ADVANTAGES OF COMPUTED RADIOGRAPHY TECHNIQUE IN CASTING INSPECTION WITH HIGH ENERGIES

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Abstract. *Nowadays, it is possible to state that the non-destructive inspection of materials performed through computed radiography has evolved to the point of replacing the conventional radiography in many cases, such as evaluations of corrosion, for instance. However, in inspections performed on castings of thicknesses ranging between 50 and 200 mm, this technique is not used. In tests with conventional radiography, due to the low dynamic range of the radiographic films, it is not always possible to detect all of the discontinuities, especially in parts of complex geometries and critical sections and/or abrupt changes in density, such as casts. Thus, in order to detect all the discontinuities, the solution is to perform exposures with films of different sensitivities. Another possibility is to employ multiple films, which consists on the technique of composite view. In this technique, the radiography is performed using two or more films either of the same or of different ranges of sensitivity and exposed together. All these alternatives make the tests more difficult, due both to the large amount of time spent in the several exposures and to the bigger complexity of assembling an image with multiple films. Concerning this problem, obtaining images in digital format is only one of the many advantages of using computed radiography. The digital image is composed of a numerical matrix, a characteristic that allows it to be transformed by mathematical processing so as to achieve better results in detection of discontinuities. The aim of this work is to obtain the sensitivity of this technique, given the minimum requirements for efficiency in the detection of critical discontinuities that may be generated during the casting process. The results showed that the technique of computed radiography was able to identify the discontinuities with only one exposure, whereas with conventional radiography, in order to get the same result with a composite view, either the multiple-films technique had to be applied or many exposures had to be held. These results show that the feasibility of using the CR technique in casting inspections is due to its high range of detection, as well as to the possibility of processing the image.*

Keywords*: Computed Radiography, Casting Inspection, Image Processing*

1. INTRODUCTION

The dynamic range of common X-ray imaging-detectors differs significantly because of the limitations that arise from differences in the principle of operation. In the case of conventional X-ray film, the dynamic range is limited by the number of silverhalide grains which make up the active layer of the film. These grains are either blackened or transparent after the chemical development depending whether an X-ray quantum has hit the grain or not. In total, an S-shaped dependence of the optical density of the layer with X-ray dose results, which covers about 3 orders of magnitude of X-ray dose (Thorns, 1997).

Because of their low dynamic range, industrial radiographic films are capable of forming images only within a certain range of optical density. However, it is not always possible to detect all of the discontinuities, especially in parts of complex geometries and critical sections and/or abrupt changes in density, such as casts. Thus, in order to detect all of the discontinuities, the solution is to perform exposures with films of different sensitivities.

Another possibility is to employ multiple films, which consists on the technique of composite view. In this technique, the radiography is performed using two or more films either of the same or of different ranges of sensitivity exposed together. As for the result, the films are analyzed individually and when overlapping, analyzed together, depending on the region and the discontinuity of the sample you want to watch.

All these alternatives make the tests more difficult, due both to the large amount of time spent in the several exposures and also to the bigger complexity of assembling an image with multiple films.

Imaging plate systems are available for NDT since more than 10 years. They can be used as filmless radiography technique, which is also known as computed radiography (CR). Imaging plates are exposed as film and scanned by a laser scanner to obtain a digital radiograph. After erasing the remaining latent image with a bright light source, the same IP can be recycled up to more than 1000 times (Ewert *et al.*, 2004).

The digital image is a matrix where each element, or pixel, is represented by a numeric value that represents a shade of gray. Thus, images displayed in digital format can be processed by a computer, using programs and tools suitable for this purpose.

To process an image is to successively transform it, in order to extract more easily the latent information contained therein. The processing and analysis of images is a science that allows you to modify, analyze and manipulate digital images from a computer.

A common factor in all classes of processing is the quality. There are two subdivisions in image quality: fidelity and intelligibility. In the first case, the main concern is to approximate the processed image and the original image or a standard set that best represents. In the second case, the main concern is concerned with information that can extract the image, either by the human eye or by some processing (Scuri, 1999).

