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# Use of Positron Annihilation Spectroscopy for Stress-Strain Measurements

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# Task 14
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## BACKGROUND

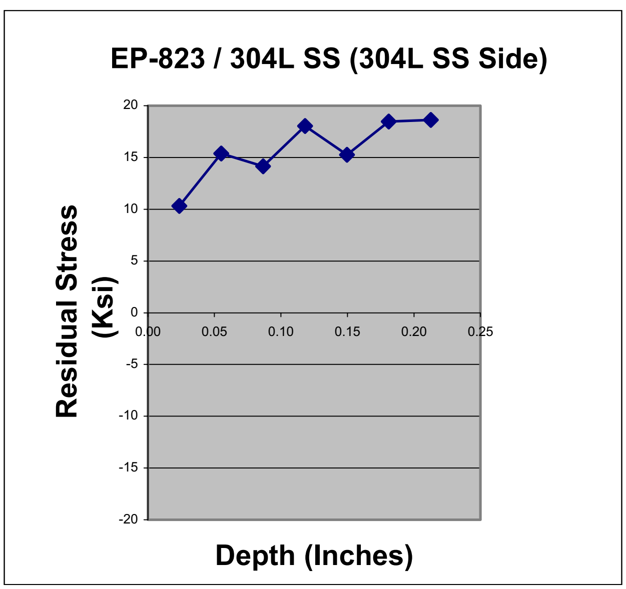
Metals and alloys, when subjected to tensile loading beyond a limiting value, can undergo plastic deformation resulting in lattice defects such as voids and dislocations. These imperfections may interact with the crystal lattice, producing a higher state of internal stresses characterized by reduced ductility. Residual stresses can also be generated in welded structures due to rapid rate of solidification, and dissimilar metallurgical microstructures between the weld and the base metals. Premature failures can be experienced in engineering metals and alloys due to the presence of these residual stresses. Specific thermal treatments commonly known as stress relief operations can relieve these internal stresses.

This project is focused on the evaluation of residual stresses by the state-of-the-art destructive and non-destructive techniques. In addition, microstructural evaluations have also been performed by metallographic techniques. Future work will involve residual stress measurements on components, deformed plastically and subsequently irradiated. Further, the effect of post-weld-thermal-treatment on the resultant internal stresses will also be evaluated.

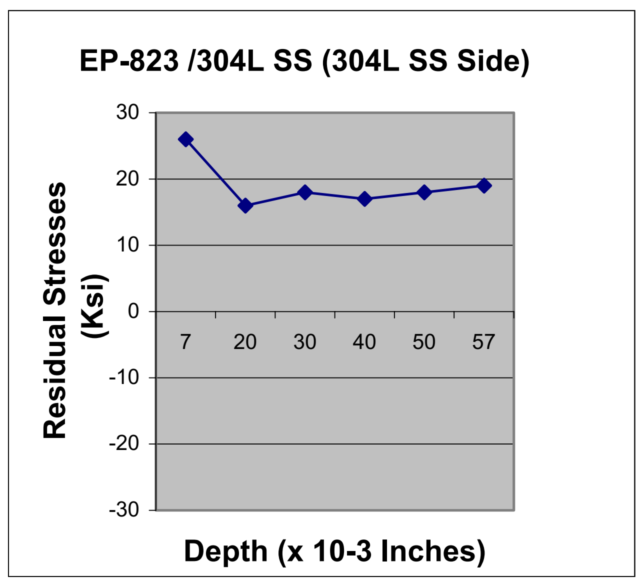
## RESEARCH OBJECTIVES AND METHODS

Residual stresses can be measured using destructive and non-destructive 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 residual stresses measured by a modified PAS method are compared to those measured by three other techniques namely, the ring-core method (RC, destructive), X-ray diffraction (XRD, non-destructive), and neutron diffraction (ND, non-destructive).

