NASA Tech Briefs
September 1990
Volume 14 Number 9

Radial Profilometry

Inner surfaces of tubes and tubelike cavities are measured optoelectronically.

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Radial profilometry, now undergoing development, is a combination of optical and electronic techniques for the measurement of the inner surfaces of cylindrical or nearly cylindrical cavities. The main advantages of a radial profilometer are that it is relatively simple, inexpensive, and easy to use; it can be miniaturized; the profilometer probe contains no moving parts; the image is displayed continuously in the image plane; and measurements are automated. Potential applications include the inspection of pipes, tubes, and boreholes, and possibly the measurement of contours in blood vessels or other internal organs.

Figure 1 illustrates the optical configuration of a radial profilometer. A diverging laser beam launched from an optical fiber passes through a projection lens, then through a specially designed "panoramic doughnut" lens to a masked collimating lens, which shapes the beam into a thin cylinder. The cylindrical beam is reflected from a conical mirror to form a ring of illumination on the inner surface of the cavity to be measured. The image of the illuminated surface is captured by the panoramic doughnut lens and focused via the projection lens onto the face of a coherent bundle of optical fibers. The bundle transmits the image to a computer system for analysis.

The panoramic doughnut lens forms an image in flat cylinder perspective, in which each concentric ring is the locus of points viewed at a constant angle with respect to the cylindrical axis of the profilometer (left part of Figure 2). There are several alternative procedures for processing the information in such an image. For example, one could initially establish a fixed coordinate system of reference marks in a portion of the cavity known to be precisely cylindrical, then calculate small deviations from cylindricity in other portions of the cavity in terms of the nonlinear relationships among the coordinates in the distorted image and the coordinates in the cavity. The profilometer could be moved along the cavity to obtain a sequence of images that could be processed collectively to yield the coordinates of the inner surface along a specified length.

Work continues to develop a more advanced version in which a known speckle pattern, instead of a homogeneous ring of light, is projected on the surface to be measured (right part of Figure 2) and in which the profilometer remains stationary. The speckle pattern in the resulting image would be digitally recorded and compared either with a reference standard or with other speckle patterns recorded as the shape of the cavity changes. The apparent shifts of

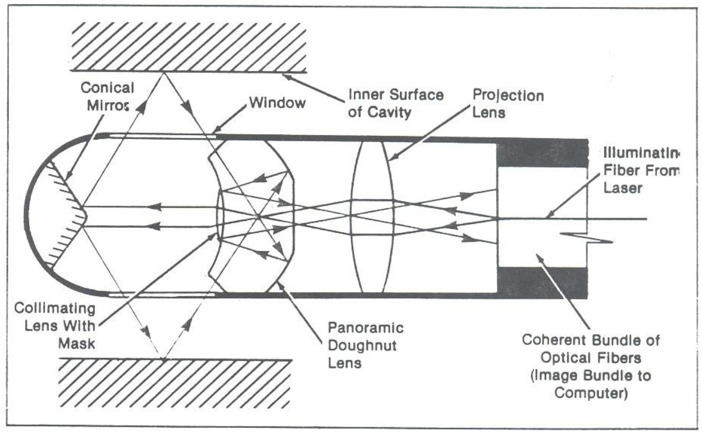

Figure 1. The **Radial Profilometer** is inserted in a pipe or other cavity to measure its shape optically. Illumination is supplied through an optical fiber, and the image of the inspected area of the cavity is transmitted through a bundle of optical fibers.

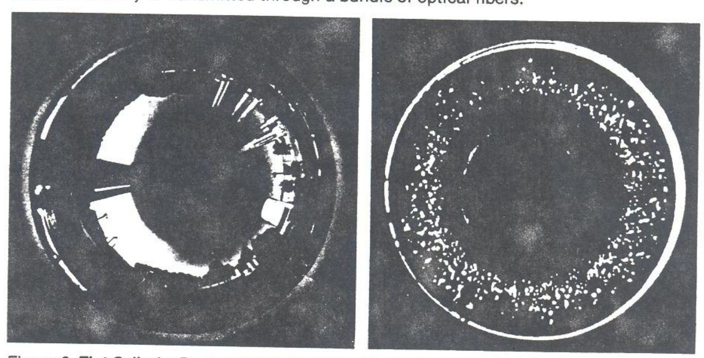

Figure 2. **Flat Cylinder Perspective** is illustrated by the image at the left, which was obtained by pointing the panoramic doughnut lens at the sky at Huntsville, Alabama's Space and Rocket Center. A speckle pattern like the one shown on the right image, also in flat cylinder perspective, can be compared to a reference pattern to measure the shape of a nearly cylindrical inner surface.

the speckle would be computed by numerical correlation of small portions of each pattern. These shifts would be used to compute the contour of the cavity with respect to the reference shape.

This work was done by J. A. Gilbert, P. Greguss, and D. R. Matthys of the University of Alabama for **Marshall Space Flight Center**. *For further information, Circle 12 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 16]. Refer to MFS-26101