Rising to the Challenge

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Abstract

As pipes are put into deeper and deeper water the challenge of laying of pipelines is intensifying. At every stage in the engineering process incremental improvements are continuously being made, and the process of laying pipes might appear as easy now as it did a few years ago when Steel Catenary Risers (SCR) were a new technology and 1000 metres of water was considered deep. This paper encapsulates some of the improvements that are being made in order to ensure that pipelines are fit for purpose. Improvements are being made across whole range of topic areas such as Automatic Ultrasonics Technology (AUT), automatic welding, material selection and coating, however this paper will concentrate on the dimensional aspects of pipes that are used for flowlines and fatigue sensitive pipes such as SCRs. Dimensional metrology not only allows engineers to ensure that precise specifications are met, but furthermore the interplay between dimensional metrology and both fit-up and AUT can offer scope for improving the assembly process, enhancing the quality of assembly that is achieved, and reducing the time taken to lay a pipeline. This paper provides case study information to illustrate the ways in which dimensional metrology is rising to the challenge.

1. Introduction

This paper will describe the various techniques used to provide the necessary quality control for fabrication of SCRs, fatigue sensitive sections and flowlines. It also describes the interplay between techniques, which, if carefully implemented can enhance the assembly process in terms of easing the process, achieving an enhanced result, and saving of time. A number of case studies will be used to provide a practical insight into the manufacturing methods.

A typical SCR geometry illustrated in figure 1(a), with a key component, the flex joint in figure 1(b) and a picture of a pipeline being laid from the end of a lay barge in figure 1(c).

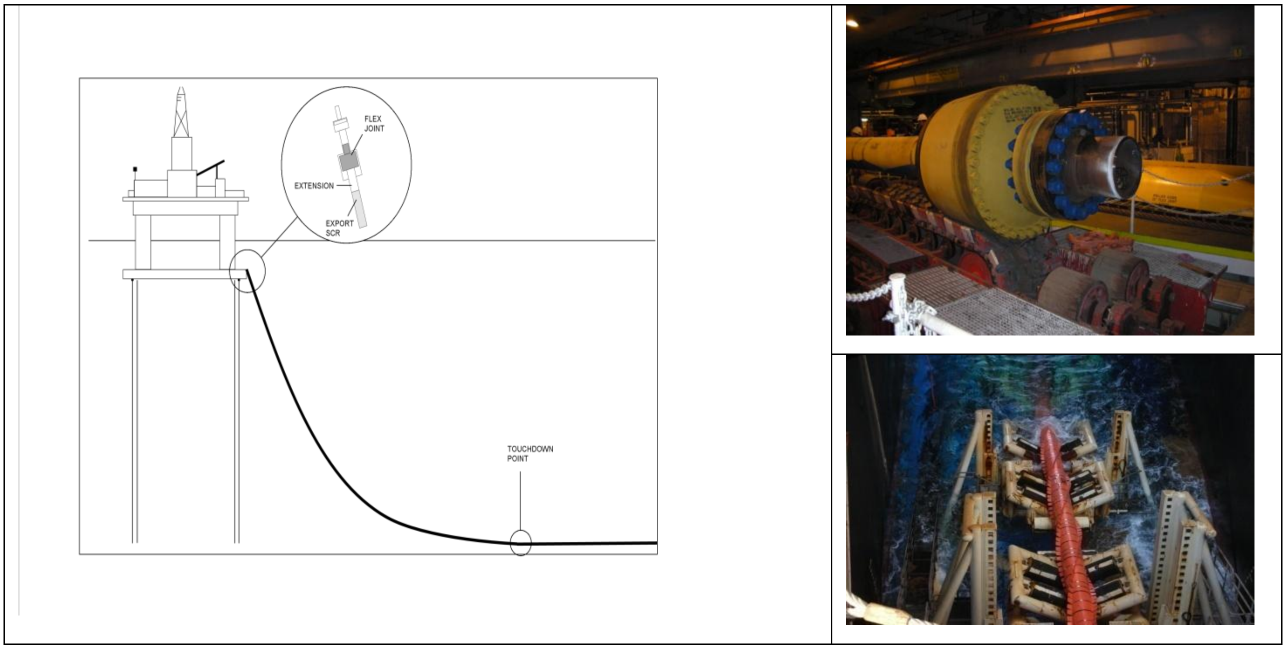


Figure 1(a) Typical SCR Geometry (left), Figure 1(b) Flexjoint (top right) and Figure 1(c) SLAY of pipe (bottom right)

Tides, ocean storms, currents and swell create a highly dynamic environment for the SCR which in turn necessitates design and fabrication processes that mitigate stress and fatigue factors. There are a number of highly critical aspects of the pipe fabrication process that have to be guaranteed to be correct.

One of these is the internal HiLo mismatch between butted pipes. This is illustrated in the following figure 2.

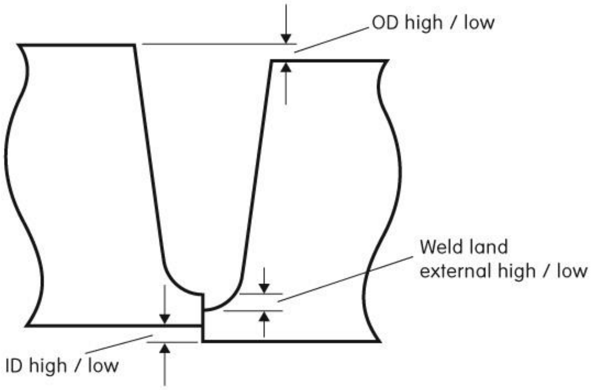


Figure 2 Internal HiLo mismatch

Minimisation of HiLo contributes to a good weld and decreases stress at the weld joint. Typically the HiLo mismatch is required to be less than 0.5 mm in fatigue sensitive pipeline sections. In engineering terms this is a considerable challenge, particularly given that the pipe used in this application is often seamless, which inherently has wall shape and thickness deviations. This leads to a possibility of using pipe end dimensional data in various ways to achieve ‘best’ fit-up. A large variety of solutions are available to be tailored to the needs of different projects. Solutions may favour: counterboring (which can be optimised by the use of 2-D geometrical data for pipe ends); end matching and rotation schemes (based on pipe end geometry); or a number of segregation/dynamic matching schemes. Some of these approaches are explored in this paper.

