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Effect of Silicon Content on the Corrosion Resistance and Radiation- Induced Embrittlement of Materials for Advanced Heavy Liquid Metal Nuclear Systems

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Task 20

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BACKGROUND

Recent studies at the Los Alamos National Laboratory (LANL) involving martensitic Alloy EP-823 containing different silicon content have revealed a beneficial effect of Si on corrosion resistance in a molten lead-bismuth-eutectic (LBE) environment. Since very little data exist in the open literature on the beneficial effect of Si on the corrosion resistance of martensitic alloys, a research task was initiated to explore the role of Si not only on the corrosion resistance but also on the radiation-induced embrittlement of martensitic stainless steels.

This task is focused on the evaluation of the effect of Si content on the corrosion behavior and radiation-induced embrittlement of martensitic steels having chemical compositions similar to that of modified 9Cr-1Mo steel. Numerous state-of-the-art experimental techniques are currently being planned to be employed to achieve the desired research goal.

RESEARCH OBJECTIVES AND METHODS

Four different experimental heats of ASTM A 213 Type T91-grade alloy steels (similar to Mod9Cr-1Mo) with different Si content (0.48, 1.02, 1.55 and 1.88 weight percent) have been melted by the vacuum-induction-melting practice at the Timken Research Laboratory. They were subsequently processed into rectangular and square bars by forging and hot-rolling. These bars were then austenitized, oil-quenched, and tempered to achieve fine-grained and fully-tempered martensitic microstructure. Machining of different types of specimens from these heat-treated bars is ongoing.

Corrosion-resistant autoclave.

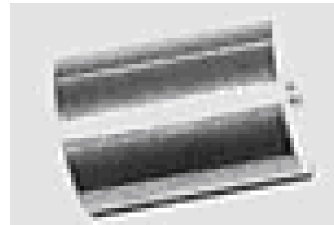
INSTRON high-temperature mechanical properties testing machine.

Tensile properties of all four heats will be evaluated both at ambient and elevated temperatures by using cylindrical specimens according to the ASTM Designation E 8. Micro-structural evaluations will be performed by optical microscopy. In order to study the effect of radiation on the tensile properties and impact resistance of the test materials, both cylindrical and Charpy V-notch specimens will be used.

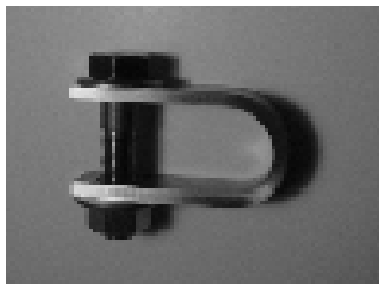
The tensile specimens will enable a comparison of mechanical properties including the yield strength (YS), ultimate tensile strength (UTS), percent elongation (%El) and percent reduction in area (%RA), with and without radiation. The notched Charpy specimens will enable the determination of the impact energy as a function of temperature, and the ductile-to-brittle transition temperature (DBTT) as functions of the Si content and the radiation dose. The morphology of failure on the tested cylindrical and Charpy specimens will be determined by scanning electron microscopy (SEM). Transmission electron microscopy (TEM) will be used to characterize the defects during plastic deformation as a function of temperature.

The general and localized corrosion behavior of all four heats of T91-grade material will be determined by using rectangular coupons. The susceptibility to stress corrosion cracking (SCC) will be evaluated by using tensile and self-loaded C-ring and U-bend specimens in both LBE and aqueous environments. SCC testing using cylindrical specimens will be performed in aqueous environments either at constant load (CL) or under a slow-strain-rate (SSR) condition. The C-ring and U-bend specimens will be tested in an autoclave in the presence of an aqueous solution at temperatures up to 650°C. The localized corrosion (pitting and crevice) tendency will be studied in an aqueous solution by cyclic potentiodynamic polarization (CPP) technique. The CPP test will determine the corrosion potential (E_{corr}), critical pitting potential (E_{pit}), and the protection potential (E_{prot}), if any. Fractographic evaluations of all SCC test specimens will be performed by SEM.

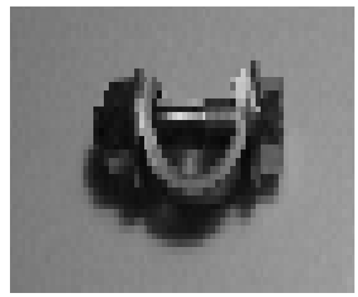
Tensile (Smooth & Notched)



Polarization



U-Bend



C-Ring

Test specimens.

FUTURE WORK

It is anticipated that this task will lead to the development of the following scientific/technical information:

- Metallurgical microstructures as functions of Si content and radiation dose.
- Tensile properties (YS, UTS, %El and %RA) before and after radiation.
- Impact resistance (impact energy and DBTT) versus Si content and radiation dose.
- Failure stress, ductility (%El and %RA), and threshold stress for SCC.
- Liquid-metal-embrittlement versus Si content.
- General corrosion rate versus Si content and temperature.
- E_{corr}, E_{pit} and E_{prot} versus Si content and temperature.
- Effect of hydrogen on SCC through controlled potential versus Si content.
- Extent and morphology of cracking (ductile/brittle, intergranular/transgranular).
- Voids due to radiation damage.
- Understanding the effect of Si on the metallurgical and corrosion behavior of T91-grade steels.

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