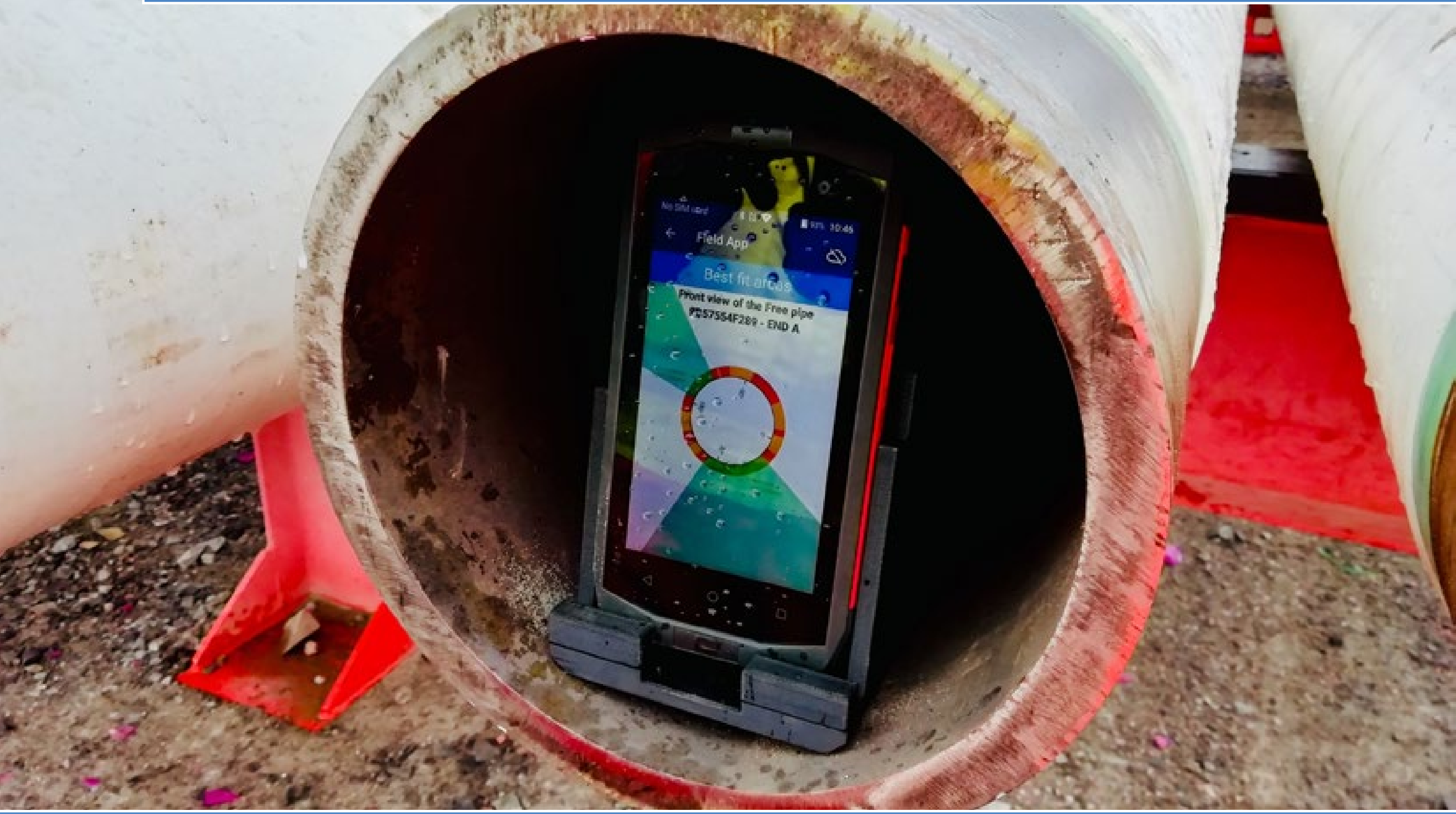
Translating Data Analytics Into Operational Instructions, An Innovative Smartphone App To Support Pipe Fit-Up Efficiency



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Abstract

Digital tools are everywhere in today's world. The Oil & Gas sector is known to be slow to adapt, however has already been embracing the digital change since several years. A wide range of initiatives and solutions have been developed, from big data and related analytics to augmented reality and internet of things.

Digital tools aim to cover the whole value chain, from engineering stage to construction and then life of field. Among the objectives are material and operations traceability, production monitoring but first and foremost ensuring operational efficiency. All those leads to data focused solutions.

