Simulation of Digital Filtering to Optimize Pipe Ultrasound Wall Thickness Measurement

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Abstract

In the ultrasonic wall thickness testing equipment of the Vallourec Group, filtering algorithms are applied on the raw data by the electronics. While the purpose of this processing is well known, that is to eliminate such problems as interference while taking into account wall thickness irregularities, our knowledge of their influence on the final measurement is incomplete, and the settings controlling these algorithms are made empirically by the operators.

In order to assist them in making these settings, a simulation software program has been developed: it aims to reproduce electronically all the possible inspection and filtering configurations and therefore determine the optimal filter settings for a given test bench.

Before testing the reference pipe, and for a given setting, the operator can now have a 2D view of its wall thickness distribution, showing the points of measurement that will be deleted by the filter algorithms, as well as an estimation of the final measurement curves that will be issued by the test equipment.

Keywords: Wall thickness measurement, Data filtering, Measurement simulation, Wall reduction

1. Definition of Wall Thickness Data Filtering

1.1 Scanning configurations

Irrespective of the ultrasonic wall thickness measurement equipment in the Vallourec Group, the pipe is scanned by one or more ultrasonic beams with either a single or multiple source (in the case of Phased Array probes).

The scanning path is generally helical but can follow other paths.

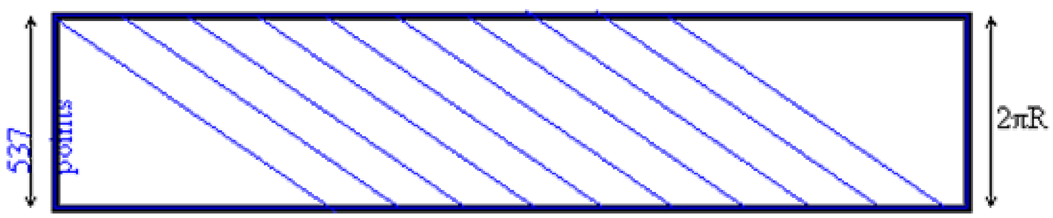

Figure 1 - Expanded view of a pipe: helical scanning

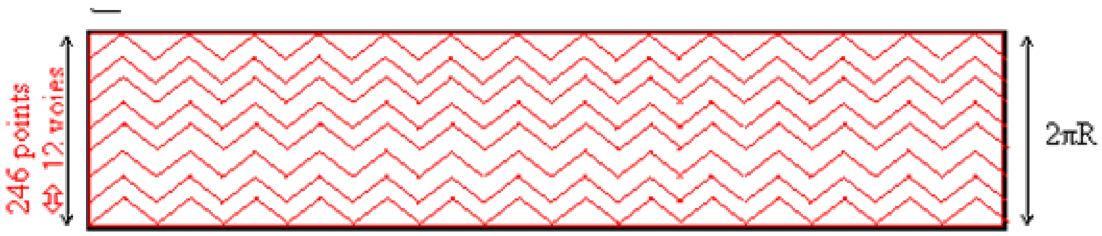

Figure 2 - Expanded view of a pipe: GEIT ROWA type linear scanning

The above figures show examples of probe paths when inspecting the surface of a pipe. On each straight line representing the path of an actual or virtual probe, we can plot the pipe wall thickness measurement points. The spacing of these points and configuration of the paths will determine the resolution of the inspection. A straight line will be combined with the flow of data relating to it and henceforth called a track. This generally corresponds to a channel of the electronics used for processing the data.

1.2 Application of filtering

During the data acquisition process, certain values may be falsified due to interference. It is therefore necessary to be able to recognize this type of value so as not to take them into account when assessing the inspection results. For this purpose, industrial wall thickness measurement equipment contains filtering algorithms implemented in the electronics in order to eliminate or attenuate these values.

As each track is equivalent to a series of data, it is processed independently of the others, which means that the data is filtered according to the inspection paths. It therefore makes sense to adapt the filtering parameters according to the type of scanning used on a given inspection bench.

The following explanations are valid for Lecoeur or GEIT type electronics.

<u>Interference suppression</u>

The consecutive signals on each track are compared and values eliminated when there is too great a variation in wall thickness at a given point. In other words, the user defines a maximum allowed wall thickness curve according to the process, enabling any aberrant values due to interference to be ignored.

<u>Measurement readjustment</u>

If the value considered to be aberrant is followed by similar values, the irregularity of the measurement is no longer considered to be due to interference but to a local flaw, the slope of whose sides is greater than the limit normally set by the process. All the measurements are then taken into account and the irregular values integrated into the inspection results. A counter is used to determine the minimum number of irregular values to be ignored before recognizing the anomaly as a flaw and taking it into account.

<u>Smoothing</u>

Sliding average or moving average type filters are used to homogenize the measurement. The width of their windows is adjustable.

