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TITLE: IMAGE ANALYSIS FOR REMOTE EXAMINATION OF FUEL PINS

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IMAGE ANALYSIS FOR REMOTE EXAMINATION OF FUEL PINS

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ABSTRACT

An image analysis system operating in the Wing 9 Hot Cell Facility at Los Alamos National Laboratory provides quantitative microstructural analyses of irradiated fuels and materials. With this system, fewer photomicrographs are required during postirradiation microstructural examination and data are available for analysis much faster. The system has been used successfully to examine Westinghouse Advanced Reactors Division experimental fuel pins.

INTRODUCTION

Remote microstructural examination of samples from irradiated fuel pins requires a great many photomicrographs that consume large amounts of time to take, process, and assemble. Also, significant time and money are spent to produce the mosaics, strips, and selected area photomicrographs needed for the traditional microstructural examination of irradiated fuel. In addition to the time and expense, there is a delay between the time the samples are examined and the time the results are available for evaluation and analysis.

Image analysis provides a less costly and less-time-consuming alternative to the traditional microstructural examination of irradiated fuel pins. Important microstructural features in the fuel and cladding can be measured. Because the microstructural features are quantitated, fewer photomicrographs of the features are required, and image analysis data are available within a few days.

IMAGE ANALYSIS SYSTEM

The Los Alamos Wing 9 Hot Cell Facility has an image analysis system that recently became operational. The system is portable and can easily be connected to any of the Facility's three metallographs or a macroviewer. Two of the metallographs are remote control units; one is installed in a blister off the alpha cells, and the second is in a blister off the beta-gamma cells. The third metallograph is in a cold laboratory. The image analysis system measures microstructural features in samples on any of the three metallographs or in photomicrographs on the macroviewer.

The image analysis system, built by Hamamatsu Systems, Inc.,* consists of a video camera, image processor, video display monitor, and keyboard control. The video camera has a chalnicon image tube, with 512 by 512 lines for more than 260 000 picture elements. The stable camera provides high geometric accuracy. The image processor measures the height, width, diameter, area, and per cent area of features. Commands are directed to the system from the keyboard control and results are displayed on the video display monitor. An imaging hardcopy unit built by Tektronix has been added to the system to record the measurements, histogram, etc., with the sample as background to aid identification of the measurement location. The image analysis system attached to the remote control Model MM-5 RT Leitz metallograph is shown in Fig. 1.

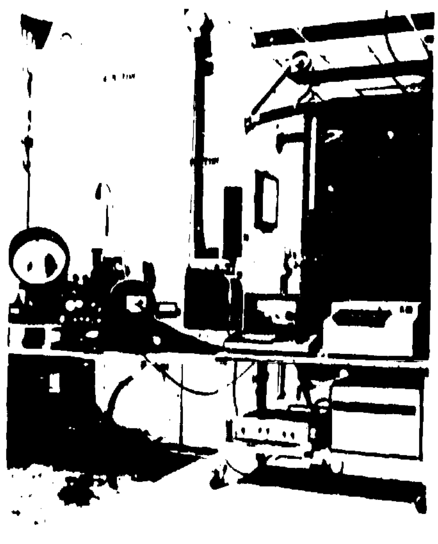

Fig. 1. Image analysis system attached to the remote control MM-5RT Leitz metallograph.

*Hamamatsu Systems, Inc., 332 Second Avenue, Waltham, MA 02154

A "+" appears on each feature as it is measured, which allows the operator to watch the features being counted. The field of measurement with counted features can be copied. Any feature not fully within the field being measured is ignored or not counted to eliminate border errors. The system provides a rectanular or circular window that can be used to limit measurements to a particular part of the area being viewed. Limits can be placed on any measured parameter to eliminate small or large features. An editor capability can be used to join or separate features, and any feature can be isolated and removed from a measurement.

The system is calibrated using gauges that are accurate to about 0.1 μm and traceable to the National Bureau of Standards. These gauges and secondary standards are used to dimension the system, with the different metallograph objectives, to read directly in micrometers; thus, areas, heights, widths, and diameters of features are measured in micrometers. For example, before a fuel pin cladding thickness is measured, the gauge nearest the thickness of the clad is measured to verify the system accuracy, and then the thickness of the fuel pin cladding is measured and recorded. Grids are used to verify system accuracy before making area and percentage-of-area measurements.

