DETERMINATION OF NECESSARY AND SUFFICIENT NUMBER OF SENSORS IN CASE OF PIPELINES WALLS' STRESS-CORROSION TESTING BY MAGNETIC FIELD LEAKAGE TECHNIQUE

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Abstract: The method of magnetic flux leakage (MFL) is widely used for examination of pipeline wall to detect the presence of internal and external stress-corrosion. The intelligent tool ("pig") in which the MFL method is realized provides the pipe wall material magnetization in the transverse to the pipe axis direction, after magnetization the MFL is registered by magnetic field sensors. The stress-corrosion defects present in the pipeline wall are detected based on information picked up by the sensors. The main problem of defects parameters estimation is the fact that basic measured parameter is subjected to influence of numerous factors including: pipe material respond on magnetization, type of sensor, their placement scheme, pipe wall thickness and gap between measuring elements and pipe surface, etc.

The scheme of examination implemented in the intelligent tool with transverse magnetization comprises magnetic modules in which the magnetic field is perpendicular to the pipe axis. Between magnets located are sensors mounted with preset step. To solve the task of stress-corrosion damage depth evaluation it is required to determine the number of required sensors and distance at which they should be positioned between magnets.

In the paper described is the problem and approaches for determination of necessary and sufficient number of sensors to register the peak amplitude of signal that further on is correlated to the depth of stress-corrosion crack.

Introduction: With increase of pipelines for oil and gas transportation length more urgent and strict become requirements imposed on their reliability. The technical diagnostics of pipelines condition suppose the evaluation of their service life by means of comparison of actual parameters with those obtained with the help of inspection instruments during the preoperational period and in the process of operation; establishing of regularities of aging process and pipe material degradation in concrete conditions.

From the design point of view a single tube or pipe is an independent structural element of the pipeline constructed from metal tubes and joint in a unified system. The failure criterion for the pipeline is the destruction of one separately taken pipe. In case of reliability estimation as a limiting condition is taken a criterion for which the maximal summary longitudinal stresses do not exceed minimal limit of metal yield with taking into account of biaxial stressed state of pipe metal.

Today for pipeline inspection use is made of various NDT methods: radiographic, ultrasonic, magnetic, and electro-magnetic and others. The use of NDT methods for oil and gas pipelines examination is limited by the fact that most of the pipelines are laid underground and there is no access from the ground, i.e. from external side. That is why to perform the examination of pipelines walls with the goal to find out the defects (discontinuities in the wall) existing in them the use is made of equipment for internal pipeline diagnostics, i.e. intelligent tools that are traveling inside the pipeline in the product flow and cause minimal disturbances of standard pipeline operation.

Below the magnetic intelligent tool, in which implement is MFL technique, will be discussed. The main idea of this technique is the following: the magnetic field generated by the constant magnets and electro magnets is induced in the pipe wall, in the places of discontinuities of the pipe wall the magnetic field comes out the limits of pipe wall. The magnetic field over the pipeline wall is measured with the help of matrix of magnetic sensitive elements placed at some distance from each other.

Further will be discussed the procedure how to estimate and determine the distance between magnetic sensitive elements to provide most accurate crack depth evaluation.

Results: When MFL technique is used the examined pipeline part is magnetized to the condition of technical saturation with the help of either constant current, or constant magnets. Presence of stress-corrosion crack in the pipeline wall will cause re-distribution of the magnetic flux along the direction of the least magnetic resistance that, in its turn, will cause the flux leakage in an environment. Flux leakage is registered by the magnetic sensitive sensors. As this takes place, the distribution of normal and tangential components over internal and external cracks will look like presented in Fig. 1 & 2 (a & b) correspondingly.

