

DEVELOPMENT AND PRODUCTION OF LARGE-DIAMETER LINE PIPE FOR OFFSHORE APPLICATIONS

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Abstract

The continuous analysis of market requirements for large diameter line pipes used in offshore application reveal that overall the requirements are becoming more and more stringent. This development is triggered by the fact that offshore pipelines are installed in deeper water and operated under higher pressures. Therefore the line pipe material has to show higher strength properties with simultaneously increased toughness. In case that the gas to be transported contains certain amount of H₂S additional requirements regarding HIC resistance have to taken into consideration. As installation of offshore line pipes play a significant role within the whole project costs also the pipe geometry has to be improved steadily with tighter tolerances especially for out of roundness and wall thickness in order to facilitate and speed up pipe laying. Similar tough requirements on ovality but also straightness are applied in case of tendon pipes connecting the Tension Leg Platform and its topside with the sea floor.

Consequently the applied technologies from steel making to pipe production are continuously improved in order to increase the quality level and the productivity by reducing non-quality costs. In this paper, the crucial manufacturing steps necessary to fulfil these stringent requirements for offshore line pipes are described. Special attention is paid to the pipe forming, the welding process and its control as they are of essential importance for the intrinsic pipeline safety. This will be supplemented by review of current project examples for different offshore applications with specific requirements such as thick wall pipe for North Sea offshore application, production of sour service line pipes and tendon pipes.

Introduction

The steady increase in the operating pressures of oil and gas pipelines, pipe laying and service under extreme conditions in the offshore regions have led to increasingly severe property requirements for pipeline steels. Today, not only greater wall thicknesses but also higher strengths are needed. Further requirements are related to excellent toughness, good weldability and pipe geometry within narrow tolerances. In case of sour service application the line pipe steel has in addition to withstand the aggression of corrosive media.

The most economic production method for line pipes fulfilling such high quality requirements is the UOE manufacturing route with submerged arc welding process in two passes. However the quality control for DSAW line pipes of EUROPIPE already starts in the steel plant of the plate manufacturer. Table 1 gives an overview of the different manufacturing

steps and quality aspects, which are of primary importance during the production flow of large diameter line pipes.

Product Stage	Manufacturing Step	Primary Quality Aspect
Steel	Ladle Treatment BOF Secondary Metallurgy Continuous Casting	Chemical Composition Cleanness/Inclusion Control Segregation Control Surface Quality
Plate	Slab Reheating Rolling Parameter Cooling Parameter	Microstructure Mechanical Properties Corrosion Resistance Plate Geometry
Pipe	Forming Welding Expanding NDT	Pipe and Weld Geometry Mechanical Properties Reduction of Residual Stresses Weld Quality Corrosion Resistance

Table 1: Main manufacturing steps and quality aspects for SAW large diameter line pipes

The steel making practice is outlined in Figure 1. The figure shows schematically the various steel making steps involved and their metallurgical objectives.

The production of steel with high cleanness begins with the hot metal desulphurization. The carbon and phosphorus contents are reduced in a BOF converter with bottom stirring to achieve values required within the metallurgical design selected for the particular application.

The application of a vacuum tank degassing enables a strong desulphurization and degassing, i.e. the expulsion of nitrogen and hydrogen to be achieved simultaneously. Following the vacuum degassing the molten steel is stirred with an optimized inert gas ratio to improve the cleanness further. As a result, the total contents of residual elements like P, S, N, H and O are reduced to very low values providing an excellent cleanness of the steel [1].

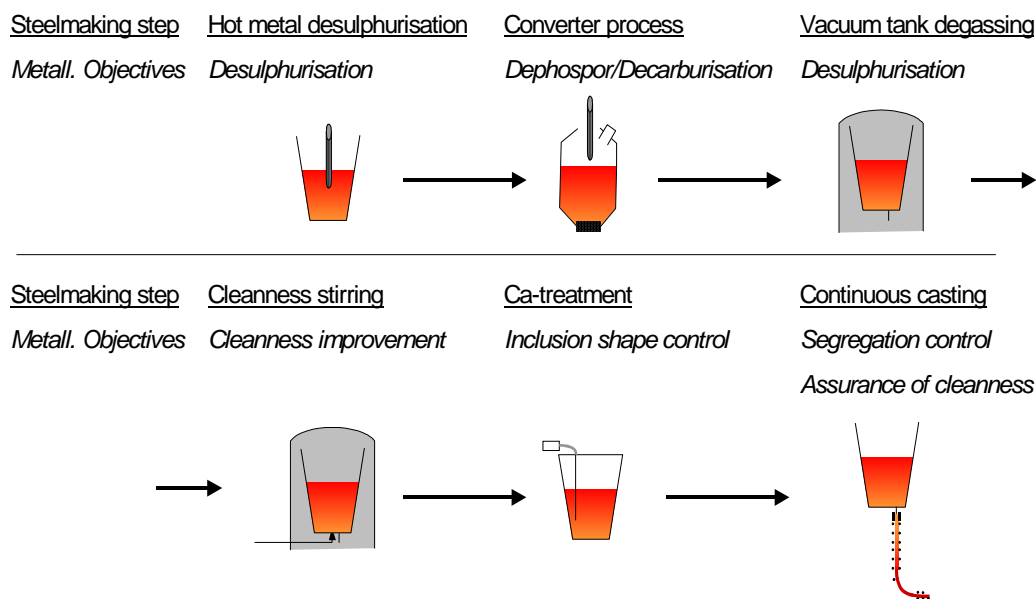


Figure 1: Steel making process for high quality line pipe steels

The molten steel is continuously strand cast into slabs in a sealed off system including shrouding of the pouring stream. Soft reduction is applied to minimize centerline segregation.

