Combined Application of In-Line Inspection Magnetic Technologies for Detection of Stress Corrosion Cracks in GAZPROM "Yambourg - Elets-1" Gas Pipeline

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Many Russian big diameter trunk gas pipelines in Ekaterinburg area had stress corrosion cracks (SCC) in mid-1990s. It resulted in ruptures of gas pipelines. Yambourg-Elets-1 Gas Pipeline 56" diameter was ruptured up to 3 times per year caused by stress corrosion cracks at that period. In 1999, Spetsneftegaz NPO JSC inspected it, using its brand new invention: high resolution transverse flux inspection (TFI) in-line inspections tool, which enabled to detect, size and locate all emergency stress corrosion cracking zones. Based on results of TFI information, GAZPROM replaced all pipes with stress corrosion cracking zones in the mentioned pipeline during the same year.

Aims

Main aims of in-line inspection on this pipeline with high stress corrosion cracking (SCC) damage level were to prevent both explosions and SCC growth. This pipeline is unique by the number of in-line inspections, which were carried on this pipeline. Since 2001 in-line inspection were performed each year. This allowed making an analysis of SCC and general corrosion growth rates.

On most pipelines the period between in-line inspections is 5 or 10 years. If pipelines are suffered by SCC of northern type it is known 3 year period is enough for keep pipeline safe. So, most of the pipelines operators do not have experience of performing in-line inspection each year.

What kind of information can be get performing in-line inspection each year? First of all, it is information of required period of in-line inspection for SCC damaged pipelines. It seems to be obvious to get general corrosion growth rates. But, comparing real corrosion growth rates on pipelines with corrosion protection potential being in good conditioning with accuracy level of magnetic in-line inspection, it becomes clear, that no growth rates can be determined. Thus, one year period in-line inspection can be used as a tool for estimating variance of defect parameters determined by in-line inspection tool.

This is very powerful instrument for estimating the value of random errors of in in-line inspection. Using this information provides an estimation of accuracy which can be achieved by calibrating in-line inspection results by number of defect field measurements during digging operations. And such estimation is the second aim of this works.

