IL TROVATORE

Innovative Cladding Materials for Advanced Accident-Tolerant Energy Systems

OBJECTIVES

The Fukushima Daiichi event has demonstrated the need for improved nuclear energy safety, which can be ensured by the development of accident-tolerant fuels (ATFs). ATFs are expected to overcome the inherent technical shortcomings of the standard zircaloy/UO_2 fuels, thus relieving the industry from the huge financial penalty associated with beyond-design-basis accidents leading to fuel cladding material failure and release of radioactive fission products to the power plant containment and the environment. The main objective of IL TROVATORE is to identify the best candidate ATF cladding materials for use in Gen-II and Gen-III/III+ LWRs and to validate them in an industrially-relevant environment, i.e. under neutron irradiation in PWR-like water. The innovative ATF cladding material concepts proposed in IL TROVATORE are expected to demonstrate significant improvement in performance when compared to the current fuel cladding materials, in response to the requirements of the amended Nuclear Safety Directive. The development of ATF clads will eliminate redundant safety systems, improving the market profile of current reactor designs, and the overall envisaged innovation will strengthen the competitiveness of European industries in both nuclear and non-nuclear sectors.

DESCRIPTION OF WORK

A critical pre-selection of ATF cladding material candidates has already been performed, taking into account the latest global academic and industrial achievements. The pre-selected ATF cladding material concepts are:

1. **SiC/SiC composites:** select composite concepts produced by different processing routes and with different – but equally-promising in terms of performance – critical fibre/matrix interfaces.
2. **Coated cladding material concepts:** the application of coatings on commercial clads (zircaloys, stainless steels) will not change the performance of the substrate clads. The following coating types are considered:
   (a) **Nanolaminated ternary carbide (MAX phases) coatings**
   (b) **Nanocrystalline oxide coatings**
3. **GESA surface-alloyed commercial clads:** the appropriate surface modification of commercial clads aims at the in-service formation of thin oxide scales that can provide corrosion and wear protection to the substrate clad. The GESA process surface-modifies commercial clads by means of an intense pulsed electron beam.
4. **Oxide-dispersed-strengthened (ODS) iron-chromium-aluminium (FeCrAl) alloy clads:** this ATF cladding concept is expected to combine the high-temperature oxidation resistance of FeCrAl alloys (alumina-formers) with the superior resistance of ODS ferritic alloys to irradiation creep and swelling.

Validation of the ATF clads in an industrially-relevant environment will be achieved by means of their simultaneous irradiation in BR2, so as to pinpoint the material(s) that can address the ATF challenge. Only the ATF clads that have passed *a set of critical screening tests* will be irradiated in BR2. The first 2 years of the project will be dedicated to material optimisation, followed by two full years of neutron irradiation in BR2 (max targeted displacement dose: 7 dpa).

MAIN RESULTS / HIGHLIGHTS

- Optimisation and down-selection of ATF clads prior to the BR2 irradiation based on a set of critical tests assessing resistance to aqueous corrosion & high-temperature steam oxidation, hermeticity & ion/proton radiation tolerance
- Validation of the best ATF clad candidates in an industrially-relevant environment, i.e., under neutron irradiation in PWR-like water (targeted TRL 5). This step will accelerate the transfer of the well-performing materials to market.
- Accelerated material development based on high-throughput material screening tools (ion/proton irradiation, select modelling approaches) that can assess material performance prior to its demonstration in industrial conditions.

DURATION

1 October 2017 – 31 March 2022
4.5 years

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