Process of Production of Cermet Based on DUO_2 – Steel in Cold Crucible Induction Melter to be Used as Protective Material for spent nuclear fuel container's structures

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Introduction

Depleted uranium dioxide - steel cermet takes advantages of another materials used now in construction of protective

containers for spent nuclear fuel and radioactive wastes as follows:

- advanced gamma and neutron radiation protection at the expense of more higher density then steel and metal concrete and presence of oxygen of DUO_2;
- unlike metal depleted uranium, cermet of stainless steel and DUO_2 is more resistant to aggressive medium that is very important property in the case of use of cermet containers for long-term (in geological time scale) storage of spent nuclear fuel and radioactive wastes burial in underground depositories.

Statement work

The main problem of creation of cermet containers for storage of spent nuclear fuel and radioactive wastes lies in development of cost-effective technologies for uranium cermet production with high radiation-protective and field-performance data and manufacture of large products (protective shells, baskets, etc.).

Centrifugal casting method is more preferred. It allows to make cylinder products immediately. In this case the main problem is interaction of iron or stainless steel (Fe, Cr, Ni and etc.) melts and DUO_2 powder. This problem proposes to solve by raising reaction ability with respect to melts containing Fe, Cr and Ni.

Theoretical basic of process of cermet production

UO_2 has wide homogeneous area from $UO_{1,66}$ to $UO_{2,2}$ [1]. It is expected that reduction of $UO_{2,2}$ or UO_2 to $UO_{1,66}$ leads to arising reaction ability of UO_{2-x} with respect to melts containing Fe,Cr and Ni and hereunder will provide high-quality cermet production at crystallization.

It is obvious that the most reactionability products with respect to metal melt will be UO_{2-x} produced immediately before reduction, i.e. without cooling and loading from reactor to another one.

Based on results of thermodynamics analysis of reduction reactions of U_3O_8 and UO_2 by carbon and taking into account that:

- U_3O_8 is primary product of industrial technologies of depleted uranium hexafluoride conversion and therefore it is low-cost product;
- carbon is low-cost reducing agent as well and reduction reaction of U_3O_8 to UO_{2-x} is thermodynamics realizable at temperature above 1400^0C and pressure of 10^{-4} мм mercury column;

it is appropriate to make process of production of active UO_{2-x} by thermal carbon reduction method in vacuum.

Technologycal process and equipment

The above technological process is conducted in cold crucible induction melter that provides intensive electromagnetic agitation of components and homogeneous suspension production consisting of steel melt and solid particles of UO_{2-x}. This suspension is raw material for casting cylindrical bases of containers for storage of spent nuclear fuel and radioactive wastes.

Technological process is intended to realize in vacuum induction furnace with cold crucible(ICCM) with drain device for melt [2] according to the following operational procedures:

- loading steel, U_3O_8 or UO_2 and carbon (smut) powders required for reduction to UO_{2-x} into cold crucible;
- maintenance at vacuum lower than 10^{-4} mm. mercury column and temperature of 1700-1780K (below melting point of steel) for production of freshly reduced UO_{2-x};
- raising temperature up to 1830-1870K for melting steel;
- electromagnetic agitation of melt for uniform distribution of solid UO_{2-x} into steel melt, suspension formation at advantageous conditions for interaction of solid UO_{2-x} and steel melt;
- draining of homogenious cermet suspension and crystalization in ingot mold including centrifugal ones with cast cermet formation and its products.

References

1. Interaction of metals and gases. Proceedings of III Soviet-Japanese symposium on physical-chemical principles of metallurgical processes. Moscow , “Nauka”, 1973, pp. 9-15.
2. Patent of the Russian Federation 2177132.