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

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Task 10

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A. K. Roy and B.J. O'Toole

BACKGROUND

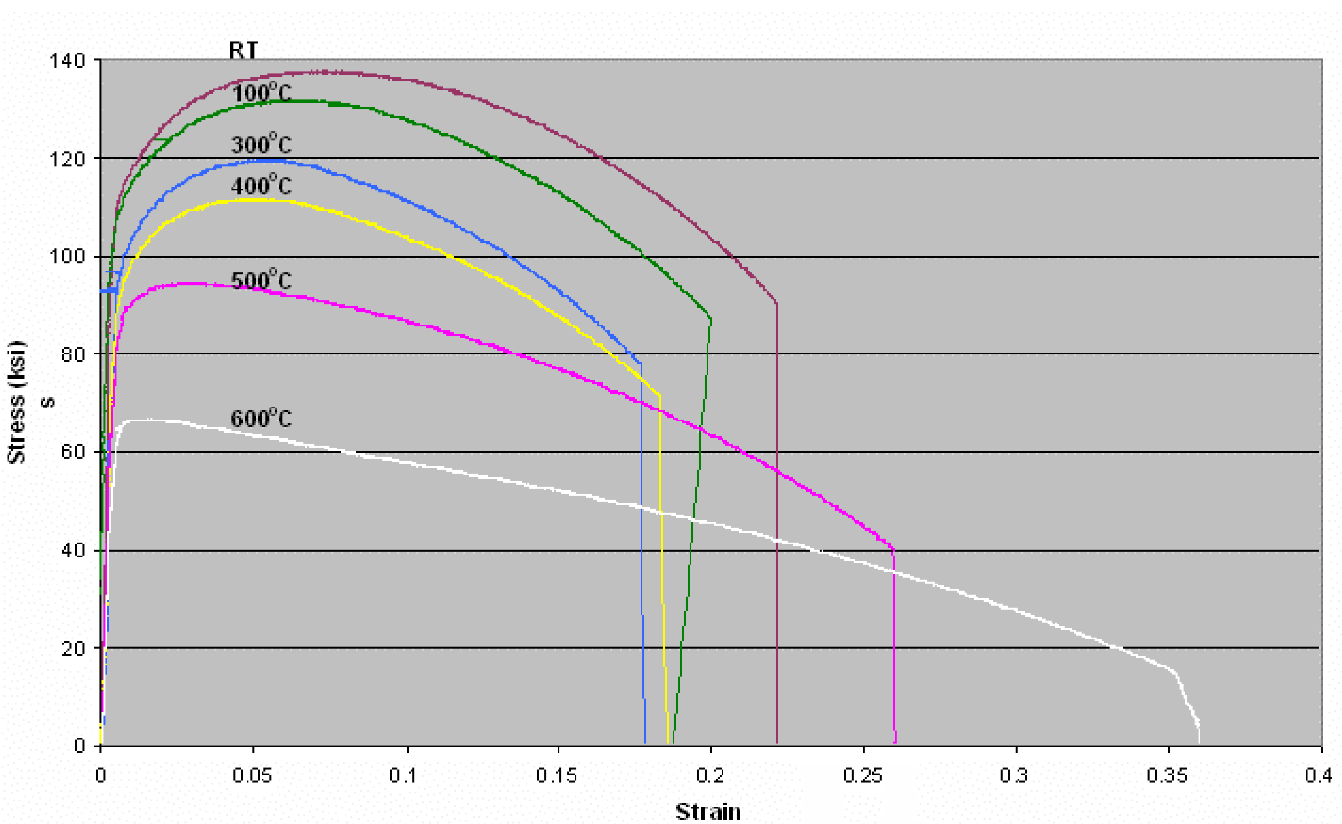
Materials used in the target for accelerator-driven transmutation systems (ADS) will be subject to extreme temperatures and corrosive environments. The mechanical properties such as the yield strength and ductility parameters, for most candidate materials have yet to be evaluated under these conditions. Martensitic alloy EP-823, a leading candidate target structural 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 and other martensitic alloys having similar compositions. The information obtained through this work describing the mechanism of elevated-temperature deformation will assist in developing suitable target structural 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 three martensitic alloys, namely Alloys EP-823, HT-9 and 422 at temperatures relevant to the transmutation processes. Testing has been performed to evaluate the tensile properties of all three alloys at temperatures ranging from ambient to 600°C. The test materials were thermally-treated (quenched and tempered) prior to the evaluation of their tensile properties. The deformation characteristics of these tensile specimens, upon completion of testing, have been evaluated by scanning electron microscopy (SEM). Identification and characterization of defects in the tested specimens are ongoing using transmission electron microscopy (TEM).

