MULTIDISCIPLINARY PIPELINE INSPECTION PROJECT, DEVELOPMENT OF IN-LINE ULTRASONIC INSPECTION TOOL TO BE ABLE TO PASS MULTIPLE MITRE BENDS AND 1D BACK TO BACK BENDS IN ONE INSPECTION RUN

By: L.J. Gruitroij, A.Hak Industrial Services B.V., The Netherlands

Abstract

Difficult-to-inspect pipelines meet their match in Netherlands' A.Hak Industrial Services B.V.

<u>Company profile:</u>

With the important intention of providing an unrivalled service to inspect and assess the integrity of difficult-to-inspect (or 'unpiggable') pipelines, A.Hak Industrial Services has become one of the industry's most important companies. Its high-specification rotating-mirror ultrasonic technology mounted on the free-swimming *Piglet*® tools can – like a well-known beer – reach pipeline parts that others cannot, and provides real-time analyses of the inner and outer pipe walls for all sorts of complex geometries, loading lines, dead ends, and other hard-to-access pipeline structures.

The tool's measuring system uses ultrasonic waves for measuring the wall thickness and inner radius of the pipe via a pulse towards the pipe wall sent from a centrally-mounted transducer. The pulses generated by the transducer are reflected towards the pipe wall via a rotating mirror, which enables measurements to be taken of the complete circumference of the pipe. Depending on the diameter of the pipeline and the area of the surface therefore to be inspected, the travelling speed of the *Piglet*® through the pipe can range from 200 m/hr to 1 km/hr. Data gathered by the tool are transmitted in real time via the fibre-optic cable back to the operator, where the associated software gives an immediate analysis of pipe wall thickness, features, and anomalies. The data are stored for more-detailed post-run analyses, which are normally undertaken at the company's Romanian office, and which are passed to the Tricht headquarters in the Netherlands before being given to its client in what is often a three-four day turn round. When the *Piglet*® reaches the end of its run, it is returned to the launch point by simply reversing the flow; the hair-width fibre-optic cable at that time has no further use, and is effectively destroyed as the pig travels back along the pipeline.

As well as its inspection equipment, what is most impressive to the visitor about the company is its dedication to a holistic approach to pipeline inspection. This is typified in its newly-constructed €multi-million new Training and Technology Centre at its Tricht site, accompanied by three 200 m long test loops with 6, 8, and 12 in diameters. The three test loops are water powered, and have been purpose-designed to allow spools of many different configurations of geometry and diameter to be inserted. Spools with machined or actual defects can similarly be added, to allow tool performance to be verified, the company's skilled staff to be comprehensively trained, and its clients and others to become familiar with what can be achieved using the company's inspection equipment.

<u>*Definition of resolution:*</u>

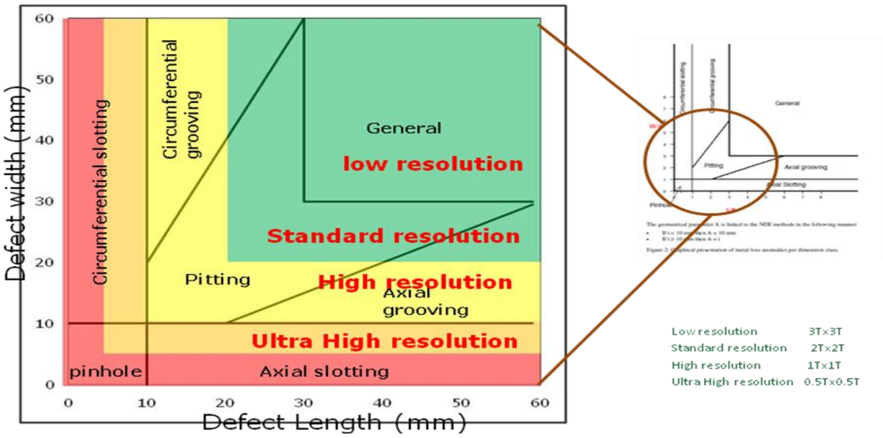
In the pipeline in-line inspection industry it is not clear defined what is meant by low-high resolution of the inspection tools. Contractors talk about high resolution tools, but no clear definition is given, which may lead to misunderstandings between client and the contractor.
In the Pipeline Operator Forum (POF) the nomenclature of anomalies is standardised and is related to the anomaly size (length/width), but no nomenclature is mentioned in relation to the detectabillity. This is normally mentioned in the industry as being low, standard, high and ultra high resolution.

We were faced with this problem and defined a correlation between the used terminology, (low-, standard-, high,- to ultra high resolution) and the detection performance of inspection tools as defined in the POF document, which is also integrated into the API-1163 codes. This correlation is given in the table below..

Nomenclature inspection tools	Detection performance (T in mm)*
Low resolution	3T*3T
Standard resolution	2T*2T
High resolution	1T*1T
Ultra High resolution	0.5T*0.5T

* Where T is the nominal wall thickness. (For T<10mm → T=10mm, For T>10m →T=T)

We hope that this will be used in the future by the industry, to clarify any misunderstanding and which should lead to compare the detection performances between the contractors uniformly. A graphically display as used by the POF is given below.



