UF Herbert Wertheim College of Engineering
UNIVERSITY of FLORIDA

Florida Advanced Multiphysics Modeling and Simulation

- **PI: Dr. Justin Watson, Dr. Christopher McDevitt**
- Members: Sutapa Biswas, Kaela Kieler

The **F**lorida **A**dvanced **M**ultiphysics **Mo**deling and **S**imulation (FAMMoS) performs research to develop state-of-art analysis tools for nuclear reactor safety analysis. Research areas involve many different aspects of reactor analysis from fuel management and core design to full scale thermal hydraulic analysis of nuclear reactors. Areas of particular interest are:

- Advanced Reactor Physics Methods
- Cross Section Modeling Methods for Reactor Analysis
- Implicit Numerical Solution for Coupled Reactor Physics/Thermal Hydraulics
- High Performance Computing for Reactor Analysis
- Coupled CFD/System Code analysis

Dr. Christopher McDevitt

Dr. Chris McDevitt is an Associate professor in the Nuclear Engineering Program at the University of Florida where his research is focused on the theory and simulation of fusion plasmas. Prior to joining UF in Fall 2019, he completed his B.S. in physics at the University of California at Santa Cruz and subsequently completed his Ph.D. in physics at the University of California at San Diego, where he focused on the description of turbulence in magnetic fusion plasmas. After a short stint as a visiting scientist at Ecole Polytechnique, he moved to Los Alamos National Laboratory where he worked as a staff scientist.

Dr. Justin Watson

Dr. Justin Watson joined the Nuclear Engineering Program at UF in September of 2018. Prior to joining UF in Fall 2018, he was Head of the Computational Methods Development Department at the Applied Research Laboratory at the Pennsylvania State University. During his time at ARL, he oversaw a group of engineers that developed state-of-the-art computational fluid dynamics codes and models to solve some of the Navy's most challenging problems. His research at ARL involved developing new numerical methods for solving space and time dependent coupled reactor physics/thermal hydraulic problems for nuclear reactor safety analysis.

High Temperature Gas Core Reactor Fission Plasma Stability

Kaela Kieler and Sutapa Biswas, NE Majors

Abstract

The formation, stability, and first wall interactions of a fissioning plasma for a gas core reactor (GCR) are investigated in this research. Determination of the fission and heat rates, fuel and coolant gas ionization, and core heat removal are necessary to determine the interaction conditions of the plasma with the first wall.

Our model uses a spherical homogeneous core design which can maintain a continuous fuel cycle and higher operational temperature than a conventional nuclear reactors (1,500 K - 80,000 K). At high temperatures (>10,000 K), electrons can become free from the atomic structure, resulting in as ionized gas called a plasma that is confined by a magnetic field.

Envisioned applications of the GCR include nuclear thermal propulsion, process heat generation for industrial applications, and tritium production for fusion reactors. Analysis of the GCR design is performed using Monte Carlo method-based particle transport codes OpenMC and MCNP to quantify the fission process and determine reaction rates and multiplication factors for different fuel types and enrichments. Gkeyll (an opensource plasma physics code) has been utilized to evaluate plasma stability within the containment structure of the GCR model.

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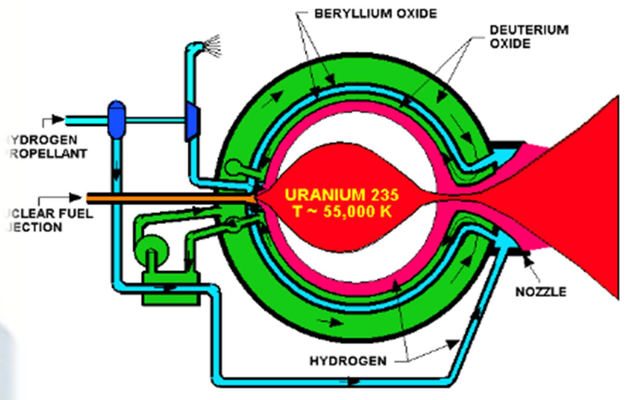
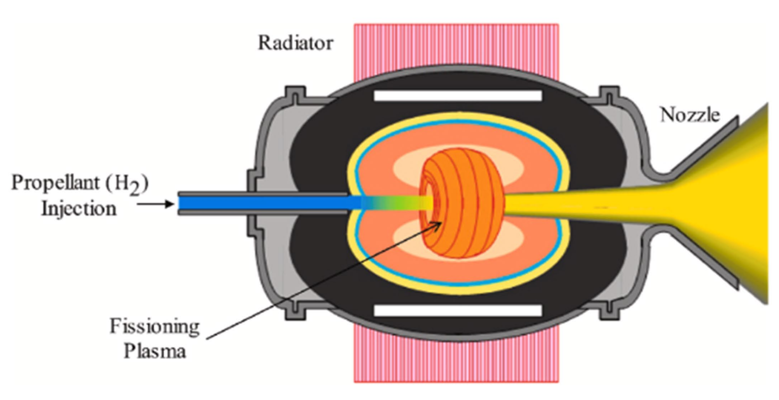
The unique characteristics of GCRs offer several advantages. The gaseous state of the fuel allows for direct energy deposition into the working fluid, enhancing heat transfer efficiency. At high temperatures, the gas becomes ionized, forming a plasma that enables the use of MagnetoHydroDynamic (MHD) power cycles. This, combined with the potential for additional gas turbine or superheated steam cycles, contributes to the reactor's high efficiency. Furthermore, GCRs align with Generation IV reactor goals, including improved sustainability, economics, safety, and proliferation resistance, thus making them a promising technology for future nuclear energy systems.



