NON-DESTRUCTIVE TESTING OF PIPELINES

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Abstract

This paper shall present different, contemporarily available non-destructive testing (NDT) methods of pipelines and compare them to each other from the technical and economical point of view. An evaluation of their suitability for CERN activities, based on the opinions and experience of various specialists at CERN (LHC, ST, TIS), is also introduced.

1 INTRODUCTION

This paper will present five different non-destructive testing (NDT) methods suitable for pipelines. Their principles, advantages and disadvantages will be described and their suitability for CERN use evaluated. The aim is to raise discussion on the applicability of other NDT methods than radiography, at CERN.

2 NDT METHODS FOR TESTING OF PIPELINES

2.1 Radiography

Radiography is the most commonly used non-destructive testing method for pipeline inspection. The principle is that a source of radiation is directed toward the inspected object. A sheet of radiographic film is placed behind the object. The setup usually takes a few minutes, the exposure 1-10 minutes and film processing about 10 minutes.

Advantage of this method is its reliability. Nowadays digital images can also be used and information saved and transported by computers. Disadvantage is the radiation danger. [1]

2.1.1 SafeRad Radiography

Radiography method, where no radiation danger is present, has been developed and patented in UK. This eliminates the personnel evacuation and does not cause any work disruption. The method is otherwise similar to the before-described radiography but it uses together a flexible radiation attenuating material to block the radiation and a special exposure container where the radiation beam can be controlled in such a way that only the area of the sample under examination is exposed to the radiation. This way the radiation controlled area can be reduced to as little as 1 meter from the exposure container. [2]

The method is a bit more expensive than the “conventional” radiography, but on the other hand there is no need to evacuate and therefore cost savings could be achieved. As a slight disadvantage could be seen the extra time needed to wrap the pipes with the radiation attenuating material.

2.2 Ultrasonics

Ultrasonics is used as an NDT-method to evaluate the integrity of automatic welded pipeline girth welds. The principle is to employ high frequency acoustic waves to probe the inspected sample. As the acoustic wave penetrates the sample, the wave is attenuated and/or reflected by any change in the density in the material. By observing the returned signal many of the characteristics of the material can be determined.

Setup takes less than an hour and scanning time varies from a few minutes to hours depending on the size of the sample and the desired resolution. Advantages are that there are no health risks for the environment, and it is possible to define very accurately where the defect is located and how big it is. On the other hand the suitability for thin objects, like pipes, is restricted. Ultrasonic inspection also requires that the inspecting technicians must be very experienced in order to get reliable results. [1, 3]

2.3 Eddy Current

In eddy current testing, a time varying magnetic field in induced in the sample material by using a magnetic coil with alternating current. This magnetic field causes an electric current to be generated in conducting materials. These currents, in turn, produce small magnetic fields around the conducting materials. The smaller magnetic fields generally oppose the original field, which changes the impedance of the magnetic coil. Thus, by measuring the changes in impedance of the magnetic coil as it traverses the sample, different characteristics of the sample can be identified. The testing time is usually a few hours. Eddy current method has a limited depth of penetration, 4…8 mm only. [1,3] In pipe industry it is however a widely applied inspection method. It is suitable for detecting for example porosity, cross and seam cracks and checking seams and butt welds. The testing method is relatively simple and costs moderate. [6]

2.4 Fluorescent or Dye Penetrant

This method is suitable for detection of cracking and porosity in welded joints. The principle is that the surface of the sample is coated with a penetrant in which a colorful or fluorescent dye is dissolved or suspended. The penetrant is pulled into surface defects by capillary action. After a waiting period to insure that the dye has penetrated into the cracks, the excess penetrant is cleaned from the surface of the inspected part. A developed, a white powder, is sprayed over the part. This lifts the penetrant out of the defect and the dye stains the developer. By visual inspection under white or ultraviolet light, the visible or fluorescent dye indications can be identified defining the defect. Less than one hour is usually required as an inspection time. The method is a lot cheaper compared to radiography or ultrasonics, but can only detect external defects. [1,3]

2.5 Magnetic Particle

Magnetic particle method can be used for identification of surface or near-surface defects. The principle is that the sample is magnetized by dusting magnetic particles over it. A surface defect will form a magnetic anomaly, attracting and holding magnetic particles and thus giving a visual indication of the defect. The evaluation time is typically few minutes. The sample must be ferromagnetic and therefore this technique can not be used on most stainless steels. This method also is a lot cheaper compared to radiography or ultrasonics, but like the dye penetrant, it only can detect external defects. [1,3]

3 SUITABILITY OF DIFFERENT METHODS AND USE AT CERN

Figure 1 presents for what kind of testing the different NDT-methods are suitable. [3] Table 1 concludes some of the opinions and experiences of CERN piping specialists regarding the NDT-methods presented in this paper. [4]