Case study:

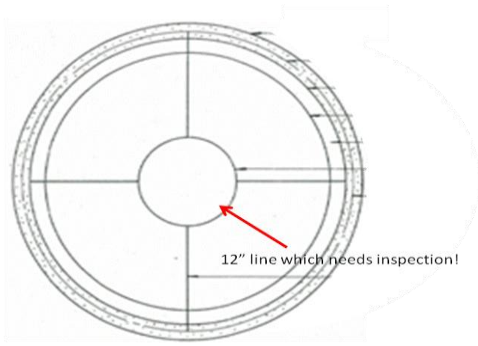
Often we get a simple email from a potential client with a question if we are able to inspect their pipelines. Normally their pipeline has never been pigged, having a large amount of debris/waxes, no launcher/receiver and on top of this, the pipeline consists of even more challenging mechanical restrictions, but due to company rules and changing legislation the integrity of these lines must also be determined.

Most of the time it is the beginning of a challenging project.

This paper the following project is discussed in more detail, starting from a simple request, engineering a complete new inspection tool, building a mock-up, executing a qualification test till the actual inspection including local engineering, cleaning (mechanical/chemical) and the advice to the client to secure the integrity of the pipeline into the next decade.
The email below, with a simple question is obtained from the customer:

Are you able to inspect the 12" pipeline with the following condition?

(1) Size : OD=323.2 mm and 318.5 mm
(2) Length : about 3.1 km
(3) Wall thickness : 14.3 mm and 10.3 mm
(4) Bend radius : Please refer to the attached drawing
(5) Fluid transported : Heated Crude oil or Sea water
(6) Operating pressure : 0.5 - 0.6 MPa
(7) Temperature : Ambient
(8) Pipeline structure Double pipes consisting of 12" inner pipe and 38" outer pipe



As you can see in the attached drawing, there are bend restrictions such as ***forged bends(<1.0D****) and* ***mitre bends(R=1448mm).*** figure 1,2

Due to the mechanical restrictions and operating conditions, no standard tool is currently available on the market which is able to pass these type of restrictions. Together with the client it was decided to develop a complete new 12 inch ultrasonic in-line inspection tool based on the Piglet® system from A. Hak Industrial Services. figure 3.

The Piglet® tool is based on one ultrasonic transducer mounted centrally and using a rotating mirror principle which reflects the ultrasonic beam to the surface of the pipe. The mirror can be used to focus the ultrasonic beam creating a small footprint at the pipe surface or inside the pipe wall allowing very small defects to be detected and sized. The rotating mirror principle allows for extreme high resolution as the number of measurements per circumferential scan can be set without restriction and the tool's speed can be lowered to enhance the axial resolution.

The tools performance was verified by a full scale pump test of a 12" mock-up figure 4, containing mitre bends and back to back 1 D bends. The final test was witnessed by representatives of the client in order to ensure that the tool was performing within the specification, mechanically as well ultrasonically.
After acceptance of the test, the tool was transported to the client and the actual inspection could be started.

The pipeline to be inspected was a 12" crude oil loading pipeline. The pipeline consists of a pipe in pipe (38") pipeline having wall thickness of 10.3mm and 14.3mm and a length of 3.12km. Figure 1,2 The pipeline runs from the tank farm to the mono-buoy.

Onshore temporarily pipe work and the launcher/receiver were connected to the pipeline Figure 5. As the pipeline is a pipe in pipe a special hose was connected to the outer pipe at the mono-buoy, which was used to create a loop for the pumping.

The cleaning program was started by our local agent, running MD foam pigs and HD brush pigs, Due to variation in the ID no standard BiDi pigs were used, but special developed dummy tool was used to remove the debris which was also used to determine the piggability to ensure safe passing of the inspection pig.

When the pigs were close to the end, the water was examined at the vessel and either pumped into the 38" line or collected for disposal. The pigs were sent back by reversing the flow via the 38" outer pipe, after collecting the dummy tools, the inspection tool was loaded into the receiver.

When the pipeline was fully inspected the flow was reversed and the tool was retrieved back into the launcher.

The data was analysed on-site, to give a brief overview of the condition of the pipeline, were after detailed analyses was carried out in our data centre. The report with all the findings was issued and the client could examine the results and determine the strategy to insure the integrity for the remaining lifetime of the pipeline. Figure 6,7

