SOME ASPECTS OF APPLICATION MAGNETIC SCANNERS

Alexander Sedykh, Alexander Kovalenko, Sergey Makarov

JSC “Avtogaz”, Moscow, Russia

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. Magnetic scanner in which the MFL method is realized provides the pipe wall material magnetization, 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 magnetic scanners comprises magnetic module which create the magnetic field in the pipeline wall. 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. There are mention different models of magnetic scanner in the paper.

1. 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. Below the magnetic scanners, 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.

2. 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 Figures 1 & 2 (a & b) correspondingly.

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 Figure 3.

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:

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

For the external crack:

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

where HS – 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 HS is reached when x =0, thus the number of unknown parameters subject to determination is equal to four (HS, 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:

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

where HX max – the maximal value of magnetic flux amplitude.

It follows from the formula that to determine the value of HX max it is required to have three values of HX from the curve of tangential distribution of the magnetic flux over the crack.

3. 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. The results were put in the base of developing and manufacturing of the magnetic scanners by specialists of JSC “Avtogaz”.

The magnetic scanners are designed for reveal and evaluate the defects size, which presents in pipelines walls, welds and tanks for storing crude oil and oil products. At that, separates cracks, cooperative cracks group (stress-corrosion), pitting and general corrosions on the internal and external inspected object surfaces are detected as well as lack of fusion and cracks in welds.

The defects, detected by magnetic scanners showed on the Figures 4-9.

It is necessary to note, that defects with small transverse and longitudinal sizes (smaller the pipe wall thickness) are detected and measured well, if its height more, then defined value, which dependents from the linear sizes of defect.

Because of presence of magnetic noise connected to local changes of magnetic properties of a pipe, caused by change of wall thickness, structure heterogeneity, and other interfering factors, there is some threshold size of detection a defects on depth, which generally makes approximately 5 % of pipe wall thickness.

The magnetic scanners, in which realized the MFL method, provide magnetization ferromagnetic material of the pipe wall to the condition of technical saturation. Then, the magnetic field flow dispersion registers by Hall’s sensors. The defects presents in a pipe wall are identified on the basis of the information, that received from Hall’s sensors.

Nevertheless, the basic problem of defects identification procedure is that fact, that main measurable parameter is subject to influence numerous variable, including speed of moving a measuring system, susceptibility of a pipe material to magnetization, type of sensors and their disposition, thickness of the pipe wall, stresses of the pipe, etc.

So, to solve the task of creation the stable scheme of decoding signals, it is necessary to really represent, how just listed factors and values is influence on disperse of magnetic field flow. The importance and necessity of development the theoretical models for understanding the rules of interaction a defect / signal in conditions of parametrical influence of an environment is doubtless. Therefore, development adequate procedure of definition defects parameters should be based on precise representation of a mutual ratio a defect / signal in conditions of influence multiparametric of environment area.

In the given development applied the new approaches to modeling behaviors the magnetic scanners, working by MFL method, and also solved the inverse tasks for various kinds of defects. At the same time, examination of the pipes walls can be carried out in presence of insulation up to 3.5 mm. Examination productivity for:
- storage tank walls – up to 150 sq. m. per hour;
- pipes walls and welded joints – up to 0.5 m per sec.

The magnetic scanners will look like presented in Figures 10 & 11.

Magnetic scanners have special execution “increased reliability against explosion”. Self-contained power supply provides 8 hours continuous work without battery recharge. The data of examination records to the flash card with next processing on PC.

The software is allows to receive color field of walls pipes and welded joint, to allocate defective areas, to recognize a type of defect, to estimate the sizes, to make binding defect on a examination object and to make the detailed report at once after the inspection (Figure 12).

JSC “Avtogaz” produces different models of magnetic scanner. They are shown in the Table 1.

4. 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. These results were put in the base of developing and manufacturing of the magnetic scanners.