Bulging of the slabs between the rolls is prevented by an intensive cooling that results in low slab surface temperatures. This practice stiffens the shell of the strand.

Starting from defined steel composition, the target-microstructure and corresponding properties are achieved by the application of TMCP (Thermo-Mechanical Control Process) incorporating a special time and temperature sequence. This incorporates the reheating of the slab to specific temperatures, the rolling to successive thicknesses with specific reductions at prescribed temperatures interrupted by cooling periods. The cooling after finishing rolling can be performed in water down to specific final cooling temperature (followed by cooling on ambient air) with specific cooling rate [2].

At the large-diameter pipe mill the plates are formed into pipes using the UOE process. Line pipes manufactured for offshore applications require well equipped and maintained forming presses with high forces due to the challenging combinations of wall thickness, outside diameter and steel grade. The crimping press represents the first important forming step where the basis for the final pipe geometry in terms of out of roundness is laid. The subsequent U-ing press transforms the crimped plate to an open slit pipe with vertical plate edges guaranteeing a trouble-free entry into the O-ing press. At the UOE mill of EUROPIPE in Muelheim the formed plate obtains its round shape with applied forces up to 60.000 t. Each different nominal diameter necessitates specific forming dies. High precision and permanent control of all forming parameters is necessary in order to fulfil most stringent requirements regarding ovality and straightness after welding and expansion.

The next challenging step in the production of line pipe is the welding of the longitudinal seam. A wide range of different quality requirements have to be achieved reliably and under economic conditions. The production of a weld seam suitable for the purpose of high pressure line pipe is more than just joining two plate edges. The following table 2 summarises the most important quality aspect of a submerged arc welded longitudinal seam:

SAW quality aspects		
Mechanical Properties Corrosion Resistance	Weld shape	Imperfections/Defects
Strength Matching ratio Toughness Hardness HIC/SSCC resistance	Misalignment Radial offset Weld bead height Weld contact angle Weld bead width Interpenetration Weld linearity	Undercuts Slag inclusions Porosities Lack of fusion/interpenetration Cracks
Key factors: (Welding parameters) Consumables, Base metal	Key factors: Welding parameters (Consumables)	Key factors: Welding parameters (Consumables)

Table 2: Quality aspects for SAW seams

Whereas the mechanical properties/corrosion resistance is predominantly defined by the selection of appropriate welding consumables the weld shape and the occurrence of imperfections or defects is strongly influenced by the welding parameters.

In the EUROPIPE mill in Muelheim an der Ruhr up to 15 km of weld seam can be manufactured per day. Stable welding processes are mandatory to guarantee lowest repair and rejection rates. To further improve the process EUROPIPE invested in the latest technology of digital power sources.

This new welding equipment enables to improve the welding speed in order to reach high productivity and low heat input without the risk of increasing defect rates which is essential for thick wall line pipes. Figure 2 (left) shows the optimisation of heat input while increasing the deposition rates at a given wall thickness. A reduction of 11% heat input with a parallel increase of deposition rate of 4% was achieved by using the power waves options.

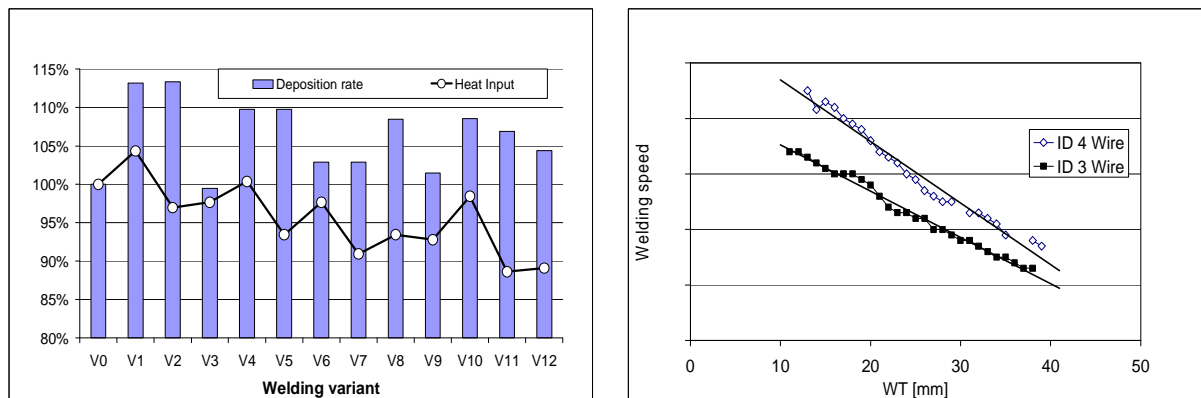


Figure 2: Optimisation of deposition rate, heat input (left) and welding speed (right)

The installation of the new power sources went hand in hand with the introduction of 4-wire welding inside and 5-wire welding outside. The resulting increase of welding speed (Figure 2, right) of 25- 30% allowed a reduction from eight to seven welding lines. Nevertheless the welding capacity could be improved by 15%.

