Delivering the Nuclear Promise
Top Innovative Practice

December 21, 2021

DNP-TIP-2021–09

Development and Demonstration of In-Situ Repair Method for Nuclear Fuel Dry Cask Storage Canisters

2021 Top Innovative Practice Winner

Southern California Edison (SCE) developed and demonstrated a method for in-situ repair of a dry storage canister. Built on relatively new but proven technology, the process accelerates nickel particles to supersonic speeds in a controlled environment to achieve metallurgical bonding to the base material. SCE worked with a material engineering vendor to miniaturize the equipment and mount it on a specially developed, magnetic-wheeled robot provided by a robotics vendor. The miniaturized technology passed laboratory testing and field demonstration and is ready for use.

Innovation

The innovation for this project started more than a year earlier when SCE was faced with the need to inspect loaded vertical canisters and to characterize possible scratching of the surfaces. This type of inspection had never been performed before and the needed cameras capable of measuring surface irregularities accurately had never been adapted for nuclear applications. SCE pulled together a team involving several vendors and adapted a system to do the inspection. The inspection was performed smoothly, as scheduled, and without incident. The robotic technology had been proven and the ability to adapt tooling to the robot had been demonstrated.

To develop the repair methodology, SCE reviewed all the technologies being researched, and developed, and were at an early implementation phase in the nuclear industry and other industries. While robotic welding is used extensively in the nuclear industry, miniaturization to be able to do welding in the tight annular gap (about 4 inches) surrounding the canister did not look achievable at a reasonable cost and during the time available to SCE. Similar challenges were faced with friction stir welding. However, a technology in use called "cold spray" had been placed into actual use in military and industrial applications and SCE had high confidence that miniaturization was achievable in the timeframe available. Additionally, cold spray had the advantage over welding since it was performed at a temperature below the sensitization temperature of stainless steel, avoiding the creation of a heat affected zone (HAZ). The HAZ surrounding a weld is an area of high stress and metallurgical changes causing the area to be much more susceptible to cracking. This is the reason that the industry has dubbed the process "cold spray." However, it is performed at an elevated temperature and management of hot delivery tubes is part of the challenge of making it work.

For simplicity, SCE chose to call the process "metallic overlay" and that term will be used herein.

The metallic overlay process uses a nozzle to accelerate, to supersonic speeds, small particles of the metal to be applied. The details of the process are proprietary, but a new nozzle had to be developed that would fit in the tight annular space. This limited the choice of motive gas to helium. To qualify the process, a rigorous test program was undertaken by the vendor. Several metals were tested, and the best was chosen. High levels of yield strength and adhesion were achieved. Additionally, the process places a compressive stress on the surface. Compressive stresses arrest SCC.

Once the nozzle was developed, we needed a way to apply it and worked with a robotics company to develop a robotic method to deploy the repair to the affected area and apply it. To properly apply the repair, the nozzle must be swept over the area of concern in a controlled manner in accordance with the qualified process. The robot had to have the ability to move the nozzle smoothly in two dimensions to apply the repair over the desired area.

After the repair nozzle was mated to the robot, testing was performed including mockup testing on a full-scale canister/storage module section at the vendor facility. After it was proved successful, all equipment was brought to SONGS where a demonstration repair was successfully performed on a test canister. The testing attracted a lot of attention in the industry and was observed by regulators, researchers, and peers.

Background

While the nuclear industry has been researching inspection and repair methods for spent fuel dry cask storage canisters for many years prior to this effort by SCE, no method existed for repair of a degraded canister. Much research has been performed in characterizing the challenges to canister integrity and is best documented in NRC publication NUREG-2214, "Managing Aging Processes in Storage (MAPS) Report." The consensus is that while dry cask storage systems are robust and qualified for a very long life, the most likely challenge to canister integrity is chloride-induced Stress Corrosion Cracking (SCC). SCC produces a short tight crack. Repair would be over a small area. Because a loaded canister has a high surface dose rate, removal of the canister from its storage location is not desirable. Performing the repair robotically in-situ is clearly the best alternative. With no repair method commercially available, SCE took the initiative to develop the metallic overlay repair technique.

Safety

It is not anticipated that canisters will crack, and in the unlikely event that a canister did crack, no significant radioactive material would be released. However, the ability to arrest the crack and maintain canister integrity through this repair method positively contributes to nuclear safety and should contribute to an elevated public perception of nuclear safety.

Cost Savings

It is hard to compare the cost of a technology where an alternative did not exist before. However, by developing this method early in the maturity process of the technology, sharing the intellectual property with our partners, and making good conservative choices for materials and robot design, this repair methodology was developed cost effectively. Having the technology on the shelf will result in tremendous cost savings should a utility need to implement a repair quickly. While it is not anticipated that a cracked canister would be significantly dangerous to the public requiring immediate repair, utilizing this repair method in a timely manner would be recommended.

Productivity/Efficiency

With no previous technology to compare to, the productivity increase is challenging to estimate. However, we can compare having the technology on the shelf to not having it developed and ready to deploy. Even in urgent situations, development of this technology without the work SCE and its vendors have done would take several months and expedited work is always much more expensive.

Transferability

Much of the work done on this project is directly transferrable to canisters stored in other configurations and in other licensed casks with minor modifications and qualification. SCE is currently developing a similar repair method for our other ISFSI system that stores canisters horizontally.

Team Members

- Allen Williams, ISFSI Aging Management Lead (SONGS)
- Jerry Stephenson, Principal Manager ISFSI Engineering (SONGS)
- Kyle Johnson, Engineering Director (VRC Metal Systems)
- Jamie Beard, President (RTT Robotics LLC)
- Stephen Canfield, Chief Technical Officer (RTT Robotics LLC)

Additional Information

Video link: https://youtu.be/Hgk8Nm_EZLg

Graphic 1: https://fs10.formsite.com/neiform/files/f-20-49-14780757_lDScbxjA_Metallic_Overlay_testing_in_Test_Fixture.tif

Graphic 2: https://fs10.formsite.com/neiform/files/f-20-50-14780757_5rOqD4RX_SONGSdeployment_of_metallic_overlay.tif