Sectorization

In order to synthesize the pipe measurement in a single track, the data filtered is grouped into three values per 100mm of longitudinal advance: these are the minimum, average and maximum wall thickness values. NB: the 100 mm value will vary according to the inspection benches.

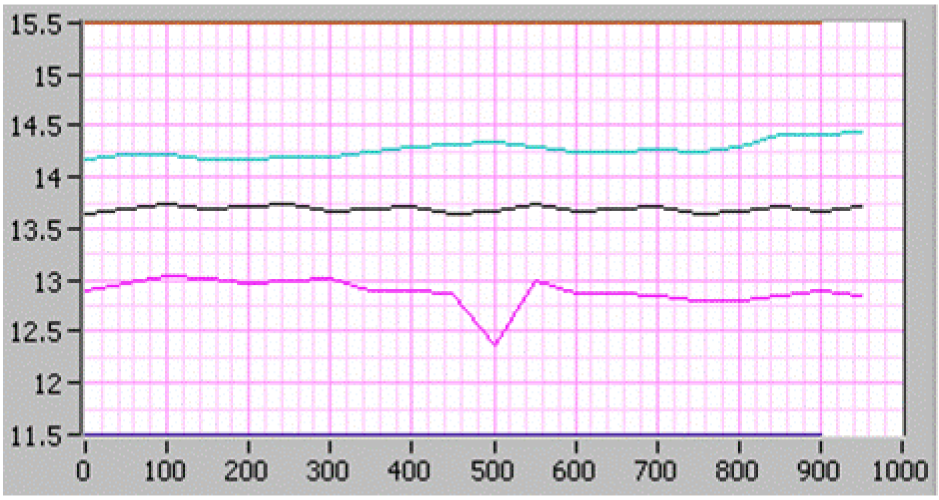

Figure 3 - Pipe wall thickness measurement curves. y axis: Wall thickness (mm) x axis: Length (mm)

2. Principle of the Simulator

2.1 Purpose

The three curves represented in the previous paragraph were obtained for some given filtering parameters. These are three to five parameters according to the inspection bench and type of inspection required. They are generally set empirically which means that there is little control or predictability of their effect.

There are various advantages in simulating the scanning of a pipe and filtering the measurements:

- The optimal settings can be defined while minimizing the number of tests to be performed in the factory.
- It enables the Vallourec Group to control the entire data acquisition process and thus know the possibilities and limits of its equipment.

2.2 Scanning simulation

The data from a reference pipe was acquired for subsequent validation in the factory. The pipe wall thickness was mapped with high resolution in order to have a point matrix equivalent to a virtual pipe.

This matrix was then “scanned” along a virtual path and the points marked on this path were stored in vectors representing the tracks.