The next step is the fast feed back between NDT and welding to avoid systematic deviations. EUROPIPE relies on a combination of visual inspection, automated UT and X-ray. As shown in Figure 3 the visual testing immediately follows outside welding. Both internal and external pipe surfaces including weld seam are controlled. All kind of surface defects are detected and entered in PRODIS, the integral production data information system. Beside real defects such as undercuts the testing registers process deviations i.e. irregular weld shape or width and height of the weld seam. An automated 100%UT of the weld seam reports all internal imperfections. UT indications are confirmed by filmless radiography called FLORAD and/or verified by manual UT [3].

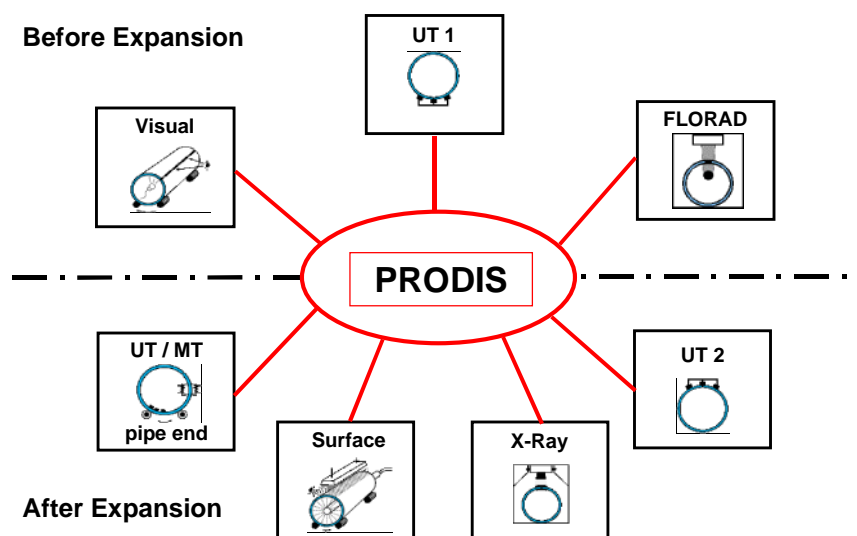


Figure 3: Non-destructive quality control linked to PRODIS

All test results are available in PRODIS. A list with all defect codes is on hand at any time to the welding operators. The consequent process control in combination with fast access to the essential information at any time and any place in the mill lead to a permanent reduction of rework and losses due to weld defects. The final forming step is expanding the pipe to its final outside diameter with carefully selected expansion ratios between 0,8 and 1,5%. Due to the plastic deformation the cold expansion reduces residual stresses within the pipe induced by forming and welding.

After expansion the remaining quality control steps according to the customer specification are performed as AUT and X-ray inspection of weld seam, hydrotesting and NDT inspection of pipe ends by UT and MPI. Optional a full body MPI can be carried out on customer's request.

In the following production results of recent line pipe projects for offshore applications are presented.

Thick wall X65 for Sour Service

First deliveries of sour service line pipe grade by EUROPIPE (former Mannesmann) were executed now more than 25 years ago. The development of line pipe steels for sour service over these years has been greatly governed by market trends. In total more than 3 million tons of line pipes for sour service in material grades up to X70 and wall thicknesses up to 41 mm have been supplied documenting greatest experience in sour service production.

One challenging order with regard to the sour service acceptance criteria in combination with stringent requirements on mechanical properties was the production for the RAS GAS project in Oman, where a grade X65 with a maximum wall thickness of 33,1mm was specified. In total 135.000t of line pipe were manufactured and delivered. The agreed HIC test acceptance criteria are far beyond the usual requirements as defined by EFC 16 [4] or ISO 3183-3 [5].

Table 3 summarizes the most important production results. In Table 3a the mechanical properties are described by means of average values for specimens orientated transverse to the rolling direction. The requirements for grade X65 pipe were comfortably met.

Mechanical Properties	Mean Value
Yield strength $R_{t0.5}$ [MPa]	480
Tensile strength R_m [MPa]	564
Y/T [%]	86
Elongation A2" [%]	50.0
DWTT @ 0°C [% SA]	89
CVN Toughness @ -10°C	
Weld metal [J]	175
FL [J]	422
FL + 2 [J]	410
Base metal [J]	433

Table 3a: Mechanical Properties

The essential requirements for the chemical composition of HIC resistant steel are low concentrations of carbon, manganese and sulphur. As Table 3b reveals these requirements have been strictly observed in the chemical composition of the pipe used for this X65 offshore project. Besides the low carbon and manganese contents the steel features micro-alloying additions in the way of vanadium and niobium, which were made to meet the requirements for the mechanical properties. The HIC test results on this order are given in Table 3c. It has to be pointed out, that the severe sour service requirements for this order could only met by using extraordinary precautions during steel making, casting and plate rolling, respectively. Under the standard test conditions according to NACE TM02-84 [6] solution A (pH 3, 1 bar H₂S) the specified acceptance criteria are reliably fulfilled.

