ADAPTIVE POLYNOMIAL CHAOS TECHNIQUES FOR UNCERTAINTY QUANTIFICATION OF A GAS COOLED FAST REACTOR TRANSIENT

Zoltán Perkó
Section Physics of Nuclear Reactors, Department of Radiation, Radionuclides and Reactors, TU Delft
Mekelweg 15, 2629 JB, Delft, The Netherlands
Z.Perko@tudelft.nl

Luca Gilli, Danny Lathouwers, Jan Leen Kloosterman
Section Physics of Nuclear Reactors, Department of Radiation, Radionuclides and Reactors
Delft University of Technology
Mekelweg 15, 2629 JB, Delft, The Netherlands
L.Gilli@tudelft.nl, D.Lathouwers@tudelft.nl, J.L.Kloosterman@tudelft.nl

ABSTRACT

Uncertainty quantification plays an increasingly important role in the nuclear community, especially with the rise of Best Estimate Plus Uncertainty methodologies. Sensitivity analysis, surrogate models, Monte Carlo sampling and several other techniques can be used to propagate input uncertainties. In recent years however polynomial chaos expansion has become a popular alternative providing high accuracy at affordable computational cost.

This paper presents such polynomial chaos (PC) methods using adaptive sparse grids and adaptive basis set construction, together with an application to a Gas Cooled Fast Reactor transient. Comparison is made between a new sparse grid algorithm and the traditionally used technique proposed by Gerstner. An adaptive basis construction method is also introduced and is proved to be advantageous both from an accuracy and a computational point of view.

As a demonstration the uncertainty quantification of a 50% loss of flow transient in the GFR2400 Gas Cooled Fast Reactor design was performed using the CATHARE code system. The results are compared to direct Monte Carlo sampling and show the superior convergence and high accuracy of the polynomial chaos expansion. Since PC techniques are easy to implement, they can offer an attractive alternative to traditional techniques for the uncertainty quantification of large scale problems.

Key Words: Polynomial Chaos Expansion, Sparse Grids, Adaptive Basis, Gas Cooled Fast Reactor, Transient Uncertainty Quantification

1. INTRODUCTION

To comply with the ever increasing safety needs for nuclear installations, regulatory bodies continuously tighten limits on operating parameters. The time consuming and complex calculations necessary to demonstrate that the predefined margins are respected traditionally use conservatism to counterbalance our lack of knowledge. Recently however there has been a shift to Best Estimate Plus Uncertainty methodologies and as a consequence there is growing emphasis on uncertainty quantification techniques providing high accuracy without prohibitive computational burden.

Statistical and deterministic methods are both available for propagating input parameter uncertainties to model responses of interest. The statistical approach relies on using direct Monte Carlo sampling or one of its variations (e.g. latin hypercube sampling, importance sampling, etc.) to quantify uncertainties with