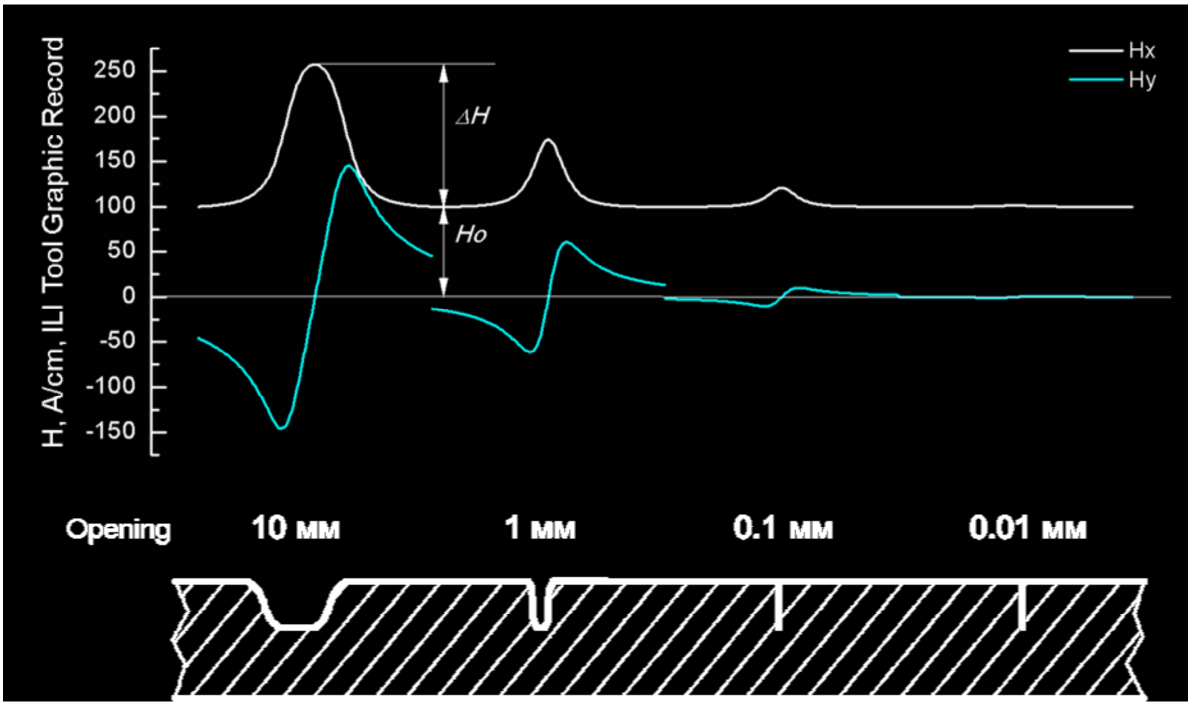

Fig. 1 Crack field opening dependence

Methods

Technology of combined application of TFI and MFL in-line inspection tools is the main one for detection of stress-corrosion cracks in Russian trunk gas pipelines. Among this a number of additional information is used for defects identification and assessment. Authors of this paper call it a Multiply Approach.

In-line inspection of ageing pipelines is complicated by increased quantity of combined pipeline defects, when corrosion damages are accompanied by mechanical and/or pipe manufacturing defects as well as stress corrosion cracks of longitudinal or transverse orientation. It means that traditional approach to in-line inspection aimed to detect, identify and size corrosion damages and girth weld defects, using only MFL ILI tools, is insufficient. Stress corrosion cracks and other longitudinal defects can be reliably detected, identified and sized only using TFI ILI tools. To detect combinations of pipeline defects, multiply approach is recommended, including the principles as follows:

- Detection, identification and severity assessment of pipeline defects must be based on clear understanding of physical reasons of defects origination and growth
- Any pipeline damage must be investigated, using maximum possible combinations of available ILI technologies
- The data obtained by using combined ILI technologies, must be compared and overlapped aimed to obtain unanimous picture
- Identification and severity assessment of pipeline defects must be performed on the basis of analysing the data, obtained as result of using combined ILI technologies.

However, sensitivity of TFI ILI tools for detection of stress-corrosion cracks is limited. This is caused by nature of magnetic methods of non-destructive testing.

Signal amplitude mainly depends on crack opening (Fig.1), though continuous upgrading of magnetic systems of in-line inspection tools and relevant data treatment make it possible to detect SCC colonies with opening of single cracks more than 50 micro meters.