C	Si	P max.	S max.	Mn	Others	CE(IIW)	Pcm
0.037	0.28	0.015	0.0015	1.38	Nb, V	0.33	0.13

Table 3b: Mean Chemical Composition (weight %)

Specification Requirements		Results on Pipe
Test Condition	Acceptance Criteria	Base + Weld Metal
pH 3 1 bar H ₂ S	CTR: ≤ 1.5 %	CTR ≤ 1.2 %
	CLR: ≤ 10 %	CLR ≤ 5 % for 90 %
	CSR: ≤ 1 %	CSR ≤ 0.5 %

Table 3c: HIC Test Results

Table 3a-c: Results on production pipes of 135,000 t with 36" ID x 27.2 - 33.1 mm WT Grade X65 intended for sour service pH 3

Offshore SAWL 485 IFD

The Langede pipeline will transport natural gas from Nyhamna on the Mid West coast of Norway via the offshore platform Sleipner to Easington in England. Unprocessed gas is transported by two 30"OD pipelines from the Ormen Lange field at about 1000m water depth outside mid-Norway to the gas terminal at Nyhamna, where the gas is treated before it is sent through Langede as the first pipeline bringing gas from Norway directly to the U.K (see figure 4). The Langede North is a 630km long 42"OD pipeline. The design pressure out from Nyhamna is 250bar, requiring up to 34mm wall thickness. In order to optimise the steel quantity and the welding time, the Langede North has been designed with two different design pressures, 250 bars for the northern half and 215 bars for the southern half. The Langede South is a 550km long 44"OD pipeline. The design pressure in this case is 156 bars, requiring a wall thickness of 23 to 24 mm. The design of the pipeline is according DNV-OS-F 101 in grade SAWL 485 IFD [7].

EUROPIPE had to supply 835 km or 630,000 t. About 800 km were produced in Mülheim and the remaining part of 35 km in Dunkerque pipe mill. Pipe production started in April 2004 and was finished in December 2005. A lot of 30,000 t per month had to be shipped to Norway to receive corrosion and heavy coating. The following will summarize the pipe production and the logistical challenge.



Figure 4: Major pipeline projects in the North Sea

For this project logistics in terms of plate delivery, handling of samples and specimens and pipe dispatch was quite a challenge.

In total about 630 kt of steel, of plate and of pipes had to be produced for 25 delivery lots and to be transferred from one production step to the next and all quality assuring topics had to be taken into account. About 3,700 heats were cast to produce pipes with about 830 km total length. To get the required quantity in time all plate production routes available were used (Figure 5).

Dillinger Hütte (DH) delivered slabs to their plate mills in Dillingen (DH) and Dunkerque (GTS) where the plates were rolled. Hüttenwerke Krupp Mannesmann (HKM) casted slabs that were rolled at the plate mill of Mannesmann Röhren Mülheim (MRM). Some of the pipes were coated in Norway but almost the entire quantity of Langed North was internally coated in the EUPEC coating yard in Mülheim, while external corrosion and concrete coating application was performed in Farsund, Norway.

For Langed South with a wall thickness up to 24 mm both pipe mills in Mülheim and Dunkerque were involved in the production. The heavy wall pipes for Langed North (29.1 to 34.1 mm) were solely manufactured in Mülheim because of the higher forming forces necessary. The shipment of the released pipes started from the port of Bremen to which about 580 trains with in total about 14,500 wagonloads (average 25 wagons per train) transported the pipes from Mülheim. About 100 shiploads were carried to Norway by seagoing vessels.

