Invited Lecture

Development of high-efficiency exhaust channels of gas turbines

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Keywords: gas turbine exhaust, kinetic energy conversion, diffuser, collector.

Short abstract

Exhaust gases leaving the gas turbine have high kinetic energy, therefore, it is desirable to use diffusers at turbine outlets to convert this energy into pressure, before discharging it to the atmosphere. The investigations were aimed at developing high-efficiency exhaust channels of gas turbines for special aeronautic applications. These channels are characterized by high outlet-to-inlet area ratios, large alternations in the flow direction, changes from annular inlets into rectangular outlets, and high compactness. In order to design efficient channel configurations, a numerical flow prediction procedure, ensuring an appropriate solution quality, was elaborated. It was verified and validated against the experimental results obtained on the dedicated test stand. The obtained high level of efficiency of the elaborated designs results from a possibility to shape three-dimensionally the thin-walled channel structure. The design is based on its functional division into an axial-radial inlet diffuser and a collector. The complex shape of walls and a continuously increasing cross-section area allow for an efficient conversion of a significant part of the gas kinetic energy into pressure in the inlet diffuser. The flow in the collector is evidently more disturbed, but the losses are relatively low due to a considerably lower velocity than at the diffuser inlet, thus, the overall exhaust channel efficiency remains high.

Extended abstract

Exhaust gases leaving the gas turbine have high kinetic energy, therefore, it is desirable to use divergent channels (diffusers) at turbine outlets to convert this energy into pressure, before discharging it to the atmosphere. The more effective the conversion process, the lower the gas pressure at the outlet of the turbine (higher expansion rate), and thus its higher power and efficiency. A degree of the kinetic energy conversion depends on a configuration of outlet channels. It is usually a compromise between the available kinetic energy and the space in which this channel can be located. In order to convert a significant part of kinetic energy, diffusers with low divergence angles and large dimensions are required. Unfortunately, there is usually little room for extended installations, especially in aeronautic applications.

The aim of the investigations was to develop high-efficiency exhaust channels of gas turbines for special aeronautic applications. These channels are characterized by high outlet-to-inlet area ratios, large changes in the flow direction, changes from annular inlets into rectangular outlets, and compactness.

The exhaust channel is shown schematically in Figure 1. Exhaust gases leaving the turbine flow into the inlet diffuser, where the initially axial flow direction changes to radial due to the shaping of the internal and external walls. Their complex shape and a continuously increasing cross-section area allow for an efficient conversion of a significant part of the gas kinetic energy into pressure. The inlet diffuser is smoothly connected to the collector (exhaust hood) in order to collect the fluid and transport it to the channel outlet. The thin wall element with a bent end allows for controlling an interaction of the stream leaving the inlet diffuser and the one in the swirl motion in the collector, while simultaneously stiffening the thin-wall structure. The flow in the collector is evidently more disturbed, but the losses are relatively low due to a much lower velocity than at the diffuser inlet, thus, the overall exhaust channel efficiency remains high.

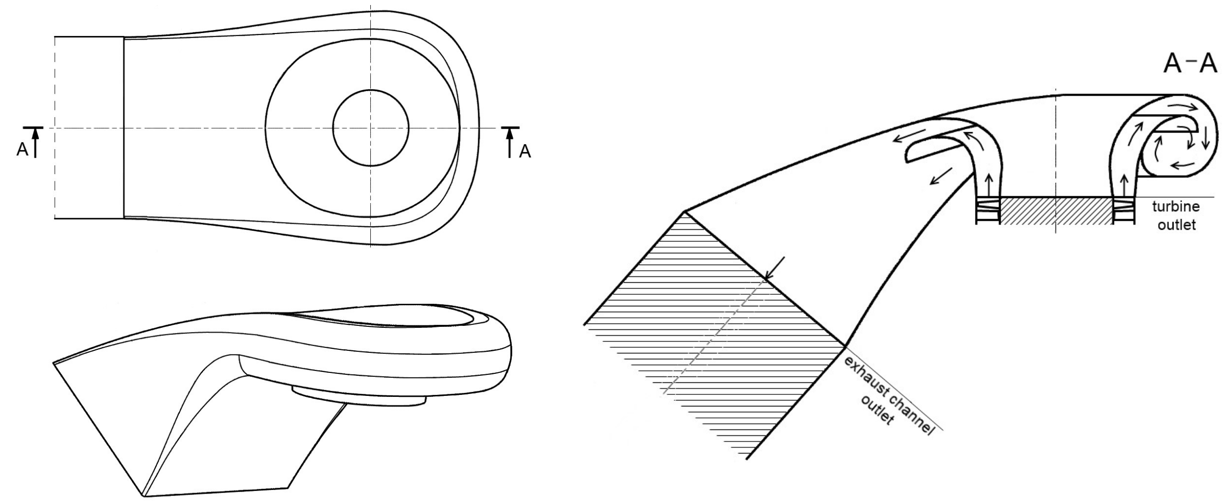

Figure 1. General view of the turbine exhaust channel and its cross-section in the symmetry plane with schematically marked flow directions

A configuration of the exhaust channels consisting of an axial-radial diffuser with an annular cross-section connected to the collector/hood is to be found in numerous references. Such channels are used in the installations at the outlets of condensing steam turbines, stationary gas turbines or axial compressors for industrial applications. However, relatively small dimensions of the channels allowed for complex three-dimensional shaping of a thin-walled structure without an unacceptable increase in costs and resulted in the high efficiency of the elaborated designs.

The research was based on flow simulations. High-quality solutions were required to search for efficient designs. Therefore, a procedure of the numerical flow prediction was developed, verified and validated. The numerical investigations on the discretization uncertainty and the boundary conditions impact were performed. Additionally, the model outcomes were validated with the experimental investigation results, confirming thus an appropriate precision of the obtained flow solutions.