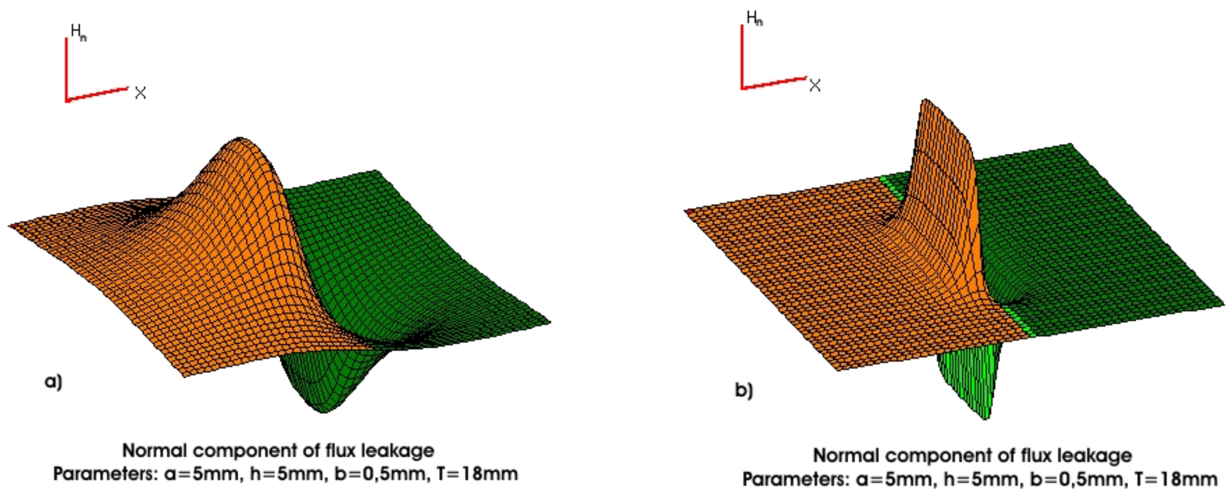

Fig. 1. Distribution of normal component over external (a) and internal (b) defects.

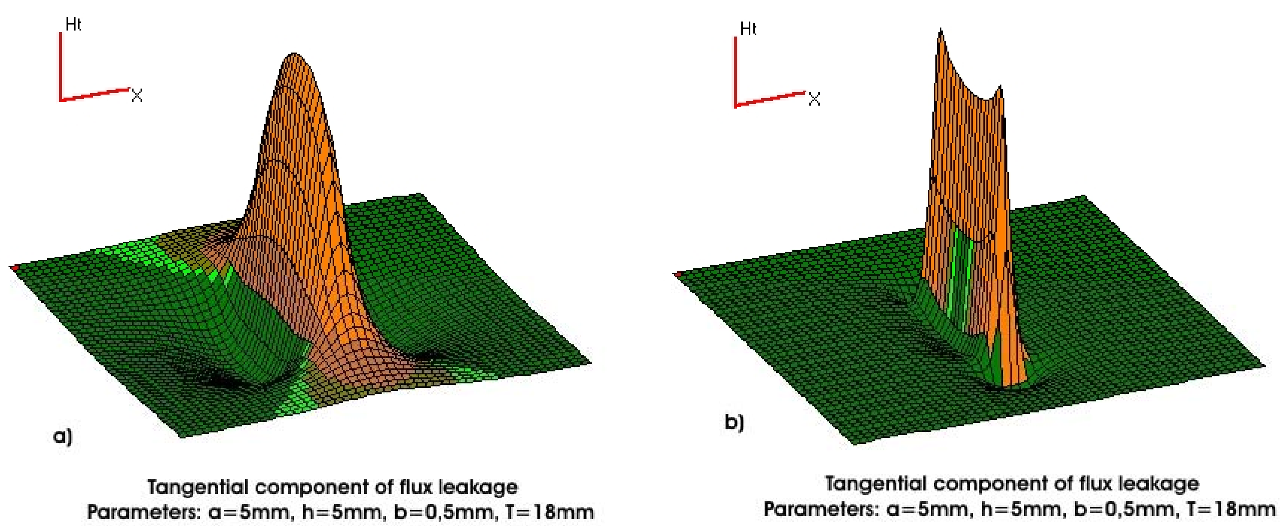

Fig. 2. Distribution of tangential component over external (a) and internal (b) defects.

In the direction perpendicular to the pipe axis and in the middle of the crack, the distributions of tangential and normal components for external and internal defects look as in Fig. 3 (a-d).