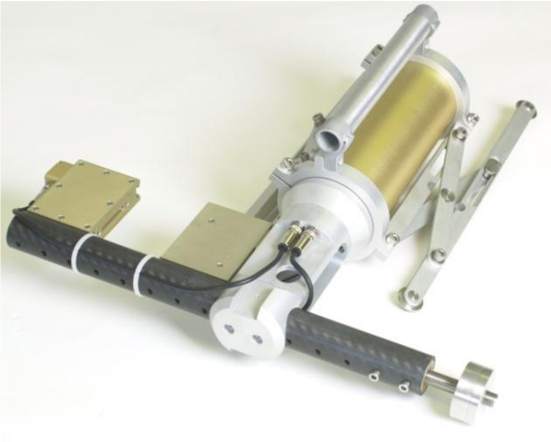
Once welding has been carried out, each weld must be comprehensively checked to ensure that there are no defects in the weld. Automated Ultrasonic Testing is normally used for this purpose and this method introduces further constraints on the fabrication process. AUT calibration blocks are necessary in order to ensure that the ultrasonic inspection of the pipe weld can be relied upon. However the AUT equipment must be checked using a calibration block that is commensurate with the thickness of the pipe wall, a typical limit being pipe wall thickness (WT) within ± 1mm of the calibration block value for an SCR. If there are variations in pipe WT that lie outside the limit, then multiple AUT passes are required together with multiple calibration cycles using appropriate calibration blocks. The length of time to scan a weld and to check the resulting data is usually smaller than the pipe welding cycle time if a single calibration block is used. If the pipe wall thickness is outside of this range then the AUT inspection can take longer than the weld cycle time and hold up the production to a significant degree. This leads to a possibility of using pipe end dimensional data to optimise assembly based on AUT considerations. One approach is to quarantine pipe that cannot be inspected with a single AUT pass. Another approach is to plan assembly, for example such that pipes requiring multiple AUT passes are welded into doubles or quads onshore while the ends of the doubles or quads are selected to require only a single AUT pass during the offshore operations.

2. Measuring Equipment

It is important to realise the difference between the type of data that can be obtained with traditional callipers and the like, vs. the type of data that can be obtained using a laser profiling tool. Both types of measurement can, if carefully carried out, yield the required accuracy. However, the data that is generated via callipers is not taken about a common datum and will remain a series of separate measurements. On the other hand, a laser profiling device rotates laser measurement heads around a fixed axis. All measurements are thus referred to the same axis system and can be combined to form a 2-D map of the pipe end geometry. This allows for analysis to be performed that takes actual pipe shape into account. The move to laser based profiling is one of the ways that dimensional metrology is rising to the challenge.

OMS has a range of pipe end measuring equipment to measure every pipe size typically used in offshore projects.

The OMS tool is illustrated below in figure 3(a).



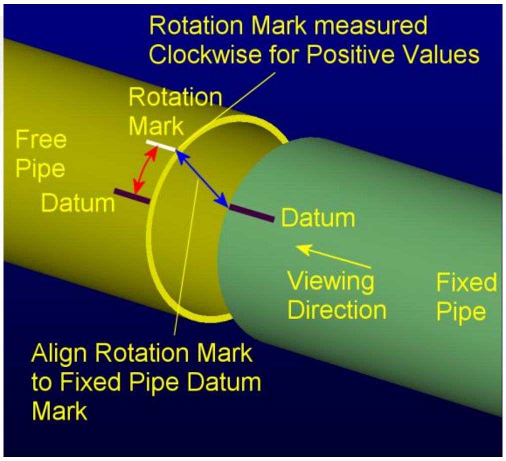


Figure 3(a) OMS Laser Measurement tool

Figure 3(b). Definition of the Rotation Mark location with respect to the Free Pipe

The OMS tool is able to measure more than 2000 internal and external points around the pipe circumference in around 10 seconds. After analysing the measurement data it is possible to plan for a particular assembly approach to suit the particular requirements of a given project. For example, a sequence of pipes can be found using end matching in order to construct strings of pipes that are able to satisfy the 0.5 mm criteria without counterboring. Or alternatively a counterbore plan can be constructed possibly using some groups of counterbore diameters, whereby the maximum amount of material removed and the minimum remaining can be optimised together with applicable HiLo and WT limits. In either case, all AUT requirements can be taken into account to manage such pipes that are outside of the optimum AUT cal block range. In the case where pipes are not counterbored figure 3(b) illustrates how these pipes are rotated directly to a position where the internal HiLo is reduced below the 0.5 mm limit.

The ‘fit-up’ process involves bringing pipes together in an alignment prior to welding. Dimensional data can be used to mark each pipe end with a rotation mark (as shown in fig 3(b)) so that pipes can be rotated directly into the optimal position to minimise fit-up HiLo. A ‘line up clamp’ tool is used to temporarily hold pipes in the correct position for welding. The next step is to weld the pipes together beginning with the root pass weld. This process is often automated as illustrated in the following figure 4.

Figure 4. Automatic welding process with two welding 'bugs'

The remainder of this paper discusses specific cases and sets out more detail regarding how dimensional metrology can be used to assist in the fabrication process outlined above.

3. A Seamless Pipe SCR Example

For this Gulf of Mexico project 692 pipes had to be measured in order to create two SCR strings for gas and water injection. A critical element for this project was to determine which AUT calibration block to use for each pipe end. Two calibration blocks of 23.1 and 23.6 mm were provided. Four cal block groups were allocated and pipes were placed into groups depending on the analysis of WT data. The data below shows the groups and the number of pipes in each group. There was a further number that fell outside of the range of both calibration blocks:

Group A	39 Pipes	AUT Cal. Block #1 ±1mm
Group B	276 Pipes	AUT Cal. Block #1 ±1.5mm
Group C	66 Pipes	AUT Cal. Block #2 ±1.5mm
Group D	143 Pipes	AUT Cal. Block #1 -1.6mm & Cal. Block #2 +1.5mm

The majority of pipes fell into a single calibration block category leaving about 37% requiring a dual scan. Experience has shown conclusively that engineers cannot predict what the pipe manufacturer has produced in advance of receiving the pipe and measuring it. Therefore it is something of an art to be able to balance the trade off between ordering too much pipe (with associated purchase cost) and ordering too little which may entail additional complexity and knock-on cost during the pipeline assembly process. Getting measurement data early on can help to quantify the likely assembly parameters and can typically ease the assembly process significantly, e.g. by segregating ‘problem’ pipes and finding ways to deal with them.

The geometry for the GAS SCRs was as follows:

- Section 1 – Requiring 10 joints from ‘Group A’ for the critical section
- Section 2 – Remainder of riser stacked up using required number of pipe from ‘Group B’.
- Insert Section 1 into Section 2 at appropriate location, 5,347ft to 5,677ft measured from the TSJ top of taper.
- Ten contingency pipes for riser.
- Total length of riser 6984 feet.

In order to ensure that the critical section was inserted into the correct location it was necessary to take the actual pipe lengths into account and modify the number of pipes for each riser accordingly. The pipe measured for this project was 6.625” (168.274mm) seamless pipe with a nominal internal Diameter of 4.813” (122.250mm) and 0.906” (23.012mm) wall thickness.

As a rule, seamless pipes are never perfectly round or oval due to the way in which these pipes are manufactured. The rollers and mandrels used all affect the shape of the finished pipe. Datasets that represent various characteristics of the pipe have been chosen and plotted for illustration. The pipe with the roundest internal diameter (ID) is illustrated in the following figure 5.

