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Tomographic system based on Plasma Focus X-rays

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Abstract A system oriented to develop an image processing system, which takes advantage of radiation flashes from a plasma focus, by optimizing the emission-detection-reconstruction procedure, is presented. A computer technique for 3D reconstructions was combined with radiographic images of objects X-rayed with a compact plasma focus. The technique is able to automatically determine the position of the rotation axis, reconstruct the 3D-attenuation map, and display inner cuts. The system was demonstrated in introspective tomographic imaging of a stainless steel BNC elbow.

Key words defectoscopy • image processing • plasma focus applications • tomographic reconstruction • X-rays

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Introduction

Radiation pulses from a plasma focus (PF) provide unique characteristics compared with other radiation devices, namely very short flashes (10–50 nanoseconds) of high intense beams. This feature opens interesting possibilities in industry and medicine. Very short radiation pulses have been proposed in recent years for ultra-fast tomographic scanning to obtain fast cross-sectional information [2]. Three-dimensional images of the internal structure of key components or critical parts in production lines have an enormous potential from the point of view of quality control. One can imagine a step in the production line where the quality of certain critical components is automatically monitored by means of tomographic identification of material defects.

A computed tomography is a 3D image of an object constructed from a certain number of photographs of the attenuated radiation passing through the object at different angles. Using the traditional reconstruction methods, substantial numbers of projections are required [1]. However, using special processing, certain images can be reconstructed from a small number of imperfect projections. The present work shows a computer technique for 3D reconstructions that succeeded in reconstructing tomographic images of objects x-rayed with a compact plasma focus.

Tomography with PF radiographs

An experimental radiographic session was performed using a small-chamber 30 kV, 4.7 kJ PF as an X-ray source. A stainless steel BNC elbow was placed on the electrode axis, 83.5 cm away from the focus, outside the stainless

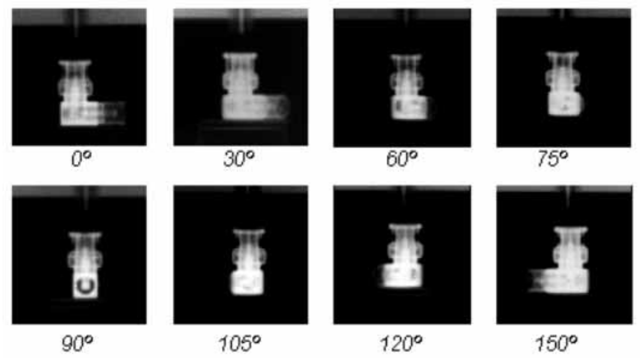

Fig. 1. Radiographs of a BNC elbow X-rayed with plasma focus.

steel chamber. All the shots were made at filling pressures of 4–5 mbar pure deuterium. The sample was mounted on a small acrylic platform that rotates to allow for taking images at different viewing angles. The rotating axis was set vertically and 8 viewing angles were used: 0, 30, 60, 75, 90, 105, 120, and 150 degrees. The axis was marked with a sharp metallic needle. Fig. 1 shows a set of radiographs of the piece at different angles. It can be seen that, even controlling carefully the operation, there are always differences in brightness and focalization. Therefore, in order to be useful in a tomographic system, we should be able to reconstruct inner cuts processing imperfect projections.

The Monte-Carlo method is a flexible technique that can handle quality differences of the information input. Basically, Monte-Carlo tomographic reconstruction is a stochastic searching process, where the computer bounces randomly in the set of all possible digital 3D images (called *instances*), guided with a selection criterion that ensures the convergence toward the actual inner attenuation field.

The reconstruction algorithm in our case is based on the comparison of the actual radiographs with the projections that would produce the *instance* image. The general procedure is as follows:

1. Starting with an initial guess *instance*, modify slightly the tone of a pixel chosen at random.
2. Calculate the projections $p(\theta)$ of the *instance* in each direction θ.
3. Calculate an error indicator averaging the square deviations of $p(\theta)$ with respect to the actual projections $p_0(\theta)$, according to:

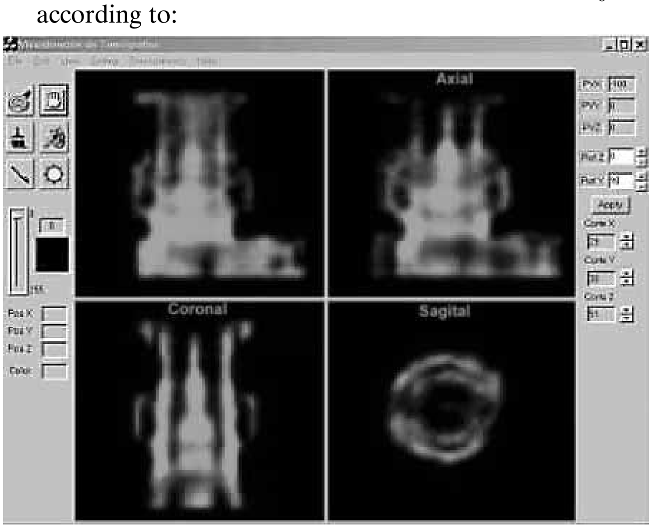

Fig. 3. Display of inner cuts of the piece.

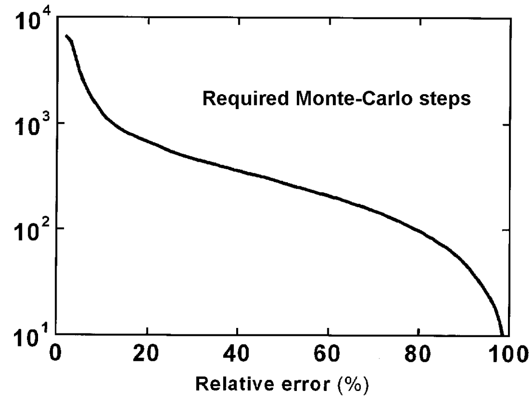

Fig. 2. Number of Monte-Carlo steps required to reduce the error of the initial guess.

(1) $$\varepsilon = \sum_{0} w_i \left(p(\theta) - p_0(\theta)\right)^2$$

where w_i are the weight parameters that are used to handle the difference in quality of each projection $p_0(\theta)$. In Eq. (1) the summation is performed over all rays for each θ.

4. If the error of the new *instance* is lower than the previous one, the modification is accepted.

Fig. 2 shows the performance of the technique in the tomographic reconstruction using Fig. 1. It can be seen that the number of steps needed to reach an error lower than the value of the horizontal axis increases steadily after an initial transient. The algorithm is very efficient to generate reconstructions with errors down to 10% of the initial guess.

The method was implemented using the object oriented programming, in Visual C++. A visualization system completes the tool, allowing the fast inspection of inner cuts of the attenuation field. The hardware requirement is just a Pentium personal computer, and the system runs in MS Windows environment. Fig. 3 shows the display of different cuts of the BNC on the control panel of the application. The visualization of the inner cuts shows details down to 0.3 mm resolution.

Conclusions

Tomographic images of a metallic object X-rayed with a compact plasma focus were presented. In order to handle the X-ray pulse differences between shots, a reconstruction algorithm based in the Monte-Carlo method was developed. The process was implemented in a computer system, providing tools for automatic visualization of inner cuts. The technique can be applied in quality control procedures of key components or critical parts in production lines.

References

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