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Powder-Metallurgical Experiments and Manufacturing Studies of DUO_2-Steel Cermets for Spent Nuclear Fuel Casks

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Powder Metallurgical Experiments and Manufacturing Studies of DUO_2-Steel Cermets for Spent Nuclear Fuel Casks

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Cermets are being investigated as an advanced material of construction for casks that can be used for storage, transport, or disposal of spent nuclear fuel (SNF). Cermets, which consist of ceramic particles embedded in steel, are a method to incorporate brittle ceramics with highly desirable properties into a strong ductile metal matrix with a high thermal conductivity, thus combining the best properties of both materials. Traditional applications of cermets include tank armor, vault armor, drill bits, and nuclear test-reactor fuel. Cermets with different ceramics (DUO_2, Al_2O_3, Gd_2O_3, etc.) are being investigated for the manufacture of SNF casks.

Cermet casks offer four potential benefits: greater capacity (more SNF assemblies) for the same gross weight cask, greater capacity (more SNF assemblies) for the same external dimensions, improved resistance to assault, and superior repository performance. These benefits are achieved by varying the composition, volume fraction, and particulate size of the ceramic particles in the cermet with position in the cask body. Addition of depleted uranium dioxide (DUO_2) to the cermet increases shielding density, improves shielding effectiveness, and increases cask capacity for a given cask weight or size. Addition of low-density aluminium oxide (Al_2O_3) to the outer top and bottom sections of the cermet cask, where the radiation levels are lower, can lower cask weight without compromising shielding. The use of Al_2O_3 and other oxides, in appropriate locations, can increase resistance to assault. Repository performance may be improved by compositional control of the cask body to (1) create a local geochemical environment that slows the long-term degradation of the SNF and (2) enables the use of DUO_2 for long-term criticality control.

While the benefits of using cermets follow directly from their known properties, the primary challenge is to develop low-cost methods to fabricate 100-ton casks with variable cermet compositions as a function of position in the cask body. Two powder-metallurgy fabrication methods are being developed. In each process, a mixture of iron and ceramic powders is ultimately converted into a high-integrity SNF cask. The recently patented Forge Cermet Cylinder (FCC) process produces the cylindrical cask body in a near-final form as a single piece. The process starts with a steel preform that ultimately becomes the outer and inner shell of the final cask. The FCC process minimizes the number of processing steps and maximizes cermet performance; however, large equipment is required—particularly for the one-piece forging step. The Cermet Extrusion Section (CES) process produces extruded cermet pieces that are then assembled into the cask body. The size of the individual pieces minimizes process equipment sizes and facility investments but, adds steps to the fabrication process and results in somewhat lower cask performance. The two fabrication processes are described and compared. The results of preliminary experimental work and fabrication studies are reported.