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''SERUS'' AN EXPERT SYSTEM FOR THE ULTRASONIC EXAMINATION OF FUEL RODS

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"SERUS" AN EXPERT SYSTEM FOR THE ULTRASONIC EXAMINATION OF FUEL RODS

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ABSTRACT

The use of pattern recognition functions and the modelisation of the human expert reasoning, allow the automatic identification of defects in welds or structures. The proposed application uses an ultrasonic examination to detect and classify 3 types of defects in end plug welds of PWR fuel rods.

KEYWORDS

Non destructive - Testings - Ultrasonics - Automatic identification - Graphic representation.

INTRODUCTION

In many applications of non-destructive examination techniques, the recognition of defects detected by the examination is based on their graphic representation.

The expert uses the image and its components to give a description based on criteria which he regards as decisive to form his judgement. Such criteria may relate to location, orientation, shape, colour, pattern, resolution, etc.

The expert's interpretation is the summary of the following three processes :

- Perception or acquisition of the picture in its environment, and description of that picture

- Consideration of the acquired data, or comparison of such data with the expert's knowledge

- Arrival at a model, known or unknown, through a deductive or comparative process.

The above processes are simultaneous, and the deductive process requires a large number of iterative steps of the "perception - consideration - deduction" type.

Only an expert is capable of such reasoning.

One may wonder, however, whether experts are irreplaceable in all cases, and whether their knowledge can be "borrowed."

This paper describes the application of artificial intelligence techniques to the ultrasonic examination of welds. Knowledge was transferred through reasoning modelled on an expert's sensorial and mental processes.

THE "SERUS" SYSTEM

CEA has developed an intelligent perception system, the design of which is based on the concepts stated above. "SERUS" stands in for the expert's vision and knowledge, taking his place to perform the identification and sorting functions.

The "SERUS" software implements in real time all the following processes :

- Perception

Image acquisition is based on an "object" type presentation in a space defined by the geometrical boundaries of the examination (C-SCAN). All objects are identified and characterized by a series of descriptive and quantitative parameters selected from a set of 25.

The parameters are numbers which can be conveniently handled by data processing systems.

- Consideration

The expert's knowledge, i.e., the link between the visual data and the experience acquired in the field, had to be reproduced in model form. That knowledge is transferred on a step-by-step basis through pictures of standard defects. Such a learning process provides the capability of emulating human-type reasoning.

- Deductive process

The deductive process is implemented through a logic system designed to select the objects eligible for identification as defects, and then to apply conditional tests which verify whether all descriptive conditions are met. Final identification is achieved through an algorithm covering all the solutions proposed by the expert. Because of its heuristic approach and modular structure, "SERUS" can be considered for many applications to short-cycle or continous testing.

APPLICATIONS DEVELOPPED

We present the industrial prototype of a system for the ultrasonic examination of end plug welds in PWR fuel rods. This weld, with 10mm diameter and 0.6mm thickness, provides the cladding-plug seal.

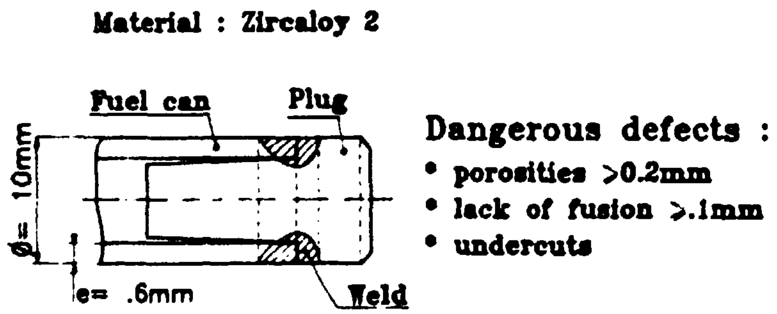

Fig. 1 : The end plug weld and its potential defects

High standards of quality and reliability are required of this process, which may involve a production rate as high as 2000 welds per day.

Defects to be detected are porosities, lack of penetration and inward deformation of the cladding. The following instrumentation is used :

- local immersion tank with three ultrasonic sensors with different angles of incidence. Examination thread is 0.2mm per turn

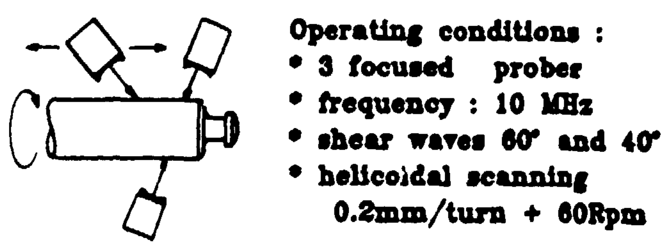

Fig. 2 : Ultrasonic examination

- ultrasonic apparatus of the S80 type, by AUTOMATISATION INTERNATIONALE, equiped with communication interfaces.