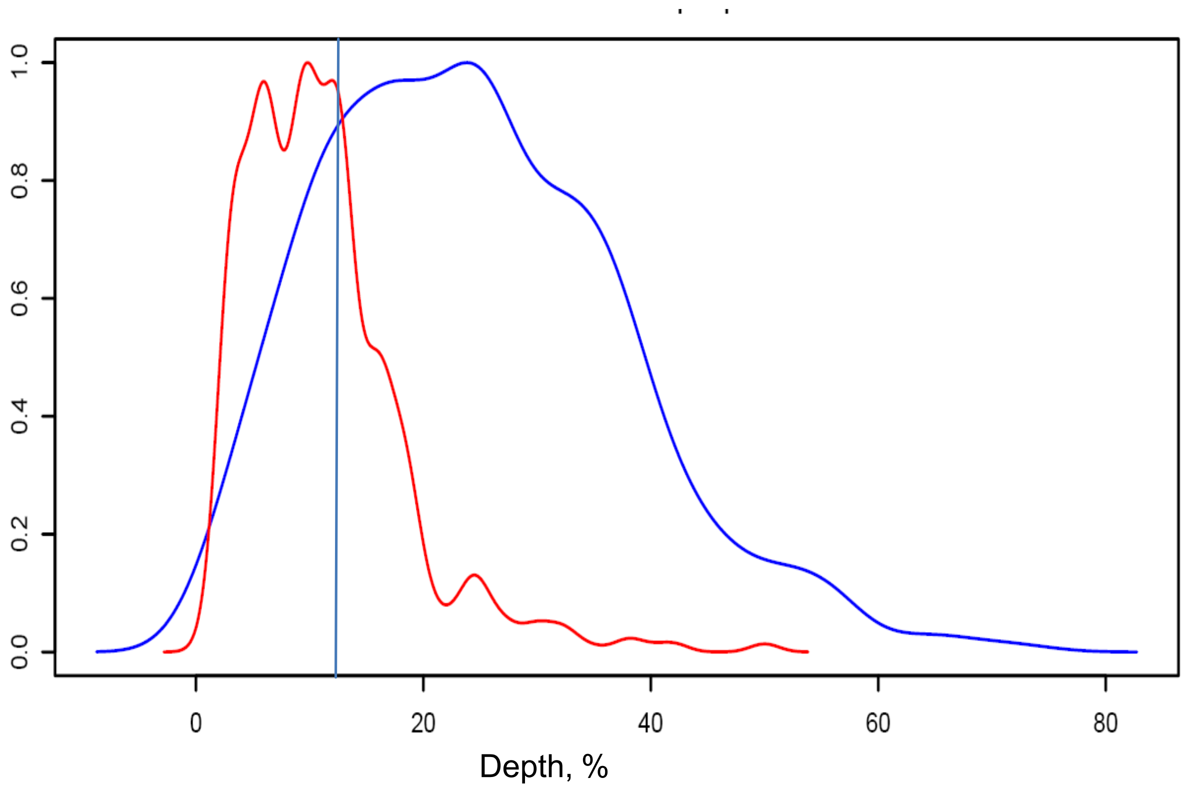

Fig 2. Relative number of confirmed SCC (blue line) and relative number of missed SCC zones (red line)

Having analyzed 1411 SCC colonies, which were confirmed by digging excavations, the graph of sensitivity of TFI in-line inspection tools was compiled (Fig. 2). This graph testifies to the fact that sensitivity level (the middle line between confirmed defects and missed defects)

