METHOD OF CHARACTERISTICS-BASED DESIGN AND NUMERICAL SIMULATION OF A MICRO-ORC SUPERSONIC TURBINE NOZZLE RING

Marta Zocca*, Antti Uusitalo, Teemu Turunen-Saaresti and Alberto Guardone

*Department of Aerospace Science & Technology
Politecnico di Milano,
Via La Masa 34, 20156 Milan
Italy

ABSTRACT

A waste heat recovery micro-ORC test rig was recently built at the Laboratory of Fluid Dynamics, Lappeenranta University of Technology. The system uses the exhaust gases from a Diesel engine as heat source and linear siloxane MDM (Octamethyltrisiloxane $C_8H_{24}O_2Si_3$) as working fluid. The prime mover of the ORC is a hermetic high-speed turbo-generator-feed pump, in which the working fluid also acts as lubricant. The system has proven capability to convert low-grade heat to electricity.

In this work, the design of a new turbine nozzle ring for the turbogenerator unit is presented. The turbine is of the radial inflow type, and it is characterized by a highly supersonic flow at stator outlet. For the design of the supersonic portion of the blade passages, a design method based on the method of characteristics is devised, which treats the diverging portion of the blade passage as a planar asymmetric nozzle with a curved mean line. Numerical simulations are performed for the complete stator geometry to assess the behaviour of the flow in design and off-design conditions. Both the design of the stator blades and numerical simulations are performed using accurate and well-established thermodynamic models, which account for the non-ideal behaviour of the working fluid in the range of expected operating conditions.

Results presented in this work provide new guidelines for the design of supersonic stators of ORC turbines. The proposed design method for supersonic planar asymmetric nozzles proved to be suitable to the design of nozzle rings for supersonic radial turbines. In addition to the application presented in this work, the method could potentially be adopted to define baseline geometries for blade optimization problems. Numerical simulations of complete stator geometries give insightful information about the performance of the stator both at the design point and in off-design conditions.