The aim of this study is to evaluate the feasibility of employment of the industrial computed radiography technique in the detection of discontinuities generated during the casting process, using to the report the various processing tools available for manipulation of digital images, comparing the results with conventional industrial radiography technique.

2. MATERIALS AND METHODS

For the tests with the sample were used two sources of radiation. The first one was a linear accelerator manufactured by Varian, model Linatron - 400, with energy of 4 MeV and focal spot size of 2 mm. The minimum dose is 0.1 Gy and can be adjusted according to the application in steps of 0.1 Gy. Figure 1 shows a picture of the linear accelerator.

Figure 1. Varian Linear Accelerator Linatron-400 of Confab Industrial SA - Equipamentos.

The second one was a radioactive source of cobalt-60 with dimensions of 2.0 x 2.0 mm and activity of 834.72 GBq (22.56 Ci). The characteristic energy peaks of cobalt-60 are 1.17 and 1.33 MeV, as can be seen in the energy spectrum of radioisotope shown in Figure 2.

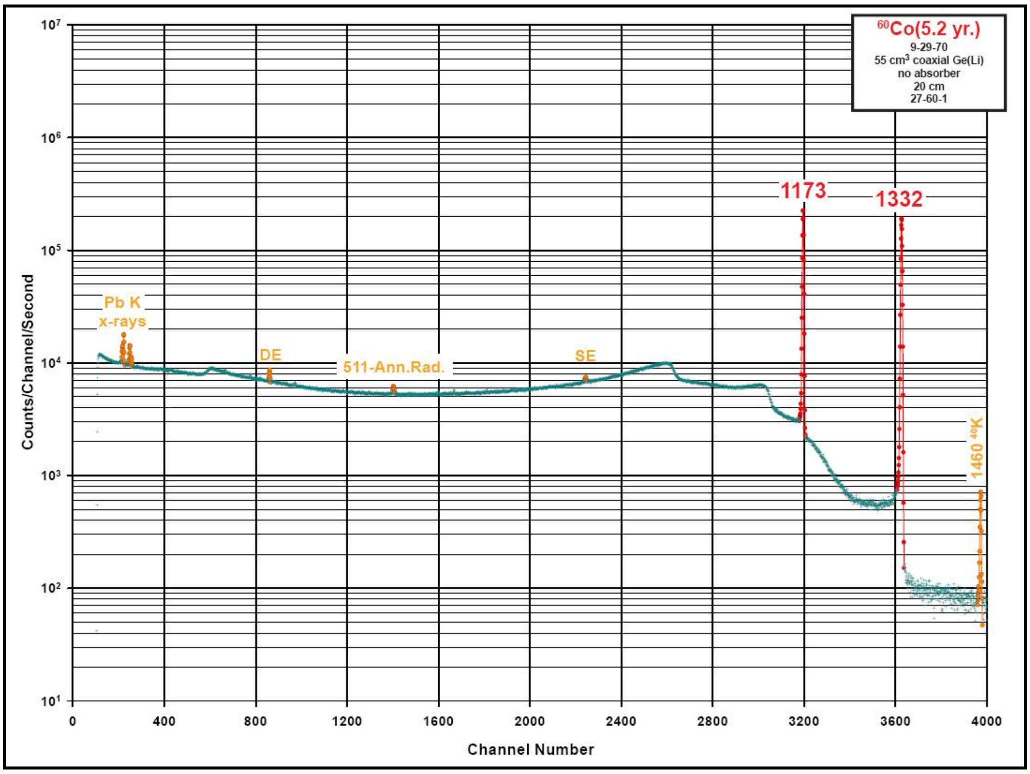

Figure 2. The energy spectrum of the radioisotope Cobalt-60.

The industrial computed radiography equipment used was CR50P, manufacturing of GEIT. For acquisition and processing of images were used the softwares Rhythm Acquire and Rhythm Review, respectively. This system has a range of gray levels that varies between 0 and 49,140, scanning the image plate with laser spot size of 50 μm and generate images with pixel sizes varying between 50 and 200 μm. After the scanning, the image plate is erased by the system and is ready for a new radiographic exposure. Figure 3 shows the industrial computed radiography equipment CR50P.

