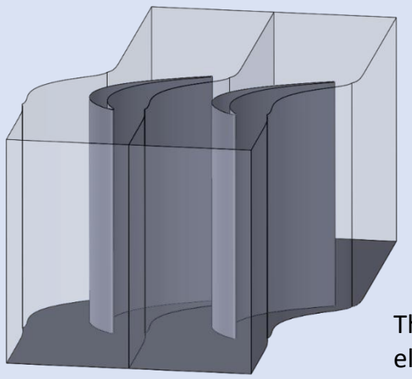

## ABSTRACT

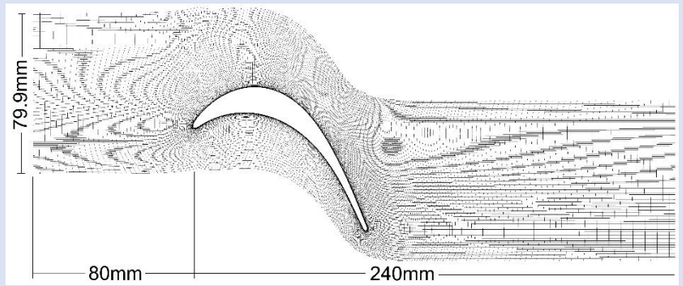

Numerical investigations of the flow field in simple linear turbine cascades have been conducted for decades in order to clarify the general flow picture and its complex secondary flow phenomena. In this framework, both RANS and LES investigations for the widely used T106 cascade under simulated conditions for a real engine ($M_1 = 0.35$, $M_{2,is} = 0.59$, $Re_{2,is} = 120000$) were selected as a reference point.

Based on these, in the present study, a CFD investigation of an equivalent configuration has been performed in the commercial numerical solver ANSYS Fluent. The formation of vortex structures such as the passage vortex, and quantities such as the pressure coefficient, the turbulent kinetic energy and velocity field have been evaluated and compared to experimental results. Due to limitations in the computational capabilities the quantitative agreement of the results was compromised. However, qualitatively there was good agreement.

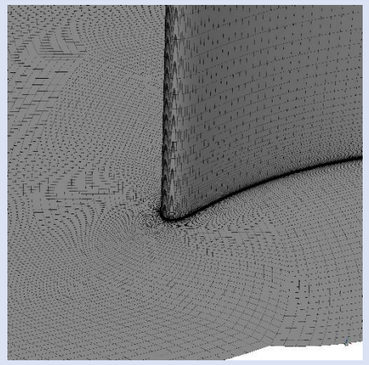

## GEOMETRY AND COMPUTATIONAL MESH

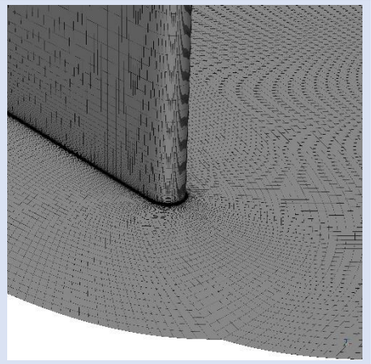
The geometry of the fluid domain is 1 pitchwise period for computational cost reduction purposes. The chord of the blade is $100mm$.






The computational grid consists of 4 million hexahedral mesh elements and was constructed in ICEM CFD.