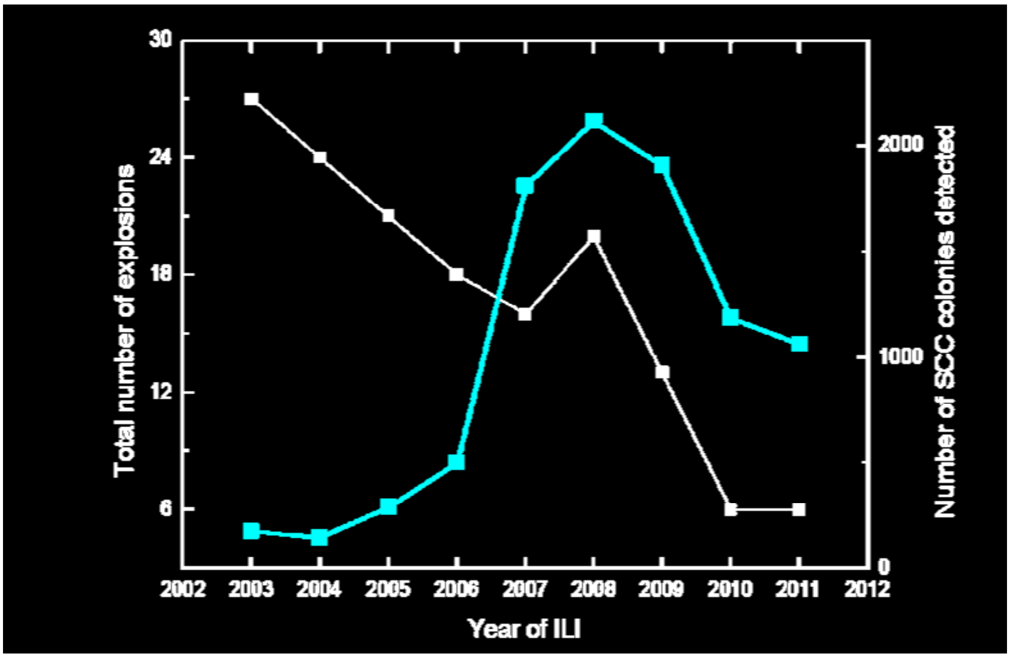

Fig. 3 SCC dynamics in Russia gas trunk pipelines

makes up 15-20% pipe wall thickness. Such result was reached after three upgrades of TFI in-line inspection tools in 2003, 2007 and 2011.

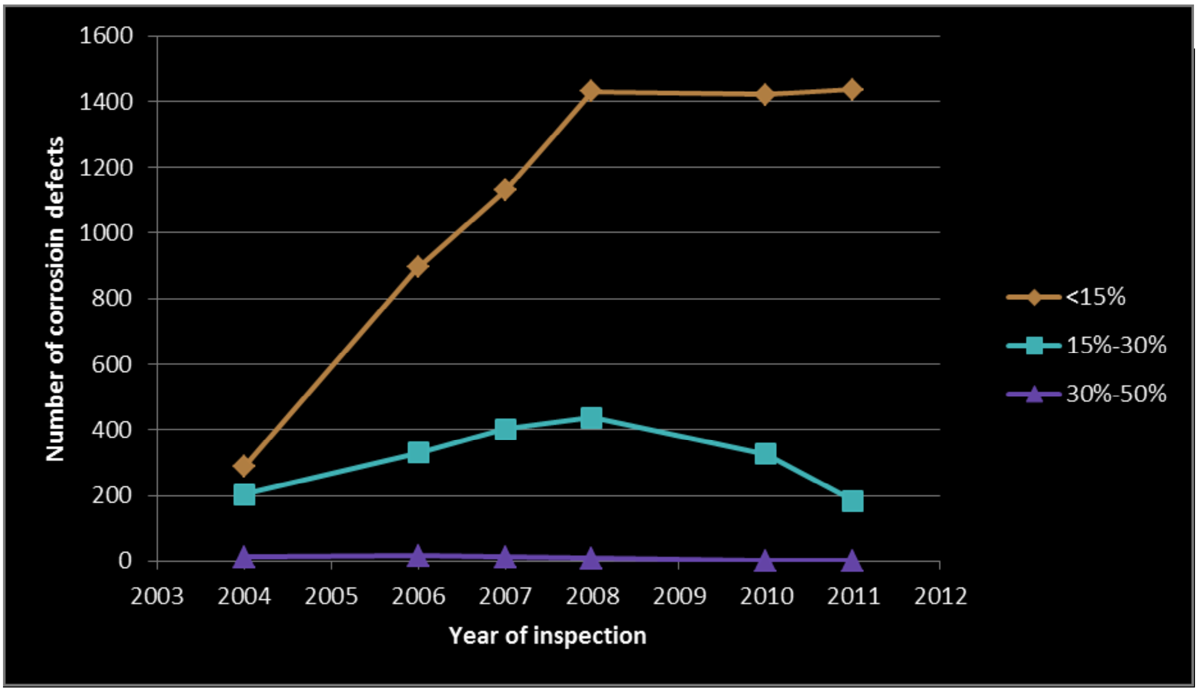

Fig 4 General corrosion dynamics in one pipeline section

SCC dynamics on pipeline section under consideration

Growth of sensitivity of magnetic in-line inspection tools resulted in total reduction of emergencies of trunk gas pipelines in Gazprom JSC, with due regard that growth of quantity of stress corrosion cracking defects was observed prior to 2008, that shows high efficiency of application of magnetic in-line inspection technologies for detection of stress-corrosion cracks (Fig.3).