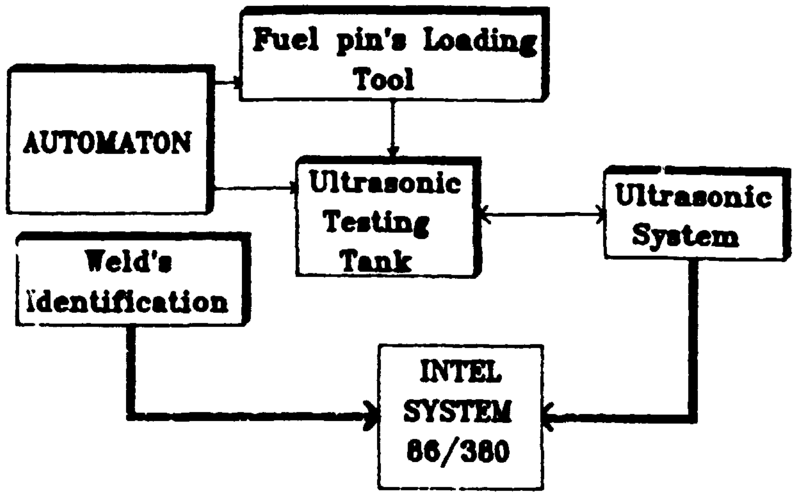

Fig. 3 : The Data acquisition system

- 86/380 INTEL computer with IRMX 86 real time operating system, featuring a streamer and 40 Mbytes INTEL DISK. Language : PLM86

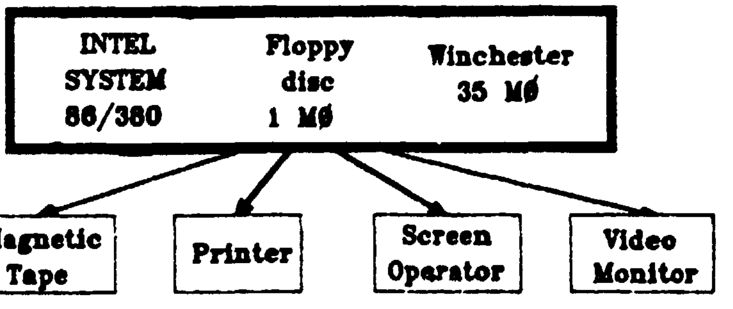

Fig. 4 · The Data processing system

Image processing by the "SERUS" system involves four successive steps.

DATA acquisition

The main ultrasonic signals are digitalized and associated with the relevant geometrical positions of individual sensors with respect to the weld. An instant map shows all the reflectors detected in the weld.

Image processing

Phase 1

The map is made selective by deriving the contours of the ultrasonic pictures using variable analysis thresholds which are dependent on signal amplitude. This process assists in characterizing the three defect types by distinctive graphic signatures.