5. References

[1] 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

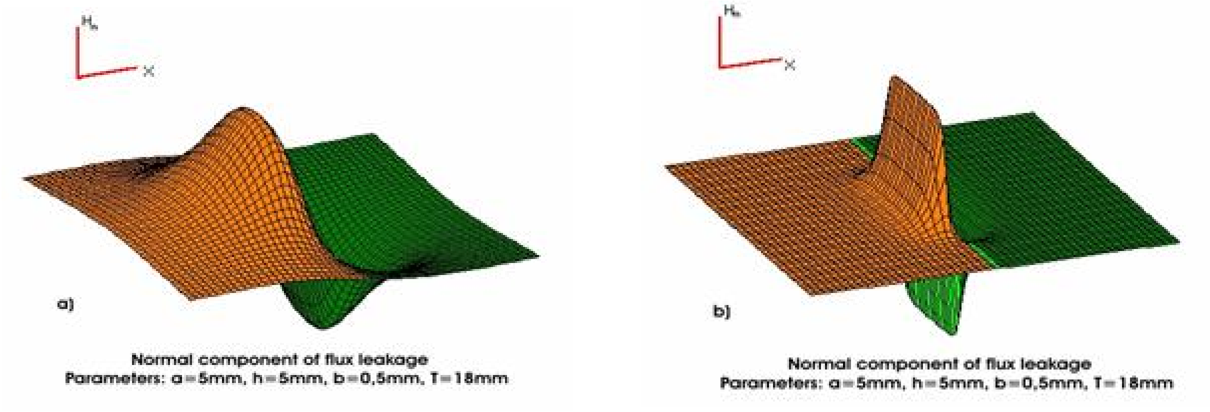

Figure 1. *Distribution of normal component over external (a) and internal (b) defects.*

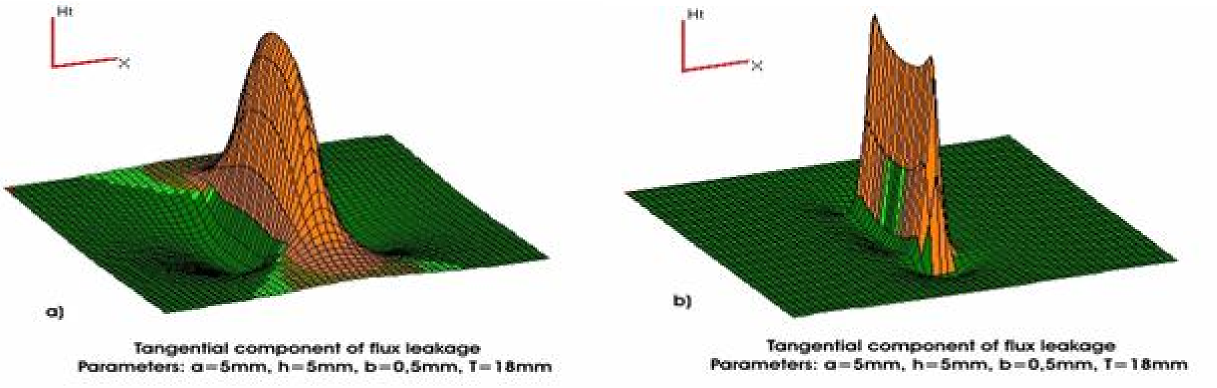

Figure 2. *Distribution of tangential component over external (a) and internal (b) defects*.