Use of data focused solutions implies to develop the right analytics to maximize the use of recorded information. It also requires developing the right translation of those analytics to actual operational instructions to yield its full benefits.

This paper introduces an example of defining operational instructions based on data analytics, dedicated to line pipe welding operations. Based on pipe end measurement data and their analysis, the developed smartphone app provides pipe alignment instructions to the welders so that optimum positioning is instantly reached. It contributes to securing the production flow, anticipating risks prior to start of production and reducing production time. Last, being a digital solution also enables usage of the app by existing staff and remote implementation, removing mobilization constraints of physical services.

1. INTRODUCTION

Pipeline construction involves complex operations, from material manufacturing to pipe laying. This translate in constant research of efficiency improvement. During welding, high productivity is key to contain laying costs, while compliance to welding specifications is a must.

Fatigue and other engineering aspects lead to minimizing the acceptable misalignment (Hi-Lo) between pipes for a better assembly as well as reducing related welding defects. Variability of the pipe geometry therefore requires trial and errors at fit-up station which slow down operations and impact project planning.

Using unique pipe-end identification technology, the newly developed solution enables calculating achievable Hi-Lo value based on pipe-end measurement data. Operational efficiency is reached using a smartphone app providing pipe alignment instructions to existing personnel. App is built to be used in full autonomy by existing staff, thus enabling remote implementation. The solution is designed to result in optimized welding operations: reduced Hi-Lo, faster fit-up and reduced repair rate.

Additionally, pipe-end identification enables the app to support traceability of the welding operations by linking manufacturing data and enabling as welded sequence record to directly issue a digital twin.

This paper will give an overview of the analytics performed but will focus on their translation to operational introductions - smartphone app usage in the field - and its benefits.

2. SOLUTION OVERVIEW: FROM DATA ANALYTICS TO SMARTPHONE APP USAGE

The solution is fully independent from pipe production, and operates in the following sequence:

- Unique pipe-end identification
- Pipe-end Measurement data integration or on-site collection
- Compatibility analysis & associated recommendations
- Smartphone app usage at site

The solution fits within project workflow by design: pipe ends are identified and measured either during manufacturing or subsequent pipe transformation operations such as cladding or coating. Compatibility analysis report is then issued – during operations planning stage – to enable proper evaluation and define necessary on-site fit-up support. Last, whenever app usage is considered, smartphones will be delivered to existing teams with physical or remote training.

A. UNIQUE PIPE-END IDENTIFICATION

Unique pipe-end identification is key to ensure traceability of the data and easy identification of the pipe on-site. Pipe identification can today be achieved through various means and generally depend on material producers or customers' requirements.

In our case, a unique identification number will be allocated to the pipe-end. Each end will then be identified using data matrix tags – see Figure 1 – which will be applied on the outside surface of the pipe or the coating every 120° at three different locations from the pipe-end. These stickers ease and speed up the pipe-end identification, and redundancy is ensured by linking the unique identification number to the pipe tally number.

Figure 1: Data Matrix tags ensuring unique pipe end identification

Tags enable quick reading on site and remove risks of manual inputs error when identifying pipes. Specific ones were chosen to answer operational requirements such as tagging under the snow in Northern Europe, or withstanding high storage temperature in the Middle East – not to mention handling constraints.

B. PIPE-END MEASUREMENT DATA: INTEGRATION OR ON-SITE COLLECTION

Pipe measurement data can be either collected during pipe manufacturing and then integrated in the solution database or collected on-site using portable equipment.

With a productivity of 100 pipes per shift and per equipment, the portable measurement tool – see Figure 2 - can accommodate pipe sizes from 6'' to 60''. It is a carry on one thus enabling operations anywhere, in any configuration (e.g. pipes laying at coating premises, stored in racks). The tool allows live view of the measurement using a tablet, and upon measurement completion a report is issued including Inside Diameter (ID), Wall Thickness (WT), Outside Diameter (OD) and local or global out-of-roundness. Such report is of great benefit for quality control.

Last a reference line is drawn on pipe OD, ID and bevel face to represent the 0° position of the measurement. In

Figure 2: Portable Pipe End Measurement Tool

the case of welded pipes, the seam area can serve as the measurement reference position.

C. DATA ANALYTICS: THE PIPE-END COMPATIBILITY ANALYSIS

Once data has been collected, data analysis can start. Process aim to evaluate compatibility of the pipe-ends to ultimately anticipate the Hi-Lo that can be achieved during welding - and can be performed either considering inside Hi-Lo only but also both inside and outside ones.