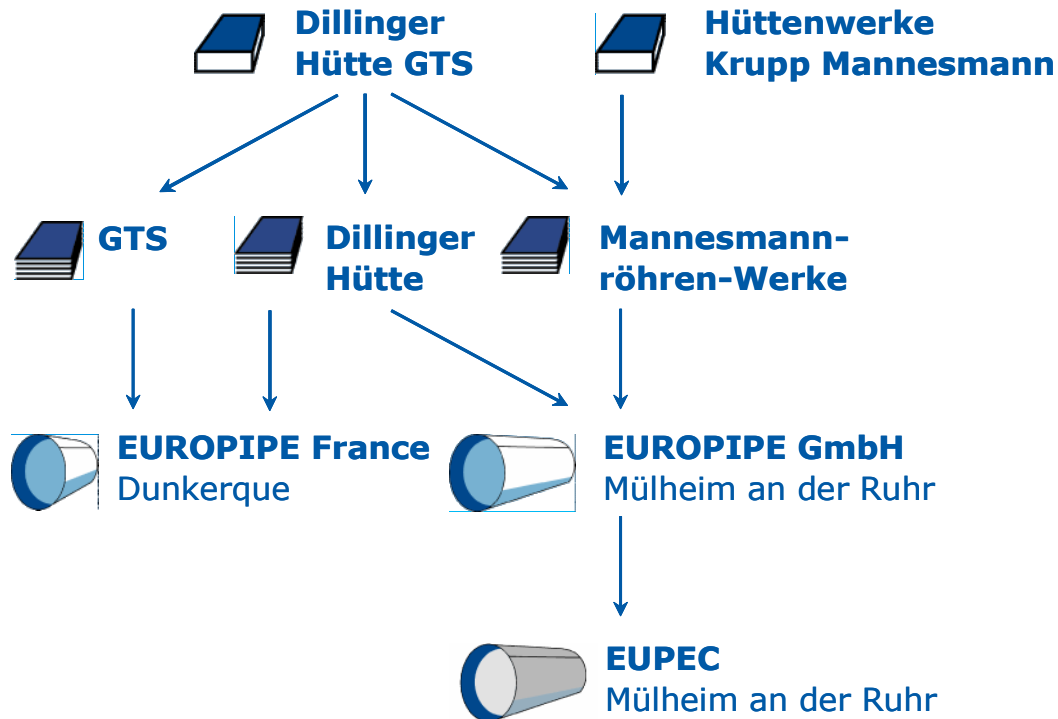


Figure 5: Material flow of the Langeled order

In order to fulfil delivery of pipes in time a big amount of tests had to be carried within a short time frame. According to DNV OSF 101 each production route had to be qualified through a testing programme, followed by testing of each heat by 3 tensile tests, 9 sets of CVN tests and 1 hardness test consisting of 30 hardness indentations. For the 163 km (13,302 pipes) of pipes with 23.3 mm wall thickness used in the southern part, 581 heats (Table I) were required. That resulted in testing of every 23rd pipe. For the northern pipeline, 604 heats were necessary to produce 109 km (8,800 pipes) of 34.1 mm wall thickness making 15th pipe/heat. Special care had also to be focused for the minimum pipe length requirement, as short length pipes would result in rejection. In total about 10,900 tensile specimens and 32,600 sets of Charpy-V specimens (97,800 single specimens) had to be machined and tested. About 3,600 cross sections were made and about 109,000 hardness indentations were set. Especially the high amount of Charpy-V testing made the final release in time to a challenge. A reasonably reduced test programme should therefore be discussed for future projects of this size.

The fundamental requirement for steels intended for offshore line pipe for the North Sea can be defined in terms of internal homogeneity and high toughness of the material at low temperatures, i.e. microstructural design.

All steps in the production of such steels have to be optimized in order to meet the requirements. The first step in the design has been the choice of the chemical analysis. After several rolling trials at the research lab with very promising results a few heats were casted and used in the steel works in order to roll heavy plates in the entire wall thickness range from 23 to 34mm. The assessment of the plate properties revealed that all required mechanical properties on plate was reached safely with one chemical composition, but optimized Thermo-Mechanical-Control Process (TMCP) rolling concepts adapted to individual wall thickness. The thicker wall required a more stringent accelerated cooling after rolling of the plates. The chosen composition is given in table 4. With this concept the properties of strength, toughness, weldability and fabricability were comfortable met.

C	Si	P max.	S max.	Mn	others	CE(IIW)	Pcm
0.08	0.3	0.015	0.003	1.6	Nb, Ti	0.38	0.19

Table 4: Mean Chemical Composition (weight %)

Compared to routine approaches the present steel had no Vanadium additions and is very lean in composition. The steel was desulphurized and dephosphorized to low sulphur and phosphor levels, respectively. The carbon and manganese contents and the microalloying elements Titanium and Niobium served to ensure that the steel attained the required mechanical properties.

As can be seen from the data given in the table 5, the pipe could be produced with a high statistical confidence level, despite its heavy wall. Both the transverse and longitudinal tensile properties of the pipe are comfortably above those required for grade SAWL 485 IFD. The comparison of mechanical properties in transverse and longitudinal direction showed that the yield strength is on the same level but the tensile strength in transverse direction is about 20 MPa higher.

Mechanical Properties	Mean Value	Mechanical Properties	Mean Value
YS R _{10.5} (MPa)		YS R _{10.5} (MPa)	
Transverse	522	Transverse	513
Longitudinal	515	Longitudinal	520
UTS R _m (MPa)		UTS R _m (MPa)	
Transverse	628	Transverse	623
Longitudinal	603	Longitudinal	603
Y/T (%)		Y/T (%)	
Transverse	83	Transverse	82
Longitudinal	85	Longitudinal	86
Elongation A5 (%)		Elongation A5 (%)	
Transverse	20.8	Transverse	22.6
Longitudinal	22.5	Longitudinal	23.9
CVN energy @ -30 °C		CVN energy @ -30 °C	
Weld metal (J)	151	Weld metal (J)	125
HAZ (J)	225	HAZ (J)	243
Base metal (J)	209	Base metal (J)	260

Table 5: Results on 44"OD x 23.3 - 24.0 mm (left) and 42"O.D. x 29.1 - 34.1 mm W.T. (right) SAWL 485 IFD line pipe production for the Langeded project

The Charpy V-notch impact energy values measured on the base material at -30°C are all in excess of 200 J. Even at test temperatures as low as -70°C the CVN energy is safely above 150 J. The high toughness of the base material is shown in the temperature transition curve for the CVN (Figure 6) and the Battelle Drop Weight Tear Test (BDWT test) (Figure 7) for the heavy wall material.

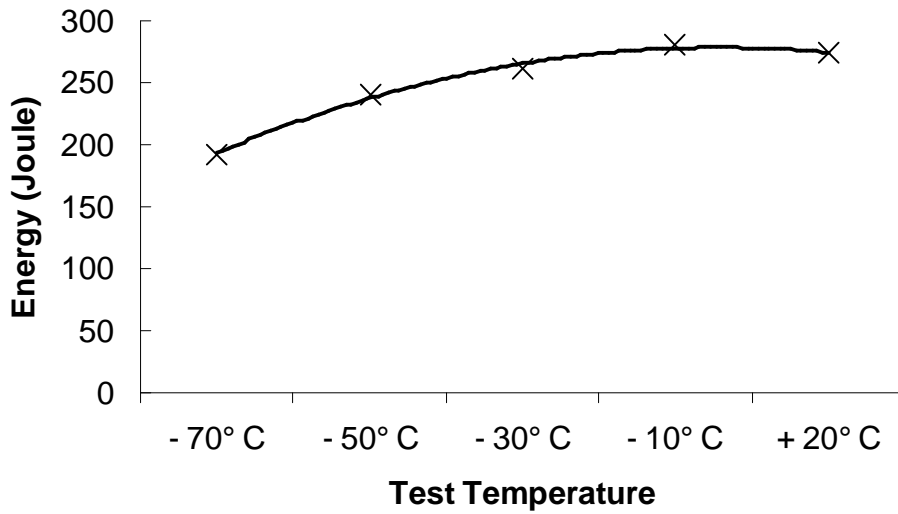


Figure 6: CVN temperature transition curve for 42"OD x 33.3 mm W.T., SAWL 485 IFD