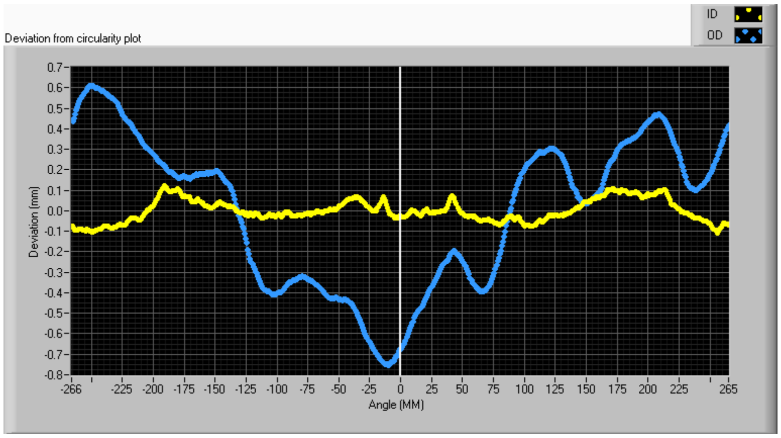


Figure 5. Roundest internal shape pipe (Int: yellow / ext: blue).

The yellow plot relates to the internal shape of the pipe and is the deviation from a circle fitted to the internal measurements around the pipe from -180 to +180 degrees. The shape of the pipe deviates by little more than 0.1 mm from circular. The blue plot is the external shape of the pipe with regard to the inside of the pipe centre determined by a best fit process. The features of the outside of the pipe will be discussed later.

The pipe end with the largest difference in ID has been plotted in (figure 6) below.

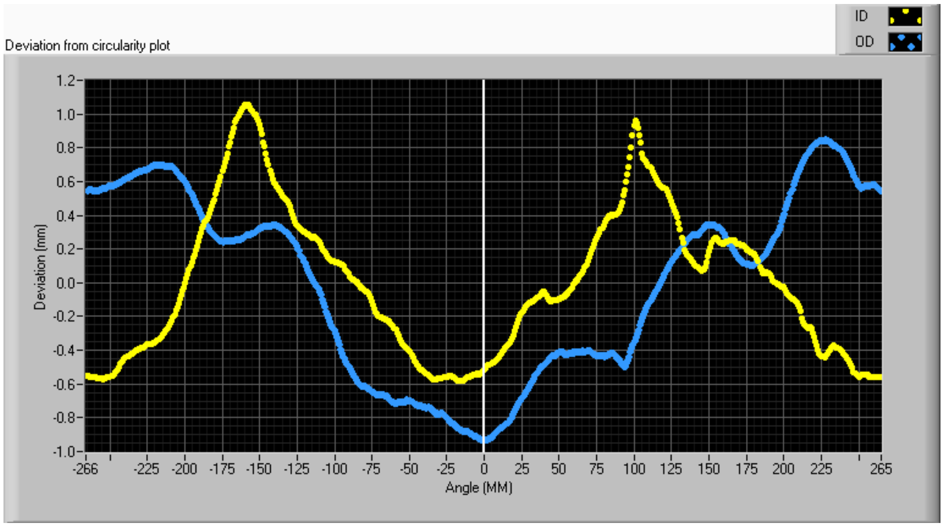


Figure 6. Pipe with the largest ID variation.

This pipe end has deviations from a best fit circle of nearly 0.58mm (yellow plot) towards the pipe centre and 1.06mm away from it. The two peaks and two troughs indicate that the inside of this pipe end is oval. If perfectly round pipe were matched to this pipe of exactly the same average internal diameter, then the HiLo would be the height of the largest peak (i.e. nearly 1.06 mm). In addition to internal geometry variations it was also necessary to deal with the considerable wall thickness variations in these pipes to manage the client AUT requirements. Variations in wall thicknesses (calculated as max WT – min WT) ranged between approximately 0.7 mm to 4.7 mm. Unique string architecture was created for each SCR which took into consideration all of the calibration block requirements but most importantly the internal fit-up of the pipes. The following table 1 is a sample from the architecture at the critical touchdown region.

AUT Cal Group A		AUT Cal Group B		AUT Cal Group C					
Joint Number	**Pipe Fixed (mm)**	**Pipe Free (mm)**	**ID Max Hi/Lo**	**ID Min Hi/Lo (mm)**	**ID Rotation (mm)**	**Length (m)**	**Length (ft)**	**Accumulated Length from Flowline (ft)**	**Accumulated Length from TSJ (ft)**
173	03507_B	03144_B	0.92	0.31	-98	9.862	32.356	1115	5815.1
172	03144_A	**03174_A**	1.21	0.34	18	10.435	34.236	1149	5780.8
171	**03174_B**	**03448_B**	0.99	0.44	-18	10.312	33.832	1183	5747.0
170	**03448_A**	**03618_B**	1.09	0.43	-196	10.331	33.894	1217	5713.1
169	**03618_A**	**03660_B**	0.77	0.28	-142	10.278	33.720	1251	5679.4
168	**03660_A**	**03655_A**	1.16	0.39	-150	9.976	32.730	1284	5646.6
167	**03655_B**	**03635_B**	0.59	0.28	-184	10.282	33.734	1317	5612.9
166	**03635_A**	**03546_A**	0.77	0.34	48	10.483	34.393	1352	5578.5
165	**03546_B**	**03634_A**	1.12	0.36	-61	9.999	32.805	1385	5545.7
164	**03634_B**	**03624_B**	0.53	0.28	-252	10.483	34.393	1419	5511.3
163	**03624_A**	**03453_A**	1.00	0.33	148	9.968	32.703	1452	5478.6
162	**03453_B**	**03263_A**	1.08	0.37	-183	10.381	34.058	1486	5444.6
161	**03263_B**	03049_B	1.07	0.32	166	10.374	34.035	1520	5410.5
160	03049_A	03212_B	0.66	0.28	25	10.445	34.268	1554	5376.3

Table 1. Example from the SCR architecture

Table 1 illustrates the particular pipe end and pipe number that was to be joined together with the predicted ID HiLo and the rotation angle necessary to achieve that internal HiLo. The architecture was created by exhaustively checking each end of each pipe with every other end in order to achieve the lowest possible internal HiLo. The graph of the HiLo maximum achieved for the string is given in the following figure 7.