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




*(a) ND measurements*



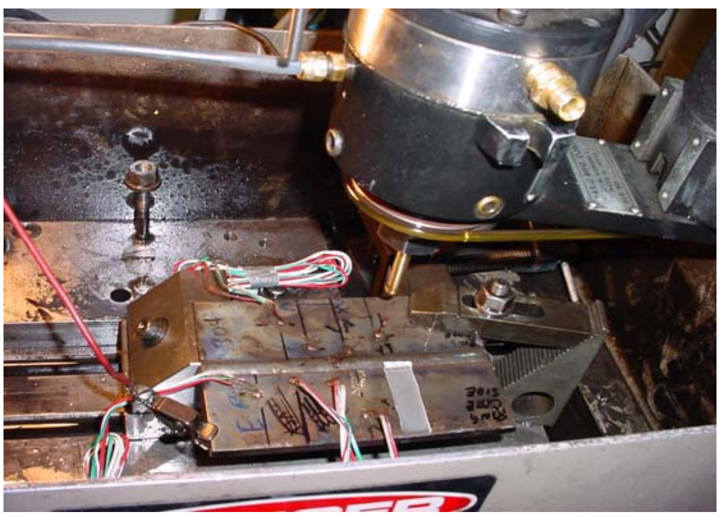

*(b) RC measurements*

*Comparison of residual stresses measured by (a) Neutron Diffraction and (b) Ring-Core methods at the fusion line of the welded specimen.*

## RESEARCH ACCOMPLISHMENTS

Residual stress measurements have been performed on three-point-bent, cold-worked and welded specimens of all three alloys. Neutron diffraction measurements have been performed at the Atomic Energy of Canada, Limited (AECL), Chalk River, Ontario, Canada. Currently, efforts are in progress to measure residual stresses by the PAS technique at the Idaho Accelerator Center (IAC). Simultaneously, ring-core data have recently been generated at the Lambda Research Laboratory, Ohio. Comparisons will soon be made upon availability of all generated data. Calibration of tensile specimens loaded to different stress values are also ongoing at IAC to determine the magnitude of line-shape parameters resulting from the PAS measurements.

The results indicate that for welded specimens made of Type 304L SS and Alloy EP-823, the residual stresses measured along the fusion line of the Type 304L SS side were tensile in nature.



*Ring-Core Method*

## HIGHLIGHTS

- "Residual Stress Measurements by Nondestructive and Destructive Methods," ANS Annual Meeting, June 1-5, 2003, San Diego, CA.
- "Residual Stress Measurements for Spallation Target Materials," American Society of Metals (ASM) International Surface Engineering Conference, September 15-17, 2003, Indianapolis, IN.
- "Residual Stress Measurement By Positron Annihilation Spectroscopy," 46th Annual Non-Destructive Testing Forum, September 22-25, 2003, Montreal, Quebec, Canada.
- "Residual Stress Measurements in Target Materials," Society for the Advancement of Material and Process Engineering (SAMPE) International Technical Conference, September 28-October 2, 2003, Dayton, OH.
- "Characterization of Residual Stresses and Defects in Target Structural Materials" ASNT 13th Annual Research Symposium, March 8-12, 2004, Austin, TX.
- "Residual Stress Measurements and Metallurgical Characterization of Target Structural Materials," ANS Student Conference, April 1-3, 2004, Madison, WI.
- "Comparative Analyses of Residual Stresses in Target Structural Materials," ANS Student Conference, April 1-3, 2004, Madison, WI.
- "Measurement of Residual Stresses due to Plastic Deformation and Welding" American Society for Testing and Materials (ASTM) Symposium on Residual Stress Effects on Fatigue and Fracture Testing and Incorporation of Results into Design, May 19-20, 2004, Salt Lake City, UT.

## FUTURE WORK

The following work scope will be pursued during the third year of this project:

- Development of calibration curves based on stress measurements on tensile specimens.
- Analyses and characterization of defects/imperfections by transmission electron microscopy.
- Residual stress measurements on irradiated specimens by all applicable techniques.
- Determination of the post-weld thermal treatment effect on the resultant internal stresses.

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