

## Task 10

# Development of a Mechanistic Understanding of High-Temperature Deformation of Alloy EP-823

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## BACKGROUND

Materials used in the target for accelerator-driven waste transmutation systems (ADS) will be subject to extreme temperatures and corrosive environments. The mechanical properties, such as the yield strength and ductility parameters, for most candidate materials have yet to be evaluated under these conditions. Martensitic alloy EP-823, a leading candidate material for use in ADS applications, has demonstrated excellent corrosion resistance in lead bismuth eutectic (LBE) nuclear coolant applications, such as those needed for fast neutron spectrum operations.

The focus of this work is to determine the effect of elevated temperatures on the tensile properties of Alloy EP-823. The information obtained through this work describing the mechanism of elevated-temperature deformation will assist in developing suitable target materials possessing enhanced LBE corrosion resistance at process temperatures, allowing the continued development and eventual deployment of these technologies.

## RESEARCH OBJECTIVES AND METHODS

The purpose of this task is to evaluate the mechanical properties of Alloy EP-823 at temperatures relevant to the transmutation processes. Testing has been initiated to evaluate the tensile properties of martensitic Alloy EP-823 stainless steel at temperatures ranging from ambient (25 °C) to 600°C. The test materials were thermally treated prior to the evaluation of their tensile properties. The deformation characteristics of these tensile specimens, upon completion of testing, will be evaluated by surface analytical techniques such as scanning electron microscopy (SEM) and transmission electron microscopy (TEM).

The ASTM Standard E8 (“Standard Test Methods for Tension Testing of Metallic Materials”) served as the guide for evaluating the tensile properties in the presence of an inert atmosphere. Cylindrical tensile specimens were machined in the longitudinal rolling direction. An elevated temperature chamber with an inert gas (nitrogen) atmosphere, in conjunction with the Materials Testing System (MTS), enabled researchers to perform the desired testing. The resultant data include the uniform elongation, reduction in area, yield strength, and ultimate tensile strength as functions of the test temperature and thermal treatments. Investigators initiated testing of three specimens under each of the three metallurgical conditions at these temperatures.

## RESEARCH ACCOMPLISHMENTS

The MTS machine was modified to accommodate ambient and high-temperature testing in the presence of nitrogen. A high temperature chamber capable of testing tensile specimens in the temperature range of 200 to 1000 °C was added to this machine. A pair of custom-built water-cooled specimen grips, made of maraging steel (M250), was attached to the MTS machine. This water-cooled assembly was designed to prevent the grips from being heated from the temperature inside the chamber by conduction.

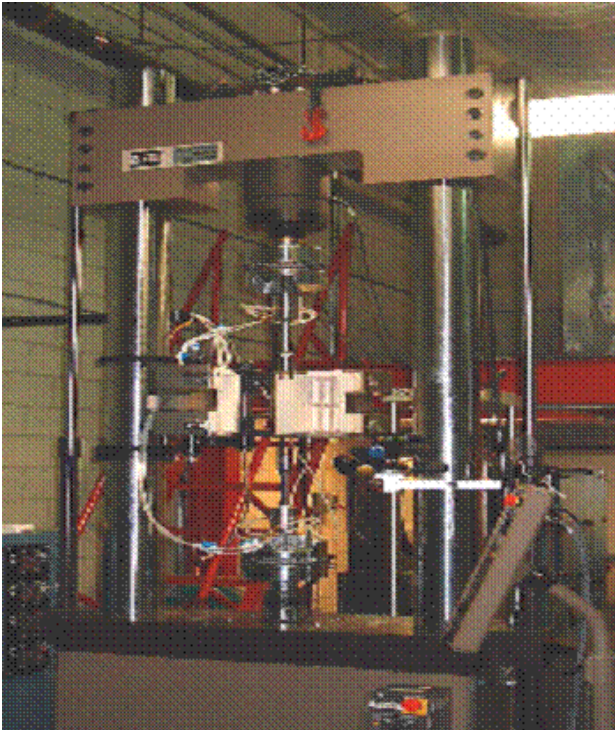
A laser extensometer, added to the MTS unit, measures the displacement of the test specimens in their gage sections. This displacement occurs during plastic deformation under tensile loading at the desired strain rate.

Testing has so far been performed at ambient temperature and 100 °C using tensile specimens fabricated from vacuum-melted and heat-treated (at the Timken Company) bars of martensitic Alloy EP-823. Preliminary data indicate that both the yield strength and the ultimate tensile strength of the tested material were slightly reduced at the elevated temperature. However, no significant reduction in ductility was observed in these tests.

Temperature profiles have been developed to determine the times needed to achieve the desired test temperature, as part of the furnace calibration process. Tests are in progress.



*Testing specimens.*



*High Temperature Mechanical Testing in Inert Atmosphere (up to 1000°C)*

## **FUTURE WORK**

Testing of Alloy EP-823 will continue. The current test matrix includes testing at 300, 400, 500, and 600 °C. The tensile properties at all testing temperatures will be evaluated as a function of thermal treatments that include austenitizing followed by quenching and tempering. These tests are expected to enable the measurement of the following tensile properties:

- Uniform elongation vs. temperature;
- Reduction in area vs. temperature;
- Yield strength vs. temperature;
- Ultimate tensile strength vs. temperature;
- Metallurgical microstructure vs. thermal treatment;
- Failure modes (ductile vs. brittle) vs. thermal treatment (SEM) and,
- Deformation modes (TEM).

## **HIGHLIGHTS**

- ◆ “High-Temperature Deformation of Alloy EP-823 for Transmutation Applications” presented at the ANS Student Conference, Berkeley, CA, April 2-6, 2003. Martin Lewis received a Best Paper Award.
- ◆ “High-Temperature Deformation of Alloy EP-823 for Transmutation Applications” presented at the ANS Annual Meeting, San Diego, CA, June 1-5, 2003.



*Tensile testing machine with elevated temperature jacket.*

The metallurgical microstructures of the failed tensile specimens will be evaluated using the standard metallographic methods of polishing and etching. SEM will be used to determine the morphology (ductile versus brittle) and extent of failure in each specimen tested at different temperatures. TEM will be used to develop high-temperature deformation characteristics including the distribution and nature of dislocations and other imperfections. This information will aid in the development of deformation mechanisms for Alloy EP-823 as functions of thermal treatments and testing temperatures.

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