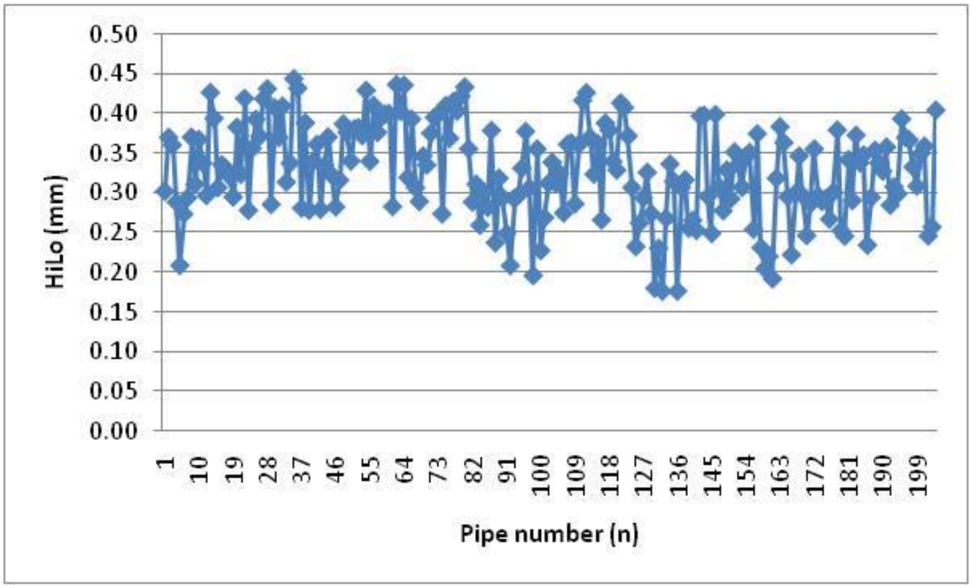


Figure 7. Maximum HiLo around the weld joint circumference for each of the 199 joints

692 pipes were measured at a Louisiana facility over a four day period. Two strings were created from the available pipes and these pipes were successfully welded prior to installation in 2008. Contingency planning was also carried out, and some contingency management was subsequently implemented to deal with changes that became necessary during the fabrication stage due to damage to pipes etc.

4. A UOE Pipe SCR Example

This project required the measurement of a set of 20” UOE pipes which were to be used for a deep water SCR in the Gulf of Mexico. OMS carried out the measurement of various pipes for the project. The activities for this project can be summarised as follows:

- Measurement of 16 x 20” pipes in Rotterdam prior to fatigue testing.
- Provision of fatigue sample fit-up sequence.
- Measurement of fatigue samples to assess post welding HiLo.
- Measurement of fatigue sample pipes following testing.
- Measurement of 298 pipes in Louisiana, USA, for primary and secondary string.
- Measurement of forgings.
- Computation of primary and secondary SCR strings.

- Contingency planning.
- Offshore support on board pipe lay vessel (SLAY), including deployment of capability to analyse contingency pipes.

Figure 8. Measurement of 20” pipe ends using the pipe measuring tool

Following the measurement stage, analysis of the measurement data was carried out. Early measurement and analysis revealed that the UOE pipes ordered for this project were difficult to match together to the specification requirements due to the geometry of the pipes. This allowed the engineers involved to agree a variation on the HiLo requirement for this project. With the HiLo variation in place, further analysis was conducted to determine a specific sequence of pipes and rotation angles between pipes in order to achieve the HiLo. A solution was obtained.

A further study was conducted in order to determine the best contingency pipe from the secondary string to replace any of the pipes in the primary string if needed. A set of pipes were identified and taken offshore along with a contingency plan.

The required rotation positions were marked onto pipe ends relative to datums, such that during offshore operations the corresponding marks could be aligned so as to quickly achieve the optimum rotation prior to welding. Figure 9 shows the alignment marks as the pipes are being rotated to the correct position.

Figure 9. Pipes being rotated into the datum position (both black lines together)

The rotation procedure together with the sequencing of the pipes onto the vessel and into the firing line was used to deliver the optimized array for the primary and secondary strings.

Personnel from the company supervised the fit-up on board the SLAY vessel and were on standby to re-measure pipes or to determine the correct contingency pipe to be used in the event of any problems in the fit-up of the pipes. The following summarises some of the outcomes from the project:

- The fit-up of the pipes on board the pipelay vessel was considered excellent by all the personnel involved in the process from AUT inspectors to the QC inspectors.
- Fit-up related welding problems were completely avoided within the entire project.
- The measurement of the HiLo achieved onboard the pipelay vessel were compared with the predicted results from the OMS software.

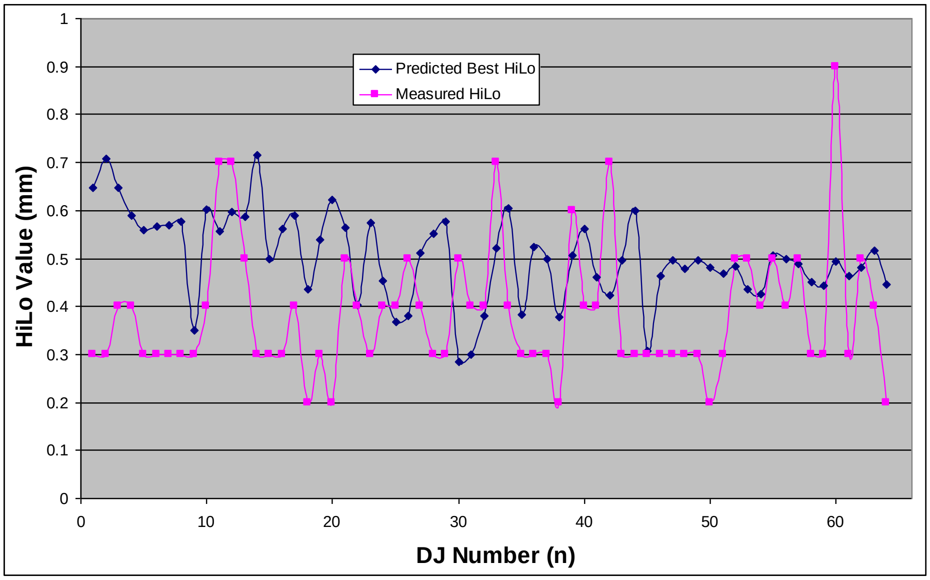


Figure 10. Double Joint Predicted and Measured HiLo

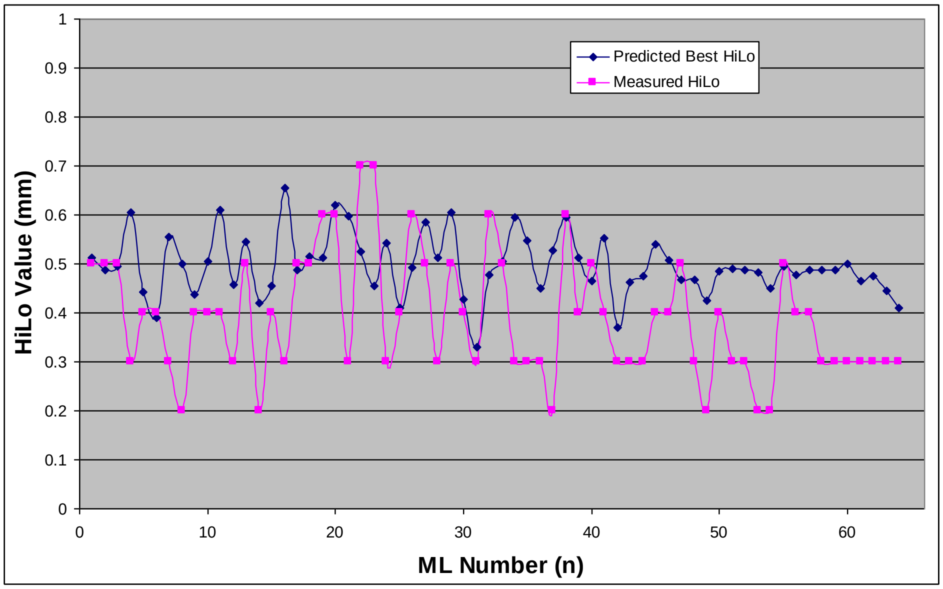


Figure 11. Main Line Predicted and Measured HiLo

The results show that the majority of the HiLo measurements on board were well within the predicted ranges. In a small number of cases yielded HiLo values were over-predicted (though still within the specification) and the over-predicted values were attributed to one of two things: (1) some pipes were not always rotated optimally as requested and (2) the accuracy of the fit-up is also affected by the line-up clamp that may not always achieve the optimum positioning of the pipes with respect to each other.

