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Theoretical and experimental contributions on ultrasonic contactless examination of underground pipes through which pressurized fluids circulate

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Theoretical and experimental contributions on ultrasonic contactless examination of underground pipes through which pressurized fluids circulate

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Abstract. In any civil or industrial construction, there are many embedded pipelines through which pressurized fluids or gases are circulate and which, over time, are subject to corrosion. Examination and monitoring of corrosion/erosion process in order to determine the service life of pipelines through which fluids circulate at different temperatures and / or pressures is a particularly important task for both the designer and the owner because knowledge of "health status" of these in time is extremely. On-site ultrasound control of wall thickness is based on simple propagation time measurements and is typically used to evaluate corrosion and erosion. The paper presents a non-destructive control used to determine pipe corrosion and lifetime, most notably ultrasonic examination without contact, using Lamb dispersing waves. For experimentation, the most important zones of a pipeline were chosen. Thus, methods of examination for 90^0 pipe elbow, welded pipe sections, reduction pipes, and seamless pipe sections have been established. The main parameters that have been taken into account are: actual and effective phase angle, temperature of the environment, roughness of the controlled surfaces, geometry of the controlled surfaces and the nature of the fluid flowing through the pipes (air, liquid or steam).

1. Introduction

The main defects that may arise and affect on any civil or industrial construction are defects in manufacturing, material defects and exploitation defects. In the case of earthquakes there is an important physical wear under the action of stresses on the materials in the structure of the resistance structure (micro-cracks and internal cracks, breaks and damage to the pillars and resistance beams, cracking of reinforcements and beams, joints in the masonry or between masonry and slabs, degradation of embedded piping systems, degradation of electrical installations, etc.). Most of the defects listed above can be highlighted using the ultrasonic examination method in several variants: pulsed, impulse transmitted and echoes repeated. Ultrasound examination methods have a number of drawbacks related to the very high sensitivity of the method, the need for an acoustic coupling, the essential dependence on the interpretation of the results by the operator and the impossibility of controlling two or more opposite sides of a wall, pillar [1-3]. Since the problem of acoustic coupling is very difficult to solve in the case of invasion of civil and industrial building elements, the problem of

using the air to make the acoustic coupling between the ultrasonic transducer and the controlled environment has been raised.

2. Control method used in experimentation
The control technology that has been developed includes several steps in a logical sequence based on the experimental stand presented in figure 1, model SECU-01FC.
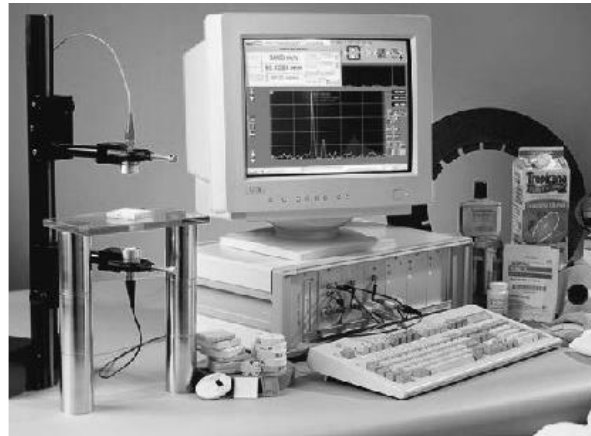

Figure 1. Experimental stand model SECU 01-FC for contactless ultrasonic control using non-contact transducers and a screen displaying thickness and speed through controlled material.

The same like in direct contact ultrasound control, the impulse transmitted to the contactless ultrasound control is also reflected and emitted at different interfaces through the control medium. Various examples of reflection and ultrasound trajectories are provided as well as functions of the test material interfaces and their volume are presented in figure 2 [4, 5].
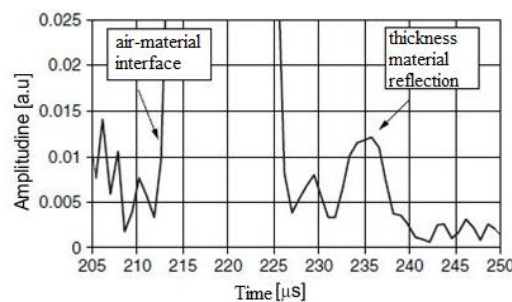

Figure 2. Reflection and emission of ultrasounds as functions of test material interfaces where: F_i is the incident angle in the air; θr - the refractive angle in the test material; Va - the speed of ultrasounds in the air; Vm - the speed in the test material.

