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A LITERATURE SURVEY FOR THE ULTRASOUND USE IN THE RADIOACTIVE WASTE CHARACTERIZATION

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ABSTRACT

This paper presents the outcomes of a literature survey of reports on the use of ultrasound methods in the characterization of radioactive wastes. This research is motivated by the necessity to characterize radioactive wastes constituted of ion exchange resins and activated charcoal beds generated at the nuclear research reactor IEA-R1 and that are stored in twenty one 200 L-drums at the Waste Management Department. These two waste types come from the water polishing system of the nuclear reactor where they are used to remove impurities as fission and activation products from the water. After same time in the water treatment system, these two adsorbents are unable to keep the water quality and are then replaced becoming radioactive waste. Previous work determined the concentration of radioisotopes in dried samples of the adsorbents. As the water content varies largely among different drums, it is necessary to determine the water content of each individual drum for the total activity to be calculated. Ultrasound imaging was thought as an appropriate tool as a characterization method. The different acoustic impedances of liquids and solids alter the propagation of the sound waves and can disclose the content of the waste packages.

Keywords: ultrasound, characterization, imaging, radioactive waste

1. INTRODUCTION

The Radioactive Waste Management Laboratory (RWL) is responsible for performing the temporary storage and the treatment of the wastes generated by the Nuclear and Energy Research Institute (IPEN), located in São Paulo, Brazil. Among the IPEN's installations there is a nuclear research reactor, which is a pool type reactor, used for the production of radioisotopes and irradiation experiments. The RWL has as one of its assigned duties, to characterize wastes so that they meet the safety requirements established by Brazilian legislation. The characterization performed by RWL involves several steps, among them the determination of radioisotope content in the waste packages.

This determination is required in two cases: characterization of the raw waste and characterization of waste forms. The characterization of radioactive raw waste is needed to guide the treatment process, to establish the requirements of radiation protection for waste treatment, and to prescribe the operational details of the treatment, as the number of packages and storage space. For waste forms, the radioactive inventory of each package is needed for transportation and the acceptance of waste at a repository.

For that, it must be developed characterization methods, which avoid at most the contact with the radioactive waste and which provide accurate results. To give support to the characterization process, the use of ultrasound is being evaluated.

Ultrasound is defined as sound inaudible to the human ear, having frequencies above 20 kHz, which requires relatively simple equipment for its generation and detection, as for instance piezoelectric transducers in direct contact with objects surfaces or under immersion in the medium to be analyzed [1].

The sound waves that are produced and processed by the ultrasound transducer, return as echoes, are detected and then converted into electric signals whose frequencies and amplitudes are analyzed and converted into images [2, 3].

The ultrasound waves may undergo refraction, reflection and diffraction when the beam encounters an interface between two contiguous materials with different acoustic characteristics [4-7]. The principle for the acquisition of information with the use of ultrasound is the analysis of the acoustic waves scattered by the medium in which it propagates by one of the three interaction processes above [6].

These characteristics are, for example, ultrasound propagation velocity and attenuation of wave energy. The changes observed during the testing of interfaces are produced by different acoustic impedances or attenuation of the signal through the medium [4-9]. The acoustic impedance corresponds to the product of the density of the material by the speed of sound in it. When the ultrasound beam passes through an interface between two media with slightly different acoustic impedances, the wave undergoes refraction. If the difference is large the wave is reflected at the interface. In both cases the interface is identified in the image [10, 11].

Based on this behavior, two experimental methods can be used to characterize materials using Ultrasound: the transmission-reception method and the pulse-echo method, also called reflection. The combination of these two methods allows obtaining information on distance, velocity and wave attenuation in the media being analyzed [7].

