LA-UR- 00-1090

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Submitted to: Presented at: ICONE-8 Conference
April 14, 2000
Baltimore, MD

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Proceedings of ICONE-8
8th International Conference on Nuclear Engineering
April 2-6, 2000, Baltimore, MD USA

ICONE-8815

Determining Strain/Stress Profiles in PIGMA (Pressurized Inert Gas Metal Arc) Weld between Beryllium Metal Rings by Neutron Diffraction and Comparing Results Obtained from Finite Element Analysis

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ABSTRACT

The welding of beryllium has been a problem of interest to Los Alamos National Laboratory. Considerable effort has been expended in the modeling of such welds, with the intended outlook being the fabrication of a superior bond between beryllium pieces through an optimization of weld parameter, e.g., amount of pre-heat and the times needed for melting and solidification.

1. Introduction

Neutron diffraction measurements were conducted on two PIGMA-welded beryllium rings (of right circular cylindrical shape).

Residual strain/stress in welded beryllium metal structures may arise from processing operations (for example, volume changes during solidification of the weld melt, in our case of the Al 88-Si 12 wt. % eutectic). Microstructures could also possibly develop as a result of incompatibilities between grains of phases in the PIGMA weldment. We are using neutron diffraction (ND) methods for strain stress determination because of their non-destructive nature and ability to measure entire strain/stress tensor.

Residual strains are measured in depth by a ND method that employs the spacing of atomic lattice planes as an intrinsic strain gauge. The analysis is based on measuring the strains in different directions from the observed diffraction peak shifts (which are then converted into average stresses using measured elastic constants and the Poisson's ratio for the material).

2. Experimental Approach

For strain measurements on the Neutron Powder Diffractometer (NPD) at the Los Alamos Neutron Science Center (LANSCE), we define a sampling gauge volume of 27-mm^3 (the schematic for the diffraction geometry used at NPD is shown in Figure 1) in profiling the residual strain in the Be weldment regions in the bulk. A pulsed white beam of neutrons is used. The advantage of this time-of-flight (TOF) method over the measurements using steady-state reactor source neutrons is that many diffraction peaks are obtained simultaneously at fixed scattering angles. We can obtain an average engineering strain by taking an average of strains from displacements of all relevant diffraction peaks. Analysis of individual diffraction bands may yield information on inter-grain interactions and possibly an estimate of dislocation densities.

Accordingly, use of the NPD facility has enabled us to determine macro- and micro-stresses as a function over a bulk volume.

In contrast for the diffraction experiments we conducted at TAS-8, Riso Research Reactor, Denmark, we used a continuous monochromic neutron beam (λ + 3.156 Angstroms). The slit configurations used yielded sampling gauge volume of ~8 mm^3. With a large incident neutron wave length and the limited motion of detector allowed, we could only observe the Be (100) peaks at diffraction angles of 106.3 degrees. The experimental set up is shown in Figure 2.

3. Results

The resulting radial and axial strain measurements at NPD and the Hoop strain measurement at Riso are shown in Figure 3; the solid circles represent data resulting from finite element (FE) analyses.

High tensile strains (~600 Microstrains) near Be-weldment interfaces are observed.

4. Conclusions

We are targeting benchmarking Finite Modeling tools so as to derive mutual benefits. This has resulted in heightened effort at our laboratory to develop applicable materials modeling tools such as the Polycrystal Model for beryllium.

5. Acknowledgement

We gratefully acknowledge the support extended by the Beryllium Testing Program (LANL's Stockpile Systems Materials program) and the Science Based Stockpile Stewardship Program at Los Alamos National Laboratory.