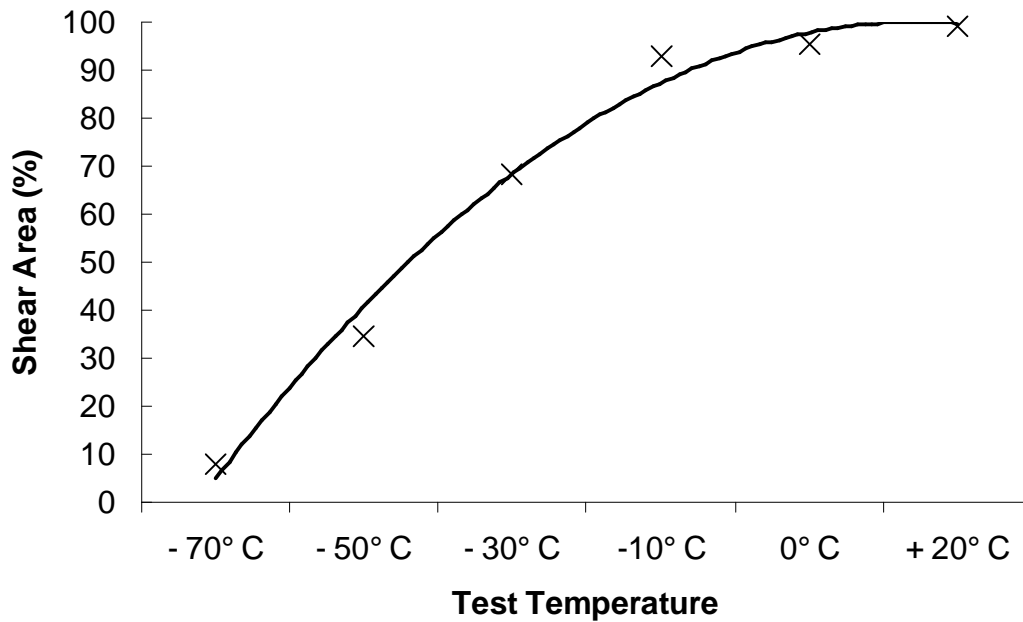


Figure 7: BDWT temperature transition curve for 42"OD x 33.3 mm W.T., SAWL 485 IFD

In the course of the production the base metal chemistry has been further optimised, e.g. reduction of Carbon and Titanium content in order to promote the properties in the base metal and HAZ.

Thus, the steel chemistry selected and the steel making practice adopted as well as the rolling and welding parameters have proven the right approach to execute this big order successfully.

In order to allow efficient handling during offshore welding the following severe dimensional requirements were set (Table 6):

Dimension	Tolerances
OD pipe ends	-0,6/+1,6mm
Ovality pipe ends	Max. 5 mm
Peaking	1.5 mm
Wall thickness	±1mm
Straightness	0,15% Length

Table 6: Main Dimensional Requirements of Linepipes for Langed Projects

In Figure 8 the statistical distributions for the ovality and the wall thickness measurements are shown as example for the production with 29,1mm wall thickness. The specified tolerances are met with high statistical reliability. For more than 80% the measured ovalities are below 4mm and the actual delivered wall thickness range amounts to 1,2mm for more than 95% of the pipes.

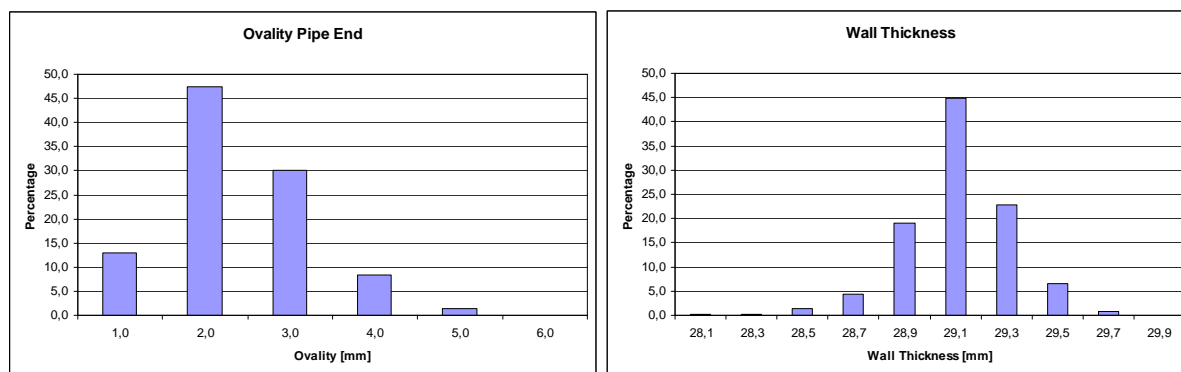


Figure 8: Statistical distribution of ovality and wall thickness for 29,1mm nominal WT

Heavy Wall X70 Tendon Pipes for Tension Leg Application

Assembled to strings Tendon Pipes connect the Tension Leg Platform (TLP) and its topsides with the sea floor (Figure 9). The platform is slightly submerged so that the natural buoyancy of the structure applies a tension on the vertical pipe strings. This principle provides the most stable system beside gravity based platforms with only little movements as reaction to the waves and current. The maximum realized water depth for a TLP project has been so far 4,700 feet in the Gulf of Mexico. New TLP concepts are under investigation to pass 5,000 feet and going even beyond 7,500 feet. The new larger oil and gas fields in the GoM are in the 6,000 to 7,000 feet range. Reaching these water depths the Tendon Pipes carry not only the loads from the platform but in addition the collapse pressure of such water depths [8].

