学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Investigation of Corium/debris field behavior for Decommissioning and Nuclear Safety Assessment
(廃止措置と原子力安全評価のための溶融コリウム・燃料デブリの挙動研究)

As past events have shown, severe accidents in Nuclear Power Plants (NPPs) often end with the melt-down of the reactor fuel into what is called, in the Nuclear Energy field, corium, a mixture of molten steel structure components and molten fuel debris. As it is the responsibility of the NPP's owner to assure the safety of the population, knowing how the corium will behave, keep it properly contained and cooled, was and still is a prime concern in the Nuclear Energy field.

Through the years, research emphasis was put on investigating the corium behavior in the case of a Reactor Pressure Vessel (RPV) melt through. In such a scenario, a wild array of phenomena can be observed and are detrimental for safety assessment and decommissioning such as the molten corium jet formation, its spreading behavior, or fragmentation if an encounter with coolant occurs, its solidification and behavior under confinement.

The goal of the present study is to investigate the corium/debris field to provide insights useful for the decommission of damaged NPP, such as Fukushima Daichi, and Nuclear Safety assessment. Therefore, the study is organized into four chapters that include a literature review on the topic, the presentation of a special collaboration with TEPCO for Fukushima decommissioning and works on the molten material jet phenomenon, from the formulation of a maximum spreading coefficient to jet's simulation with the commercial software Star CCM+.

In chapter 2, a literature review of a selected number of phenomena is provided. The phenomena presented are all impacting the corium behavior in the case of an RPV's melt-through. The focus was especially put on jet formation, jet breakup, spreading, fragmentation, and solidification of the corium. From there, the goal was to provide the background necessary for the next chapters of this study.

As a special assignment, chapter 3 presents the collaboration project with the Tokyo Electric Power Company (TEPCO) for Fukushima Daichi's decommissioning. To help the decommissioning effort, the project aims to gain knowledge of the thermal behavior of the reactor build through the accident. This knowledge is critical as it will allow knowing how deep is the radioactive contamination inside the concrete surrounding the reactor core. Through the use of simulations built with the commercial CFD software Star CCM+, temperature profiles for the reactor building were obtained that will help Fukushima's decommissioning.

In chapter 4, the focus was put on formulating an expression that could be of use for the Nuclear Safety Assessment in the case of a corium's melt-through. To realize this object, the previously mentioned experimental data was used to devise a formulation of the used simulants maximum spreading ratio in a way suitable for safety assessment.

Taking inspiration from this collaboration, as a way to improve safety assessment, the present study

focused on the corium behavior after the melt through the event. Therefore, in chapter 5, with the use of Star CCM+, molten metal jet simulations were built and compared to experimental data where Copper, Zinc, and Tin were used as corium's simulants. From that comparison, the limitation of the Star CCM+ was drawn and potential ways of improvement devised.

Keyword: Nuclear safety; CFD; Fuel debris, Heat transfer characteristic, Fukushima NPP, Decommissioning; molten metal; severe accident; rapid solidification

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