The aims of the project to manage the fit-up of the misshapen UOE pipes and fit them together with a HiLo within the specification were fully met. The Project Engineer stated that he would be happy to undertake this process again and that the costs of the exercise were fully justified by the end results.

5. A Flowline Example

This project is an example of how measuring pipe ends can assist the fabricator for less critical pipelines such as flowlines. In this example a methodology was designed and implemented that was able to reduce ID and OD fit-up issues in the firing line, while avoiding the need for a specific sequence of pipes to be created. The benefits of the method are:

- First time optimal fit for both ID and OD using specially designed software.
- Avoid the need for pre-sorting pipes and thus avoid additional pipe movements.
- Allow pipe delivered to the firing line to be immediately assessed, and rotation marks applied to enable best fit-up.
- A few pipes that won’t fit at any rotation orientation can be identified at this stage and set aside. Approx 1 in 20 pipes can typically need to be set aside. The ‘problem’ pipes are identified dealt with separately, rather than interrupting the flow of welding.

Overview: Measured pipes are brought from the pipe yard by a loader. The loader may carry approximately 5 pipes at a time. Pipes are unloaded on a pipe rack adjacent to the bevelling shed. Pipes are rolled into the bevelling shed. The bevelling shed can accommodate more than 10 pipes, but the sequence and orientation of pipes never changes inside the bevelling shed. There is space for one pipe to be rejected at a time out of the firing line. Pipes are moved through the bevelling shed into the firing line in sequence, and are welded. The loader returns unladen to the pipe yard. This allows an operator with a laptop PC and a database of pipe measurement data to recall and assess data for each pipe end prior to committing a pipe into the firing line. OMS created specific ‘visualisation’ software to facilitate this process. Using the software, pipe data is recalled from the database and assessed the pipe ends are marked with a rotation mark or if there is an issue, marked for rejection.

Fixed and Free Ends of Pipes: Pipes that are welded into the pipeline become 'fixed' as they cannot any longer be rotated. The fixed end of the pipe is always the end that is facing away from the welded pipeline. Pipes that are offered up for welding are 'free' in that they are free to rotate (as they have not been welded yet). The 'free' end of a pipe is always the end that faces towards the welded pipeline.

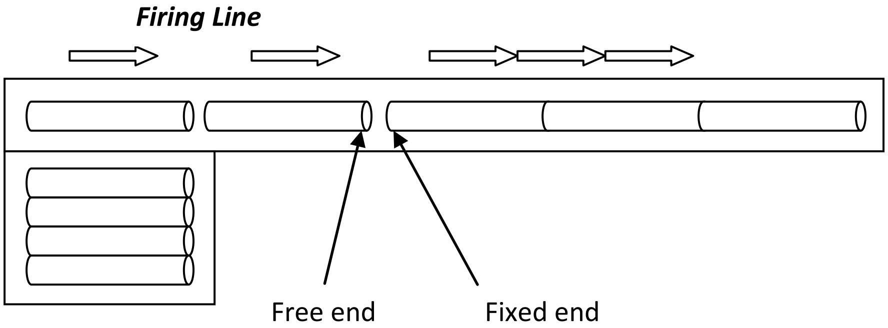


Figure 12. Layout of the pipes in the bevelling shed and firing line

In figure 12 above, all the ends that face away from the welded pipeline will become fixed ends in due course, while all the ends that face the welded pipeline are 'free' ends'. Correct identification of fixed and free ends is vital in the pipe rotation procedure. The pipe number for fixed and free ends must be entered correctly into the laptop PC software so as to recall the relevant measurement data.

Using the Visualisation Software: The laptop PC running visualisation software is located at the position indicated 'V' in figure 13 below. This position gives access to mark the free ends of pipes with a rotation mark or a reject mark.

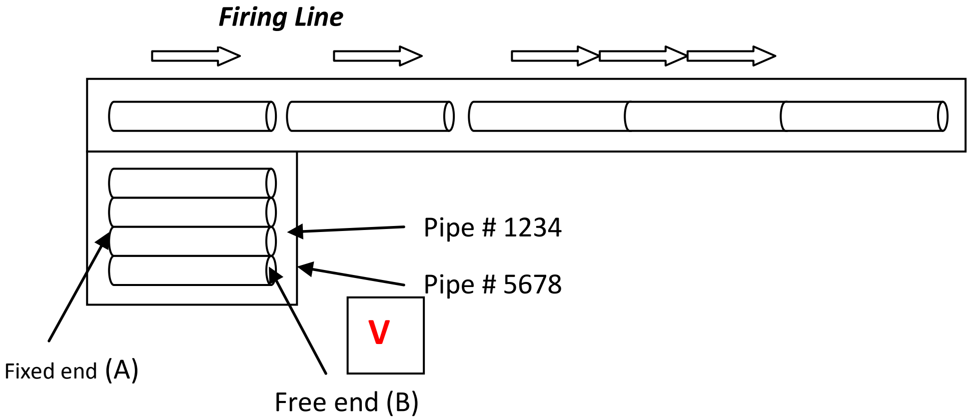
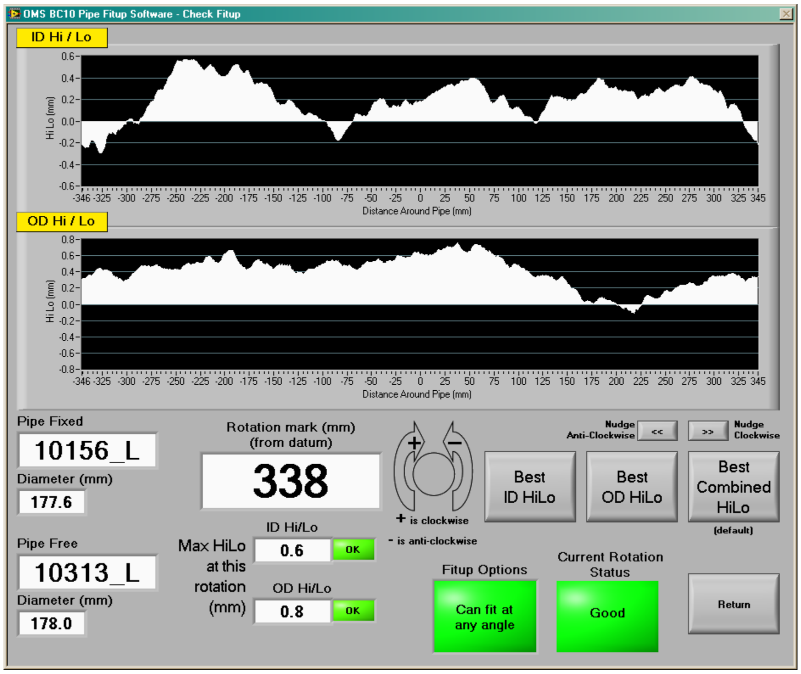


Figure 13. Position of the visualisation software running on a laptop PC.