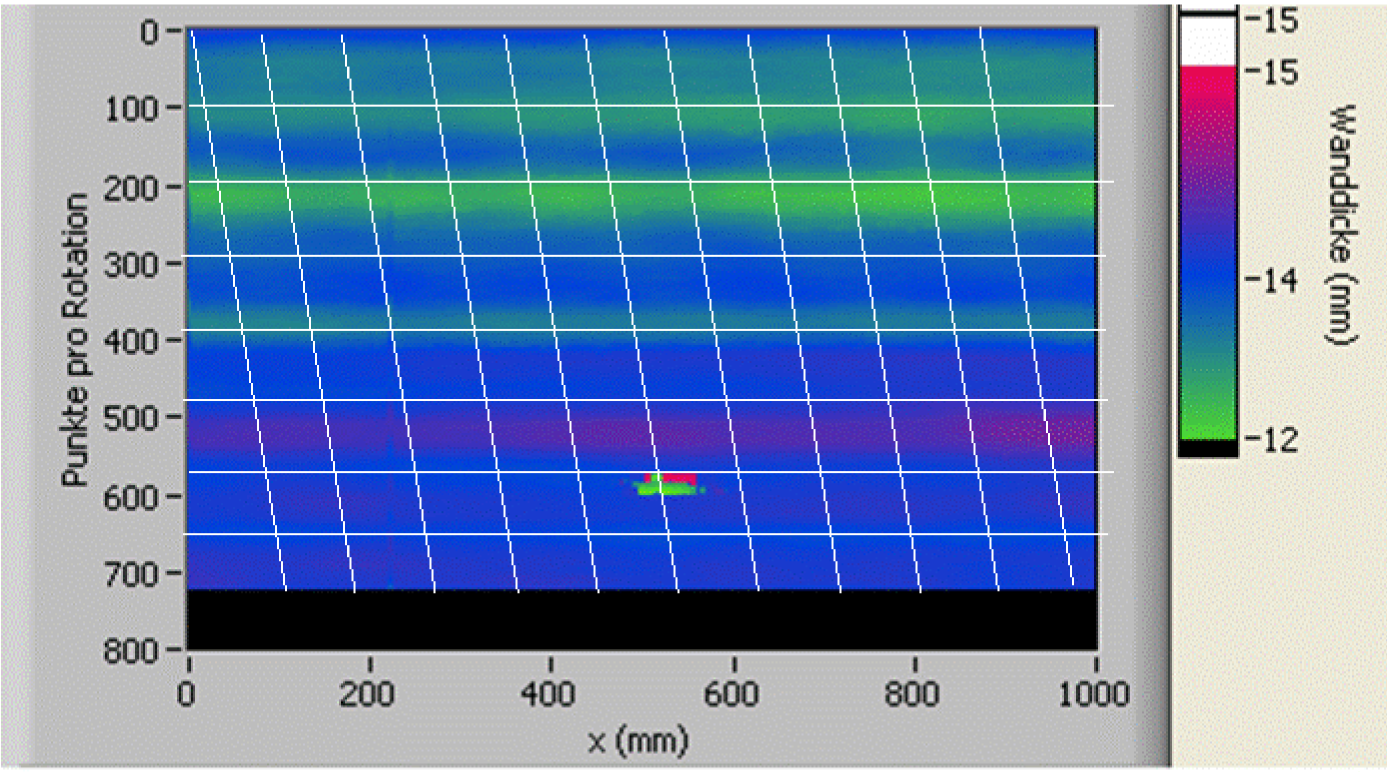

Figure 4 - Pipe scanning matrix shown in white

2.3 Filtering simulation

The same algorithms as those used by the electronics are applied to each of the tracks.

It is important that the simulator interface has the same input parameters as the setting interface of the inspection equipment.

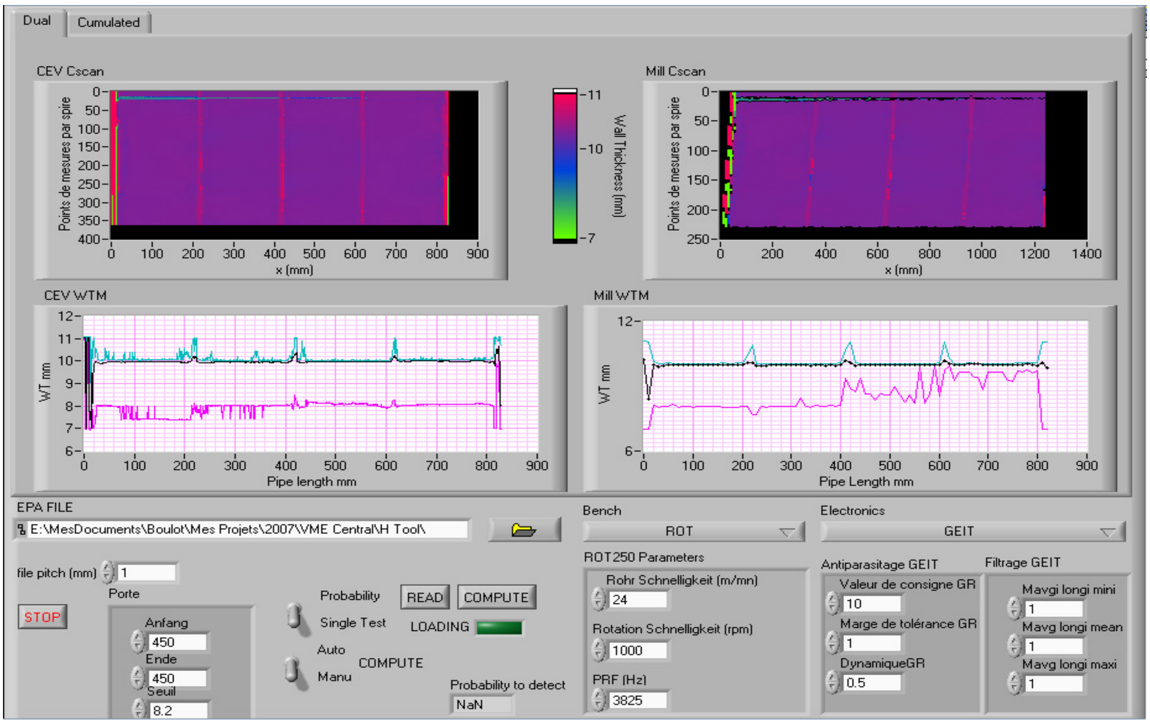

Figure 5 - Example of the interface for a GEIT ROT type benche On the left are the reading parameters for the virtual pipe and on the right are the curves and settings for the simulated measurement

3. Validation

3.1 Description of the tests

The tests were performed on a reference pipe with four reductions in wall thickness machined according to the following diagram.