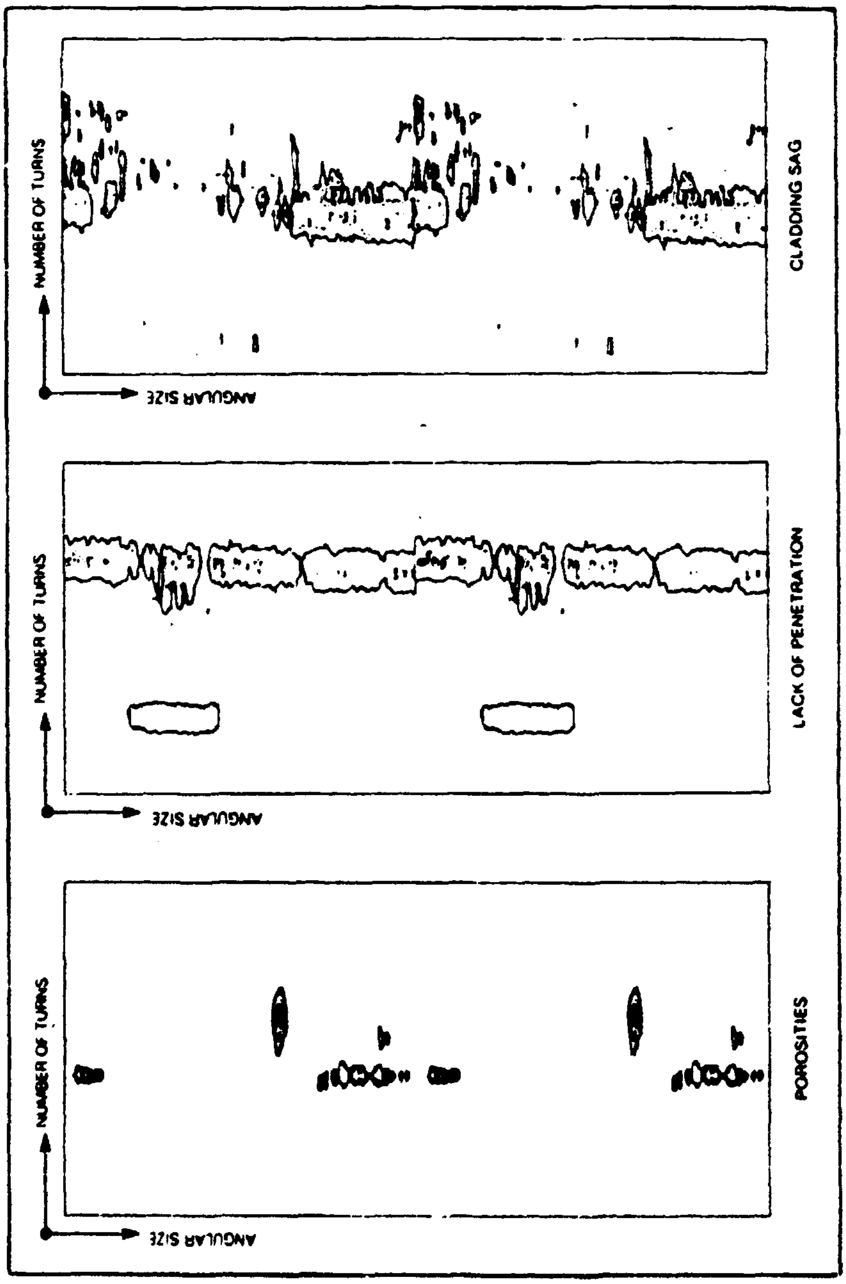

Fig. 5 : Graphic signatures for the 3 types of defects

The image is accurate enough to identify those reflectors, characteristic of a lack of penetration, which are only a few hundredths of a millimeter in size.

Phase 2

All mapping data are singled out, identified and encoded in object form using a set of 13 parameters.

Image analysis

Learning phase

The expert characterizes the three defect types on the basis of their graphic signature, using pictures of standard welds. A utility software is used to display the object on a monitoring screen, and to derive its specific parameters. The fluctuation range of the parameters is then assessed through a specialized software which provides the statistical operational limits for each parameter.

Each defect type is also viewed through a specific conceptual model showing the defect in its environment.

Computerized expertis phase

The expert assessment rules drafted during the learning phase are translated into a procedure algorithm. All object pictures are subjected first to selection tests, then to conditional tests which confirm the metallurgical nature of the defect. These operations are performed in real time, without mapping.

Other identification criteria, e.g., object density or number of pixels per unit area permit assessments based on the common characteristics of a family of objects.

DEFECT EVALUATION - RESULTS

Acceptance and rejection criteria are entered in the image analysis algorithm. They can be adjusted by an interactive process, according to the quality standards required.

Results are available in two forms :

- printout showing weld number, defect type, defect location, defect class and decision made

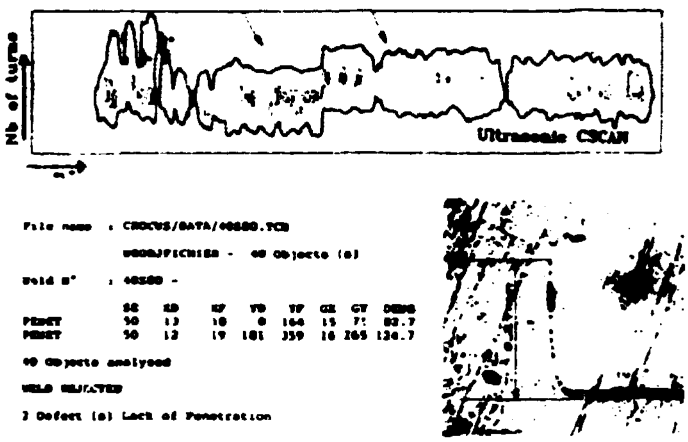

Fig. 6 : An example of automatic analysis with the associated magrography of the defect

- magnetic cartridge used for filing source data and results. The initial analysis can be retrieved at any time.

CONCLUSION

"SERUS" is a tool which assists in the expert analysis of pictures which may originate from any source as long as the representation space is defined.

The validity of the decisions made rests on an analysis by the expert, and on computerized procedures implemented under the expert's supervision.

Because of real time requirements in the application presented, a multi-processor system has been adopted.

The system can be transferred to more economical or less ambitious versions, and to other languages.

"SERUS" is of course suitable for applications outside of the NDE field.