Each possible pipe-end combination will be simulated by the developed algorithm, transforming geometrical data into an operational one. For one defined position of pipe ends, ID and OD Hi-Los are recorded all the way along the circumference. The maximum value will be kept as the decisive value. Next, the pipe is rotated by 1° and all the Hi-Los are recorded and maximum value kept. The process is repeated to cover the full circumference. In other words, for one pipe end combination, a total of 130 000 Hi-Los will be calculated.

These values will be used to generate a graph which show the evolution of the maximum Hi-Lo depending on the pipe rotation – see Figure 3 – and which introduce the concept of optimum pipe positioning.

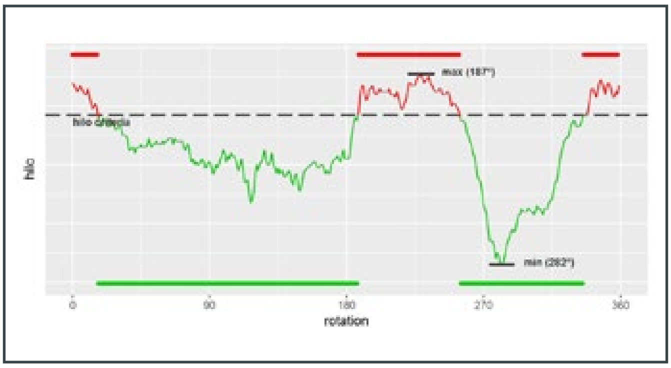

Figure 3: Hi-Lo evolution depending on pipe position

The minimum and maximum of the previously mentioned Hi-Lo curve of each combination will then be plotted in a chart providing the global compatibility of the batch vs the specified Hi-Lo requirement – see Figrue 4. A variety of colors highlight the different results:

- Green dots are pipe-ends combinations complying with the specified Hi-Lo regardless of their positioning and are therefore fully compatible.
- Yellow ones are pipe-ends combinations requiring one of the pipes to be rotated in order to comply with the specified Hi-Lo.
- Red ones are incompatibilities, pipe-ends combination not meeting the specified Hi-Lo.

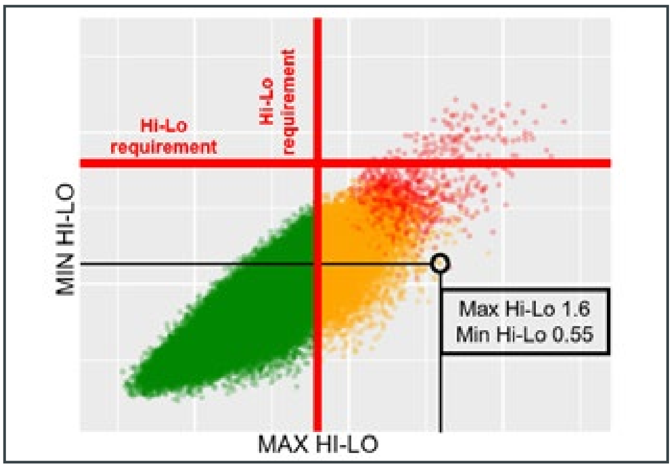

Figure 4: Compatibility Analysis Chart

This chart therefore provides a comprehensive overview of the capability to meet the Hi-Lo criteria using the defined batch of pipes and without sequencing, as well as the identification of potential necessary measures to ensure production efficiency.

D. OPERATIONAL RECOMMENDATIONS BASED ON DATA ANALYTICS

Operational recommendations are defined upon pipe-end compatibility analysis issuance and can serve different project objectives. Figure 5 describes the possible analysis results as well as the recommended approaches.

In the case of good compatibility, project teams may proceed as is or choose to reduce the defined Hi-Lo level for greater quality or installation benefits: fatigue performance, line lifetime or wider offshore laying window. Reducing the acceptance criteria might result in more pipe-ends combinations requiring a rotation and a greater number of incompatibilities.

