Fit-up at your fingertips

Thibault Masse and Nicolas Gotusso, Vallourec, France, explain the application of a digital solution for tracing pipes and transforming welding assembly operations.

A new digital solution to trace pipes and transform pipe fit-up operations has recently been created by Vallourec, called Smartengo Best Fit. This solution relies on an advanced algorithm providing a full batch of pipe compatibility analysis, and a smartphone application to be used in full autonomy by welding personnel. This is designed to result in optimised welding assembly operations: reduced hi-lo, faster fit-up, and reduced repair rate.

Why is hi-lo important?

Hi-lo is a critical parameter for both engineering and operational teams (Figure 1). At the design stage, hi-lo plays a major role in fatigue calculations – which is linked to overall line lifetime – but is also an essential variable in the engineering critical assessment (ECA) performed when preparing installation as well as during the laying: the lower the better, provided operations can meet the specified value. Should the defined hi-lo be too stringent, fit-up duration will increase – impacting project planning – and so will the weld repair rate.

The objective of Smartengo Best Fit is to respond to both challenges: to give visibility on achievable hi-lo to the design team before start-up of welding operations; and to allow welders to meet (for two random pipes) the specified hi-lo in an efficient way by using the dedicated smartphone application.

How does it work?

This solution operating mode is threefold:

- Pipe identification and data collection – pipe ends are uniquely identified using an in-house data matrix, and geometry is recoded using carry-on laser equipment.

- A full batch compatibility analysis – the Smartengo Best Fit patented algorithm will simulate all possible pipe end combinations, at every rotation degree, and record related hi-los. A global overview of the batch compatibility is then shared, allowing for potential measures to meet project objectives (hi-lo reduction or improved efficiency) to be anticipated.

- On the firing line: no sequencing, only a smartphone – during welding operations, no additional personnel are sent to site. Field teams scan two random pipes and the Best-Fit-Finder application can provide them with the compatibility areas, no more trial and error, and no time loss. Teams know immediately the best positions to meet the welding specification.

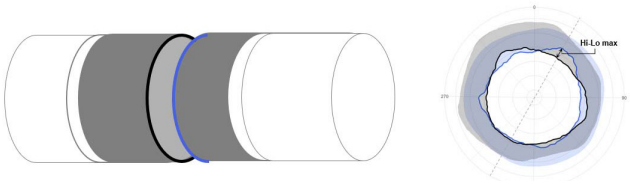

Figure 1. Illustration of the hi-lo between two random pipe ends.

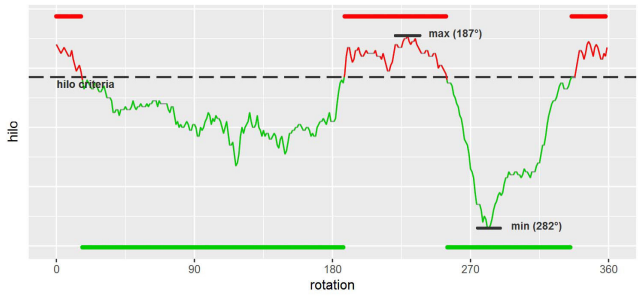

Figure 2. Maximum hi-lo evolution function of pipe position: rotation of one pipe vs another.

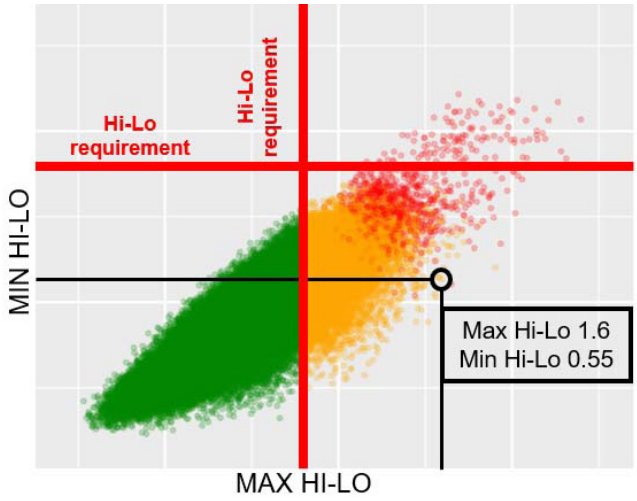

Figure 3. Visual output of the compatibility analysis, representing minimum and maximum hi-los for all possible pipe combinations.

Pipe identification and data collection: any pipe, anywhere, any time

Each pipe end is uniquely identified using data matrix tags. A reference line is drawn on pipe ends, which will be the starting point of the measurement. Redundant markers of this reference position will be used to ensure the reliability of the 0° reference line – vibro-engraving on pre-bevel, use of the longitudinal seam weld. Recording of the pipe end geometry is then performed using a laser measurement: outside diameter (OD), wall thickness, inside diameter (ID), and out-of-roundness are recorded every 1° at several longitudinal positions.