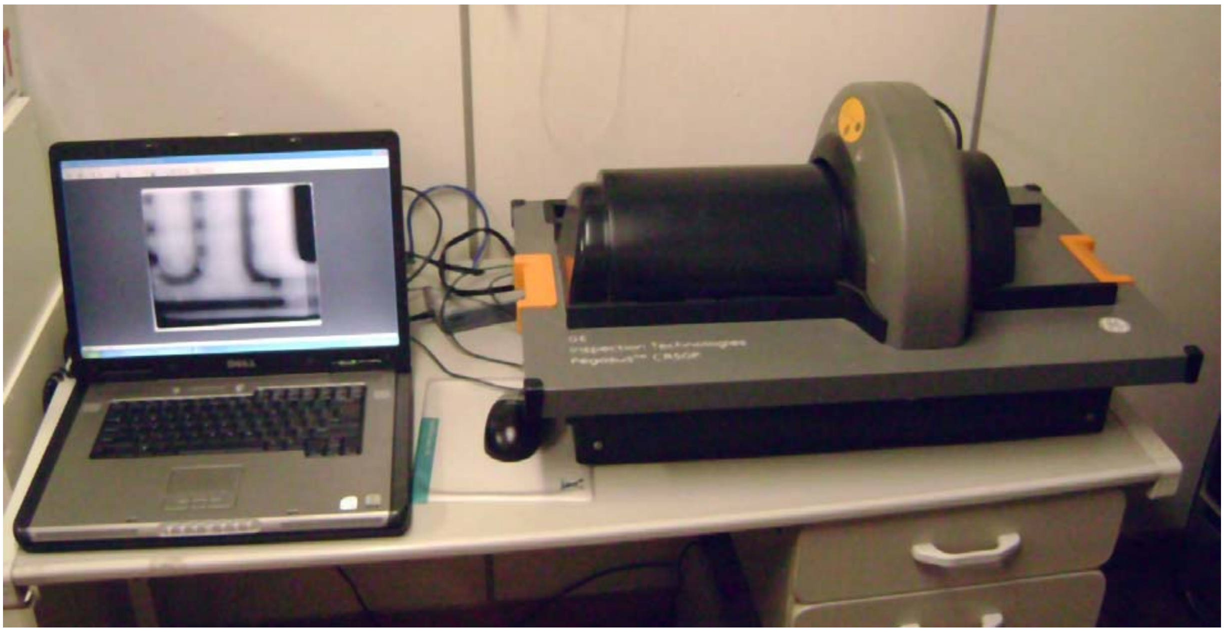

Figure 3. Industrial computed radiography equipment GE CR50P.

In tests with industrial computed radiography, with the two sources of radiation, was used a high resolution image plate, called IPX, also manufactured by GE IT. The pixel size of the scanner was kept fixed at 50 μm and the voltage of the photomultiplier at 600 V.

For inspection by conventional industrial radiography, in tests with the linear accelerator, were used films of two classes (ASTM Class 1 - Kodak M100 and ASTM Class 2 - AA400 Kodak), exposed together and separately. In the tests with the source of cobalt-60, two films Class 2 were used. After obtaining the images, they were scanned, but the identification of discontinuities was performed using negatoscope.

For the tests, was used a copper sample with 150 mm maximum thickness, with internal coils. Discontinuities of different sizes and shapes, generated during the casting process are located in critical regions and close to the walls of the coils. Figure 4 shows the sample used.

Figure 4. Test sample.

The radiographs were performed with linear accelerator at Confab Industrial SA - Equipamentos in a bunker suitable for irradiation with high energy. The source to detector distance was maintained at 2000 mm. The dose of radiation of the linear accelerator was 4.2 Gy to conventional radiography and 5 Gy to computed radiography. Radiographs with Cobalt-60 was performed in ARCTEST Serviços Técnicos de Inspeção e Manutenção Industrial Ltda, also in a bunker appropriate. The source to detector distance was maintained at 1000 mm. The exposure time was 6600 seconds for the conventional radiography with the composed in view and 9000 seconds for computed radiography.

