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Recognition and Improvement in the Classification of Imperfections Detected by Eddy-Current Inspection

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Abstract

The system presented in this paper shows the interest of image technique for the selectivity improvement of the non destructive benches. It was developed for a Vallourec Group facility that manufactures pipes for the mechanical industry.

Installed in the final inspection of the finished products, the system is dedicated to the external soundness inspection by punctual EC. Highly stringent criteria have to be met at this stage to ensure the quality of the end products. Consequently, the rate of "false alarms" is relatively high in order to keep the client risk near to zero.

The purpose of the system is to distinguish the main imperfections that cause these "false alarms" (e.g. insufficient fusion type flaws), by multi-channels acquisition in real time, followed by 2D imaging at an industrial process rate. The amplitudes of the indications are then weighted according to the type of imperfection recognized. The system then determines if rejection of the part is founded or if it is a potential false alarm that remains to be verified.

The article describes the method used and gives information regarding industrial validation.

Keywords: Defect classification, Punctual EC, 2D imagery, Tubes

1. Description of the Problem Encountered

The system presented, which has now been industrialized, was developed for a Vallourec group mill producing pipes for engineering applications. Prior to their end use, these pipes are machined by Vallourec group customers.

After the manufacturing process, non-destructive inspection systems are installed for on-line inspections.

At present, two types of flaw are the main sources of selectivity problems on the Eddy Current test bench:

- Rolled-in slugs, which are shallow surface flaws which give an immediate amplitude response owing to their profile (layer of metal protruding from the surface of the pipe) whereas in theory they should not trip an alarm.
- Fine flaws whose depth is greater than the set limit (0.2 mm) and which have a response amplitude under that of the reference pipe.

In order to ensure detection of flaws belonging to the second category, in the current inspection procedure the Eddy Current inspection is set to be over-sensitive and UT is performed even when not specified by our customers.

Rolled-in slugs whose depth is under the specification limit (0.2 mm) and would be removed by machining currently represent 27% of the cases where the alarm is tripped.

This is why the Vallourec Research Centre was asked to design a system to reduce the number of false indications, without increasing customer risks.

2. Description of the Solution Developed

2.1 Image-processing algorithms

The technical solution developed is based on use of the image reconstructed from the response amplitude (module) of the punctual Eddy Current system.

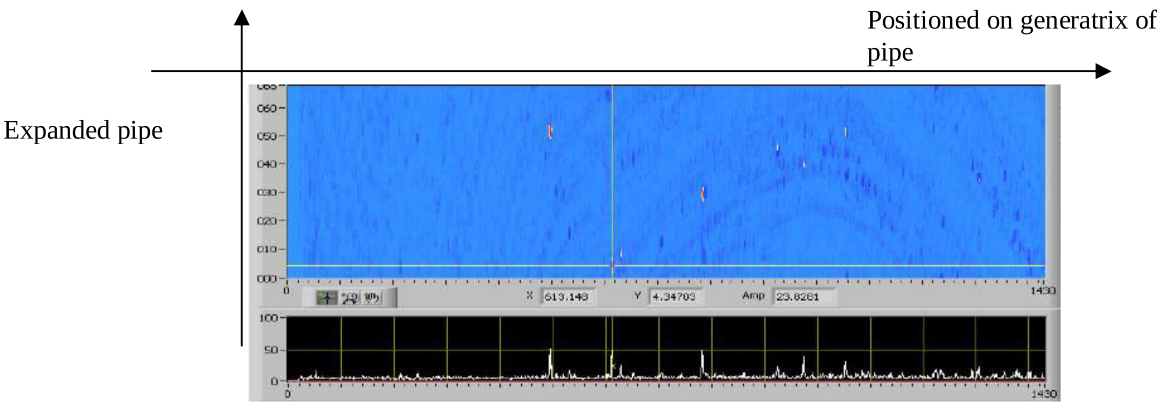

Figure 1: Representation of the expanded EC image of the pipe compared with the conventional recording below.

The image-processing algorithm first defines the zones of the image that contain potential indications and draws a contour around this zone to be analyzed.

Rolled-in slug type flaws are generally short flaws. The second stage involves evaluating the length of the imperfection relating to the indication. If this imperfection is long, the alarm threshold defined by the current procedure is applied. If the imperfection is short, the image is analysed in more detail.

A third stage of the algorithm consists in recognizing a characteristic response zone in the image. If a “raised piece of metal” is recognized, the algorithm indicates that it considers it has found a slug and prevents the alarm from being triggered automatically. If the information in the image do not allow a rolled-in slug to be recognized, the threshold of the current procedure is used.

