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Development of Gamma Industrial Process Computerized Tomography for Multiphase Systems Analysis in Brazil.

Margarida M. Hamada, Carlos Henrique de Mesquita

[1] *Instituto de Pesquisas Energéticas e Nucleares (IPEN/CNEN-SP),*
Av. Prof. Lineu Prestes, 2242, Cidade Universitaria, 05508-000 Sao Paulo, Brazil
mmhamada@ipen.br

I. INTRODUCTION

The physical integrity of the distillation columns and the dynamics of the distillation components are important factors that lead to the quality of the products generated. Over time, distillation columns suffer degradation due to the appearance of soot and polymer crusts and thus the heat exchange efficiency in the column components decreases. As a consequence, there are four implications, namely: (1) in the production line, there is a reduction in the distillation efficiency due to the decrease of the coefficients of heat exchanges, (2) in the sequence there is a loss of quality of the distillates and as a corollary the (3) inherent economic losses and the (4) competitiveness of the products. In today's globalized world, the causes (2) to (4) are deadly to the economy of any country that has the ambition to win the international market. Therefore, continuous quality control of the means of production of a company is the key to ensuring the competitiveness of its products. As we know, in the consumer market, acceptance of any product needs to meet two items: price and quality. What differentiates a competitive company is its productivity [1] achieved with the strategies of the use of new technologies and the technical competence of its professional board.

As far, in Brazil the nuclear technique application in industrial processes have concentrated mainly in the radiotracer technologies. The Brazilian Institutes, such as IPEN and CDTN, have been routinely giving the technical support to chemical, petroleum, metallurgical, water and waste water treatment industries to control and identify operational failures, using the radiotracer methodology. Optimization is essential in modern industrial and chemical processes to increase the efficiency and to decrease the downtime and maintenance costs. It is observed in the literature a constant progress in science and technology (especially in computer science) providing new advances in the methodology and interpretation of the industrial processes. For instance, the use of the Tomography in industrial processes began to appear in large number in the literature [2-13].

For industrial processes evaluation, the gamma ray computed tomography technique in multiphase systems has been indicated as the most promising, in order to visualize the structure and the movement of the material inside the industrial processing column in real time, without interrupting the operation. These systems are used in a wide range of industries, such as chemical, food pharmaceutical and oil sectors. The Gamma process Computed Tomography is a real time imaging technique for flow pattern visualization of multiphase flows inside process columns (packed columns, bubble-columns, multiphase flows, fluidized beds and porous media) and it is important for improving the design, operation and troubleshooting of industrial processes.

Currently, the interest of a wide range of industries, such as chemical and oil sectors in the use of computed tomography began to appear in large number, for improving design, operation and troubleshooting of industrial processes. Computerized tomography for multiphase processes is now a promising technique and has been studied for advanced research centres. To follow this trend and to keep update, Brazil needed to implement the gamma industrial tomography methodology in its institutes, aiming to give technical support to the industries, improving their processes and to spread the industrial nuclear application techniques. Thus, the IPEN laboratory began to study the development the computed tomography system for multiphase analysis.

II STATE OF THE ART OF INDUSTRIAL TOMOGRAPHY IMPLANTATION.

For many years, industrial computerized tomography (CT) has been applied to non-destructive tests and to scientific studies. Today, a new perspective of industrial computed tomography is emerging in the field of multiphase processes. Multiphase systems are structures, equipment (reactors) or pipes in which various phases such as liquids, solids or gases are in close contact for transporting or obtaining the maximum mass, heat or momentum transfer conditions within a production line of an industry. In addition to these properties, these types of systems aim at obtaining high production yields with low or no environmental impact. In addition, industrial distillation systems involve dynamic processes and transient changes occur very rapidly, requiring it to be detected instantaneously. In addition, they are usually constructed of stainless steel and have large diameters and thick thicknesses, making no suitable to analyze them with conventional X-ray bundles. For this reason gamma radioactive sources, ranging from 317 keV (^{192} Ir), 662 keV (^{137}Cs) to ~ 1250 keV (^{60}Co) instead of X-ray sources [2,7] are commonly used.

Nowadays, so-called multiphase systems have played a very important role in industrial processes. The evidence of this interest can be assessed by the number of papers published in journals and presented in the last scientific meetings [2-13] that address non-destructive analysis methodologies. In order to follow this tendency and have the competence installed and updated in the country, in 2004 the IPEN laboratory started a study for the development of the computed tomography methodology.

IPEN started its studies on industrial tomography technology, participating in a meeting organized by the International Atomic Energy Agency in 2004 (IAEA Process No. RC 12459) to address the state of the art of industrial tomography. Initially, a first-generation industrial tomography (Fig. 1), consisting of a detector and a source was developed in the IPEN laboratories using a 2x2-inch NaI (T1) detector. The electronic data acquisition system and interface for mechanical control and the software to control these systems were specially developed in our laboratories. Its results were reported in the publication [2,4,5] and dealt with the analysis of images obtained from a phantom produced by the University of Bergen-Norway and distributed to several countries by the Atomic Energy Agency.