Besides the piece to be inspected, were radiographed together with that the wire IQI (EN 462-1), to determine the sensitivity of the image and the duplex wire IQI (EN 462-5), to evaluate the spatial resolution of the image. Figure 5 shows the experimental setup used.

a)  b) 

Figure 5. Experimental setup for radiographic testing - a) Linear Accelerator b) Cobalt-60.

3. RESULTS AND DISCUSSION

3.1. Linear Accelerator

For the detection of discontinuities using the conventional radiography technique, two images were obtained with films of different sensitivities. Figure 6 shows the image with a film ASTM Class 2 - Kodak AA400, for observation of discontinuities in regions of greater thickness. Figure 7 shows the image with a film ASTM Class 1 (Special) - Kodak M100 for detection of discontinuities in regions of lower quantity of material or because the channel formed by the coil.

In computed radiography test was obtained a single image. Using the tools of image processing, it was possible to detect all discontinuities of the sample. Figure 8 shows the radiographic image of the sample, processed with the filter "Enhance Details” and with adjust of brightness and contrast.

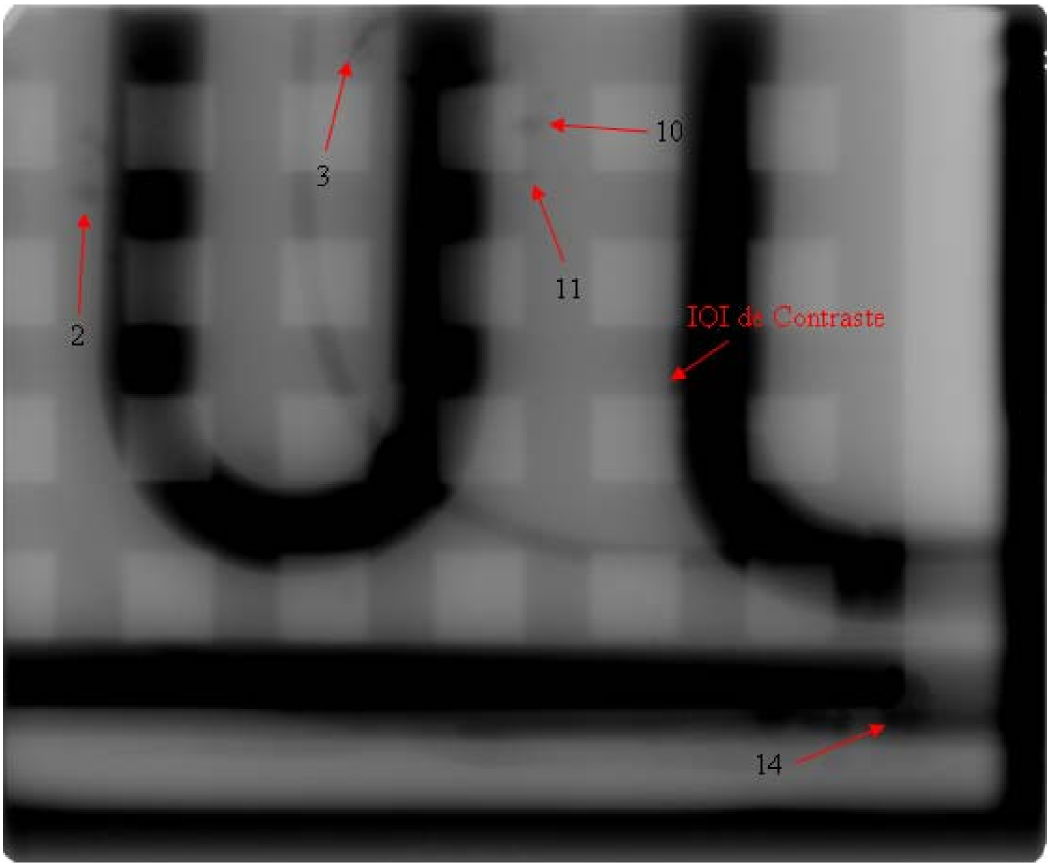

Figure 6. Image obtained with a class 2 film showing discontinuities in the areas of greater thickness.