Figure 1: Photo of the ID obstacle which needed to be overcome

Figure 2: Photo of the Mitre bends inside the pipe in pipe configuration

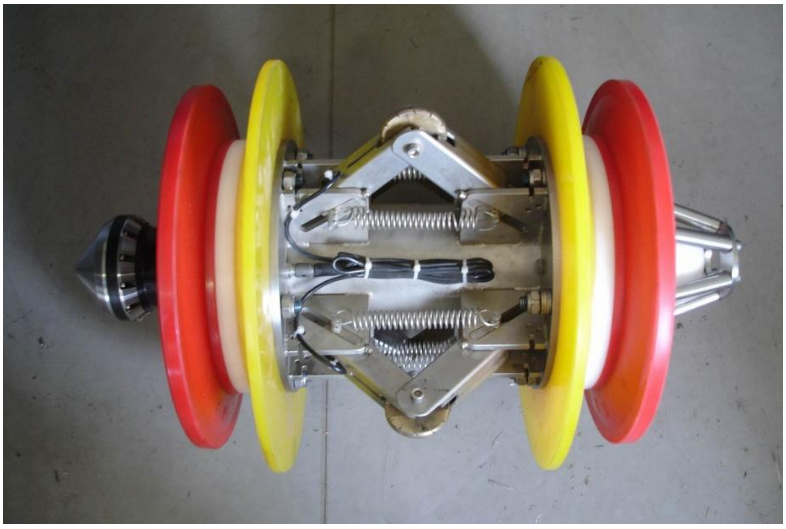


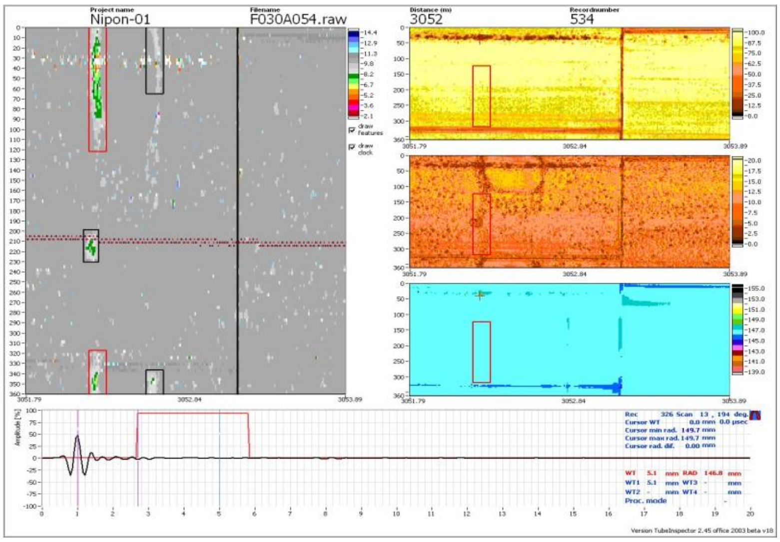
Figure 3: Special developed 12"Piglet, able to pass back to back 1D bends and the mitre bends

Figure 4: Mock-up to prove piggability of the new developed Piglet inspection tool

Figure 5: Photo of the onshore launching and receiving area

SUMMARY OF ANOMALIES Error! Reference source not found. Error! Reference source not found.	
Total number of anomalies	607
Number of metal loss anomalies	129
Number of geometry anomalies	0
Number of laminations and inclusions	478
SUMMARY OF METAL LOSS ANOMALIES Error! Reference source not found. Error! Reference source not found.	
Total number of metal loss anomalies	129
Number of internal anomalies	39
Number of external anomalies	90
Number of non applicable anomalies	0
Number of general anomalies	95
Number of pits	21
Number of pinholes	0
Number of axial and circumferential grooves	9
Number of axial and circumferential slottings	4
Number of anomalies with depth 0 - < 10 %t	0
Number of anomalies with depth 10 - < 20 %t	37
Number of anomalies with depth 20 - < 30 %t	79
Number of anomalies with depth 30 - < 40 %t	7
Number of anomalies with depth 40 - < 50 %t	3
Number of anomalies with depth 50 - < 60 %t	1
Number of anomalies with depth 60 - < 70 %t	2
Number of anomalies with depth 70 - < 80 %t	0
Number of anomalies with depth 80 - < 90 %t	0
Number of anomalies with depth 90 - < 100 %t	0
Number of anomalies with ERF 0.6 - < 0.8	0
Number of anomalies with ERF 0.8 - < 0.9	0
Number of anomalies with ERF 0.9 - < 1	0
Number of anomalies with ERF ≥ 1	0

Figure 6: Table of the anomalies found during the inspection



Anomaly no.	549	Width (mm)	425
Log distance (m)	3052.33	Length (mm)	112
Joint no.	2610	Remaining t (mm)	3.4
Average t / joint (mm)	10.2	Mean anomaly depth (%)	10.5
Average radius / joint (mm)	146.6	Maximum anomaly depth (%)	66.6
Average percentage of successful measurements / joint (%)	99	Up weld distance (m)	11.17
Average reliability / joint (0-1)	n.a.	Clock position (h:min)	6:24
Joint length (m)	12.07	Reliability (0-1)	1.00
Feature type	Anomaly	Defect assessment method	ASME-B31G
Feature identification	Corrosion	PSafe (MPa)	7.78
Anomaly dimension class	General	ERF	0.13
Surface location	External	Defect assessment comment	Present operating pressure acceptable for this anomaly
Comments	In combination with internal corrosion (Stand-off = 1.8 mm; remaining t = 5.2 -1.8 = 3.4	Feature scan name	S03052_35.jpg;

Figure 7: Example of the C-scan image of an external defect