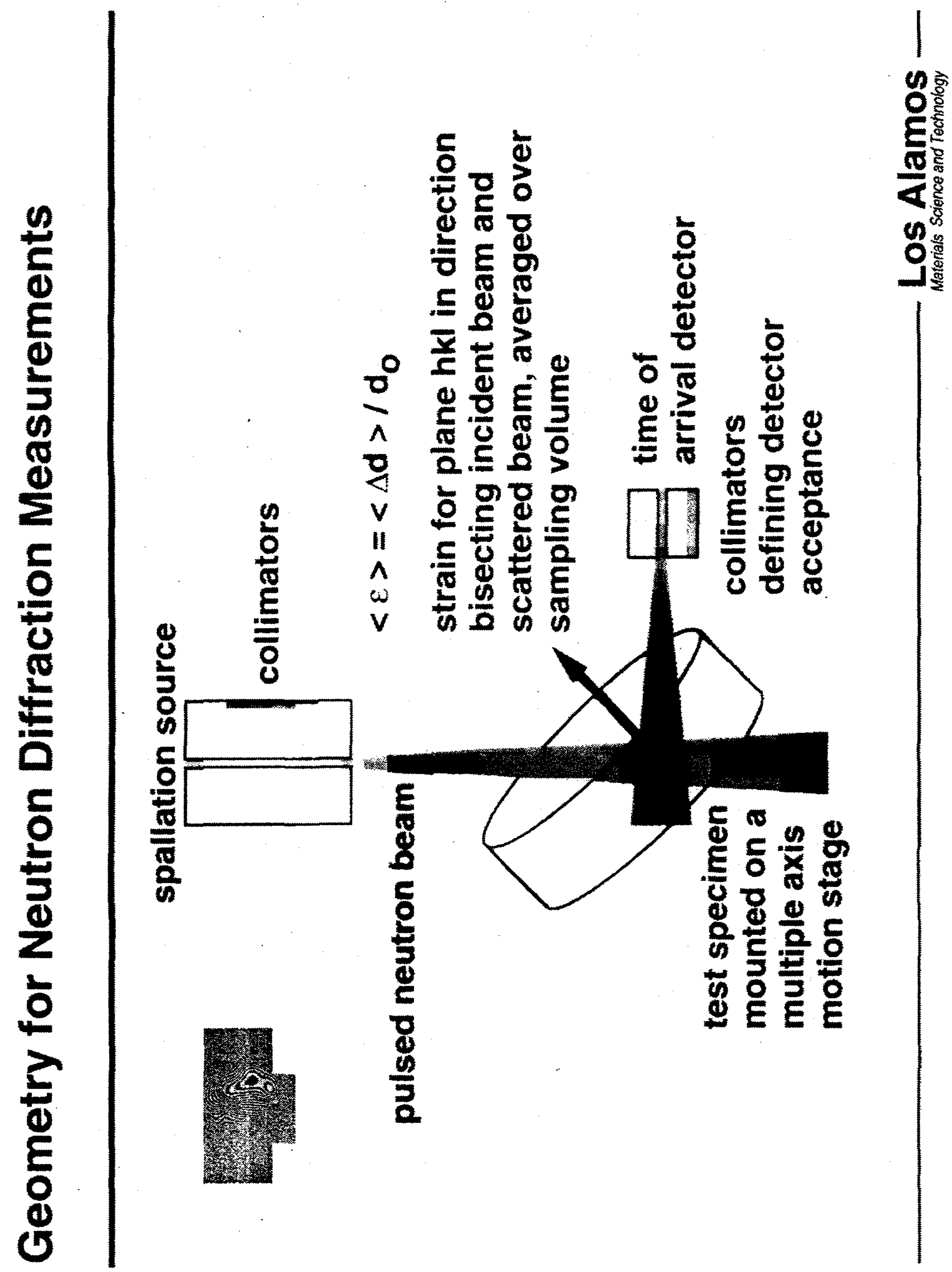
Geometry for Neutron Diffraction Measurements
spallation source
collimators
pulsed neutron beam
< ε > = < Δd > / d_o
strain for plane hkl in direction bisecting incident beam and scattered beam, averaged over sampling volume
time of arrival detector
collimators defining detector acceptance
test specimen mounted on a multiple axis motion stage
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Figure 2.