With a productivity of 100 pipes per shift and per tool, the laser measurement tool can accommodate pipes of 6 in. to 60 in. in size. In addition, being a carry-on tool enables operations anywhere, in any configuration (e.g. pipes at coating premises, stored in racks, etc.). The operational team can be mobilised at short notice, with multiple tools, enabling measurements to be performed without impacting the project timeline. Last but not least, should measurements have already been undertaken in the pipe production facility, then this data would be used, and portable measurements not needed.

Compatibility analysis: providing visibility before laying

Once data has been collected, data analysis can start. Each possible pipe end combination will be simulated by the patented 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. 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 recorded. These values will be used to generate a graph which will show the resulting maximum hi-lo evolution depending on the pipe rotation (Figure 2).

The minimum and maximum of the aforementioned 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. A variety of colours highlight the various scenarios (Figure 3):

- Green dots have minimum and maximum hi-los below the specified requirement. These combinations will be fully compatible without any rotation required.

- Yellow dots have a minimum hi-lo below requirement, and the maximum one above. A rotation will be required to reach compatibility.

- Red dots have both minimum and maximum hi-lo requirements. These couples will not be compatible.

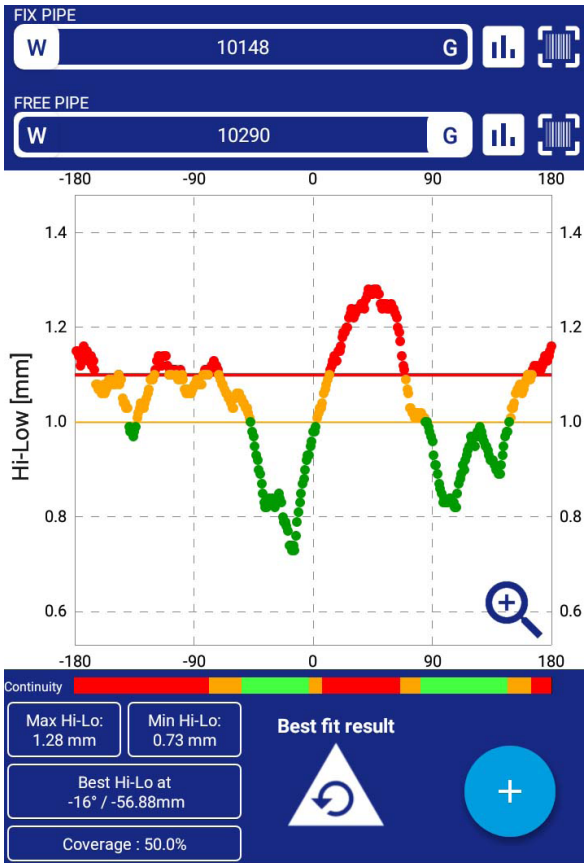

Figure 4. Best-Fit-Finder application screenshot: hi-lo curve is displayed for two randomly scanned pipes, with rotation required.

Figure 5. Best-Fit-Finder, Tag Tally screenshot: as-laid sequence of welded pipes is recorded, with each joint and weld being identified.

This overview is fully deterministic as each and every possible combination is tested – 104 billion positions analysed for 2000 pipes. The coverage of combinations opens the door to many possibilities:

- Should the project team's objective be to maximise efficiency of the laying campaign, then pipes creating the most incompatibilities could either be segregated, used for welding procedure qualification, reworked or intelligently grouped. Such intelligent grouping would be undertaken using a social media algorithm, creating links based on affinities in terms of hi-lo. On the other hand, if the project team's objective is to reduce the hi-lo as much as possible, then tailored recommendations on hi-lo reductions would be discussed (Figure 8). This would support the improvement of ECA accuracy by considering the actual reachable maximum hi-lo.

Important to note is that all the aforementioned activities are performed prior to actual operations. This allows proper planning to be undertaken for the laying campaign, and thus removes the schedule variability that is usually observed.

No sequencing required, just a smartphone

At this stage, the Best-Fit-Finder application goes into action. No sequencing is required. Existing personnel only need to scan a first pipe (called the fixed pipe because usually this is already welded to another one) and then scan the free pipe (i.e. the one about to be welded). The App will then automatically provide the hi-lo curve, but more importantly the Best-Fit result, of which there could be three types (Figure 4):

- Full compatibility: pipes are compatible in any position (i.e. green dots of Figure 3).