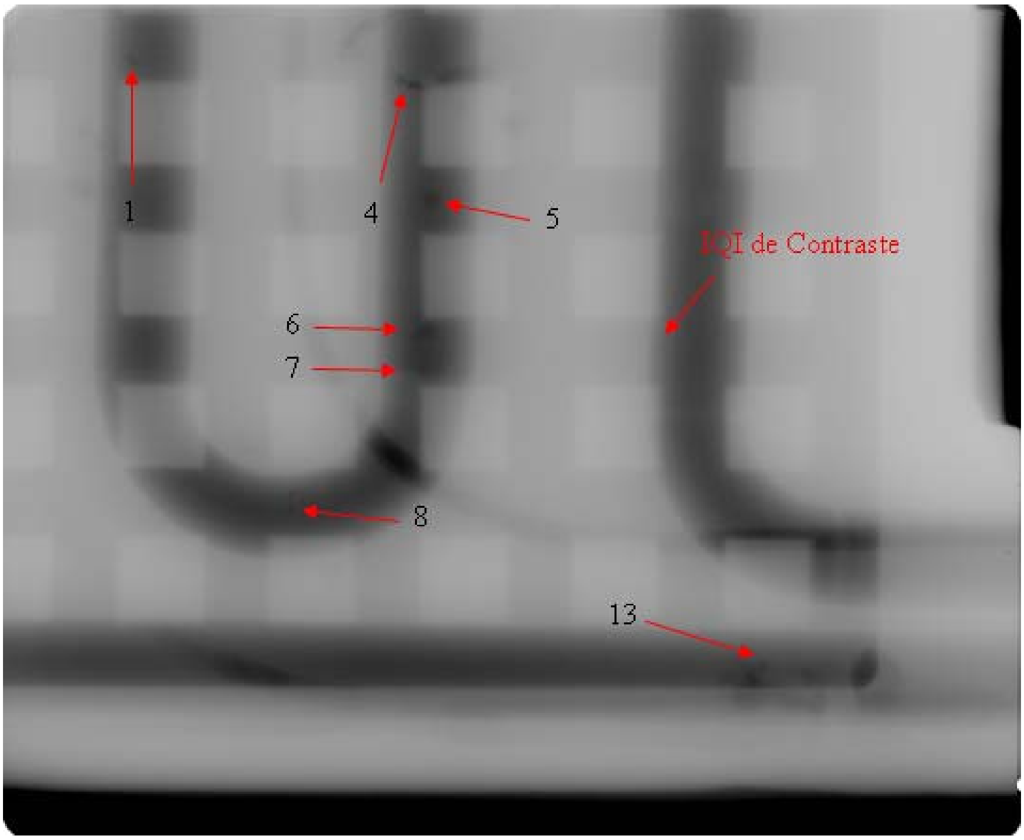

Figure 7. Image obtained with a class 1 film showing discontinuities in the areas of smaller thickness.

