NoPig: a new inspection technique for non-piggable pipelines

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Abstract

Non-piggable pipelines account for thousands of kilometres around Europe alone. The integrity management of these pipelines requires some non-destructive evaluation techniques, which can be applied without inserting inspection tools into pipelines. Some indirect techniques like DC voltage gradient or current mapping are used for this purpose. These methods can detect coating damages like holidays and thus can only be used for external corrosion detection, they give no information regarding metal loss. The NoPig technique was developed as an alternative (or supplementary) technique for inspecting unpiggable pipelines. The performance of the NoPig technique was significantly higher than existing corrosion detection and could also detect metal loss. The NoPig technique has been extensively tested with natural as well as artificial metal loss defects under field and laboratory conditions. The NoPig technique has been used successfully across Europe and overseas for inspecting gas, oil and fuel pipelines. The principle of the NoPig technique is based on measurement and analysis of the surrounding AC magnetic field around the inspected pipeline. The magnetic field is induced by the AC current passed through the pipeline from a special current source. For this purpose two contact points maximum 1 km apart must be available on the pipeline. The range between the contact points will be inspected. The inspection tool contains a sensor unit and a data collector unit. In the sensor unit many magnetic field sensors are combined to cover a step length of 1 m. During inspection the tool will be moved step by step above ground over the pipeline. On this matter the whole distance between two connection points will be inspected. The magnetic field data is obtained and analysed at different frequencies. Due to the skin effect and stray magnetic flux (in case of metal loss) a frequency-dependent difference in magnetic field data takes place if a metal loss is present. Using this principle metal loss defects will be detected. Information concerning metal loss the depth of coverage and current plots are supplied after a NoPig inspection. The current plots are used for detection of current leakages through damaged coating. The NoPig inspection tool can be used for seamless as well as for long seam pipelines within the diameter range of 3” to 16” (TÜV certified) which can be extended towards large diameters to 36” (experimentally tested). Both external and internal metal loss defects can be found.
1. Introduction

Oil and gas pipelines are vital for product transportation across the globe. Pipeline integrity is the most important factor for safe, secure production and transportation. Although practically all pipelines are operated using cathodic protection (CP) as an anti-corrosion measure, a lot of undesired environmental factors are present which lead, despite CP, to corrosion of pipelines. To avoid hazardous development of corrosion in pipeline walls some different techniques are actually in use. The mainly used ones are: (i) water pressure test, (ii) inline inspection (intelligent pigging) [1], (iii) DC voltage gradient survey (DCVG) [2], and (iv) current mapping (CM) [3]. Inline inspection is the only method that gives direct information about the condition of the pipeline wall. Unfortunately not all pipelines can be inspected using intelligent pigs. The main limitations of inline inspection are their inability to inspect varying inner diameters of pipeline joints, the tool is sometimes unable to negotiate acute bends/valves and the inherent lack of pig launches/receivers in pipelines. The other techniques either deliver only “passed” / “not passed” assessment (hydrostatic pressure test) or indicate a damaged pipeline coating which probably can lead to corrosion and needs the line to be exposed for physical verification.

As an alternative to indirect survey techniques for unpiggable pipelines a new method called “NoPig” was developed by N.P. Inspection Services in Hildesheim, Germany. This development was started in 1998 with experimental and analytical investigations including modelling which resulted in patents [4, 5]. During this time a lot of important tests and certifications were completed. The NoPig method delivers information about metal loss, girth weld positions, depth of coverage and coating defects of an inspected pipeline. The NoPig inspection is performed above ground along the Right Of Way (ROW) of the pipeline. Two electrical contacts to the pipeline on the edges of the inspected range are needed.

Since the year 2000 the NoPig technique has been extensively used in the oil and gas industries. In this time many tests and improvements to the equipment have been performed which has culminated in the award of a TÜV certification in 2006 for the technology. The NoPig technique can be used for inspection of unpiggable pipelines in a wide range of diameters from 3” to 36” whilst remaining truly non-destructive and as the product line can operate normally during inspection which is completely non-obtrusive to operations.