- Compatibility achieved via pipe rotation (i.e. yellow dots of Figure 3). Compatibility areas are then to be marked on the free pipe.

- Incompatibility: pipe then to be temporarily quarantined, and later called back by the App.

If pipe rotation is to be considered, the application will display the compatibility area along the circumference. Welders only need to put the smartphone in the free pipe, and mark accordingly the compatibility areas on the pipe OD (Figure 6). When it comes to fit-up, the reference line of the fixed pipes shall fall within one of the compatibility areas of the free pipe – and not just a line-to-line match as carried out by today's existing solutions, requiring a systematic rotation.

In case pipe is to be temporarily quarantined, the App will record the same and will propose bringing back the pipe from quarantine whenever compatibility is found with a subsequent pipe scanned.

This results in fast fit-up – when the pipe reaches the fit-up location, the right position is already known and

identified. The solution is designed for no more trial and error but instant matching of specified hi-lo.

The application works in both online and offline modes; is able to manage double jointing; and can perform live hi-lo calculations based on defined settings – settings that are being adjusted directly on the smartphone. If a more stringent laying area is reached, teams can simply adjust the settings and thus reach a lower hi-lo value, leading to more pipe rotations.

As pipe is easily identifiable using the tags, traceability features have been developed. Data from pipe manufacturing and/or operations can be embedded in the application to be directly accessible when scanning tags on pipe. Additionally, by using the Tag Tally feature of the App, the full as-laid sequence can be recorded – with joints and welds identification – and exported in a format that is easy to exploit (Figure 5).

These features are typically adjusted depending on each project requirement, i.e. for spool bases an alert for cumulative length check can be integrated, in order to stay within the working range of each firing line station.

The design of this solution brings full autonomy: Smartengo Best Fit in the field is a simple mobile application to be used by the existing personnel. No additional workforce is required. Furthermore, compared to existing solutions, Smartengo Best Fit can provide a deterministic analysis instead of a probabilistic one, and it also does not require sequencing – thus removing the need for extensive pipe handling.

Field proven benefits

Smartengo Best Fit has so far been used in six projects: Solveig, North Sea, UK; Tor II, North Sea, Norway; Shell Brent, North Sea, UK; Seagull, North Sea, UK; Katmai, Gulf of Mexico, US; Perigrino II, Brazil; and Safaniya TP21, Saudi Arabia. In total the projects have covered over 8000 welds both onshore and offshore, proving useful on seamless, welded, and cladded pipes.

Unique identification using tags and portable pipe ends measurement allows for the improvement of QA/QC processes and reduction of non-conformities, related either to incorrect geometry or identification.

The compatibility analysis allowed up to 33% reduction on past operation, decreasing from 1.5 mm to 1.0 mm without any incompatibilities during welding operations (Figure 8). Pipes showing incompatibilities have been identified and removed. The same is explained in the following example whereby, as a result of this solution, the cut-out reduction was reduced from 4.3% to 1% – generating direct time and operational cost savings. The use of the Best-Fit-Finder application in the field can result in secured line pipe assembly workflow, improved weld quality, and production time reduction by a minimum of 10% variability is removed. In some cases, by decreasing fit-up time the solution allowed debottlenecking of the fit-up station.

Overall, significant operational cost savings are observed: from US$20 000/km (for onshore welding operations) to US$75 000/km (for offshore welding assembly). Those are purely generated by operational time savings. Hi-lo reduction savings are also considered, as they allow for the increase in engineering accuracy, as well as opening the door to larger benefits such as line lifetime improvement. Finally, the tally feature records the as-built incoming tally construction (i.e. as-welded, as-laid sequence) and immediately issues a digital twin to eliminate the risk of manual input errors.

Figure 6. Based on the Best-Fit-Finder recommendations, welders mark accordingly the compatibility areas on the pipe OD.

Figure 7. If pipe rotation is to be considered, the application will display the compatibility area along the circumference.

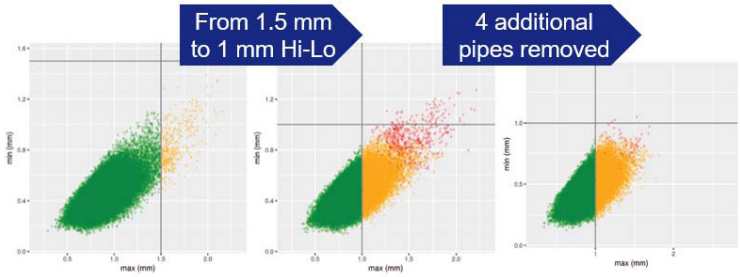

Figure 8. Example of hi-lo reduction opportunities based on the compatibility analysis result. By segregating four pipes, operations will reach a maximum hi-lo.