Task 14
Use of Positron Annihilation Spectroscopy for Stress-Strain Measurements

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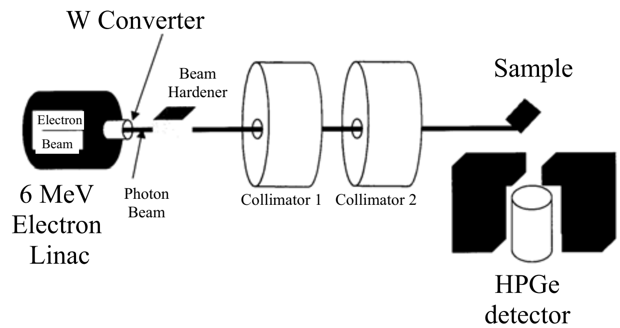
BACKGROUND

One of the greatest challenges in evaluating the performance of materials in the real world is the determination of residual stresses, or the stresses induced in a material. Plastic deformation of metals and alloys produces an increase in the number of lattice imperfections known as dislocations, which by virtue of their interaction results in higher state of internal stress and reduces ductility. These stresses, if not properly annealed (released) can significantly degrade the long-term performance of the materials.

Due to the high temperatures and radiation fields typically encountered in most nuclear systems, such as accelerator-driven transmutation systems (ADS) and nuclear power reactors, the residual stress in materials can be even more significant. To minimize the impact of residual stress, most designs limit the residual stresses allowed in the structural materials in the systems. As a result, the ability to measure these residual stresses, while potentially challenging, is essential to the design and operation of nuclear systems.

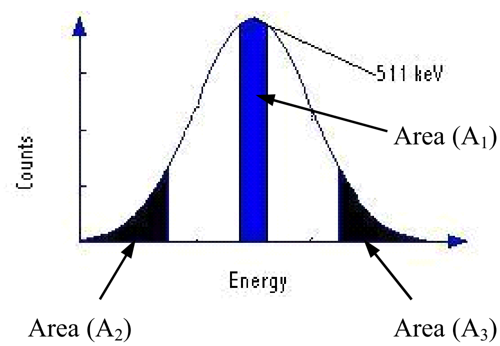


Positron Annihilation Spectroscopy Experimental Setup

RESEARCH OBJECTIVES AND METHODS

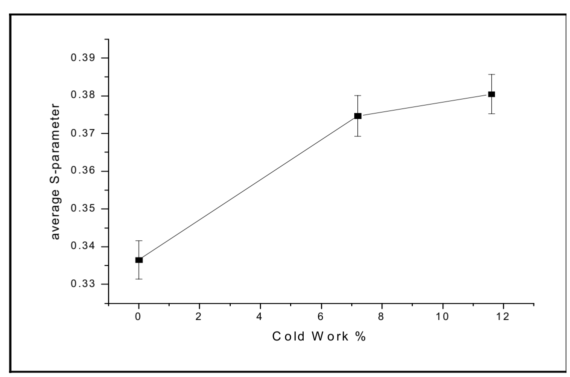
Residual stresses can be measured using destructive and nondestructive techniques. The primary focus of this research is to evaluate the feasibility of determining residual stresses in engineering materials for transmutation applications using a new nondestructive technique based on positron annihilation spectroscopy (PAS). In this project, the modified PAS method is compared to residual stress measurements performed by three other techniques: the ring-core method (destructive), X-ray diffraction (XRD, Non-destructive), and neutron diffraction (non-destructive).

These four techniques are being used to measure residual stresses in cold-worked and welded samples of austenitic Type 304L stainless steel (SS), and martensitic Alloys EP-823 and HT-9. Alloy EP-823 is a leading structural material to contain molten lead-bismuth-eutectic (LBE) nuclear coolant needed for fast spectrum operations of the ADS system. Type 304L SS is a universally known corrosion resistant low carbon iron-nickel-chrome alloy having optimum formability and weldability.