The operator must first enter the number for the fixed end of a pipe as it goes past them to the firing line, then they must enter the number for the free end of the next pipe. In the above example of figure 13, pipe 1234 is going into the firing line ahead of pipe 5678. The operator would have already marked the free end of pipe 1234 at this stage, and now must mark the free end of pipe 5678. First they will enter the fixed end of the preceding pipe, i.e. they will read 1234_S from the free end and they will enter 1234_L for the fixed end of the preceding pipe. Next they will enter the free end of the pipe and mark, i.e. 5678_S. A typical user screen is shown in figure 14 below.



Pipe Fixed: 10156_L
Diameter (mm): 177.6
Pipe Free: 10313_L
Diameter (mm): 178.0
Rotation mark (mm) (from datum): 338
Max HiLo at this rotation (mm)
ID Hi/Lo: 0.6 OK
OD Hi/Lo: 0.8 OK
Fitup Options: Can fit at any angle
Current Rotation Status: Good

Figure 14. Visualisation software which indicates the rotation (in mm) of the pipes for best ID and OD HiLo

Once pipe numbers have been entered, the visualisation software will provide the best rotation. The operator will measure from the datum mark of 5678_S and will inscribe the rotation mark on the pipe following OMS rotation procedures. Then the operator will want to mark the next pipe, so they will repeat the procedure, starting by entering the fixed end for 5678 (i.e. 5678_L).

A small number of pipes have shape/WT deviation/eccentricity etc that will mean the pipes cannot be fitted at any rotation to meet HiLo specifications. The operator will see from an alarm displayed by the visualisation software if any pipes meet this condition. These must be temporarily put to one side. The operator will mark affected pipes clearly with paint so they can be rejected via the ‘rejected pipe’ rack. The loader operator will be notified, and will return the affected pipes to a ‘bad pipe’ stack in the yard, to be dealt with separately at a later time. Prior analysis and simulation had shown that upwards of 1 in 20 pipes can be affected in this way.

A process flow is shown in figure 15 below.

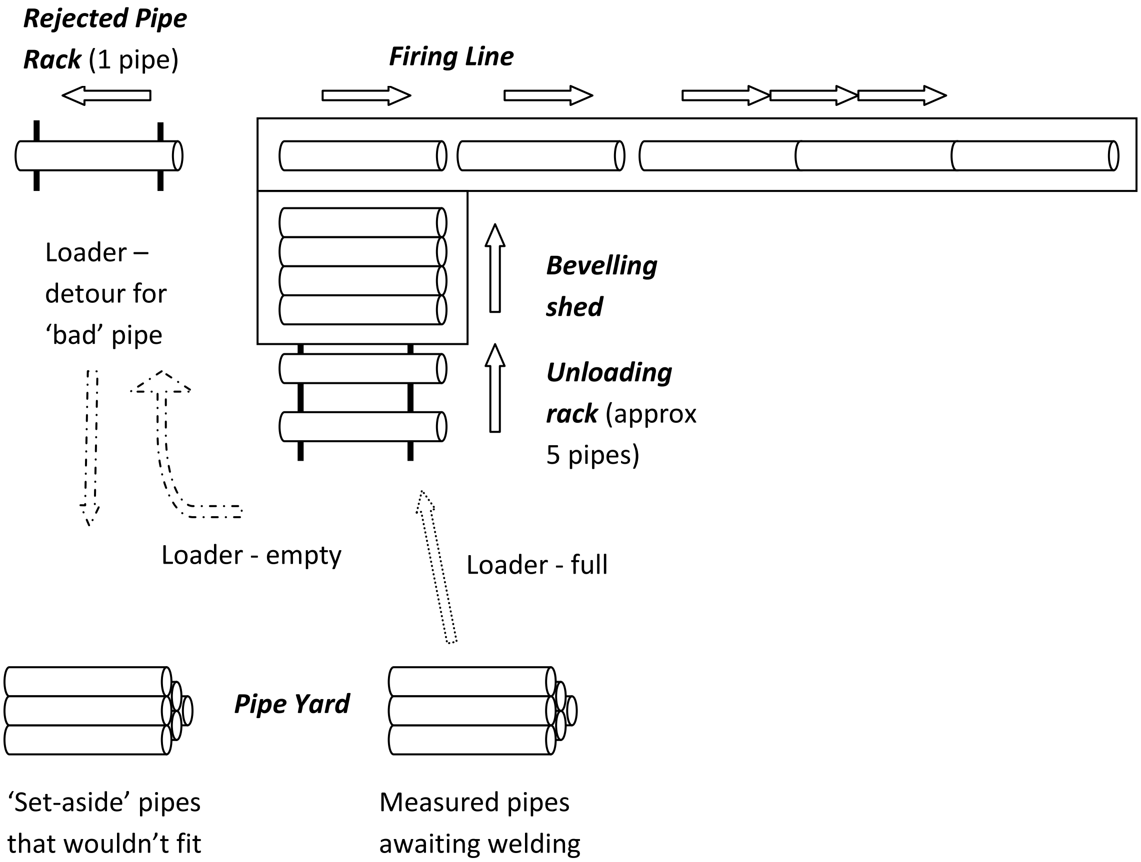


Figure 15. Process flow for pipe-handling operations

Summary

- The procedure is based on an ID HiLo of 1.0mm and an OD HiLo target of 2.0 mm.
- All pipes must be pre-measured, and the data accurately logged into the database.
- Laptop computers containing visualisation software and the flow line data are used by trained fabrication company staff.
- The Laptop software indicates the rotation distance for the pipe.
- OMS rotation procedures are followed to mark up, and then achieve the indicated fit-up/HiLo for the joint.
- The small proportion of pipes that will not fit at any rotation to meet the required HiLo are indicated by the software and these are set aside and reintroduced into the sequence of pipes as and when possible.

6. SCR Counterbore

OMS was contracted to conduct pipe end measurements in Norway in order to assist a client in planning the counterboring process for a set of risers for a Gulf of Mexico project. There were 675 SCR pipes and 182 Fatigue Sensitive flowline pipes. The pipe measurement survey was carried out in a coating yard over a period of 6 days with up to 230 pipes being measured per day. The following graphs illustrate the variation in internal diameter and wall thickness for the pipes.