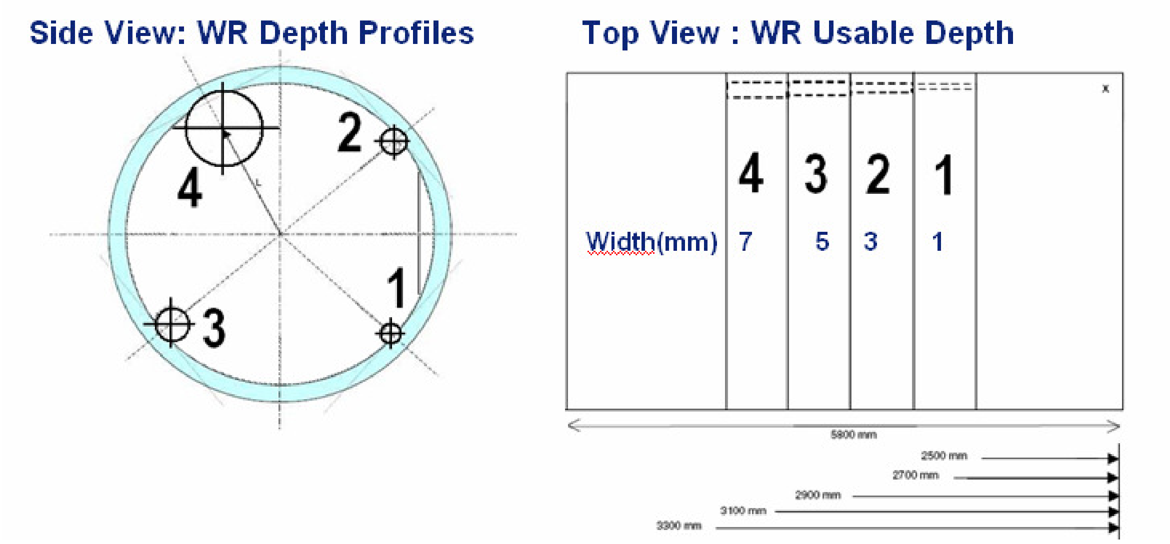

Figure 6 - Description of the reference pipe used for validation

The cartography of the pipe at the CEV (Vallourec Research Centre) showed that wall thickness 1, 1 mm wide, would only be visible once at the most and would therefore be considered as interference. If the bench is capable of detecting this wall thickness (impossible in the process), the inspection is over-sensitive and any interference will affect the measurement results.

The aim is therefore to find the optimal settings for detecting wall thicknesses 4, 3 and 2 without detecting wall thickness 1.

The purpose of the trial is to achieve this optimization in an empirical manner and compare the values with those predicted by the model. The initial value of the parameters is defined by the simulator.

4. Results

From a qualitative point of view, the model was faithful to the experiment: variation in a parameter had the same positive or negative effect on detection of a flaw.

From a quantitative point of view, improvements need to be made.

For a given setting, the model gave the detection probability of the wall thickness. The inspection bench however sorts in a binary manner. The prediction of the model is considered valid when there is 100% probability of detection or when the probability of non-detection is absolutely less than 100%.

Sous épaisseur	4	3	2
% prédictions exploitables	70%	45%	50%

In the end, several configurations of settings were defined for the ROT in order to optimize detection of each wall thickness, guaranteed with ten consecutive passes.

Wall reduction circumferential									
						4	3	2	1
Optimized Section	min val	gleitende Mittelwertbild für Minwert	FG-Toleranzbreite	FG-Dynamik	FG - Störuntersetzung	Trial result			
MH Settings	9	1	1	0,5	4	1	0	0	0
MH Settigngs with slight improvement	<8,75	1	1	0,5	1	1	1	1	0
4	<8,75 <9	3 2	0,6 0,5	0,3 0,25		1 x 10 1 x 10	0 0	0 0	0 0
3	<8,75 <9	1 2	0,8 0,8	0,4 0,4		1 x 10 1 x 10	1 x 10 1 x 10	0 0	0 0
2	<8,75	1	0,9	0,45		1 x 10	1 x 10	1 x 10	0
1	<8,75 <9	1 2	1,3 1,3	0,65 0,65		1 x 10 1 x 10	1 x 10 1 x 10	1 x 10 1 x 10	1 x 10 1 x 10

Figure 7 - Optimal configurations for the inspection of each wall thickness

5. Conclusion

The simulation tool enables us to understand better the influence of the filtering parameters on the quality of the wall thickness measurement and on the detection of local wall thicknesses. It is used to train operators in the factory in the use of the filtering parameters on industrial test benches.

Improvements are however needed before it can be used for quantitative purposes. The estimations it has provided have however allowed an optimizing trial to begin using settings close to the optimal values.