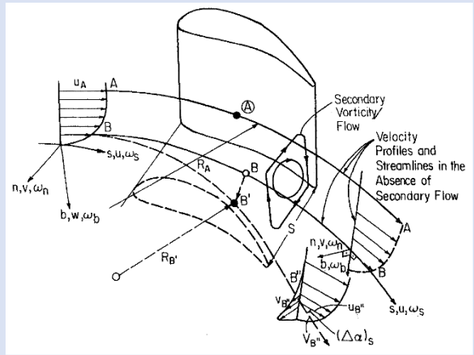


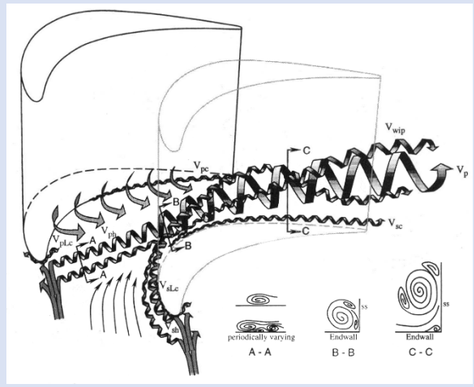
## SECONDARY FLOW

The picture of endwall flows in turbine blade-to-blade passages is extremely complex, dominated by the presence of secondary flows. The main type of secondary flow is the induced recirculating flow, which leads to the formation of a passage vortex. The source of the induced recirculating flow is the cross flow in the endwall boundary layer that forms as a result of force equilibrium in curvilinear motion. The momentum equation in the cross-stream direction can be written in the form

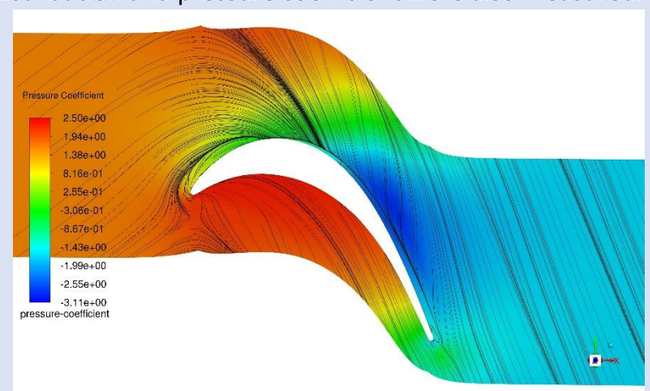
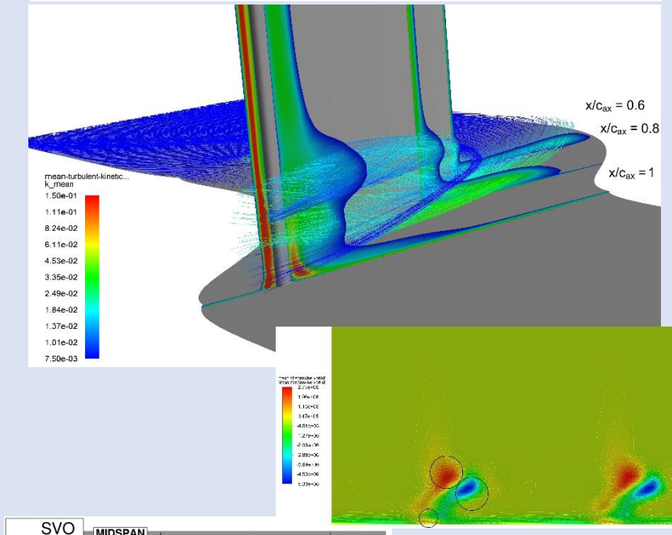
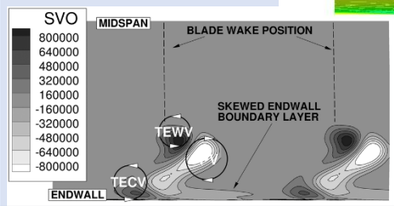
$$\frac{\rho u^2}{R} = \frac{\partial p}{\partial n}$$

With a decrease of the velocity in the boundary layer, a reduction of the streamline curvature radius in the boundary layer flow is required in order to balance the pitchwise pressure gradient formed in the channel. As a consequence, the boundary layer flow is turned more than the main flow in the blade-to-blade channel, leading to a crossflow from the pressure to suction surface in the endwall boundary layer.




Another key element of secondary flows is the horseshoe vortex which forms when the boundary layer fluid upstream of the leading edge is decelerated by the adverse pressure gradient and separated at a saddle point and is transported downstream in two legs – the pressure-side and the suction-side leg of the horseshoe vortex. The pressure-side leg subject to the transverse pressure gradient moves across the blade-to-blade passage, eventually giving rise to the passage vortex. The suction-side leg, with an opposite rotation, moves near the suction surface of the blade.

## uRANS SIMULATION

The vortex structures were captured through pathlines and limiting streamlines on the blade and endwall surfaces. The turbulent kinetic energy and streamwise vorticity were studied inside and downstream of the passage. The velocity distribution and pressure coefficient were also measured.