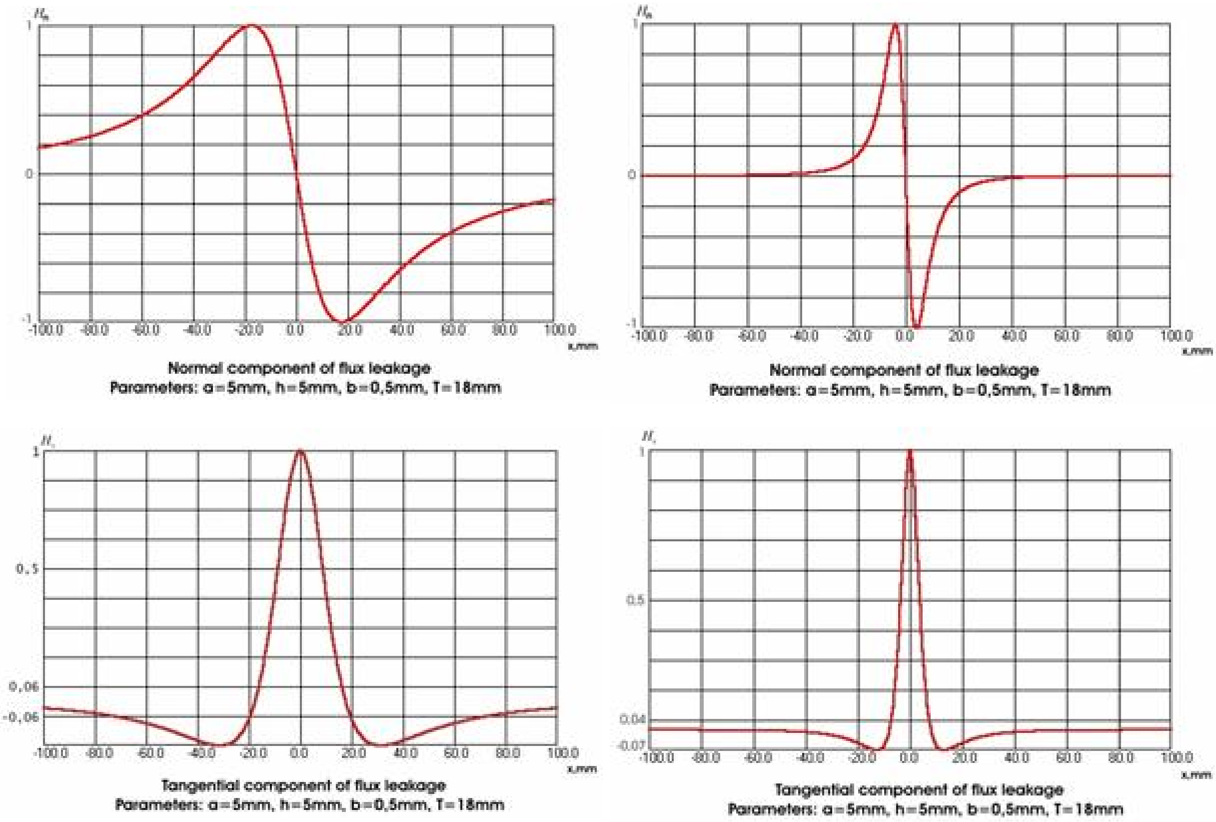

Figure 3. *Distribution in the direction perpendicular to the pipe axis and in the middle of the crack*

Figure 4. *Pitting corrosion, with depth up to 5 mm, on external pipe surface*

Figure 5. *Stress-corrosion with depth up to 5 mm located along longitudinal weld*

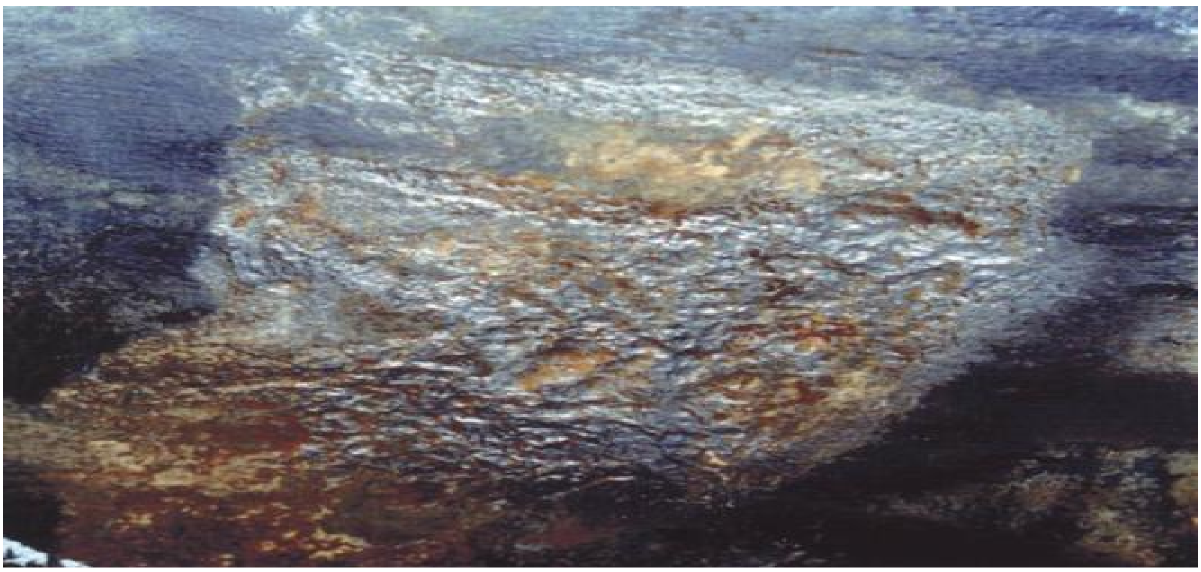

Figure 6. *General corrosion on the chemical stress concentrator (corrosion), depth 6 mm.*

Figure 7. *Stress corrosion cracks with depth up to 8 mm, located along line of fusion of parent material and longitudinal weld (factory made)*