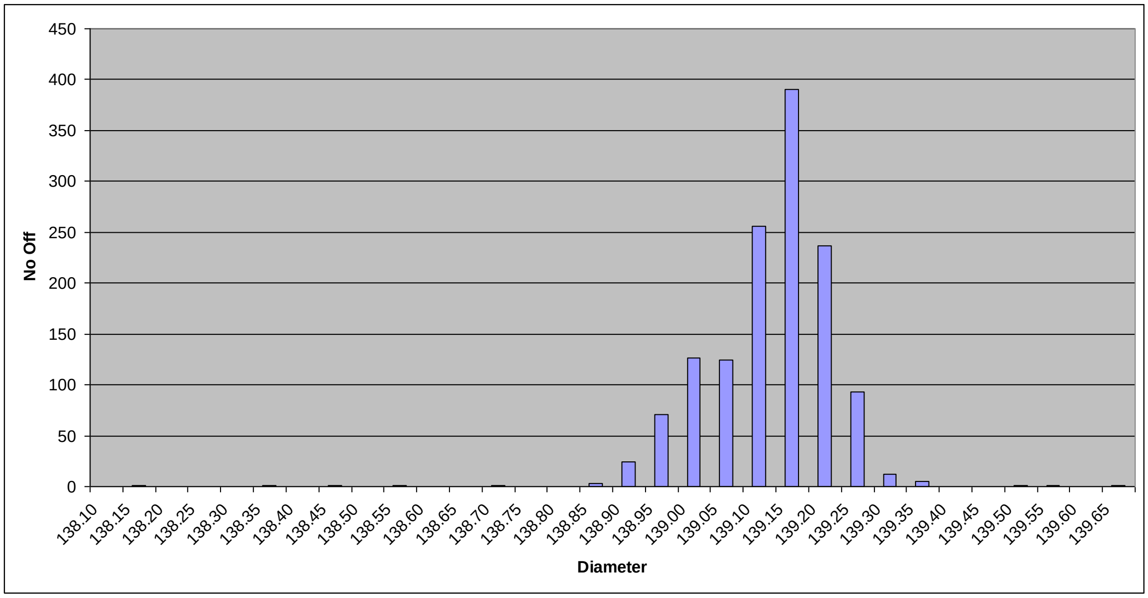


Figure 16. Internal Diameter histogram for SCR pipe

The next graph (Figure 17) illustrates the wall thickness variation histogram for the SCR pipe.

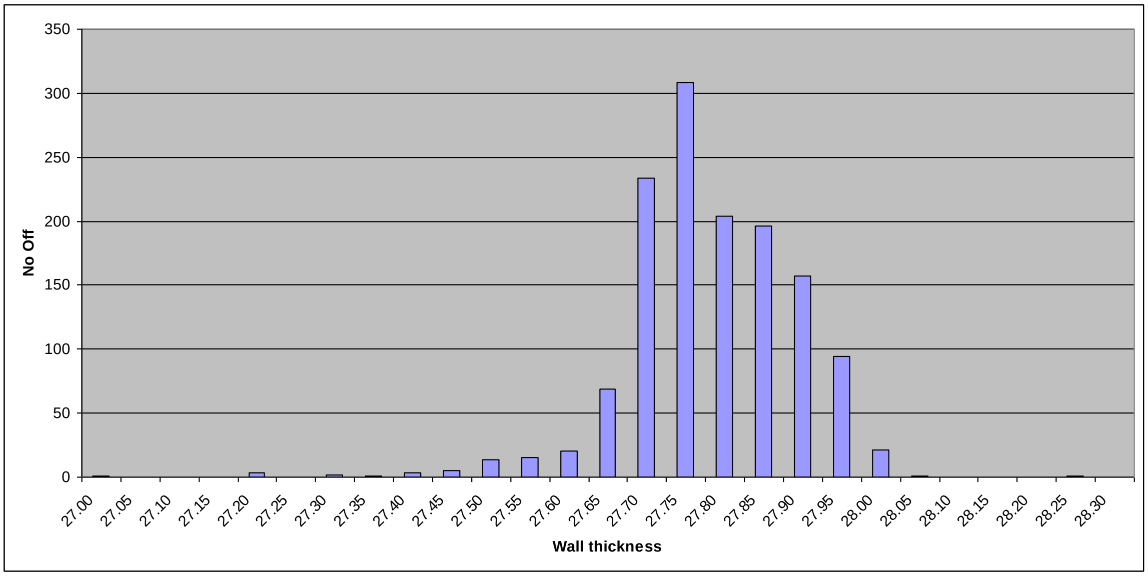


Figure 17. Wall thickness histogram for SCR pipe

Following completion of the measurement phase, computer analysis was carried out to optimise a set of counterboring parameters for the fatigue sensitive flowlines and SCRs. Pipe ends are generally different from each other in both size and shape, and in this case the analysis showed that groups of pipes of the same counterbore diameter would be the best practical scheme for the client.

In this project a 0.5mm HiLo was the maximum acceptable after counterboring. Variations of up to 0.2 mm in ID size and more than 0.5 mm in misalignment can easily occur so these have to be modelled and accounted for in the software simulation of the counterboring. As a consequence a material safety margin of 0.5 mm was configured in the simulation. Where pipe ends attain only poor geometrical consistency, this safety margin cannot always prevent a partial counterbore occurring, but an allowance for a small proportion of partial counterbores can be a useful option as part of the overall optimisation and can help to achieve a better overall trade off.

The counterboring issues are illustrated in the following exaggerated diagram which illustrates the values that have to be considered when planning the counterboring of these pipes.

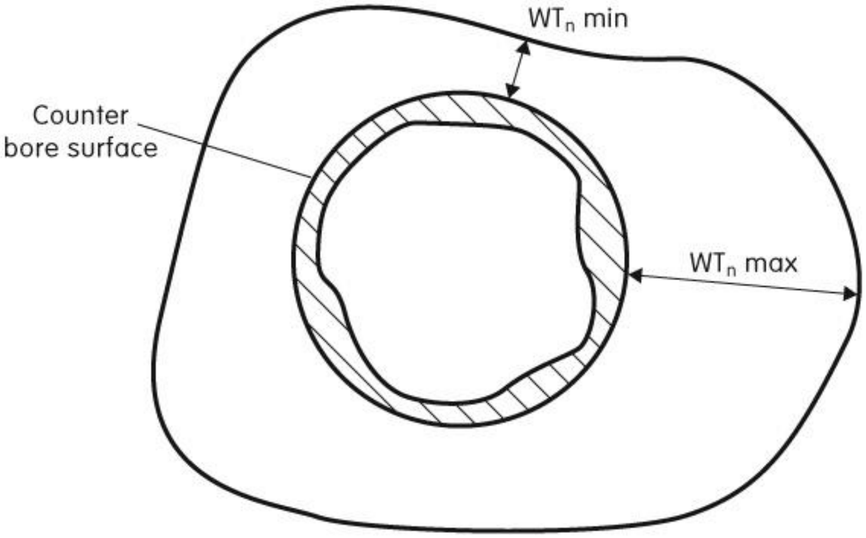


Figure 18. Counterbore wall thickness parameters

The methodology began with analysing pipe end statistics for internal diameter, external diameter and wall thickness generated from the measurement data to determine initial counterboring diameter candidates. This drove a simulation phase at which 2-D pipe end geometry was then modelled in the process of counterboring to find the post-counterbore wall thickness and the amount of material removed. It was also necessary to find pipes such that both ends would be able to meet the applicable criteria. These pipes were grouped together such that the material removed after counterboring would ideally be less than 1.0 mm. The pipes that could not meet the initial criteria were then used to select a second group with a larger counterbore size parameter and so on until all the pipes' counterbore sizes were determined. This entire process was iteratively optimised. Measurements that represent the full 2-D pipe end geometry are the fundamental enabler of this type of optimisation process.