Yambourg-Elets-1 Gas Pipeline Operator Daughter Company of Gazprom Unified Gas Transmission System took decision in early 1990s to perform in-line inspection of the mentioned gas pipeline every year, because it was heavily damaged with SCC colonies. In the period from 1999 to 2003, the total of 25 km pipes were replaced in that pipeline. It enabled to stabilize situation with stress-corrosion. Nevertheless, a lot of SCC colonies still remained. Since 2004, the number of SCC has been extremely small. And since 2009, the mentioned gas pipeline has no stress corrosion cracking defects.

We have analyzed dynamics of SCC damages of the Yambourg-Elets-1 Gas Pipeline in the period from 2004 to 2011. Besides, pipeline repair operations were also analyzed.

The given graphs (Fig.4, Fig.5) show reduction of quantity of general corrosion defects due to growth of sensitivity of magnetic in-line inspection tools, while situation with quantity of stress-corrosion cracks remains at stable low level, in spite of the fact that all SCC colonies, detected in the period of 2004-2008, were cut out of the Yambourg-Elets-1 Gas Pipeline and no new stress-corrosion cracks were detected in 2009-2011. However, it is expected that small quantity of stress corrosion cracks may appear in future.

Taking in account substantial growth of TFI tools sensitivity level in 2007 it can be concluded that, if the SCC detection sensitivity level of in-line inspection tool is 15% of pipe wall thickness 3 year inspection period is enough for keeping gas pipeline safe. If the sensitivity level is more then 25% 1 year inspection period is recommended.

The technology of combined magnetic in-line inspection has been proved to be the most effective for SCC detecting, identifying, locating and sizing. New electromagnetic-acoustic (EMAT) technologies are expected to be efficient for shallow SCC detection with nearly zero opening as well as for SCC growth prediction.