These new designs request pipes with a wall thickness of about 40 mm (1.57"). EUROPIPE proved with already delivered pipes with a wall of 38 mm in the X70 grade and with a trial production of 40 mm wall thickness X70 pipes that these pipes can be supplied. So far Tendon Pipes have been used in the OD range of 26" to 40", in lengths of 56-59 feet in order to reduce the number of girth welds, and in the wall thickness range of 25 to 38 mm, mostly X70 material.

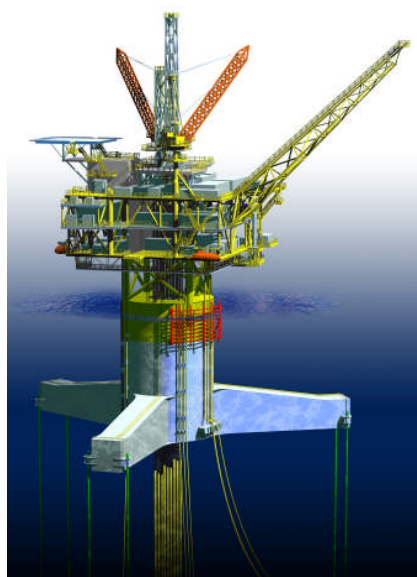


Figure 9: Principle of a TLP (the Atlantia Offshore Sea Star Design)

Fatigue is one of the main concerns for the tendon leg design. Due to the main load directions being perpendicular to the girth weld the girth welds in the leg are considered to be more critical compared to the long seam which is only little exposed due to bending loads. Beside a high toughness of the material the fatigue resistance requires excellent geometry, especially at the pipe ends. Thus the dimensional tolerances are very stringent. Table 7 shows the main dimensional requirements for these pipes. Additionally the metric weight is controlled very tightly in order to achieve neutral buoyancy of the legs.

Dimension	Tolerances
OD pipe ends	+/- 1.5 mm
Max. ovality pipe ends	5 mm (30% max)
Peaking	1.5 mm
Wall thickness	-1%/+3%
Straightness	14 mm for 18 m
Pipe weight	- 1%/+3%

Table 7: Main dimensional requirements for Tendon Pipes.

The common requirements for the mechanical properties of an API 5 L, X70 tendon pipe are listed in Table 8. Especially the high level of toughness for the weld metal and the HAZ are remarkable.

Property	Requirements
YS, long. & transv.	482 – 587 MPa
TS, long. & transv.	565 – 670 MPa
CVN BM, -10°C	81J/102 J
CVN WM, HAZ, -10°C	54/81 J
Shear area BM	85%
CTOD girth weld, 0°C	0,25/0.35 mm

Table 8: Common mechanical requirements for Tendon Pipes (by Microalloying, Houston)

Low carbon content and limited microalloying elements were chosen in order to improve weldability and to reduce the number of local brittle zones in the later HAZ as much as possible.

C	Mn	P	S	Ni	Nb+V+Ti	CE	PCM
0.05	1.6	0.010	0.001	0.4	Max. 0.15	0.35	0.2

Table 9: Mean Chemical composition (in %)

The average values of the elements used for wall thickness of 30 mm and heavier are listed in table 9. The somewhat negative impact of microalloying elements on the HAZ toughness is overcompensated by the advantage of low carbon content. As the content of V and Nb was limited, Ni was alloyed in order to achieve X70 properties.

The Thermo-Mechanical-Control Process (TMCP) is employed to produce the plates. In this TMCP process the most important strengthening mechanisms and micro-structural features are grain refinement by rolling in the non recrystallisation regime austenite, accelerated cooling (ACC), precipitation hardening (e.g. by NbCN) and dislocation hardening (e.g. due to finishing of rolling in two-phase $\alpha + \gamma$ - region).

The pipes are manufactured in EUROPIPE's 18m line in Muelheim with the UOE process. To achieve the tight geometrical tolerances the forming process was optimized by FEA analysis. The simulation of the different forming steps resulted in a well adjusted forming chain and optimized tooling. Very important is the latest forming step, the cold expansion which is performed after the welding. This production step finalizes the geometry control and provides a stress homogenisation function due to the plastic deformations implied.

Figure 10 shows the strength distributions for executed orders with a wall thickness of 38 mm. Please notice the narrow window of 80/100 MPa achieved for both the longitudinal and transverse tensile tests. Longitudinal properties are requested due to the load situation of Tendon Pipes.

In Figure 11 it can be seen that the Charpy-V toughness values for the weld material and the HAZ are on a level with sufficient margin to the specified limits. The measured values of the base material are found to be beyond 250J at the required test temperature of -11°C. The analysis concept discussed before thus leads to an excellent toughness.