Figure 1 - First- generation tomography system

The development and first-generation tomography studies contributed with valuable experience in designing and developing other industrial computed tomography systems. Thus, new hardware and software systems have been developed to be used with third- and fourth-generation CT scanners [6,7,9,12].

Next, a third generation computerized CT scanner (3D CT) was designed and built entirely at the IPEN Laboratory [6,10,14,21,22]. It consists of seven 2x2 inch NaI (T1) detectors, collimated and arranged in an arc at the center of the source, as it can be seen in Fig. 2.

Figure 2. Third generation tomography system.

In order to manage 3rd generation CT instrumentation a new electronic multi-channel analyzer, shown in Fig. 3, was designed by Mesquita in our laboratories [6,7,9,10]. This new, genuinely national electronics has the capacity to provide the spectrum of the radiation used. This new tomography philosophy is pioneer in the world, because so far all described tomography systems use single-channel analyzers. These have the disadvantage of not discriminating different energy levels of the incident radiation. On the contrary, multi-channel analysers allow carrying out tomography measurements, simultaneously, with different energy levels, for example, using ^{192}Ir sources (characteristic power peaks at 317 keV and 468 keV) and ^{137}Cs (662 keV) and thus to tomography reconstructed images with different energy levels. This advantage is particularly important in multiphase systems which contain different density materials (solids, liquids and gases) [7,11].

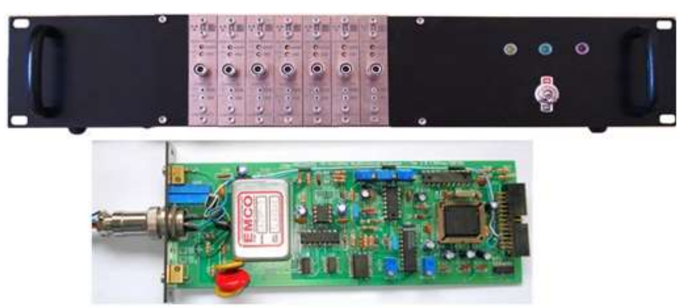

Figure 3 – – The multichannel module (top) and one of seven eight bit resolution multichannel board (bottom).

The third generation tomography system developed has a good resolution spatial and is used in the lab environment to study and to optimize column designs and industrial processes. [9,10,11]

Afterwards, in order to be applicable in the practical of industrial plants, portable non-scanning fourth generation tomography system was developed. This industrial tomography is comprised of seventy NaI(Tl) detectors of 1" diameter x 2 thickness and five shielding cases for radioactive sources,. Each shielding case is placed diametrically opposite to a fan detector set as showed in Fig. 4. As the NaI(Tl) detectors are capable to detect large range of energies, i.e. from 60 keV ^{241}Am to ~1250 keV ^{60}Co, the choose of the source to be used depends on the material densities, wall thickness and dimension of the object to be evaluated by tomography measurement. Also, the proposed tomography system can be adjusted to the column or pipes by changing the number of detector set. Thus, the tomography system has the capacity of being adapted and applied for different objects types, such as, column or pipe sizes found usually in the industrial plants. The tomography system can be mounted on a wooden platform, which is lightweight and low cost, to be replaced in future applications according to the challenges of new geometry, dimension of the objects and application requirements. Results and details of the portable non-scanning fourth generation tomography system are described in Ref [12,13].

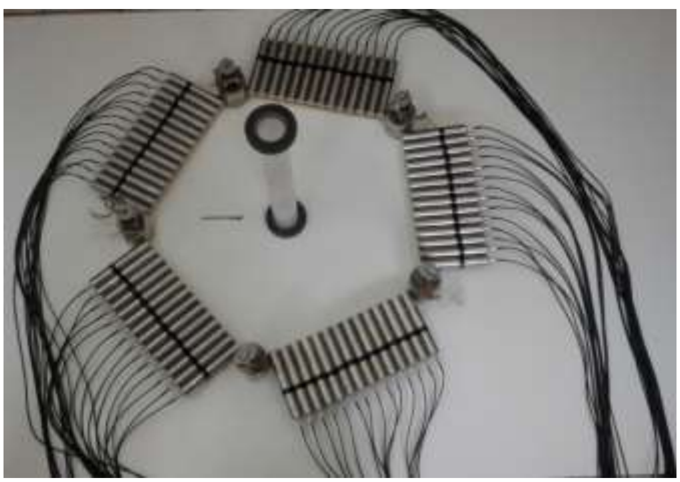

Figure 4- Portable non-scanning fourth generation tomography system

Bubble distillation and random packed columns are used extensively in chemical, pharmaceutical and petrochemical industries to perform efficient separation. The developed tomographies are used to evaluate the formation and distribution of bubbles in a distillation column and also, to evaluate the liquid distributions of a Raschig rings random packed column, at different water flows, carrying out the measurements at different column heights. The liquid-gas holdup are determined by the reconstructed images. The CT is capable of providing phase (liquid or gas) composition information in two phase systems. More recently, rocks extracted from the oil reservoir, are being measured with industrial tomography to evaluate their properties, in order to provide subsidies to increase the recovery of oil in the rocks.

These studies have also contributed in the formation of human resources, with the involvement of masters and doctoral students for the development of this work.

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