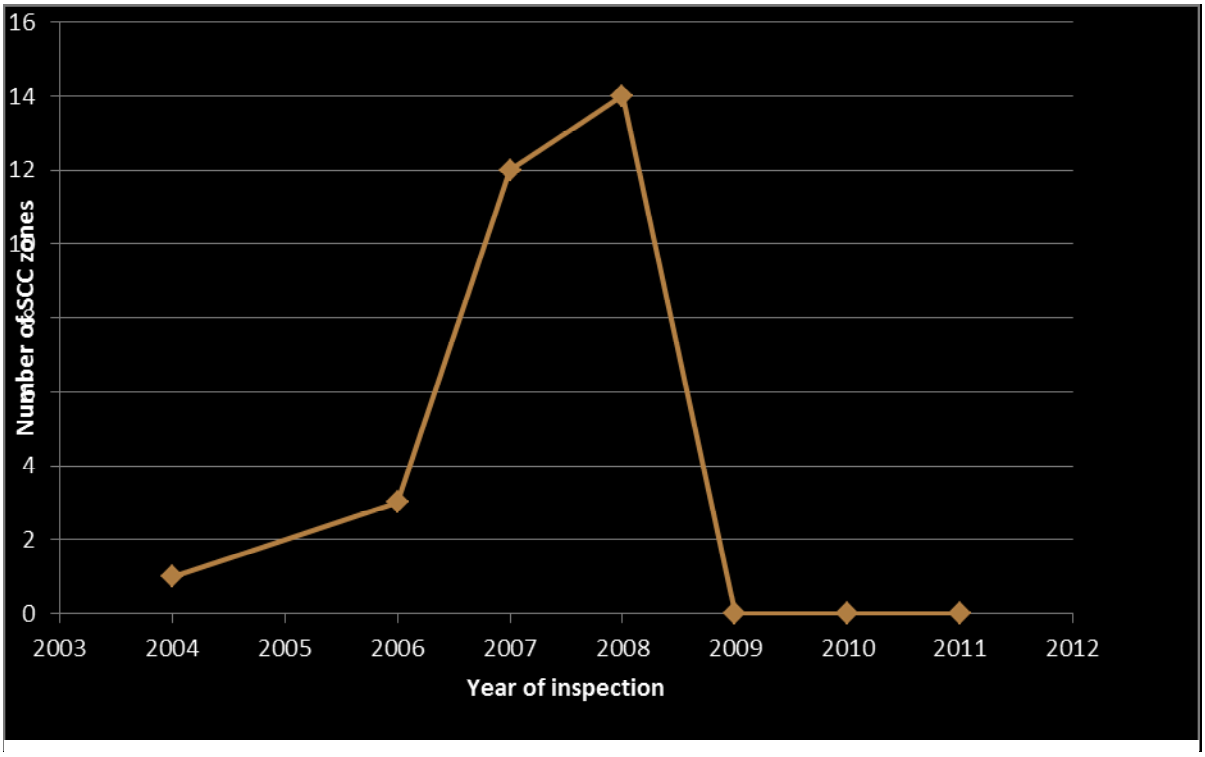

Fig. 5 Number of SCC zones detected on one pipeline section

Determination of variance in corrosion parameters detection

We made comparison of 5 last inspections, which were curried out in 2006, 2007, 2008, 2010 и 2011 years. Pipes, in which there are defects in all inspections under consideration, were selected for analysis. Different parameters were analyzed: total area of corrosion damage on each pipe, total volume of corrosion damage on each pipe, maximum and mean depth and others. As seen from Fig. 6 there is no any spatial or time corrosion defects correlation.

It means that there was no substantial growth of corrosion during period of 2006-2011 years. Using this fact we selected same defects on several in-line inspections. Variances of depth of those corrosion defects were calculated. Results are depicted on figure 7. It is seen that 90% of pipes has variance in maximum depth less then 4% of wall thickness.

Conclusion

Multiply approach has to be used for in-line inspection of gas pipeline damaged both by SCC and corrosion

If the SCC sensitivity level of magnetic in-line inspection is better then 15% three year period is enough for keeping pipeline safe. In other cases 1 year period is recommended.

If the pipeline has good CP protection there it is not possible to determine corrosion growth rate by means of in-line inspection methods on basis of 5 years.
The determined variance in integral corrosion depth estimation is less then 4%. Which means a possibility in good calibration of corrosion depth estimations.