APPLICATION

We have used the image analysis system successfully for quantitative measurements of per cent porosity and porosity distribution in fuel, the volume of second-phase precipitates in the cladding, and cladding thickness in Westinghouse Advanced Reactors Division experimental fuel pins.

Porosity measurements are usually taken across a radial strip of the fuel beginning at the cladding/fuel interface and ending at the center of the fuel. The image analysis system measures the per cent porosity, number of pores, and individual pore sizes, and provides a histogram of the pore size for each area measured and an accumulated histogram for each strip across the fuel.

The accuracy of the quantitative stereology measurements is controlled by sampling procedure and statistical adequacy of data. In general, the strips are selected to avoid large fuel cracks. Cracks are also discriminated by selecting a window or by specifying the limits of parameters being measured. The system can mark the objects being measured, thereby providing visual confirmation of the measured pores. Also, when very small pores are present (and consequently a very large number of pores), a window is used to decrease the size or width of the strip.

The statistical precision of the stereology measurement is estimated by obtaining data from several strips at different orientations, averaging the results, and computing the variance. The data obtained from eight strip measurements in experiment WSA-4 indicates that 90% confidence intervals on the expected mean values are generally less than 10% of the observed means. This level of precision allows detection of significant differences between specimens or between different zones in the same specimen.

As an example, the measured porosity distribution in two mixed-oxide fuel pins from the WSA-4 experiment is illustrated in Fig. 2. These types of data provide a basis for modeling radial migration of as-fabricated porosity and fission gas bubbles, which are key elements in describing fuel behavior in fuel pin performance analysis codes. Substantial uncertainties exist in current model predictions, primarily because of the lack of porosity distribution data and the lack

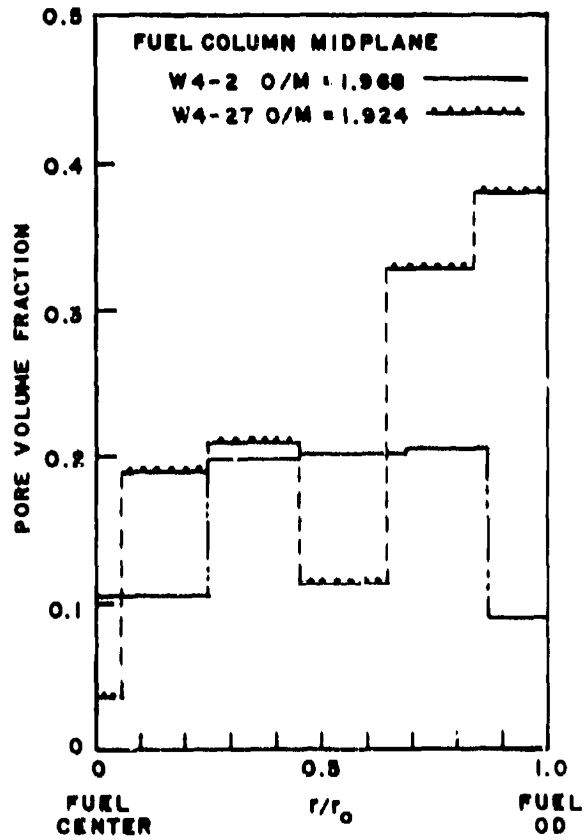

Fig. 2. Radial porosity profile in pins W4-2 W4-27.

of knowledge of the effects of various fuel parameters on migration processes.

Another application of the image analysis system has been to measure the second-phase (sigma) precipitate volume. This cladding microstructural feature, which can be distinguished easily by using appropriate etchants, has been used to estimate the cladding operating temperatures. To examine the WSA-8 fuel pins, which operated with large transverse temperature gradients, the image analysis system was used to map the azimuthal temperature distribution in various axial locations in the cladding by measuring the second-phase precipitate volumes.

The system also has been used to measure cladding thickness. Measurements made in breached WSA-8 fuel pins revealed localized cladding thinning in the breach area. These data, in conjunction with the mapping of the azimuthal temperature distribution and microstructural information have aided in determining the cause of the breach.

SUMMARY

Image analysis can be used to quantify the microstructural features in irradiated fuels and structural materials, thus aiding in developing a large data base for modeling efforts. The image analysis system connects directly to the remote control metallograph, and the results are available quickly and reduce the more expensive photomicrography work.