(a) Spherical GCNR

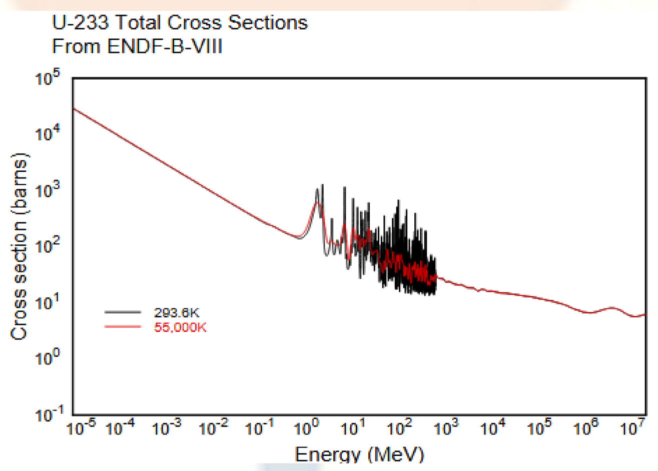


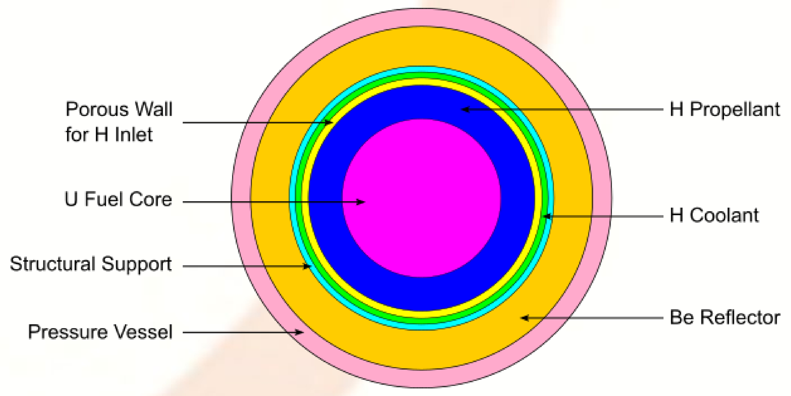
(b) Toridal GCNR

Our approach involves using software and tools like MonteCarlo Neutron Transport Code (MCNP), OpenMC, NJOY nuclear data processing code, and Gkeyll for plasma-dynamics simulation. Ongoing research draws inspiration from concepts like the Gas Core Nuclear Rocket (GCNR) and the Nuclear Light Bulb (NLB), with the current model favoring a spherical geometry. As development progresses, these models will incorporate more complex components, potentially leading to viable designs for both terrestrial and space applications, offering high power density and efficiency advantages over conventional nuclear reactors.

The objective of this project is to investigate the stability of a fissioning plasma in a gas core reactor (GCR), explore materials that limit plasma erosion, and determine the heat transfer characteristics for the GCR. Multiphysics modeling will be accomplished using NJOY21, MCNP 6.3, and Gkeyll. Challenges that will be addressed:

- Stable confinement of the fissioning plasma.
- Minimization of uranium plasma erosion on surrounding materials.
- Heat transfer optimization from fissioning plasma to the hydrogen fuel.
- Ability to simulate 3-D radiative heat transfer, neutron transport, and plasma transport.





Nuclear data processing code NJOY21 is used to generate the various cross-section ACE libraries for all GCR model materials at temperatures ranging from 1,200 K to 55,000 K. Monte Carlo N-Particle (MCNP) radiation transport code and OpenMC are used to generate the neutron particle tracking data and collision physics interactions inside the GCR model. Gkeyll, will be coupled with MCNP to provide an accurate heat transfer profile from the fissioning plasma to the pressure vessel.

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