In the case of medium compatibility, when the percentage of combinations requiring a rotation reach a certain thresh-

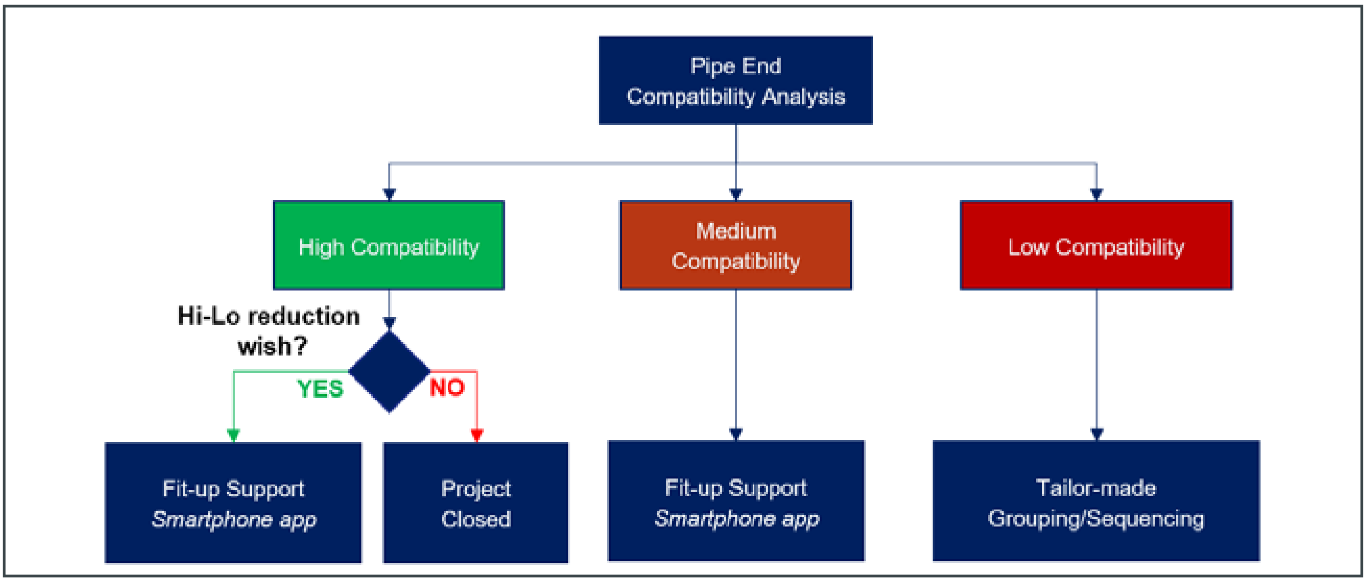

Figure 5: Decision tree upon analysis results

old (defined on project basis), on-site fit-up assistance is to be considered in order to maintain production efficiency. Idea being to provide instant match of those pipes to removes usual trial and error method creating delays.

Last, in the unlikely event of very low compatibility, specific approaches such as pipe grouping combined with the smartphone app and / or sequencing would then be used. Those are tailor-made solutions discussed with the project team.

In all cases, production efficiency is secured by providing instant match between pipes and identifying incompatible combinations as early in the process as possible. This is where operational instructions are necessary hence when smartphone app comes into play.

3. OPERATIONAL INSTRUCTIONS: SMARTPHONE APP USAGE IN THE FIELD

Easy to use, reliable and adapted to process conditions: these are minimum yet key requirements for field support solutions. In our line pipe case, conditions might be challenging ones with operations taking place in the middle of nowhere hence far from a network connection, teams might be rotating so need to be trained in a fast manner, and last the tool need to perfectly fit within the production process to ensure its adoption.

The smartphone app was developed to answer those criteria and to bring full autonomy to existing teams. Fully remote deployment is therefore possible – critical in the current times – compared to existing solutions implying support personnel being sent to site.

In the field, app is to be used right before fit-up. This enables identification of incompatibilities as well as definition of compatibility areas for pipe-ends combinations requiring rotation which removes time loss related to pipe rejection due to impossible fit-up, or empirical approaches to achieve optimum positioning.

All Hi-Lo calculations are done in-app - whether running in online or offline mode - which allow live adjustment of settings hence constant adaptation to field condition.

A. SUPPORTING ASSEMBLY OPERATIONS

During welding operations, no sequencing is required. Tags of the two pipe-ends to be welded together are to be scanned using the app. One of the two pipes is usually called of the fixed pipe as already welded to the mainline, the other one being called the free pipe. Once both identified, Hi-Lo curve will be automatically provided as well as the compatibility result.

There are three types of compatibility result – see Figure 6:

- Full compatibility, pipes can simply proceed as is to the fit-up station as Hi-Lo compliance will be achieved in any position.
- Incompatibility, in which case pipe is to be set aside in temporary quarantine
- Compatibility to be reached by rotating one of the pipes, compatible areas are then to be identified on pipes.