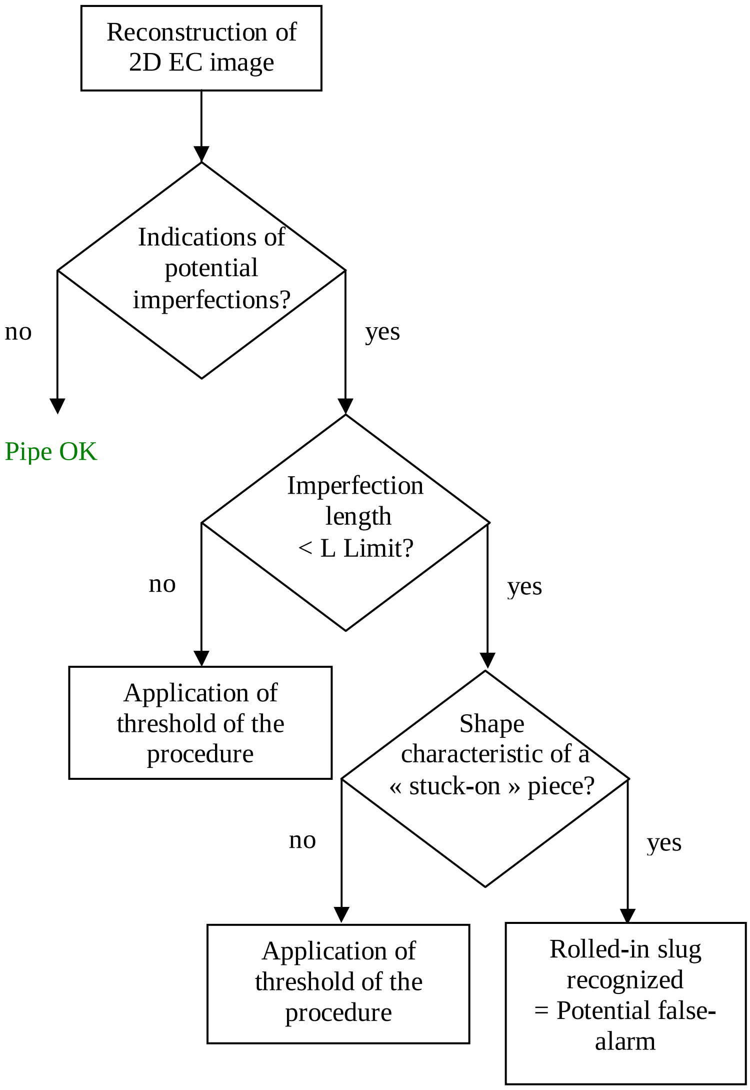

Figure 2: The algorithm for recognizing rolled-in slug type flaws proceeds in three successive stages which make it possible to only confirm the presence of a rolled-in slug when it is certain of the type of flaw.

2.2 Possibility of on-line implementation

In order to implement the system on line, it must first be capable of representing the expanded image of the EC signal module as it appears. For this purpose, the image-processing system must receive two types of data:

- Raw data from the Eddy Current electronics
- Coding of positioning of punctual probe on pipe

In order to industrialize this system, it is therefore necessary to put in place a system to encode the position of the punctual probe (gradual thumb wheel, laser, etc;) and put an acquisition system at the output of the EC electronics. The image-processing algorithm is thus triggered and can subsequently send its interpretation to the automated system already in place (Figure 3).

This process is similar to that described in the patent published by the Vallourec Group for the use of ultrasonic image-processing.

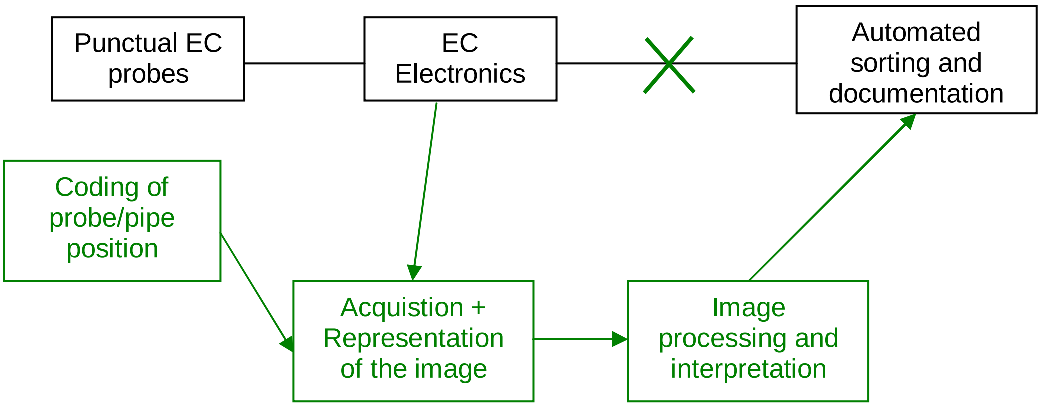

Figure 3: The items shown in green need to be added to the current system for implementing the proposed solution

3. Validation of the Proposed Solution

3.1 Semi-industrial validation

8 samples were taken from pipes tripping the alarm on the automatic Eddy Current inspection bench, with module and image acquisition and recording.

The 8 zones containing an indication were examined by micrography and their actual depths measured. The results of the predictions of the image-processing algorithm were assessed:

- On the image acquired in the mill,
- On various images acquired at the CEV for the various possible passages of the flaw in front of the punctual probes (7 different acquisition possibilities).

The results of the assessment on the 8 indications are as follows:

- 6 fine flaws whose depth is greater than the specification limit
  - The algorithm confirms the flaws in 100% of the cases on analysis of the various possibilities of images acquired,

- The correlation is better than with the present inspection system,
- The risk of a NOK pipe passing the inspection is not increased.

- 2 rolled-in slug type imperfections, whose depth is below the specification limit:
  - On the analysis of the various possibilities of images acquired, the algorithm confirms the flaws in 70% of the cases.

3.2 Industrial validation on series production

A second validation phase, on an industrial scale and large series production will be conducted. For this, it is planned to install the system parallel to the inspection bench and conduct tests over a period of several months:

- systematic sampling for assessment, or interpretation of differences between the current system and the proposed solution,
- statistical sampling of all indications found.

4. Conclusion

The system described in this paper shows the advantages of using image processing to improve the selectivity of non-destructive inspection equipment.

This system is already installed on site, and currently gives results parallel to the automatic sorting system. The industrial validation of the system on large series production is planned for the coming months.