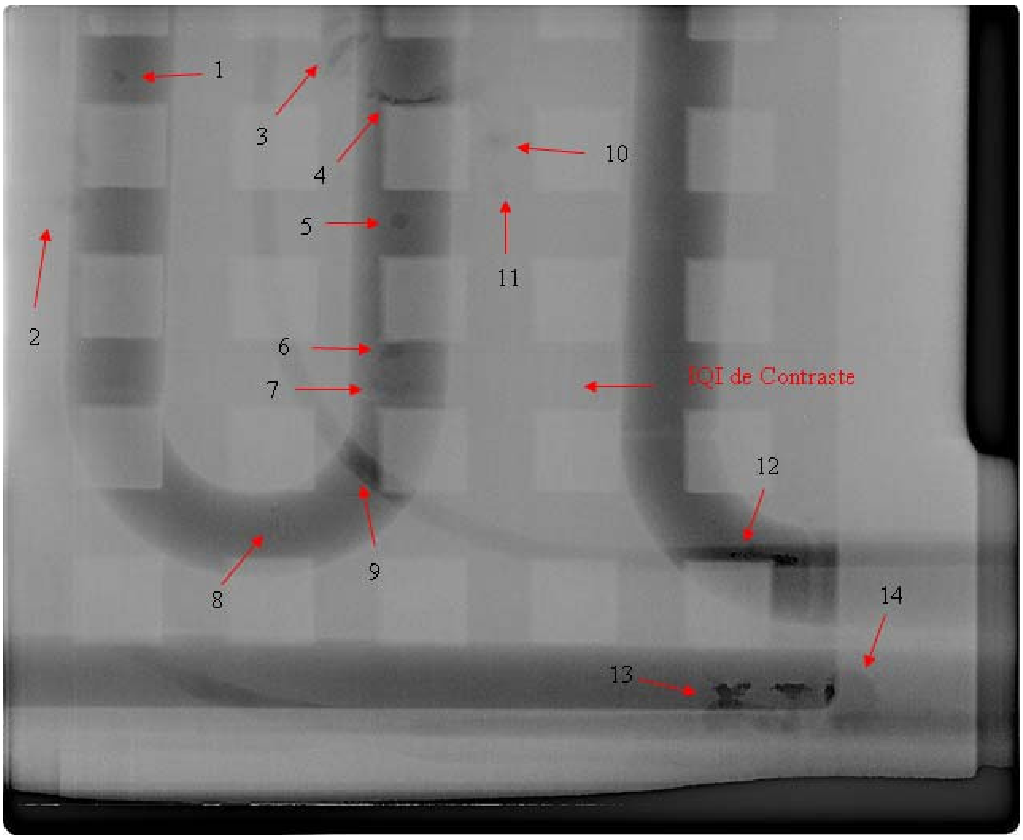

Figure 8. Image obtained by industrial computed radiography with mathematical processing.

In all images, both conventional as computed radiography, it was not possible to visualize the duplex wire IQI, due to the small diameter of the wires on the thickness of the piece and the energy of radiation. Thus, we could not get the value of the basic spatial resolution. With the industrial computed radiography technique was seen the wire 4 of the contrast IQI in the source side. Already with conventional radiography, it was viewed the wire 3 with the film class 1, the wire 6 with the film Class 2 and the wire 6 with a composite view, all at the source side. In these tests, was not used the contrast IQI at the film side.

3.2. Cobalt-60

Similarly to the test with the linear accelerator, the test with conventional radiography was performed using two films, but the same class, thereby obtaining a composite view. For the report, they were viewed together (for the detection of discontinuities in thickness larger) and separately (for detection in regions of smaller thickness, such as internal coils) and their images are shown in Figures 9 and 10, respectively.