Recommendation is for pipes to be scanned during the tally-in or stringing operations, which usually the precedes fit-up and root pass. Identifying incompatibilities at this stage

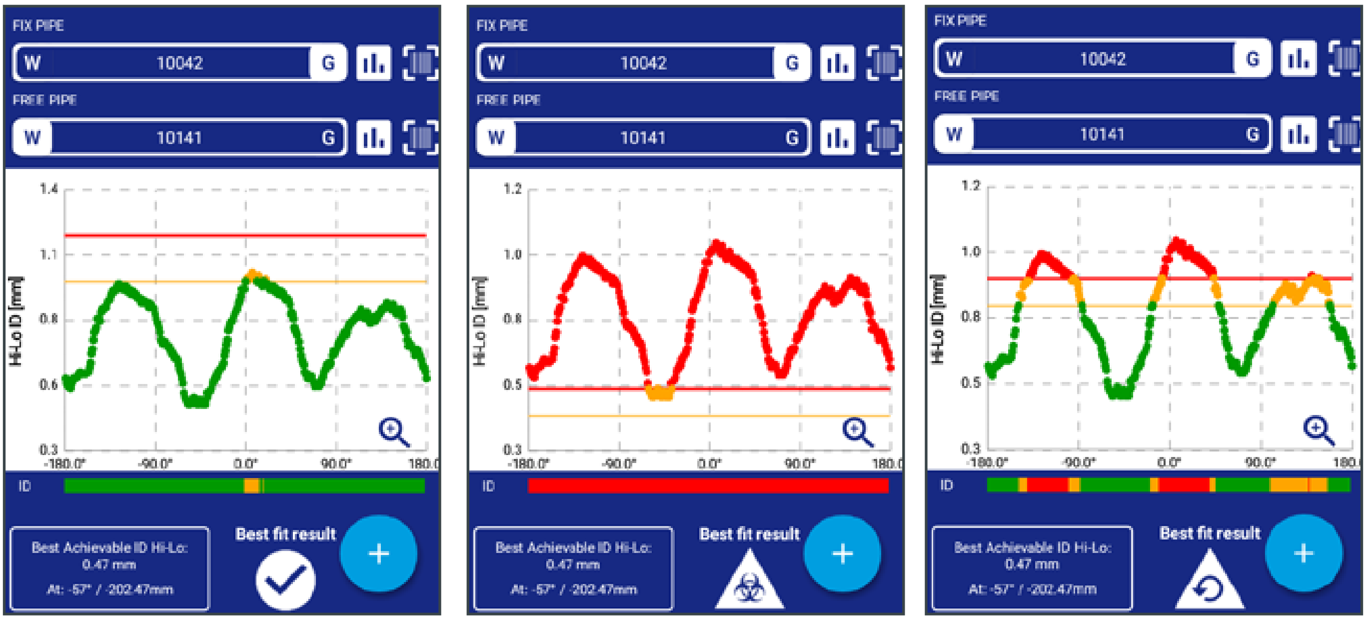

Figure 6: Compatibility results type

enables to avoid the impossible fit-up, i.e. the "no-match", and related time loss. When such case appears, the free pipe needs to be removed from the fit-up station and other one brought up, which can typically take up to 20 minutes.

Using the app, the free pipe creating incompatibility can directly be sent to the temporary quarantine. The same will be recorded by the app, which will automatically test compatibility of the quarantined pipe with all subsequent pipes scanned. As soon as compatibility is found, the app will propose to insert it again and provide compatibility with the preceding pipe and the following one – see Figure 7.

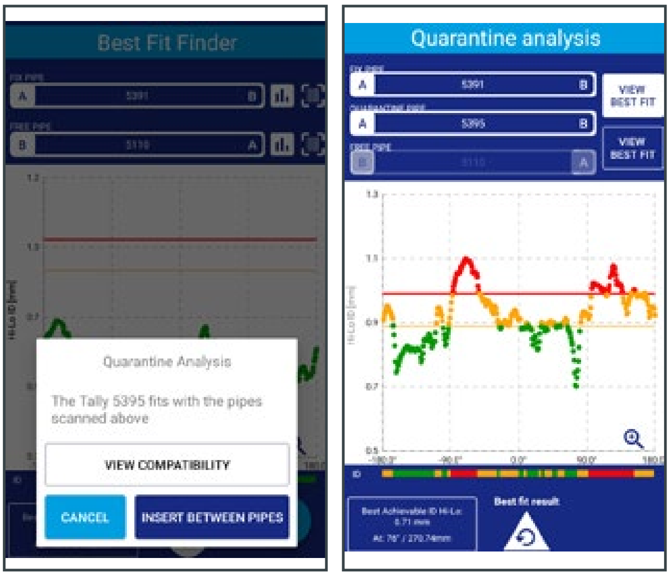

Figure 7: Quarantine call-back

Whenever compatibility is to be reached by rotating one of the pipes, compatibility areas marking is to be performed. Those will be displayed by the application along pipe circumference – see Figure 8. Smartphone then just needs to be placed in the free pipes, 0° reference line of the app adjusted with the one of the pipes, and compatible areas to be marked on pipe outside.

