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Original Article

Visualization of Crust in Metallic Piping Through Real-Time Neutron Radiography Obtained with Low Intensity Thermal Neutron Flux

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ABSTRACT

The presence of crust on the inner walls of metallic ducts impairs transportation because crust completely or partially hinders the passage of fluid to the processing unit and causes damage to equipment connected to the production line. Its localization is crucial. With the development of the electronic imaging system installed at the Argonauta/Nuclear Engineering Institute (IEN)/National Nuclear Energy Commission (CNEN) reactor, it became possible to visualize crust in the interior of metallic piping of small diameter using real-time neutron radiography images obtained with a low neutron flux. The obtained images showed the resistance offered by crust on the passage of water inside the pipe. No discrepancy of the flow profile at the bottom of the pipe, before the crust region, was registered. However, after the passage of liquid through the pipe, images of the disturbances of the flow were clear and discrepancies in the flow profile were steep. This shows that this technique added the assembled apparatus was efficient for the visualization of the crust and of the two-phase flows.

1. Introduction

In the past several years, study of two-phase flow regimes has been of great interest in the field of engineering and in the engineering industry. The importance of the forecasting of two-phase flows in the industry process is a significant but extremely complicated task. Different two-phase flow patterns are described in the literature [1,2] with regard to the function of the pipe position, whether vertical or horizontal. The best known setups of two-phase systems (liquid–gas) for vertical piping are bubbly flow, slug flow, churn flow, and annular flow. The presence of crusts in the inner walls of a

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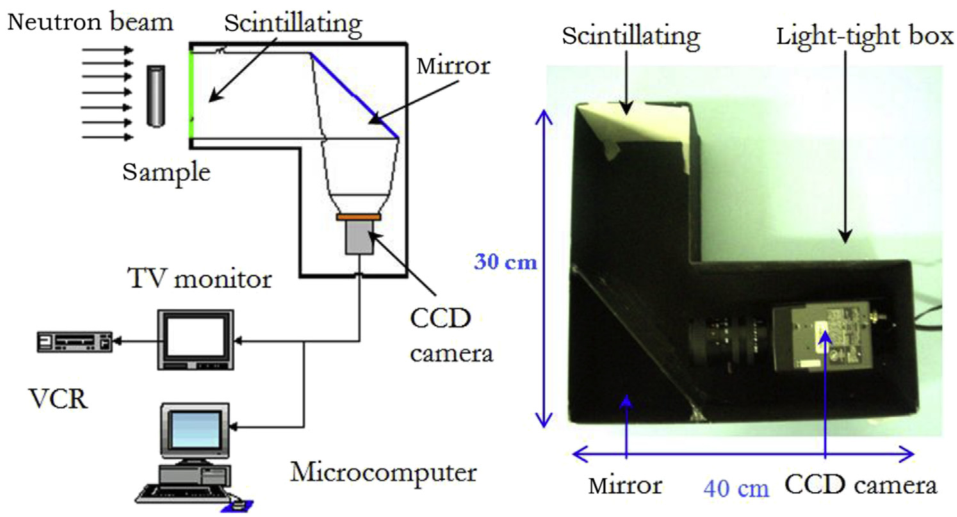

Fig. 1 – Schematic diagram of the real-time neutron radiography EIS installed in the Argonauta reactor (left). Photo of the watertight box that contains the EIS components. CCD, charge coupled device; EIS, electronic imaging system; VCR, videocassette recorder (right).

duct impairs the transportation process of a fluid because such crusts completely or partially hinder the passage of fluid, causing damage to equipment connected to the production line. Obviously, the exact localization of these crusts by nondestructive method can save time, money, and workload for companies acting in the engineering and industry sectors in terms of repairs necessary due to the presence of crust. Neutron radiography (NR) is a nondestructive test method that has been applied in special cases of inspection, in which it is difficult to use other methods such as obtaining radiographs using X-rays or gamma rays [3]. To inspect dynamic events it becomes necessary to have a system that is capable of recording images in real time [4,5]. The objective of this study was to visualize disturbances caused during water flow in aluminum ducts with small internal diameter damaged by crust using the real-time neutron radiography technique. In this manner, we used the electronic imaging system (EIS) developed and installed at the J-9 irradiation channel of the Argonauta/Nuclear Engineering Institute (IEN)/National Nuclear Energy Commission (CNEN) research reactor [6] and spheres that simulated different types of crusts in terms of the interaction of thermal neutrons with the materials that compose them.

2. Materials and methods

2.1. *Real-time neutron radiography setup*

An NR system consists of a thermal neutron beam, a collimator, a sample to be inspected, and a device capable of registering the information on the transmission of neutron beams through the sample. Visualization of flows in the interior of metallic piping has been made possible by the development and installation of the real-time EIS in the Argonauta research reactor. The main system is the thermal neutron beam of the Argonauta/IEN/CNEN reactor, which was used as a neutron source, operating at a nominal power of 340 W and providing a thermal neutron flux of 4.46×10^5 n/cm^2/s at the edge of the J-9 irradiation channel. The Length/Diameter (L/D) ratio of the neutron beam was 70 and the neutron/gamma (n/γ) ratio was 3×10^6 n/cm^2. Miliroentgen (mR) indicates the most likely level of neutron energy and had a value of 30 meV; the cadmium rate R_{Cd} was 20. This real-time image acquisition system is made of an NE-425 scintillating screen for neutrons. The typical composition is ^{6}LiF + ZnS (~ 0.7 mm thick), which converts the incident neutrons to photons emitted mainly in the green wavelength through the predominant reaction of ^{6}Li(n,α)^{3}H, which emits 1.7×10^5 light photons per neutron detected [7]. We used a Panasonic series WV-CL 920 camera with a 1.27 cm charge coupled device (CCD) (main diagonal) with 580 lines resolution operating with a minimum lighting of 0.02 LUX for lens opening, *f*, of 1.4, which adjusts the integration time of the images. In the optical coupling an $f = 1.0$ MACRO lens manufactured by Canon that allows the manual adjustment of focus was used; in addition to, a plane mirror was placed at a 45° angle to reflect light photons in the direction of the CCD

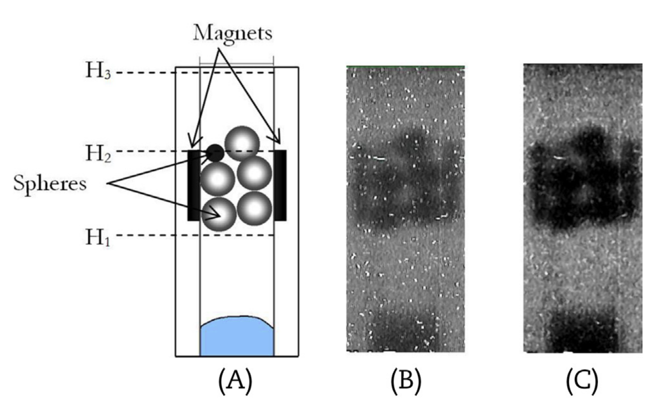

Fig. 2 – Real-time neutron radiography of a metallic pipe with crust. (A) Schematic drawing of the pipe. (B) Image obtained. (C) Previous image after digital processing.

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