S- Parameter = Area A_1/ Total Area (A)
W-Parameter = (Area A_2+Area A_3) / Total Area (A)
T-Parameter = W/S

Positron Annihilation Spectroscopy Data Interpretation



Positron Annihilation Spectroscopy Data on Cold-Worked Specimens

RESEARCH ACCOMPLISHMENTS

Experimental heats of Type 304L SS, and Alloys EP-823 and HT-9 were melted at the Timken Research Laboratory using a vacuum induction melting process. They were subsequently forged and rolled into plates of desired dimensions. Plates of both martensitic alloys were subsequently austenitized, oil quenched, and tempered to achieve a fully tempered martensitic microstructure. Type 304L SS plates were solution-annealed (austenitized and air-cooled).

Three types of specimens, namely cold-worked (7 and 11%), bent (three-point-bending), and welded specimens were prepared by using these heat treated materials. The bent specimens were fabricated at the Lambda Research Laboratory (LRL). The welded specimens were prepared by Los Alamos National Laboratory (LANL) by welding plates of similar and dissimilar materials, using gas-tungsten-arc-welding method.

All three types of specimens are currently being tested at the Idaho Accelerator Center (IAC) and LRL to determine the residual stresses using positron annihilation spectroscopy, X-ray diffraction and ring core techniques.

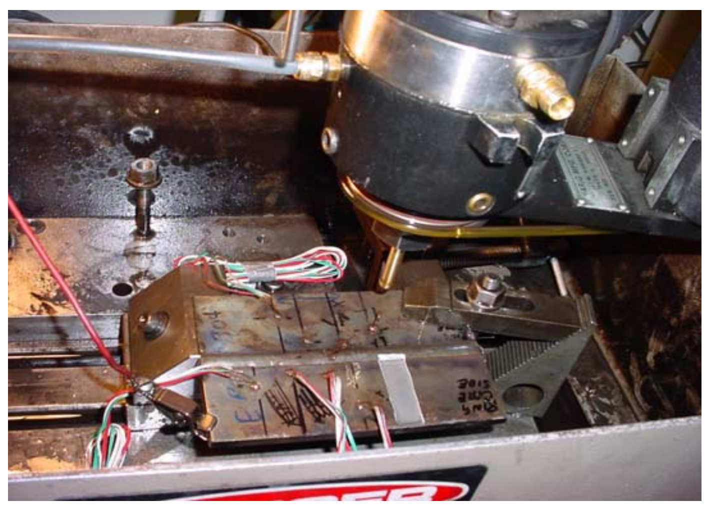
FUTURE WORK

The second year of this task includes the following scope of work:

- Perform positron annihilation spectroscopy measurements on cold-worked and welded specimens at IAC.
- Establish calibration curves by PAS measurements on unstressed/stressed tensile specimens.
- Perform residual stress measurements by neutron diffraction method at Atomic Energy Canada Ltd (AECL)/ LANL.
- Use transmission electron microscopy to analyze imperfections/defects resulting from plastic deformation/ welding.
- Perform metallographic evaluation of welded specimens by optical microscopy to reveal microstructural differences between the base metal and the heat affected zone.
- Determine residual stresses in all materials including Alloy 718, irradiated and unirradiated.

HIGHLIGHTS

- "Residual Stress Measurement in EP-823 Using Non-Destructive Evaluation Techniques", presented at the ANS Student Conference, Berkeley, CA, April 2-5, 2003.
- "Residual Stress Measurement in Type 304 Stainless Steel Using Non-Destructive Techniques", presented at the (ANS) Student Conference, Berkeley, CA, April 2-5, 2003.
- "Residual Stress Measurements by Non-Destructive and Destructive Methods" presented at the ANS annual Meeting, San Diego, CA, June 1-5, 2003.
- "Applications of Electron Linacs in Defect and Stress Measurements" presented at the ANS annual Meeting, San Diego, CA, June 1-5, 2003.
- "Residual Stress Measurements for Spallation Target Materials" to be presented at the ASM International Surface Engineering Congress, Indianapolis, IN, September 15-17, 2003.
- "Residual Stress Measurements by Positron Annihilation Spectroscopy" to be presented at the 46th Annual Non-Destructive Testing Forum, Montreal, Quebec, Canada, September 22-25, 2003.
- "Residual Stress Measurements in Target Materials" to be presented at the SAMPE Technical Conference, Dayton, OH, September 28-October 2, 2003.



Ring-Core Method

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