For external defects **For internal defects**

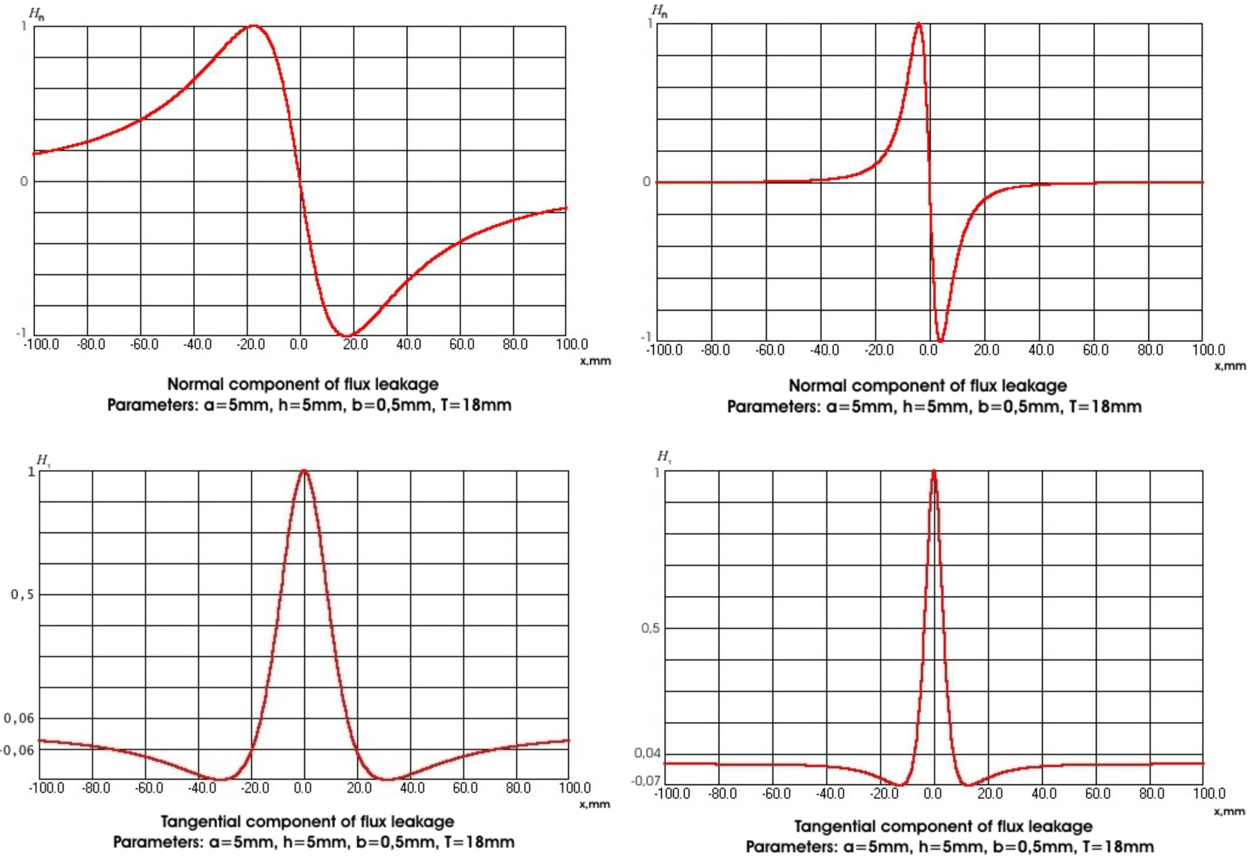

Fig. 3. Distribution in the direction perpendicular to the pipe axis and in the middle of the crack

Further for analysis will be used only tangential component of magnetic field over the internal and external cracks.

In accordance with work [1] they can be described by means of the following formulas:

For the internal crack:

$$H_X = \frac{H_S 2b}{\pi}\left(\frac{a}{x^2+a^2} - \frac{a+h}{x^2+(a+h)^2}\right), \qquad (1),$$

and for the external crack:

$$H_X = \frac{H_S 2b}{\pi}\left(\frac{a+T}{x^2+(a+T)^2} - \frac{a+T-h}{x^2+(a+T-h)^2}\right), \qquad (2),$$

where H_S – the magnetic flux value inside the crack,

2b – crack width,

a – distance between pipe surface and sensor,

h – crack depth,

T – pipe wall thickness.
As it can be seen from the formulas the maximal value H_S is reached when x =0, thus the number of unknown parameters subject to determination is equal to four (H_S, 2b, a, h). Usually **a** is determined from construction considerations or measured directly in the process of examination by individual probe.
When determining the ratio **x/a** – the magnetic flux tangential component for internal and external crack can be presented by the formula:

$$H_X = H_{X\,MAX} e^{-\lambda X^2} \qquad (3),$$

where $H_{X\,max}$ – the maximal value of magnetic flux amplitude

It follows from the formula that to determine the value of $H_{X\,max}$ it is required to have three values of H_X from the curve of tangential distribution of the magnetic flux over the crack.

Discussion: From all stated above it follows that on the segment of tangential component distribution where it can be presented by distribution (3) to solve the task of signal amplitude peak value determination it is necessary to have three point. On this assumption made is the determination of necessary and sufficient number of sensors to solve the task of the crack depth evaluation.
Further considered is practical example of the above statement implementation. Usually the distance between measuring element and the pipeline surface is varying in the limits 3-6 mm due to the mechanical peculiarities of the measuring system. Let assume that a = 6, then for internal crack when x/a $\leq$ 0.5 the error caused by the replacement of distribution (1) by distribution (3) will be approximately 5%. On this basis it is evident that step between sensors should be $\leq$ 2 mm. For the external crack and the pipeline wall thickness of ~ 18 mm at the same error of 5% the step between sensors should be $\leq$ 4 mm. For stress-corrosion intelligent tool for diameter of 1420 mm the number of sensors to determine the parameters of external stress corrosion should be at least 1024.

Conclusions: In the presented paper demonstrated is the approach to determination of the necessary and sufficient number of sensors to solve the task of evaluation of unknown stress-corrosion crack' parameters. Made is attempt to develop the model of magnetic flux over stress-corrosion crack with use of less number of measured parameters that make it possible to find out necessary and required number of sensors.

References: 1. Ф. Ферстер. Неразрушающий контроль методом магнитных полей рассеивания. Теоретические и экспериментальные основы выявления поверхностных дефектов конечной и бесконечной глубины. - Дефектоскопия, 1982, №11, стр.3 – 24. (F. Ferster. Non-destructive testing by MFL method. Theoretical and experimental basis for detection of surface defects of final and infinite depth. – Defectoscopy, 1982, № 11, pp. 3-24)