The transmission-reception method uses two independent transducers for transmitting and receiving ultrasound signals. Thus, an electrical pulse is applied to the transmitting transducer, generating an ultrasonic wave that propagates through the medium and is detected by the receiving transducer [12]. In pulse-echo method, a single transducer acts as a transmitter and as a receiver of ultrasound waves. In this case, an electrical pulse is applied to the transducer and this generates an ultrasound wave. The ultrasonic wave propagates through the medium 1 and at the interface between the media 1 and 2, part of the wave is reflected and part propagates through the medium 2. Similarly, wave that propagates through the second medium and finds another interface is partly reflected and partly transmitted. These

reflected waves are received by the transducer, which carry information about the distance or the speed of propagation. This provides information on mitigation processing the received echoes. Knowing the speed of propagation in the media, it is possible to determine distances traveled by the waves from the elapsed time between the excitation of the transducer and the moment when the reflected waves were captured [12].

A frequent problem with direct contact transducers is the quality of the thin layer of coupling between the transducer and the structure to be studied. This layer generally consists of water, oil or some kind of grease. The thickness and uniformity of the layer of coupling are difficult to control due to the movements performed with the transducer during the test in order to optimize the reception signal position. A method widely used to eliminate the effect of the coupling layer is the self-compensation technique that is also called self-calibration. The method utilizes two transducers, and combines the measured voltages, so that the effect of the coupling layers is eliminated and the measurement is directly related to the physical parameters of interest [8].

Interest on methods of generating ultrasound in a non-contact is growing. The best known of these techniques are transducers coupled to air, electromagnetic acoustic transducers (EMAT) and laser ultrasound. The air-coupled transducers have a relatively low efficiency due to large differences in mechanical/acoustic impedance between air and other materials that are studied [9]. While no direct contact transducers are widely used, correction methods are cited as increasing the transmission power so that they increase the ultrasound energy reflected, also increasing the noise signal ratio [13].

The study by ultrasound components with complex geometries have to deal with different problems such as limited access to the area being assessed, image distortion and loss of sensitivity. These effects can lead to performance degradation. The technique called "phased array" can be used to overcome these difficulties, providing an ideal mastering of the ultrasound beam through the inspected component [14]. The phased array transducer technique is able to adjust the actual surface of the part being analyzed to optimize the contact and thus the sensitivity of the test [14-16]

2. METHODS

The method of the present study consisted in a search of published literature related to ultrasound imaging techniques applied to radioactive waste characterization. National and international collections available on line were searched for, using Boolean expressions and internet searching engines. Extensive internet searching was used in a first, broad scope search, using keywords such as Characterization, Radioactive, Ultrasound, Waste and Non Destructive Testing (NDT). An example of Boolean expression used in this search is (ultrasound OR testing) AND (materials OR characterization OR non destructive).References spanning from 1978 to the present were examined. Literature published in the Web was searched for using the Google Search Engine. Data bases in the libraries of IPEN and CNEN were also used, as the Biblioteca Digital Memória (Digital Memory Library) of CNEN. Keywords in Portuguese and English were used to retrieve documents.

The retrieved documents were analyzed and kept if more recent than 80's and dealing with industrial application of ultrasound and characterization of materials.
The year 1980 was chosen arbitrarily but was a reasonable cutoff date to retrieve only reports from the last three decades.

3. RESULTS

Since 1950, ultrasound techniques are being applied in several research areas such as medicine, oceanography, metallurgy, mechanics and chemistry, among others, enabling the evaluation of mechanical, chemical and physical properties of different materials [1]. The main industrial applications of ultrasound include: measurements of thicknesses, areas, volumes, finding discontinuities and corrosion of materials, determination of faulty geometry, non destructive testing of materials and checks in submerged structures [2-5].

Nevertheless, in the searched indexed literature the application of ultrasound techniques to characterize radioactive waste packages is absent.

4. FINAL REMARKS

While the data obtained from the literature confirmed that the use of ultrasound imaging techniques is well established as an effective method for studies of objects in several fields of the industry, it is surprisingly not present in the radioactive waste characterization area.

The results obtained in this search were insufficient to establish whether the ultrasound imaging technique is inapplicable to radioactive waste characterization or it is an open field to be explored.

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