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A Systematic Framework for Effective Uncertainty Assessment of Severe Accident Calculations; Hybrid Qualitative and Quantitative Methodology

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ABSTRACT

This paper describes a systematic framework for characterizing important phenomena and quantifying the degree of contribution of each parameter to the output in severe accident uncertainty assessment. The proposed methodology comprises qualitative as well as quantitative phases. The qualitative part so called Modified PIRT, being a robust process of PIRT for more precise quantification of uncertainties, is a two step process for identifying and ranking based on uncertainty importance in severe accident phenomena. In this process identified severe accident phenomena are ranked according to their effect on the figure of merit and their level of knowledge. Analytical Hierarchical Process (AHP) serves here as a systematic approach for severe accident phenomena ranking. Formal uncertainty importance technique is used to estimate the degree of credibility of the severe accident model(s) used to represent the important phenomena. The methodology uses subjective justification by evaluating available information and data from experiments, and code predictions for this step. The quantitative part utilizes uncertainty importance measures for the quantification of the effect of each input parameter to the output uncertainty. A response surface fitting approach is proposed for estimating associated uncertainties with less calculation cost. The quantitative results are used to plan in reducing epistemic uncertainty in the output variable(s). The application of the proposed methodology is demonstrated for the ACRR MP-2 severe accident test facility.

Keywords: Modified PIRT, Severe Accident, Uncertainty Analysis, Uncertainty Importance Measures, Uncertainty Analysis plus Importance

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1. INTRODUCTION

Treatment of uncertainties in severe accidents is a daily challenge to the technical community considering the complexity of severe accidents phenomena. The involved phenomena could range from the partial core degradation to ex-vessel complex phenomena which in some areas there are still lack of enough knowledge (e.g., steam explosion).

Recent under process "State Of the Art Reactor Consequence Analyses (SOARCA) project conducted by US-NRC [1], as an update to NUREG-1150 [2], is a good example in this area. As the SOARCA reviewers' letter to US-NRC's chairman in 2012 indicates [3], priorities for future work related to SOARCA should be the performance of an uncertainty analysis. The March 2011 severe accident in Fukushima dai-ichi NPP [4] demonstrated that relying on uncertain design could be catastrophic.

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