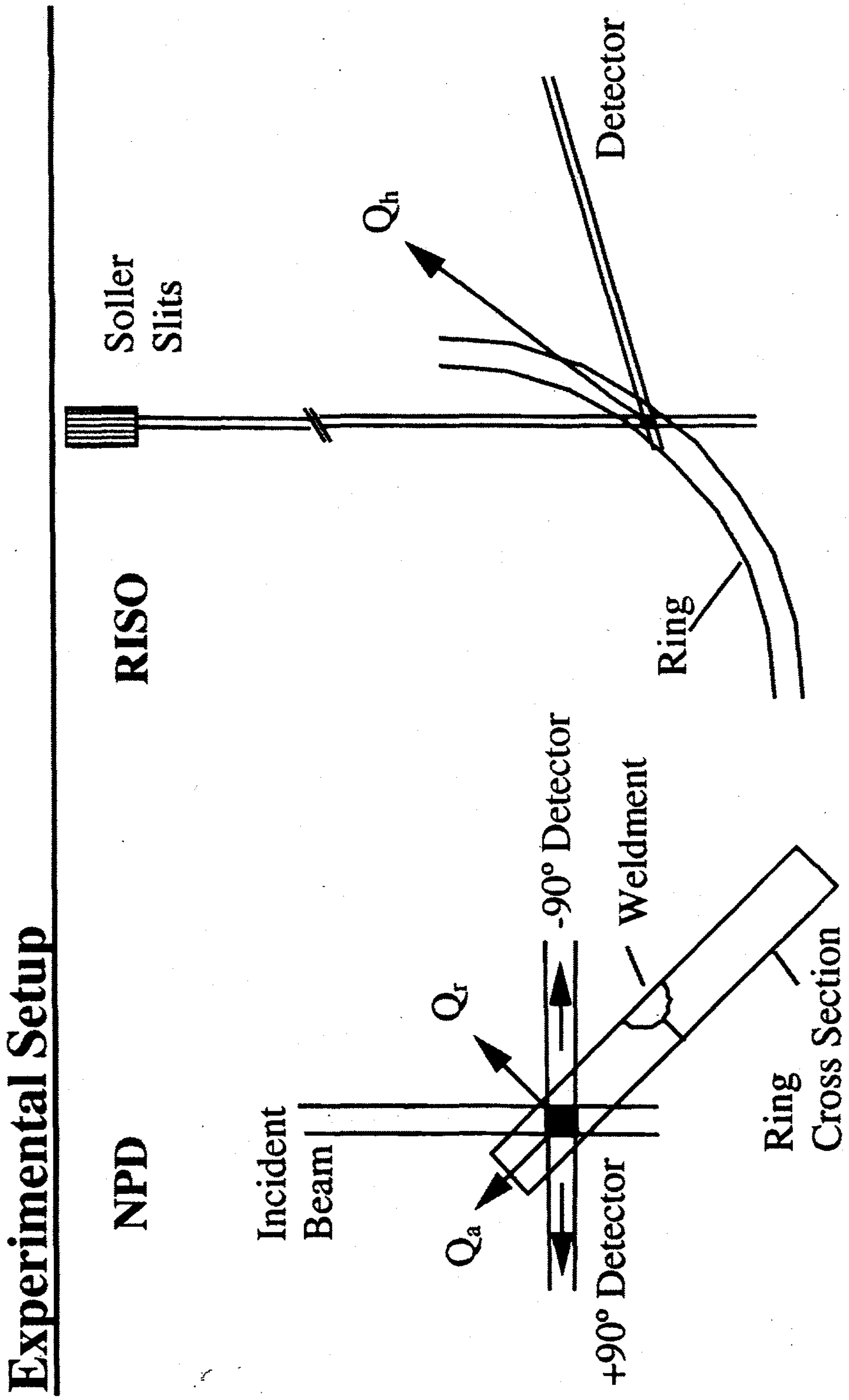
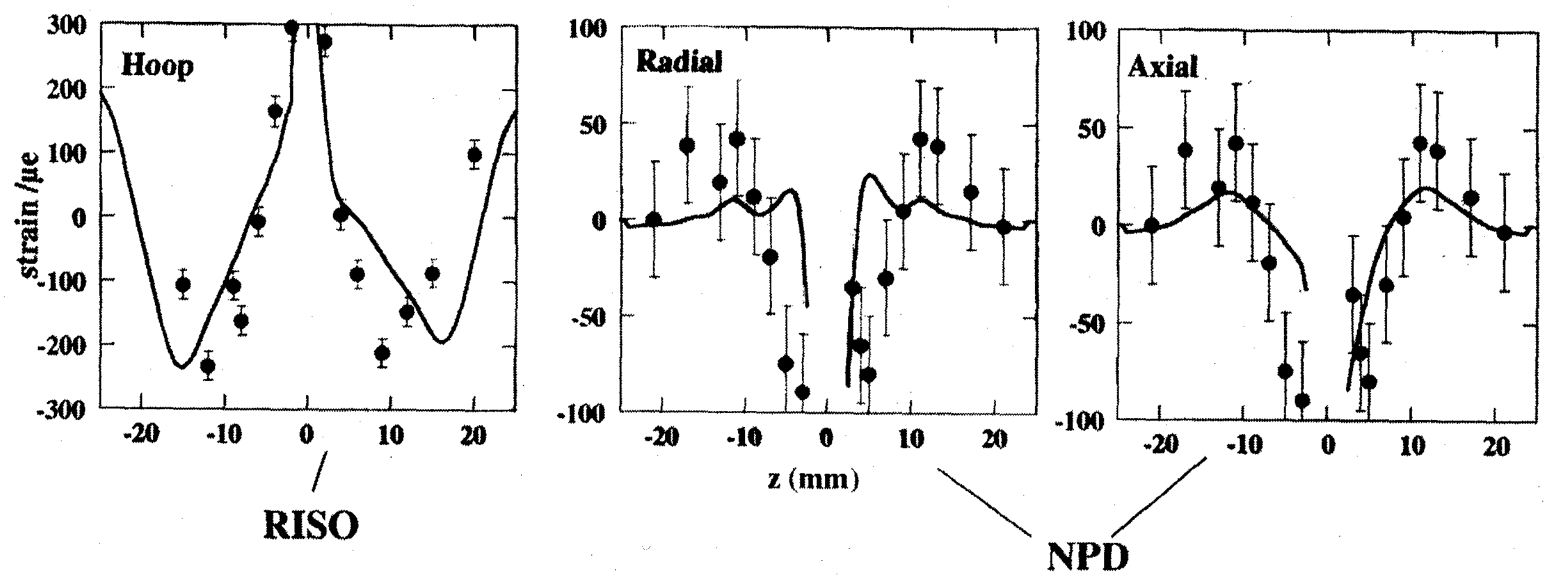

Experimental Setup
NPD
RISO
Incident
Beam
Q_a
Q_r
-90° Detector
+90° Detector
Weldment
Ring
Cross Section
Soller
Slits
Q_h
Detector
Ring

Figure 1.

Neutron Diffraction Results



- Radial and Axial Measurements Done on NPD.
- Hoop Measurement at RISO.
- Neutron Diffraction Agrees With FEM.

Figure 3.