By using two contactless transducers, an E-transmitter and an R receiver on the same side of the surface of the material to be controlled (figure 3), it is possible to measure the characteristics of the longitudinal, transverse and wave surface for virtually all types of materials [6, 7]. The generation of these types of waves is determined by Snell's law, equation (1), of the form:

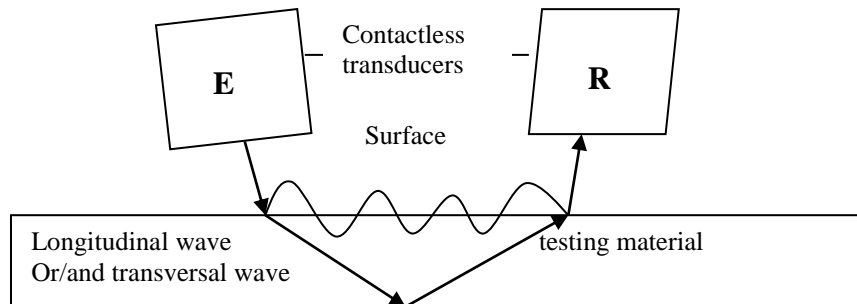$$\frac{\sin \theta_i}{\sin \theta_r} = \frac{V_a}{V_m} \qquad (1)$$

Figure 3. Principal scheme for contactless control using an E transmitter
and a receiver R.

3. Experimental results

Corrosion/erosion monitoring, in order to determine the service life of pipelines through which fluids circulate at different temperatures and/or pressures, is a particularly important task both for the designer and for the owner as the knowledge of "health status" in time is extremely important. The existence of defects, the occurrence of possible cracks can lead to accidental removal from operation, sometimes with the most serious consequences and significant damage [8, 9].

Therefore, periodic examination of buried or non-buried piping systems through which different fluids (water, air, gases and steam) are circulated at different temperatures and pressures is mandatory to know the lifetime and to determine the necessary measures to avoid various accidents [10].
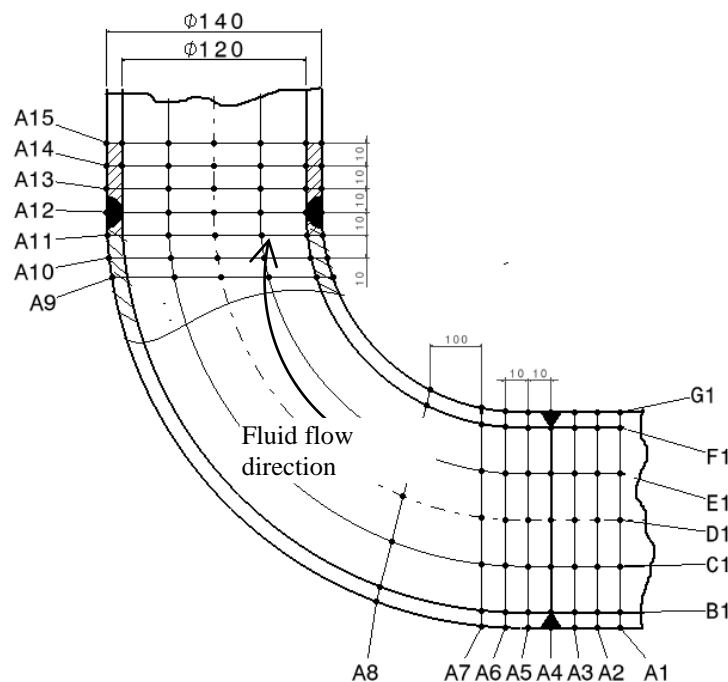

Figure 4. Ultrasound control chart of a bended pipe at 90^0:
A1 ... A15, B1 ... B15, C1 ... C15, D1 ... D15, E1 ... E15, F1 ... F15, G1 ... G1.

Experiments have chosen the most important areas of a pipeline, where there is a possibility of defects and where corrosion might be greater. Thus, there have been established examination methods for 90^0 bended pieces, welded pipe sections, reduction pipes and seamless pipe pipes. For the elbow 90^0, made of OLT60, nominal thickness 10 mm and nominal diameter 145mm (figure 4), the presented

results in table 1 were found. The control was performed using a grid marked A1 ... A15 on the generators. The bend pipe was divided into 4 equal segments of diameter and 6 bands with a width of 146 mm. A DMS2 01-FC ultrasound control device was used. The control was repeated according to the same scheme after one year of operation to show corrosion (table 1).

Table 1. Measurements for the bended pipe.

