

# MULTI-OBJECTIVE OPTIMIZATION OF A CONTRA-ROTATING HELIUM TURBINE

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In the frame of a pan-European project a contra-rotating helium turbine has been designed for a hypersonic vehicle. The use of helium as working fluid poses some specific challenges. Due to the high speed of sound of helium, the turbine airfoils will operate in the low subsonic domain. Additionally, the low compressibility of the helium implies a low divergence of endwalls across stages. The mean flow analysis and optimization resulted in three different turbine configurations: a two-, three- and four-rotor configuration (*Figure 1*). First, the two-dimensional blade sections and then the three-dimensional blade were designed for several blade rows.

An inverse design tool (INVC) and an optimization tool (developed at VKI) was used to design the blade sections. The optimization tool makes use of an Artificial Neural Network, a Genetic Algorithm and a Navier-Stokes solver to enhance the aerodynamic performance of blades. The Artificial Neural Network is used to find the approximate relation between the parametric geometry and aerodynamic boundary conditions on one side, and the aerodynamic performance on the other side. This is done by using non-linear relations between the inputs and outputs through a “learning process”. The optimizer is the Genetic Algorithm which finds the blade design delivering maximum efficiency.

The new geometry provided by the optimization is evaluated by a 3D Navier-Stokes solver. The TRAF2D/3D and MS (Multi-Stage) was used to solve the Reynolds-averaged Navier-Stokes equations. In parallel with the aerodynamic optimization, the blade stresses have been computed using a finite element solver. The off-design performance of blade sections has been studied for inlet flow angles different from the designed one. Moreover, the effect of changing the pitch has been investigated in several blade rows to find the optimum number of blades, thus the optimum pitch-to-chord ratio.

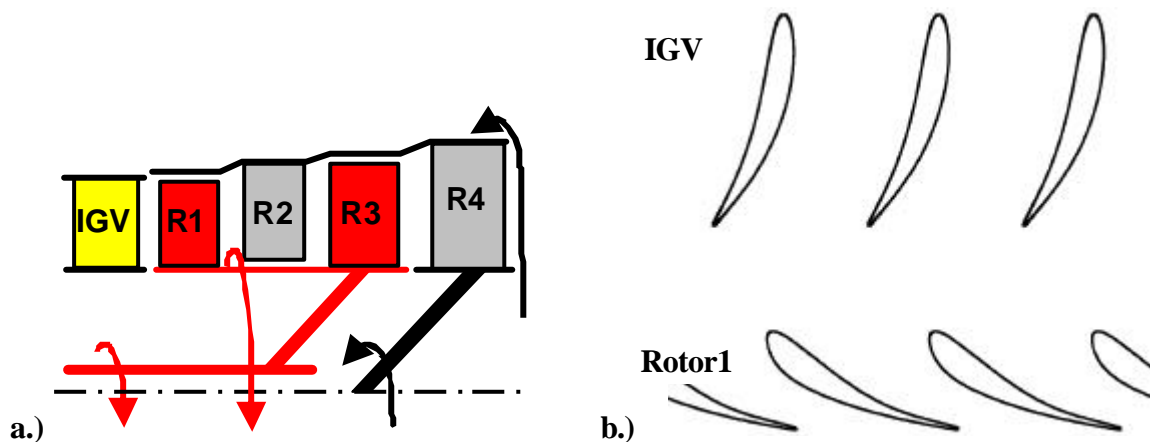


Figure 1: a - Meridional view of the 4-rotor turbine configuration  
b - Blade-to-blade plane of IGW and Rotor3