Popular Science Summary

Understanding Nuclear Reactor Cooling with Computer Simulations
How well can computer simulations predict the cooling of a nuclear reactor without pumps? The safety of next-generation reactors depends on removing heat even during failures, making reliable predictions of reactor cooling essential. This study uses computer simulations to investigate how a simplified lead-cooled reactor system can be modeled.

In this study, such a system is modeled using OpenFOAM, which is an open-source computational fluid dynamics (CFD) software. In addition to simulating the system, the study evaluates the model's ability to predict system performance and its limitations. This is achieved by comparing key quantities such as flow rates, temperature differences, and pressure drops to reference data.

The model is also used to investigate performance during natural circulation. Here, the analysis is based on qualitative comparisons and observed trends when geometry and modeling approaches are varied. The results are also used to evaluate how the model predicts natural circulation when a gas layer is present above the circulating lead.

The simulations show that the model can successfully predict how heat is removed from the reactor system. By comparing the key quantities to reference data, it is determined that the model is able to capture the most important physical processes.

When the pumps and active cooling system are turned off, the reactor is able to cool itself when the reactor height is sufficiently large. Additionally, the predicted flow is sensitive to how it is modeled since different approaches to modeling turbulence and fluid properties affect system performance.

Finally, adding a gas layer above the lead has a negligible effect on the overall performance of the system. This means that simpler models are sufficient to understand how the system behaves. It also shows that OpenFOAM is a viable option for modeling systems involving multiple fluids with large density differences. In turn, these findings provide insights that can support the design of safer and more reliable nuclear reactors in the future.