2. The NoPig Method

The NoPig method is based on an above ground measurement of the magnetic field induced by an alternative test current which is passed through the buried pipeline that is being inspected. The test current comprises multiple harmonic components with frequencies from a few Hertz to a few hundreds Hertz. The outer magnetic field induced by this current is surrounding the pipe. Due to the skin effect the current distribution in the pipeline wall is frequency-dependent. The harmonic components with lower frequencies are flowing through the whole wall cross-section, whereas the harmonic components with higher frequencies are flowing mainly through the thin layer under the outer surface of the pipe. Because the pipe is made of a ferromagnetic steel, the other physical effect plays here an important role for the metal loss recognition. This is the stray magnetic flux from the pipe wall. Similarly to the current, the magnetic field distribution in the pipe wall toward the radial direction is also frequency-dependent. Due to relatively high magnetic permeability of the steel, the magnetic field density in the pipeline wall is much higher than outside the wall. In case a metal loss defect is present, the magnetic field appears (strays) from the wall over the defect. This leads
to a corresponding deformation of the surrounding magnetic field. This effect is also frequency-dependent.

In case of a pipe without any metal loss defect (Fig. 1a) the surrounding magnetic field lines 1, 2 and 3 are circular and their position and intensity are independent on frequency. Quite a different situation takes place if a metal loss defect is present (Fig. 1b). In this case the surrounding magnetic field lines are egg-shaped and their shape is frequency-dependent. For the lowest frequency the three magnetic field lines 1, 2 and 3 are shown in Fig. 1b which have the same field intensity like the corresponding field lines in Fig. 1a. If the metal loss defect is inside the pipe the deformation of magnetic field lines is similar. At the highest frequency the deformation of the magnetic field lines is vanishing small.

**Fig 1.** Magnetic field lines for 3 different field densities at the lowest frequency: $I = B_1$, $2 = B_2$, $3 = B_3$ ($B_1 > B_2 > B_3$). 4 = measuring point. (a) – pipe without metal loss, (b) – pipe with metal loss.

Using the measurement and comparison of the magnetic field outside the pipe (e. g. at point 4 in Fig. 1) at different frequencies it is possible to clearly recognize between the situations “with metal loss” and “without metal loss”. This is the basic principle of the NoPig method. Instead of one sensor in the NoPig system, 6 sensors are used in one line which is perpendicular to the pipe. This allows the determination of the depth of coverage and the actual current flowing through the pipe. Additionally a higher sensitivity of the system is achieved. For a higher productivity of the inspection 4 sensor lines are used which are placed next to one another in the inspection direction along the pipe. On this way a 6 x 4 matrix of sensors is built – the so called Sensor Array (SA) (s. Fig. 2a).

The sensor array has extension of 0.75 m along the pipe, thus it covers 1 m of the pipe length in one inspection step without overlapping. The sensors measure the horizontal component of the pipeline’s surrounding magnetic field (Fig. 2b). The output signals from the sensors follow to the Data Collector Module (DCM) where they are digitalized, stored and used for the determination of the pipeline position related to SA and the actual current in the pipeline. DCM comprises a display which is used to show graphically the actual pipeline position
(depth of coverage and displacement). This supports correct orientation of the SA above the pipeline at every step of the inspection.

Fig. 2. (a) Sensor Array in the measuring position over the pipeline; (b) sensor line in the measuring position ($B_1 > B_2 > B_3$) over a metal loss defect.

The stored magnetic field data will later be evaluated at the offices of NP Inspection Services. For the evaluation an analysis algorithm called Differential Magnetic Field (DMF) Analysis is used which is based on a 2D comparison and filtering of magnetic field data for all used frequencies of the test current. For this purpose a special software is used which comprises different filtering algorithms. This filtering allows an essential enhancement of the NoPig system sensitivity and the reduction of different kind of interferences from outside, like magnetic field from power lines, moving vehicles etc. This software has been developed by NP Inspection Services specially for the NoPig system. Finally as output of this analysis the data about metal loss, girth weld positions, depth of coverage and current leakage through the coating will be delivered.