Figure 19 below illustrates the process of simulating the removal of material during the counterbore process in the software.

In this type of project it is often the case that eccentricity is the biggest factor in determining the allocation of pipes into groups. The pipes with the smallest counterbore size are often the pipes with the best concentricity between the outer and internal geometries.

Pipe ID: 01927S

Data collection date and time: 08 Nov 2006 - 17h 57m 42s

Diameter: 194.70

Pre Counterbore Thickness: 27.73

Counterbore Diameter: 142.8

Pipe 869 of 1323

Average Remaining: 25.9518

Max Remaining: 26.4282

Min Remaining: 25.5783

Average Removed: 1.77672

Max Removed: 3.02741

Min Removed: 0.59665

Wall thickness after counterboring

Removed material following counterboring

Figure 19. Example of a minimum counterboring cut

The following graph of Figure 20 illustrates the results of selecting five different counterboring sizes and the affect on the material removed from the pipe under perfect centring conditions (Average, Maximum and Minimum values).

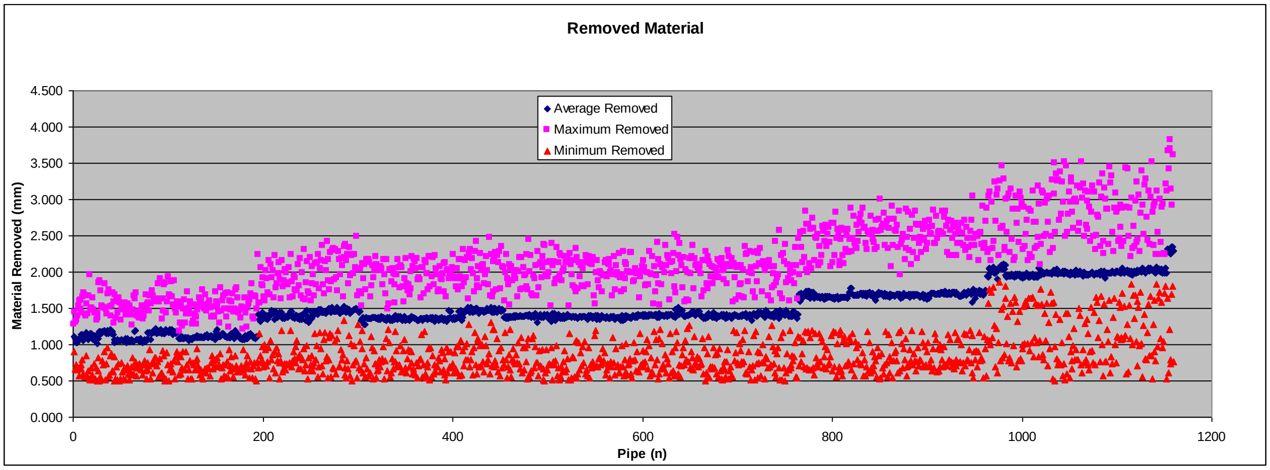
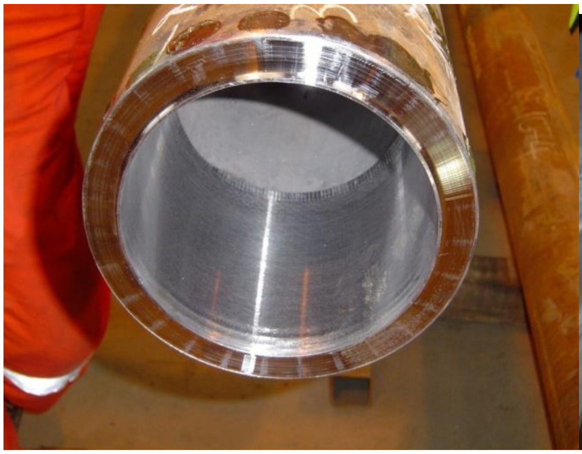


Figure 20. Average material removed for each pipe group.

The graph of figure 20 shows that a minimum of 0.5 mm was removed from each pipe end up to a maximum value of more than 1.0 mm. Often one end of a pipe can have more material removed, because of the need to have the same counterboring size for both ends whereas the pipe internal diameter and shape differ from end to end. The following figure 21 illustrates one of several counterbore tool designs.

Figure 21. A Counterboring Tool

The following figures 22(a) and 22(b) illustrate a good and a bad (partial) counterbore:



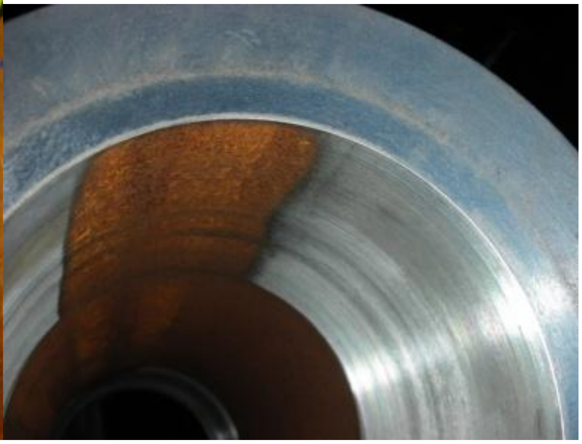


Figure 22(a) Counterbored pipe end. **22(b) Partially counterbored pipe end**

By utilising full 2-D pipe end measurement data, the various factors involved in optimising counterboring can be simulated to find the best compromise solution. The optimal solution avoids the need to remove large amounts of material and yet includes an ‘allowance’ for machining tolerances, which results in avoidance of partial counterbores in practice.

7. Conclusion

This paper describes ways in which measurement technology can be applied when fabricating SCRs and other fatigue sensitive pipes as well as flowlines. New techniques of dimensional metrology, coupled with analysis and simulation, can ensure the high standards demanded by the pipeline owners can be met by the fabrication contractors. OMS has developed tools and services for virtually all aspects of dimensional inspection of flowlines and risers. These tools and services have been vital to a significant number of pipe lay projects over the past five years. This paper has described some way in which the geometry of pipes can be managed to still meet the highest level of geometric performance.

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