No.	Measurement point	First measurement	After 1 year measurement	Differences between measurements
0	1	3	5	6
1	A1	9.54	9.05	0.49
2	A2	9.53	9.01	0.52
3	A3	9.95	9.41	0.54
4	A4	9.93	9.37	0.56
5	A5	9.47	8.82	0.65
6	A6	9.46	8.93	0.53
7	A7	9.52	9.03	0.49
8	A8	9.51	9.12	0.39
9	A9	9.52	9.21	0.31
10	A10	9.47	8.97	0.50
11	A11	9.92	8.99	0.93
12	A12	9.89	9.28	0.61
13	A13	9.74	9.60	0.14
14	A14	9.73	9.28	0.45
15	A15	9.48	9.02	0.46
16	G1	9.41	9.06	0.35
17	G2	9.37	9.21	0.16

From the results analysis we can draw the following conclusions:
- for the elbow pipe the minimum thickness was measured at point B3, where it was 8.17mm;
- in sections A1 ... G15, the maximum thickness of 9.12mm was measured at point G5;
 - the maximum corrosion occurred at point E12, where it was 0.93mm, which is explicable because it is located in the thermally influenced area, where internal thermal stresses already introduced during the welding process already exist;
- the minimum corrosion is at G8, where it was 0.11mm, because the point is in an area without the possibility of turbulence and without possible impact with solid impurities impregnated by the fluid.

For a reduction piece of the shape presented in figure 5, made of OLT60, with a nominal thickness of 10mm, which makes the transition from the maximum diameter Ø140 to the minimum diameter Ø70, the results presented in table 2 are found.
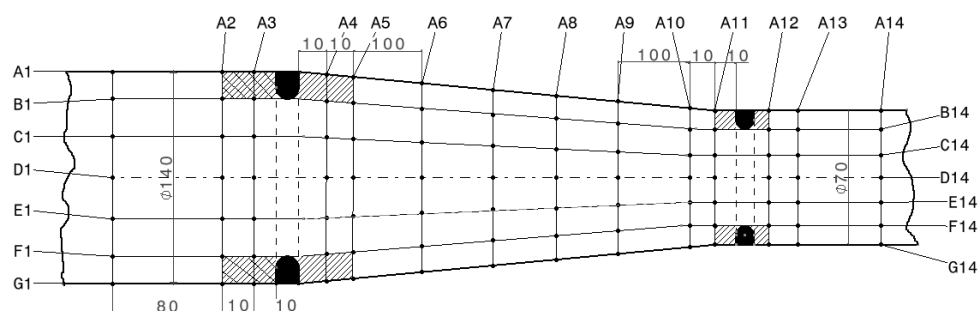

Figure 5. Ultrasound control scheme of a truncated reduction:
A1...A14, B1...B14, C1...C14, D1...D14, E1...E14, F1...F14, G1...G14-control points.

Table 2. Measurements for the truncated reduction.

No.	Measurement point	First measurement	Measured thickness after 1 year	Differences between measurements
1	A1	9.88	9.72	0.16
2	A2	9.73	9.56	0.17
3	A3	9.85	9.61	0.24
4	A4	9.21	8.92	0.29
5	A5	8.95	8.74	0.79
6	A6	8.83	8.35	0.48
7	A7	9.82	8.72	0.10
8	A8	8.98	8.78	0.20
9	A9	8.99	8.86	0.13
10	A10	9.06	8.85	0.21
11	A11	9.12	8.90	0.22
12	A12	9,37	8,99	0.38

The study was performed after a grid marked A1 ... A12 on the generators. The reduction was divided into 13 equal segments and six bands with a width of 146mm at 73mm. A DMS2-TC model control device with TC560 transducer was used for control using the experimental stand model SECU01-FC. To show corrosion, control was performed using the same scheme after one year of operation.

4. Conclusions

As a general conclusion it can be said that the component areas of pipe for fluids under pressure and at different temperatures are corroded differently on both circumferentially and in length, the strongest corroded being the elbow area where the maximum wear was 0.93mm, which means that the maximum lifetime of the elbow is 8 years, when the maximum available thickness is 2.5mm. Similarly, any other fluid flow piping systems at different pressures and temperatures can be controlled. The control results will be checked using the non-destructive control method by infrared thermography.

- Generally speaking, during the exploitation of civil and industrial constructions, a series of defects can occur such as: micro-wiping of resistance elements due to fatigue demands; the corrosion of embedded pipes through which steam, hot water or pressurized gases circulate; the corrosion of some reinforcing pillars or resistance beams and others, defects that are very difficult to determine by classical non-destructive control methods.

- Corrosion continues to be a priority for owners of any type of civil or industrial construction and regular or continuous pipeline inspection of corrosion and the monitoring of its extension are essential elements that determine the service life of a pipeline, resistance structure.

- To overcome the drawbacks of more than 85 control methods used to determine corrosion of pipes, the most recommended method is the ultrasound method using Lamb dispersing waves.

- The main parameters to consider when controlling ultrasonic conduits using Lamb Waves are: actual and effective phase angle, the temperature of the environment to be controlled, the roughness of the controlled surfaces, the geometry of the controlled surfaces and the nature of the fluid flowing through the pipes (air, steam).

- Experimentally, it has been found that areas with high velocity corrosion are those related to 90^0 pipe elbows, passage reductions, especially near welding cords (i.e. where the area is heat-affected due to welding) and where there is a possibility of turbulence or possible impact of the wall with the impurities transported by the fluid in its movement.

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