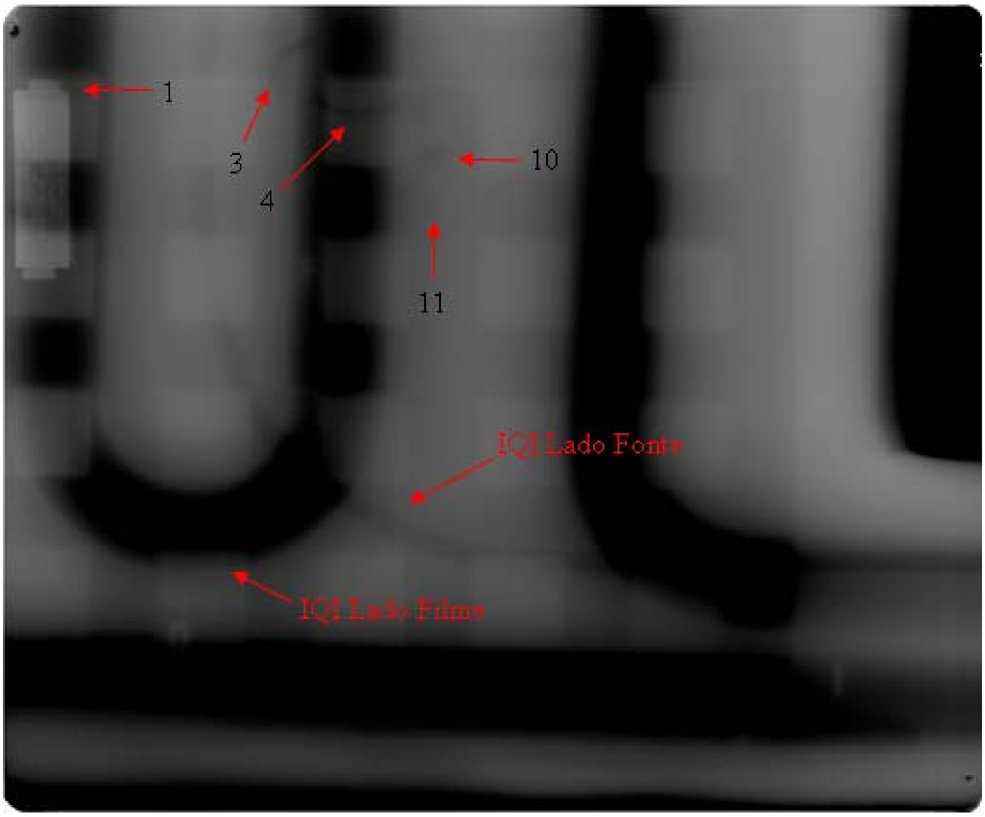

Figure 9. Radiographic image using two films class 2 (composite view).

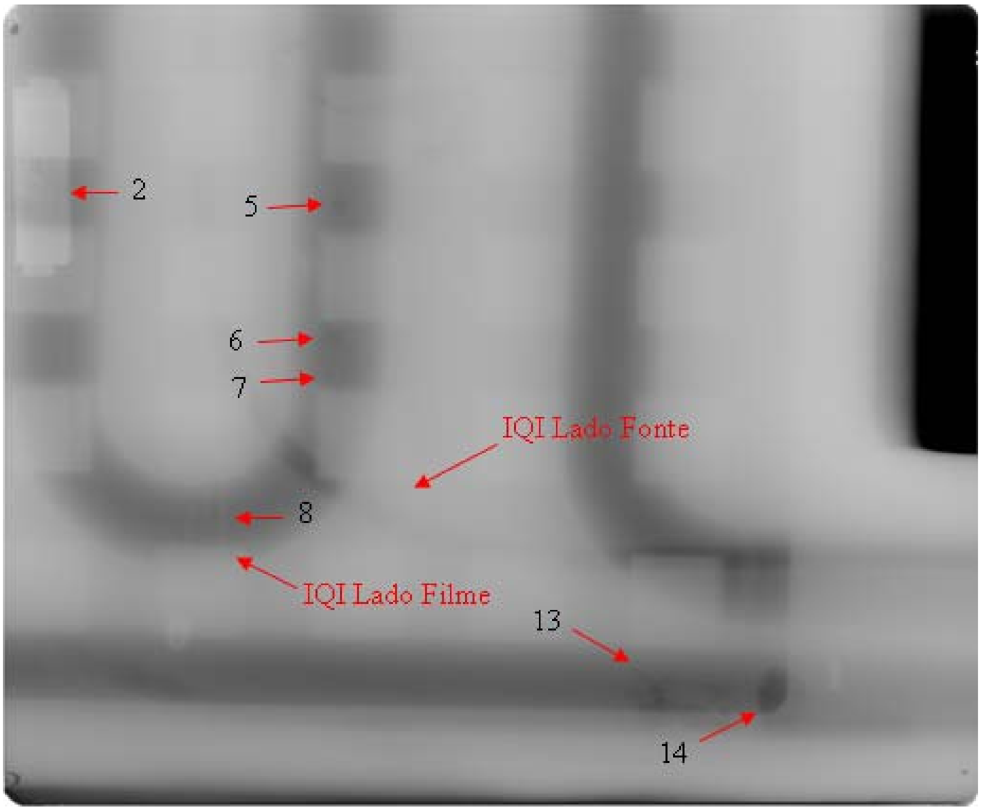

Figure 10. Radiographic image using one film class 2 (simple view).

In computed radiography test was obtained a single image, which was processed with the filter "Enhance Details" for better visualization of discontinuities, as shown in Figure 11.