The NoPig method inclusive the system was tested and certificated by TÜV South (TÜV is a German institution for the quality control and certification in industrial branches, service and commerce). This certification is based on the testing of both artificial and natural defects under laboratory and field conditions. Corresponding to the Technical Specifications certificated by TÜV the NoPig system is applicable for inspection of buried steel pipelines independent on the transported product. It can be gas, oil, fuel and even water or chemicals. The pipeline diameters can be from 3” to 16”. For these pipelines the defects will be detected which are not smaller than 50 mm x 50 mm and have the metal loss at least 50%. The Probability Of Detection (POD) for these defects is about 96%. Pipelines with a larger diameter can be inspected as well, but POD for these diameters is not yet defined. These parameters are given for the depth of cover up to 1.5 m. From 1.5 m to 2.0 m the dimension the smallest detectable defects are 150 mm x 150 mm with metal loss of at least 50%. The NoPig inspection system can be used on both seamless and longitudinally welded pipelines, spirally-welded pipelines cannot be inspected. This reason is that the NoPig method was initially developed for rather small pipeline diameters (up to 16”) where spiral-welded joints are very seldom. From the basic consideration of the method there is no fundamental
limitation for such pipelines, but lack of experience and, consequently, a corresponding algorithm for the data filtering to the moment do not allow use of the NoPig inspection technique for spirally welded pipelines.

3. Performing a NoPig Inspection

A NoPig inspection begins with deposition of the connection cable between the NoPig Current Source (CS) and the pipeline connection points. As connection points different contact possibilities can be used: available CP posts, above-ground parts of the pipeline or build-in valves, and the pipeline itself in wells specially prepared for the inspection. For one range only two contacts are necessary. The inspection will be performed between these two contacts (Fig. 3).

Fig. 3. Schematic presentation of the NoPig inspection and the conditions needed to perform it.

The maximum distance between the contacts is 1 km. The cable must have the distance to the pipeline of at least 50 m. The terrain for the cable must allow its deposition. This means that nor railroads, neither high traffic roads, neither rivers or creeks wider than 5 m are allowed crossing the way of the cable. When the cable connection is finished, the inspection team sets the test current from CS through the pipeline and starts the inspection from one contact point toward the other one. The inspection is performed step by step over the whole length of the connected pipeline part (Fig. 4).

During the measuring of the surrounding magnetic field the SA of the NoPig system must lie flat on the ground for the measuring time which is approximately 17 sec. Thereafter the SA and DCM must be moved on the next position which is 1 m apart from the actual one. The monitoring of the pipeline position on the DCM display allows the crew a correct position of the SA over the pipeline. The ROW over the pipeline in the width up to 3 m must be accessible and free of obstacles like a strong vegetation or rubbish on the whole length of the inspected range. Metal construction parts on ROW evoke magnetic field interference and thus reduce the sensitivity of the system.

The NoPig inspection technique can be used for particularly or totally unpiggable buried pipelines. If a pipeline is piggable the NoPig technique can be used for regular monitoring in ranges where intelligent pigging has indicated small defects which have not been repaired. In this case NoPig is an inexpensive alternative to verification digs for monitoring.
Assessment Approach the NoPig technique can be also used as a test approach to estimate possible metal losses before a suspicious range of a pipeline will be dug out.

Fig. 4. The NoPig crew during inspection.

4. Performing a NoPig Inspection

Since introducing the NoPig inspection technique to the market many inspections have been successfully completed on oil and gas pipelines. The terrain inspected has mainly been field or farm land, but in some cases inspections have been conducted in suburban areas and even cities. Defects found have been both outer and inner corrosion and the diameter of inspected pipelines has been from 3” up to 36”. Below two examples of found defects are shown: an outer defect in a gas pipeline (Fig. 5) and an inner defect in a crude oil pipeline (Fig. 6).

Fig. 5. An outer defect found in a seamless gas pipeline. OD = 16”, nominal WT = 10 mm, length: 250 mm, width: 450 mm, metal loss: 58%.

Fig. 6. An inner defect in a seamless crude oil pipeline. OD = 6”, nominal WT = 4.8 mm, length: 56 mm, width: 48 mm, metal loss: 52%.
5. Conclusion

The NoPig inspection technique is a new above-ground technology which can be used on gas, oil, fuel, water etc. pipelines made of steel in a wide range of diameters, from 3” to 36”. The preparation for the NoPig inspection is simple and does not require cost-intensive launches and the prior cleaning of pipelines which is usually the case if an inline inspection was to be made and that during inspection product transportation is not affected. The best sensitivity of the NoPig method can be achieved under field conditions for buried pipelines which depth of cover is below 1.5 m. The NoPig method is constantly being developed and enhanced to achieve a higher resolution report with greater detection of smaller defects. N.P. Inspection Services specialists have to their disposal a long-standing experience in the application of the NoPig technique, and this experience increases with each new inspection.

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References