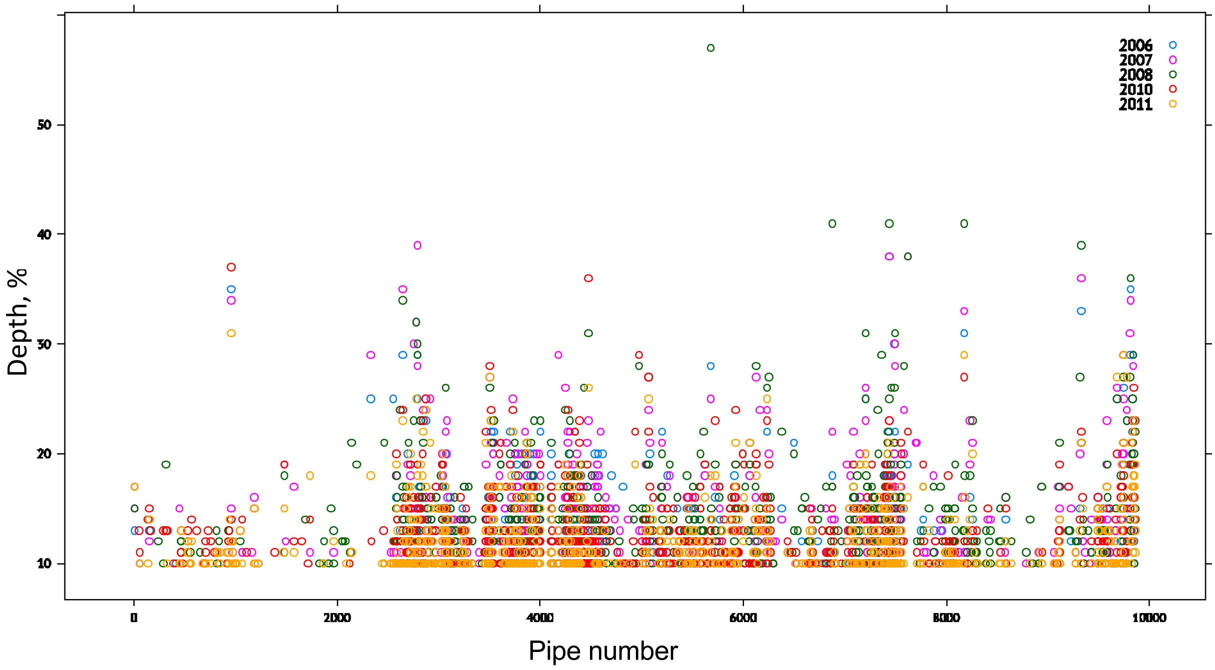

Fig 6. Corrosion defects length and depth distribution

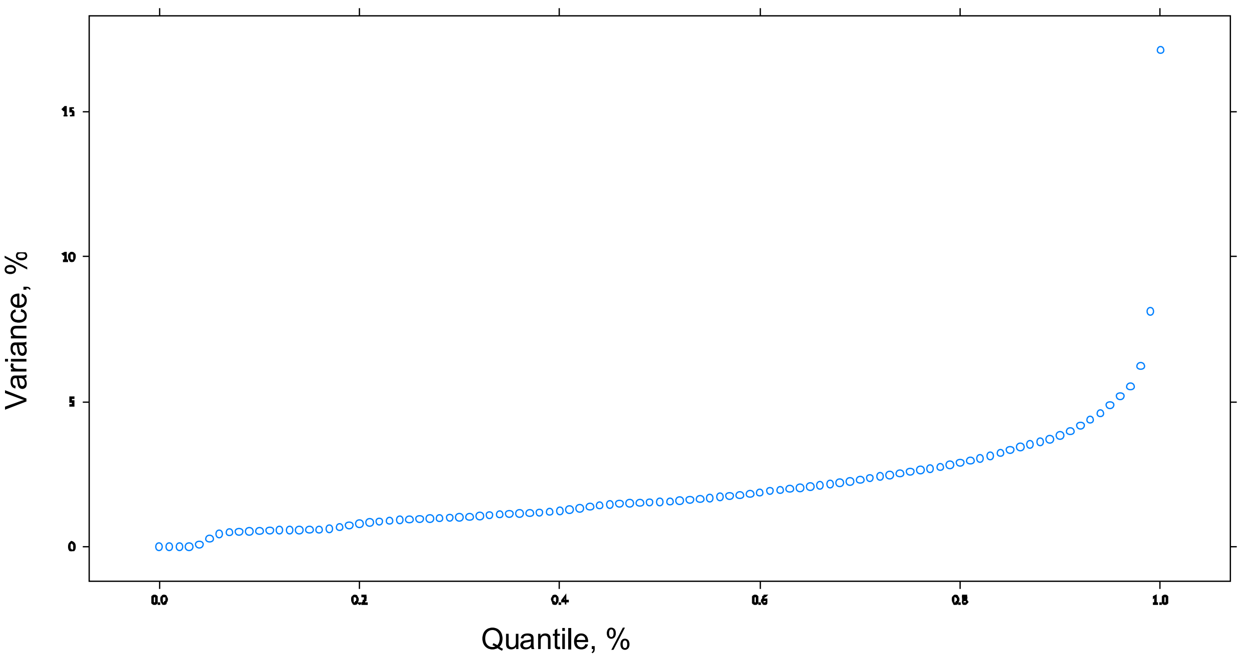

Fig 8. Variance of pipe maximum corrosion depth (in % of pipe wall thickness) probability distribution