Hot Isostatic Pressing (HIP) for Nuclear Fuels and Structural Materials

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Program: General Scientific Infrastructure

ABSTRACT:

This project will expand the Nuclear Science User Facilities (NSUF) capabilities at Purdue to include hot isostatic pressing (HIP) equipment to fabricate, densify, and/or process nuclear structural materials, nuclear fuels, radioactive waste, and radiation detectors. Conventionally, HIP has been used to consolidate stainless steel, Ni-base alloy, or low-alloy steel powders to fabricate nuclear structural components including pressure vessels. The powder metallurgy with HIP (PM-HIP) process has gained prominence in the nuclear industry relative to other advanced manufacturing technologies since HIP components can be several orders of magnitude larger than additive components. In fact, PM-HIP 316 stainless steel has recently been ASME code-qualified for nuclear applications. Beyond PM-HIP fabrication, HIP has numerous applications in the nuclear sector, including densification and performance enhancement of castings, forgings, or additively manufactured components, densification of ceramic and metallic fuels, immobilization of actinides and nuclear waste, and compaction of radiation detection and scintillating materials. Finally, since HIP offers scalability and technology readiness levels (TRL) not currently matched by additive technologies, there is a timely need to introduce students – through research and the classroom – to HIP as a near-term deployable advanced manufacturing technology that will have tangible practical relevance in their careers.

We will acquire a HIP system from American Isostatic Presses (AIP) with interchangeable furnaces to enable HIP of radioactive and non-radioactive materials without cross-contamination. The HIP will be available to NSUF users to fill national infrastructure gaps as only the fourth piece of "advanced manufacturing" equipment within the Nuclear Energy Infrastructure Database (NEID). Even more, the instrument will be unique from existing HIPs at Idaho National Laboratory because of our ability to process non-radioactive materials and our open accessibility. The HIP is also aligned with university priorities on advanced manufacturing education and research, and will become part of the Purdue Manufacturing Research Institute.

The scientific impact will transform lab-scale HIP research, accelerating deployment of novel HIP materials for current and future nuclear technologies. Educationally, the equipment will enable an innovative interconnected multicourse redesign of our undergraduate materials laboratories. This project is strategically relevant because a HIP will considerably extend the NSUF footprint into materials manufacturing, in close alignment with the October 2022 National Strategy on Advanced Manufacturing.