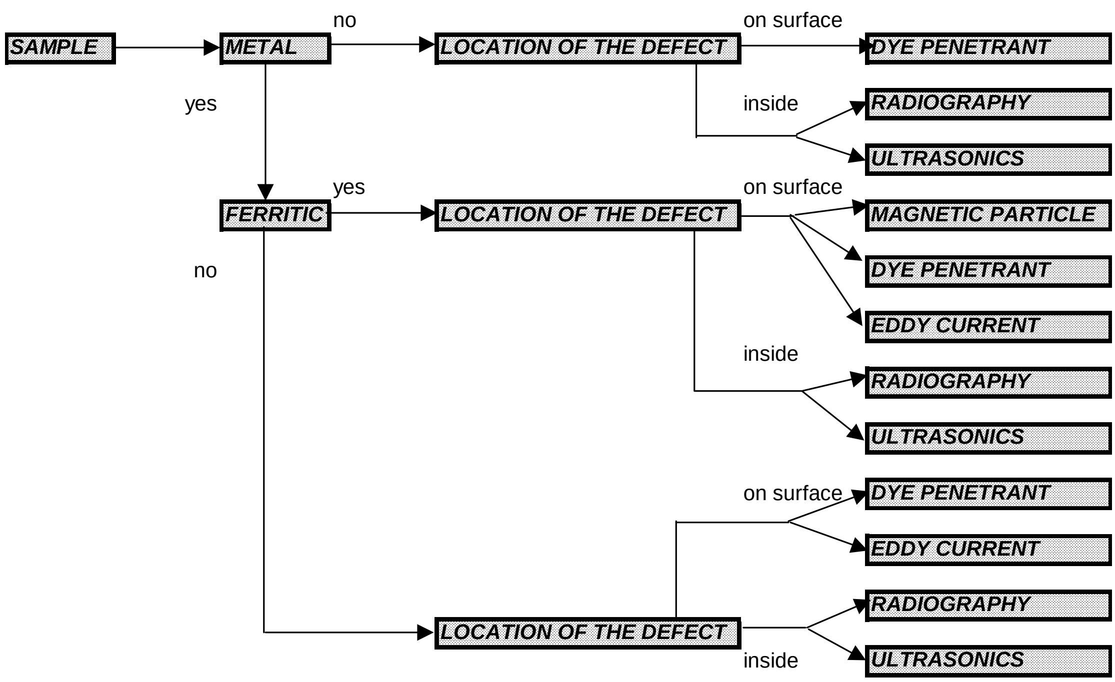

Fig. 1: Suitability of different NDT-methods

	LHC	ST	TIS
RADIOGRAPHY	The most reliable	The most reliable	The most reliable
SAFERAD	Never used, no opinion	Never used, interesting	Never used, interesting
ULTRASONICS	Not used, may not detect all the possible defects	Used sometimes for measuring thickness	Complementary to radiography, for aluminium and carbon steel a very good method, particularly for detecting corrosion inside pipelines and vessels
EDDY CURRENT	Allowed for the required 10% testing of longitudinal welds in pipes	Used in testing heat exchangers	Not used
DYE PENETRANT	Not good enough for CERN pipes since only detects external cracks	Used in testing heat exchangers and if radiography is not possible	Used when any other technique is not suitable, f.ex. angle weld, fast and cheap
MAGNETIC PARTICLE	Not good enough for CERN pipes since only detects external cracks	Not used	Not used

Table 1: CERN specialists' opinions on the presented NDT methods

4 COST COMPARISON

Cost associated in evaluating welds in pipes depends on what kinds of defects are being looked for. Dye/fluorescent penetrant and magnetic particle methods are cheap but they only can detect external defects. Radiography and ultrasonic methods can detect basically all defects in welds, but generally speaking radiography has a better cost/result quality ratio. On the other hand for checking aluminium and carbon steel pipes, ultrasonic method is may even be a better option. Eddy current is moderate regarding costs but still the radiography gives more reliable results.

4.1 Case Study

A real case study of the costs between "conventional" radiography and SafeRad radiography was got from a private company in UK. [3]

The example presents costs typical for a gas plant shutdown: Loss of revenue for a typical gas plant per day is in the order of $1million; for every hour that the plant does not produce it is losing $42000 in revenue. Costs for manpower, equipment etc are in the order of $100k per day; for every hour the shutdown costs are $4200 per hour. If the site is evacuated or partly evacuated for radiography then these are the costs that can be assumed. Conversely, if the radiography can be carried out without evacuation then these are also the 'savings' that can be achieved when comparing SafeRad radiography with traditional methods.

The cost for producing a radiograph using traditional equipment: A 6" butt weld would normally be covered using 3 shots; each shot including film and reporting would normally cost about 13.4 CHF in the UK. ie 3x 13.4 CHF = 40.2 CHF. It would be possible to carry out 20 -30 complete butts per 10-hour shift. These figures above need to be added to the evacuation costs. To compare with SafeRad radiography: it would be possible to carry out 15-20 per 10-hour shift, but no evacuation costs.

5 CONCLUSIONS

Radiography is the most common pipeline testing method at CERN, and favored by TIS, ST and LHC divisions for its reliability. The disadvantage is the radiation danger, and therefore for example in CERN tunnels, people must be evacuated when radiographic inspection is being done. For this reason inspections must be well scheduled and coordinated with other workers.

SafeRad could be a good alternative for the “conventional” radiography at CERN. Ultrasonic inspection might be an option as well depending on the material of the pipes. Additionally it must be remembered that the inspecting technicians must be very experienced in order to get reliable results. By using radiography this is not such a significant factor.

Eddy current might be a method worth closer investigation. This method is widely used in the United States nowadays, maybe CERN could use it more as well, especially since it can be applied to all metals and the method is quite simple.

There is also a way to reduce the amount of NDT - by using TIG automatic orbital machine welding in piping projects. In this case inspections can be done by sampling; if the first inspected sample welds have 100% conformity, the percentage of inspected welds on the following samples will be gradually reduced. [5] This is an interesting and attractive option generally speaking for pipelines at CERN and worth considering by the project managers.

REFERENCES

[1] http://www.nde.lanl.gov

[2] SafeRad Ltd, Durham, United Kingdom

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[5] TIS/TE/MI/CM 00-14: “Recommendations for on-site installation of welded pressurized pipelines”

[6] Brian Roberts, Prüftechnik NDT GmbH, Germany: “Applying Eddy Current Inspection”