

# Robust Optimization of a Supersonic ORC Turbine Cascade: a Quantile-based Approach

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Organic Rankine Cycle (ORC) power systems have become very attractive for the exploitation of low-temperature heat sources, such as waste heat recovery, biomass, geothermal, and solar energy, generally featuring variable heat load. ORC turbines usually operate in thermodynamic regions characterized by high pressure ratios and strong non-ideal gas effects in the flow expansion, complicating significantly their aerodynamic design. Systematic optimization methods accounting for multiple uncertainties due to variable operating conditions, referred to as Robust Optimization may benefit to ORC turbines aerodynamic design.

This study presents an original robust shape optimization approach to overcome the limitation of a deterministic optimization that neglects operating conditions variability, applied on a typical 2D ORC turbine cascade [3]. Flow around the blade is solved by means of inviscid simulation using the open-source SU2 code [2], from which a Quantity of Interest (QoI) is recovered. Non-ideal gas effects are modeled through the use of the Peng-Robinson-Stryjek-Vera equation of state [6]. Starting from a baseline blade parametrized using B-splines, we search for a shape optimizing the QoI, which is a random function. A classic Robust Optimization strategy consists in minimizing a cost function reflecting some statistical property of the random QoI. Classical cost functions are the mean, or a linear combination of mean and standard deviation. This latter has the advantage, w.r.t. the mean, to take into account the variability of the QoI, but it suffers from the strong dependence on the selected linear weights. The popular multi-objective Taguchis formulation [5] attempts to tackle this issue. Unfortunately, its drawback consists of a higher cost, by several orders, of the number of CFD evaluations. The mentioned formulations suffer from a lack of interpretation in the control of variability.

We propose here a mono-objective formulation consisting in minimizing the  $\alpha$ -quantile of the QoI, at a low computational cost. For example, selecting alpha to 95%, this formulation can be interpreted as minimizing the threshold below which 95% of the QoI realizations lie. The goal of the paper is to propose an efficient and physically sound robust optimization approach, based on a state-of-the-art quantile estimation [4] and on an advanced bayesian optimization method [1]. The robustly optimized ORC turbine shape is finally compared to the baseline configuration and to the deterministic optimal shape.

The impact the quantile level is also explored, minimizing the  $\alpha$ -quantile of the QoI for values of  $\alpha$  equal to 90%, 95% and 99%, respectively.

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