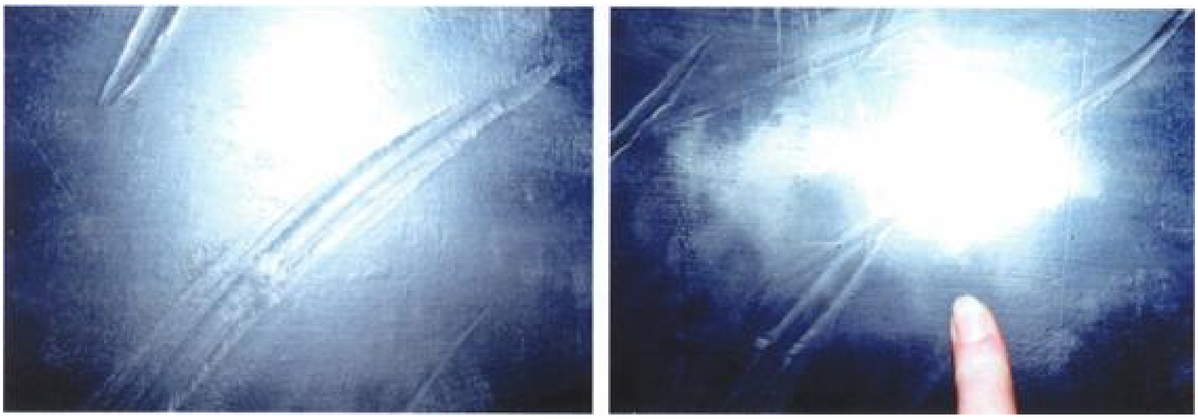

Figure 8. *Dents, depth 3 mm*

Figure 9. *Dents, depth 3 mm*

Figure 10. *Scanner “SKM-J2”, inspection of longitudinal weld joint.*

Figure 11. *Scanner “SKM-T1”, inspection of pipe with diameter 168mm*

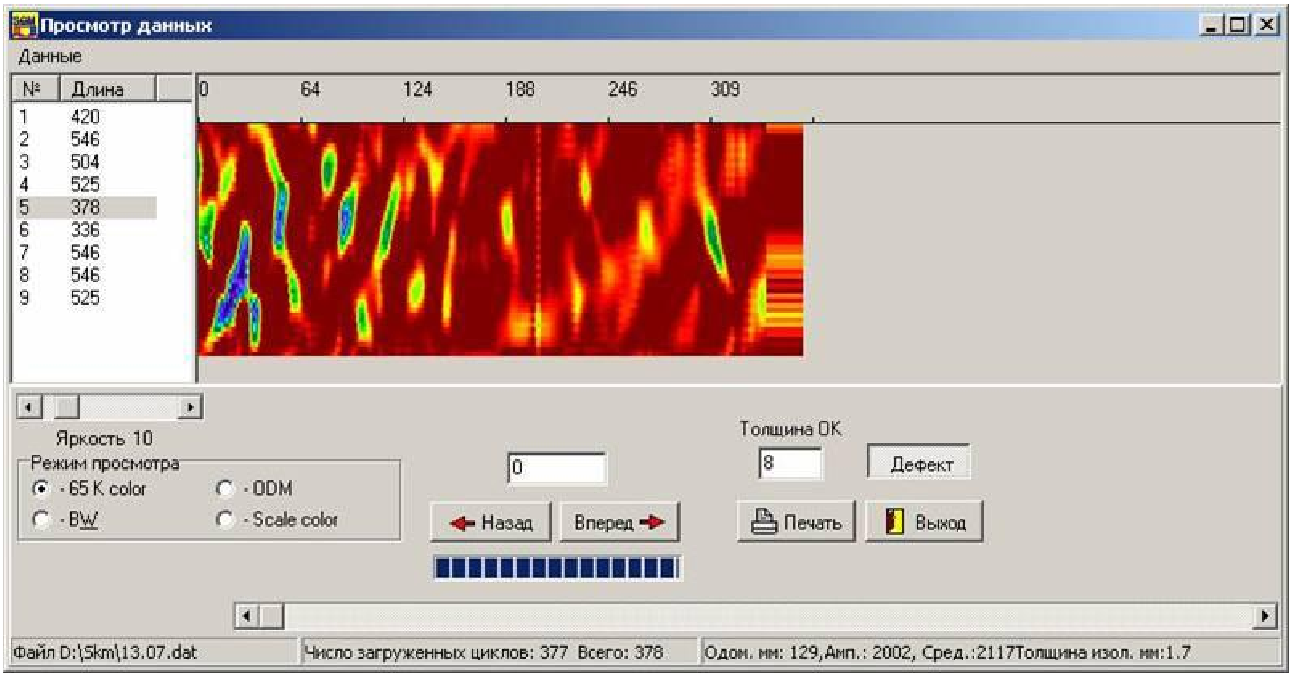

Figure 12. *Image of field distribution over examined area*

Maximal defect depth – 7.1mm
Defect type – numerous groove type corrosion on internal pipe surface (location 3 – 9 hours)

Table 1: *Models of magnetic scanner*

Scanner model	**Examined object**	**OD, (mm)**	**Wall thickness, (mm)**	**The area width examined at a time, (mm)**
SkM - 2	**Walls of storage tanks and pipes**	1420+	up to 18	130
SkM – T1	**Pipelines' wall**	114 – 219	up to 12	110
SkM – T2	**Pipelines' wall**	245 – 426	up to 15	110
SkM – T3	**Pipelines' wall**	450 – 1020	up to 16	110
SkM – T4	**Pipelines' wall**	1220+	up to 18	130
SkM – J1	**Storage tanks and pipelines welded joints and nearby areas**	1020 – 1220	up to 12	50
SkM – J2		1420+	up to 18	50