The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5-9 June 2022, Oslo, Norway

Risk Assessment for Transpiration Cooling

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Keywords: *Error Estimation, Quantile Estimation, Surrogate Modeling, Uncertainty Quantification, Transpiration Cooling*

To enable safe operations in applications as e.g. rocket combustion chambers, the materials are in need of active cooling as they will not withhold the temperatures by itself. Here, one promising cooling technique is transpiration cooling. Due to parameteric uncertainties, the model's outputs, e.g. the temperature, are random variables. Quantifying such probability distributions and efficiently estimating failure probabilities using meta-models is an active research topic [1].

In this talk, a novel approach is proposed that identifies the unknown quantile of the temperature by first propagating the parametric uncertainties using generalized Polynomial Chaos (gPC) and then utilizing its statistical output information to derive an empirical distribution system [2]. The method is tested on a coupled two-dimensional transpiration cooling model which consists of two domains, one for the flow through the porous medium based on the Darcy-Forchheimer equations and one for the hot gas flow in a rocket combustion chamber using an Reynolds-averaged Navier-Stokes model [3].

An error analysis of the suggested method will be included which makes it possible to assess the necessary accuracy of the meta-model for the desired quantile. Additionally, the closed form expression of the quantile makes directly integrating the risk assessment into an optimization context suitable which is favorable for many decision analysis questions. Furthermore, an analysis of the numerical results shows the decreased computational expense due to meta-model techniques and various contributions of the method to risk assessment for transpiration cooling in the bigger picture of rocket combustion chambers.

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