Green compatibility areas are Hi-Lo compliant ones, yellow ones are warning zones close to Hi-Lo limit and red are incompatibles ones. Yellow ones are considered to allow specific positioning that might be required by external factors such as line overall straightness.

Once free pipe marking is complete, it can simply proceed to the fit-up station. Welders only need to match the reference line of the fixed pipe with the compatibility areas marked on the free one - see Figure 9. Use of compatibility areas provide several options to the welder, whereas the line to line match used by existing solutions only offer one and thus imply a systematic rotation.

Figure 8: Compatibility areas marking on pipe

Perfect fit-up is then instantly reached as suitable positioning is already known when pipe reach the station. Considering that time for fit-up without rotation would be around 1 min where a rotation can take up to 5 minutes, the smartphone app strongly benefits to cycle time reduction.

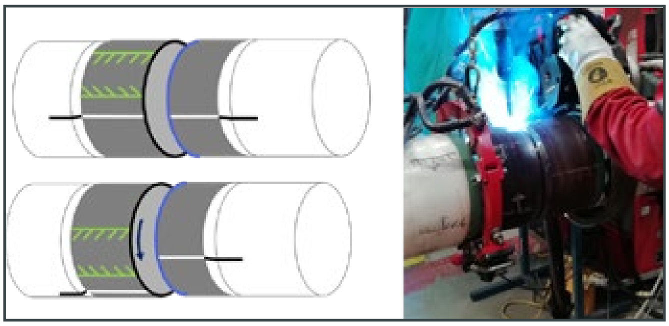

Figure 9: Use of compatibility areas at fit-up

B. APP SETTINGS: OPERATIONAL REALITY

As introduced, calculation is done in-app which enable live adjustment of the settings – Figure 10 - depending on the context. Facing a critical section, Hi-Lo can be reduced. Quarantine rate is slightly higher than expected, then continuity percentage can be reduced to lower the incompatibility rate accordingly.

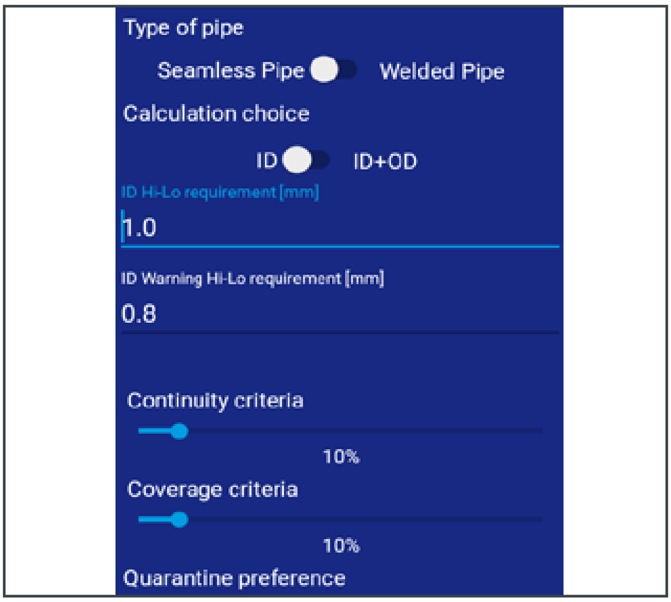

Figure 10: App Settings Screen

Hi-Lo set-up:
Two Hi-Lo values shall be defined in the app. The "Hi-Lo requirement" in mm which represents the upper Hi-Lo limit specified by the project specification and will define the red areas. The "Warning Hi-Lo" requirement considers a safety margin related to the bevel quality and other parameters that could slightly impact the measured Hi-Lo. "Warning Hi-Lo" defines the yellow areas introduced earlier.

Continuity and coverage criteria:
Expressed in % of the pipe circumference, the continuity criterion is the minimum length on the circumference respecting the Hi-Lo requirement. In other words, in case of compatibility on a short section it defines whether the app will recommend temporary quarantine or propose a rotation. The objective of this parameter is to bring operational reality in a theoretical calculation of the Hi-Lo. A compatibility area of few millimeters is often non reachable on the fit-up line due to the accuracy of the rotation applied or the marking itself. The coverage criterion represents the sum of all area respecting the minimum continuity area.