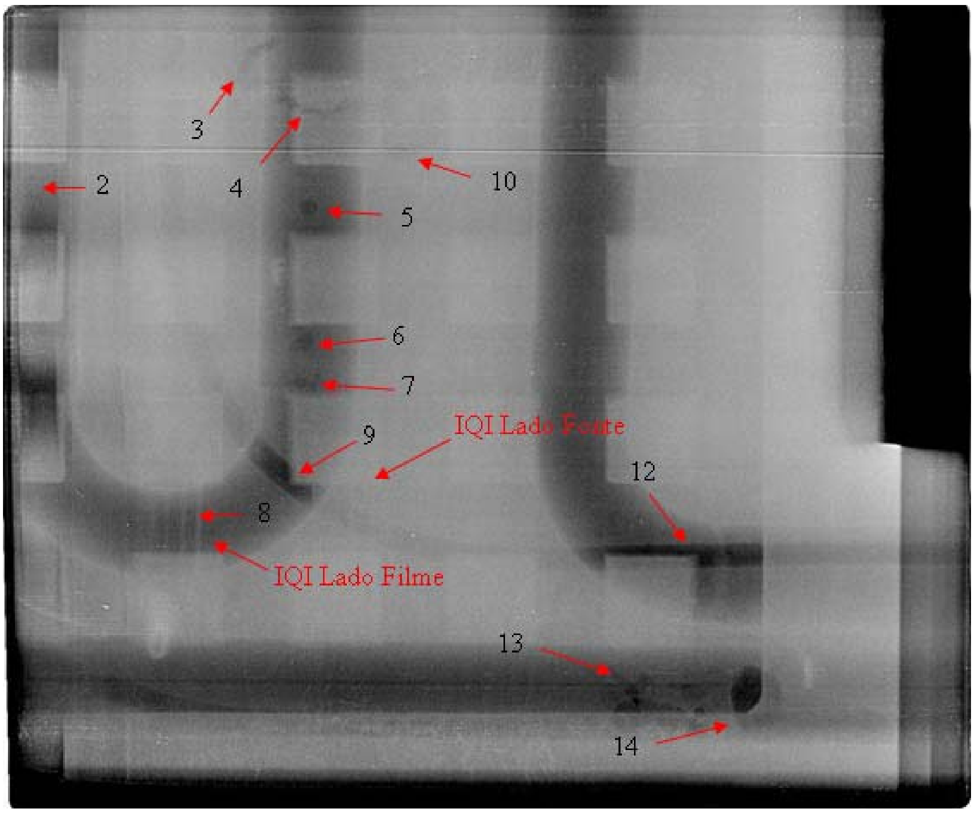

Figure 11. Industrial computed radiography using Cobalt-60.

Regarding the assessment of the contrast IQI with conventional radiography has been viewed the wire 6 at the film side and the wire 4 at the source side for single view and wire 5 on the film side and wire 4 at the source side for the composite view. With computed radiography, was seen the wire 4 at the film side and the wire 2 at the source side.

3.3. Linear Accelerator x Cobalt-60

The results showed that both in computed and conventional radiography, the inspections with the linear accelerator had better detectability of defects, giving greater clarity and definition of the edges. Furthermore, the contrast between areas of different thicknesses was better out in comparison to radiography with cobalt-60. This is due to the parameters of exposure, as higher source to detector distance, the shorter time of exposure (which generates less scattering) and energy most appropriate for this thickness. It was also noted that the images with cobalt-60 are noisier, mainly due to the high exposure time used.

4. CONCLUSION

The results of this study showed the comparison between the computed and conventional radiography techniques for the detection of discontinuities in a sample of copper with internal coils, using two sources of radiation of different energies. With the linear accelerator, it was observed that with the conventional radiography technique, the discontinuities can not be fully identified with a single film, and had to be used films of different sensitivities and the composite view technique for this compound. With the computed radiography, the discontinuities could be fully detected through processing of the image as the adjustment of brightness and contrast and inclusion of mathematic filters. With Cobalt-60, using conventional radiography, the discontinuities also could only be detected with the technique of composite view, otherwise the time would be doubled. With the industrial computed radiography, only one image was required for the identification of all discontinuities.

So even with a few experiments and a single system of CR, we can conclude that the computed radiography technique showed to be very advantageous for the detection of relevant discontinuities in the manufacture of castings, so effective in helping to report acceptance or rejection of discontinuities, as the rules of construction.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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