The ASTM Designation E 8 ("Standard Test Methods for Tension Testing of Metallic Materials") served as the guide for evaluating the tensile properties of all three alloys in the presence of nitrogen gas. Cylindrical specimens were machined in the longitudinal rolling direction. A high-temperature chamber containing nitrogen gas, in conjunction with the Materials Testing System (MTS), enabled researchers to perform the desired test-



Stress-Strain Diagrams for Alloy HT-9 at Different Temperatures.

ing. The resultant data include the percentage elongation (%El), percentage reduction in area (%RA), yield strength (YS), and ultimate tensile strength (UTS) as functions of the testing temperature and thermal-treatments. At least two specimens per material were tested under each of the three metallurgical conditions at the desired 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 100 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, measured the displacement of the test specimens in their gage sections due to plastic deformation at temperatures up to 400°C. A linear variable differential transducer was used to measure extension of the test specimens at temperatures above 400°C.

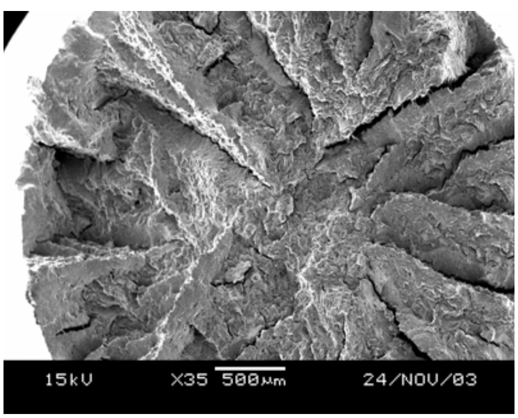
Testing has been conducted at ambient temperature, 100, 300, 400, 500 and 600°C using tensile specimens tempered for three different times. Temperature profiles were developed to determine the times needed to achieve the desired temperature as a part of the furnace calibration process. The significant conclusions are given below:

HIGHLIGHTS

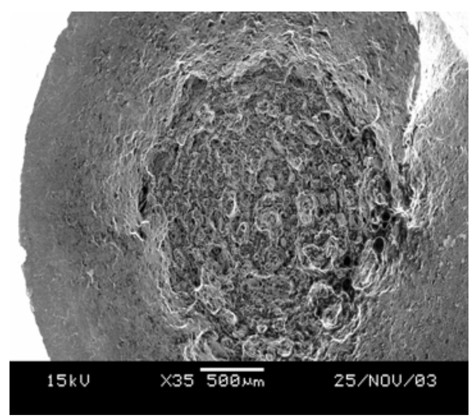
- "High Temperature Deformation of Alloy EP-823 for Transmutation Applications," ANS Conference, June 1-5 2003, San Diego, CA.
- "Temperature Effect on Mechanical properties of Target Structural Materials," ANS Student Conference, April 1-3, 2004, Madison, WI (a full technical paper and presentation).
- "High Temperature Deformation Characteristics of Martensitic Stainless Steels," SAMPE 2004 Symposium & Exhibition, Paper No. 58, May 16-20, 2004, Long Beach, CA.

- UTS and YS were gradually reduced with increasing temperature due to the enhanced plasticity at elevated temperatures, as expected.
- The extent of ductility in terms of %El and %RA was gradually increased with increasing temperature. However, the strain values were reduced in the temperature regime of ambient to 300°C possibly due to strain hardening. Beyond 300°C, the magnitude of strain was enhanced.
- The fracture stress was gradually reduced with increasing temperature, as expected.
- The morphology of failure was characterized by increased plastic deformation at elevated temperatures, as determined by SEM.
- Fine-grained and fully-tempered microstructure, characteristics of quenched and tempered martensitic stainless steel, was observed by optical microscopy.

No significant effect of tempering time on the resultant tensile data was observed in this investigation.



SEM Micrograph of Alloy HT-9 at Room Temperature (35X)



SEM Micrograph of Alloy HT-9 at 600°C (35X)

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