Longitudinal seam separation for welded pipes:
When welding longitudinally welded pipes, it is usually requested to avoid longitudinal seam to longitudinal seam butt-welding, to avoid aligning weaker areas – and hence stop as much as possible crack propagation shall one appear. In that sense a "seam separation" criterion is usually part of the project specification.

This criterion is fully managed by the app - can be entered as part of the settings and is highlighted in grey in the Hi-Lo curve but also when marking the compatibility area.

ID or ID&OD compatibility:
Hi-Lo and compatibility result can also be computed – whenever necessary - considering both OD and ID criteria instead of ID only. This is reflected by two different Hi-Lo curves; and displayed compatibility are combined ones.

4. TRACEABILITY & OPERATIONS RECORDS: ISSUING THE DIGITAL TWIN

The use of unique pipe end identification as well as a mobile device also enable the solution to enhance traceability, be it for pipes or operations. The developed app provides live and easy access to pipe manufacturing information, support further processing such as onshore multiple joint assembly and last enable recording of the as-welded pipe sequence. Those features aim to facilitate field operations. By removing the need for manual identification, it strongly reduces the risk of recording anomalies by directly issuing a digital twin.

A. LIVE PIPE DATA ACCESS

Pipe order information and actual production records can easily be linked to the unique identification number. Data from pipe manufacturing and/or operations can then be directly visualized in-app when scanning tags and or entering the identification number.

Figure 11 present examples of data that can be accessed

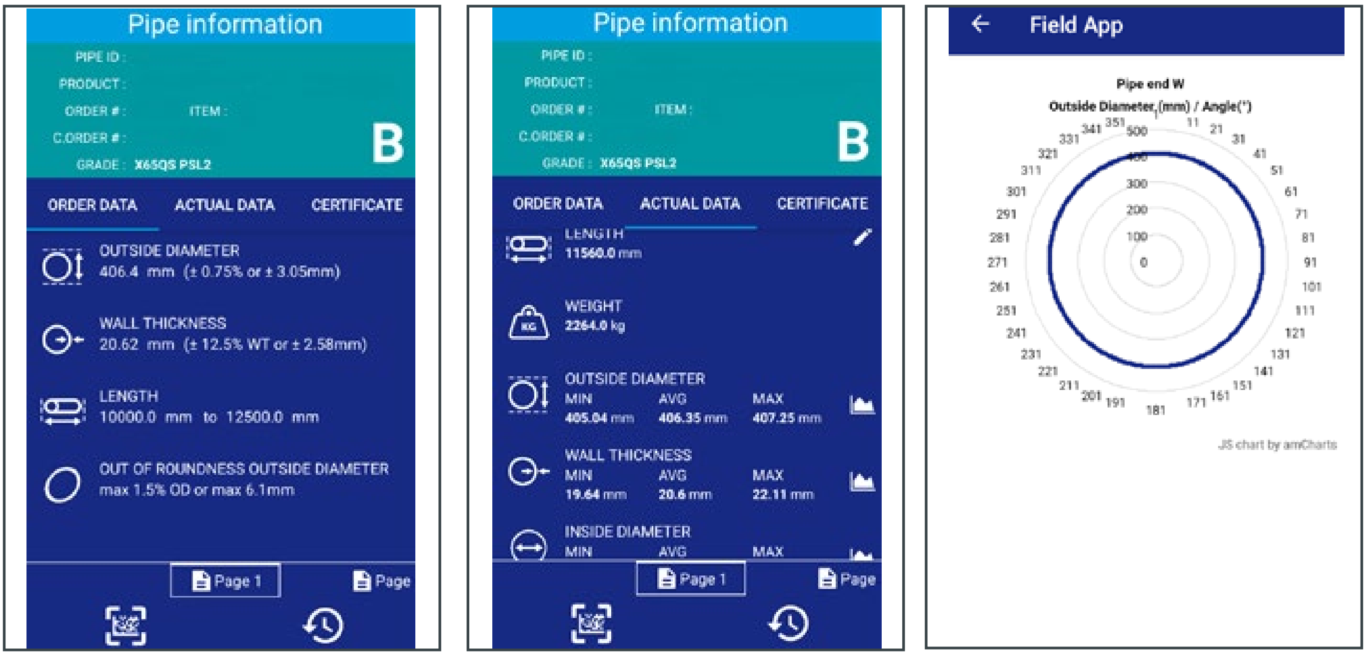

Figure 11: Live Data Access

using the app. Detailed visualization of pipe-end profile as well as wall thickness profiles along pipe length are available – all depend on data available. Inspection certificate – also known as MTC – can be accessed and extracted from the app.

Information is therefore very easy to be accessed and extracted directly in the field – even in offline mode – which translate into time savings. Additionally, risk of manual input error is removed as pipes are identified by scanning tags.

Figure 12: In-app multiple joint assembly creation process

B. MULTIPLE JOINT ASSEMBLY MANAGEMENT

Construction and installation of pipelines show very high daily operational expenditure. In order to reduce on-site or offshore operations, onshore multiple jointing is often performed – allowing to divide by at least two the number of welds during laying.

The app can also be used in such cases. The compatibility analysis can be performed on single joints in order to anticipate double jointing operations – an option could be to select the less compatible pipe-ends and weld them during multiple jointing – and app used for optimum positioning during welding operations. Once pipes are welded together and hence multiple joint created, the same can be recorded directly in the app using the multiple joint assembly management feature - see Figure 12.
A tally record is then created and can easily be extracted in MS Excel format. Once created, compatibility analysis can be re-run considering double joints only. In the same spirit, whenever used post multiple joint creation the app will also only consider multiple joints when identifying any of the pipes-ends in the field.

The same yield several benefits. First, traceability of multiple jointing operations is improved, and its tally extract can directly be embedded into the production tracking system. Second, the whole solution enables to perform time consuming operations – such as welding the less compatible pipe-ends - earlier in process to maximize mainline welding efficiency thus benefiting to the overall production flow.

C. AS-WELDED PIPE SEQUENCE RECORD

The developed app also allows to record the as-built incoming tally construction (i.e. as-welded, as-laid sequence) issuing immediately a Digital Twin to eliminate risk of manual input errors – see Figure 13. This as-built digital tally is automatically generated as pipes are scanned - and can easily be extracted.

Pipe position as well as its orientation are recorded, and information on the pipe or on the weld can be added live. The same support quality records and could also be easily integrated to production tracking system once extracted.

Last, when used for spoolbase welding the app also includes in this feature alert functionalities such as preventive alert for pipe assembly cumulative length check to prevent from manual pull and multi-jointing length dispersion.

5. CONCLUSIONS

Increased use of digital tools will benefit the line pipe industry, to support operational efficiency but also by enabling autonomy and remote deployment – critical in current times. Data centric solutions are now widely used, existing analytics enable lessons learned of past situations. When reactive enough, those can also be used for live field support as introduced in this paper.
Challenge then lies in transferring potentially complex analytics into a suitable operational assistance tool. Easiness to use, clear instructions and live adjustment are key parameters to ensure field adoption of a digital solution.

In the presented solution, pipe identification is as easy as scanning a tag with a smartphone - a gesture that is now becoming part of everybody's daily life. The compatibility analysis is transferred to the app in an easy-to-understand instruction: compatible as-is, rotation required, temporary quarantine. A clear cut and instant answer provided,

Figure 13: In-app as-welded sequence Record

which is usually the need of operational teams. Still, more detailed information – such as the Hi-Lo curve – remains available to be consulted whenever needed.
Last, reactivity is achieved by enabling live adjustment of the settings: shall there be a change of the operational context, the same can directly be reflected in-app.

The app has now been used on 10,000 welds, which resulted in clear savings. No incompatible pipe reached the fit-up station thus removing downtime linked to pipe removal. Fit-up and root-pass station time has decreased up to 10% - resulting in some cases of a debottlenecking of the station. The same combined with a reduced weld repair rate – coming from reduced Hi-Lo variability thanks to analytics - can be translated in savings from 20k$/km to 75 k$/km depending on project daily operational expenditure. Additionally, thanks to tags identification and its embedded production recording features the app enhance traceability at site and diminishes the risk of manual input errors – which support existing digital twin approaches.

It is the opinion of the authors alone that – as any digital tool – the app is called for constant evolution to further support to field operations and increased benefits.

References

1. J. Feroldi, T. Mailfait, N.Gotusso, T. Masse, "An Innovative Digital Solution to Support Pipe Welding Assembly Operations", Asia Pacific Oil & Gas Conference 2020, paper ref. SPE-202289-MS

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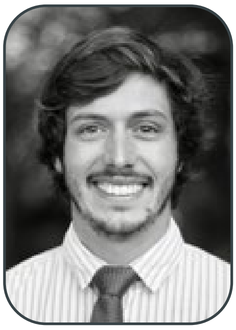

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