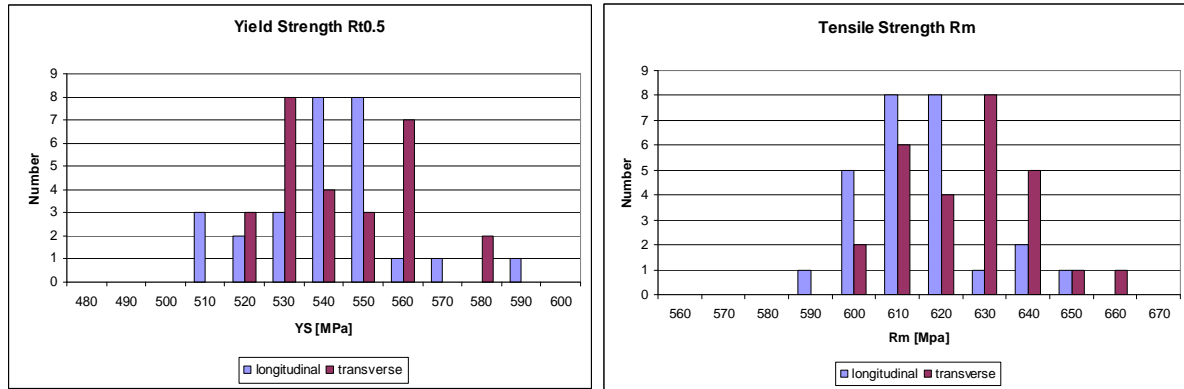


Figure 10: Tensile test results of X70 tendon pipe production with 38,1 mm wall thickness

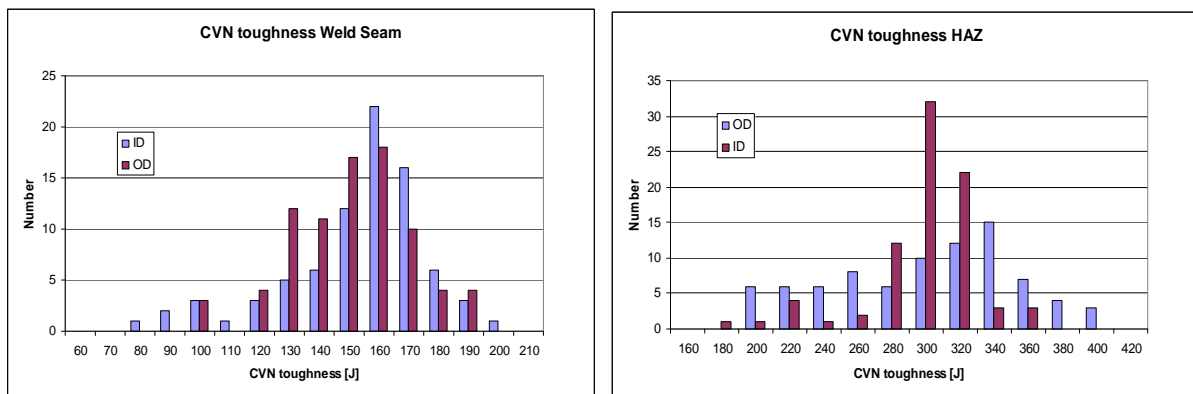


Figure 11: CVN toughness results for WM and HAZ of X70 tendon pipe production with 38,1 mm wall thickness

The geometry achieved for the 38 mm production satisfies in all aspects the limits specified by the TLP designers. To receive an outside diameter closest to the nominal of 32” (812,8mm) is important because of the neutral buoyancy being desired for the tendon section. Otherwise costly measures as buoyancy elements will be necessary in order to compensate the deviation. Figure 12 (leftside) represents produced outside diameter and the deviation from nominal. The narrow scatter assures perfect matching of the pipe ends during girth welding with a very small high-low from pipe face to pipe face. These high-low steps shall as small as possible to minimize the impact on the life time of the girth weld.

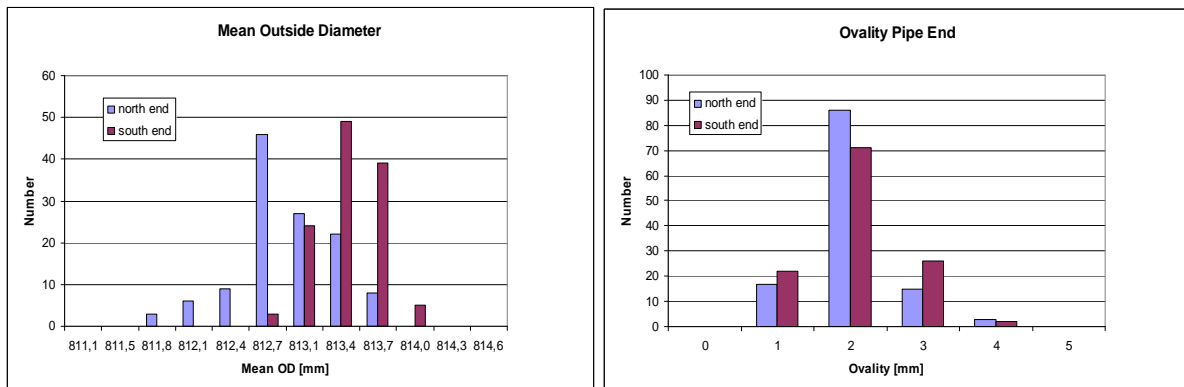


Figure 12: Outside diameter and ovality of pipe end 32” OD with 38.1 mm wall

Beside the constant OD the second factor for this criteria is a very small out of roundness (OOR) of the pipe ends combined with a consistent appearance of the location of the long

and short axis of the OOR from pipe to pipe in order to adjust the pipe ends accordingly before welding. Figure 12 (right) exhibits OOR values. An excellent roundness is being provided with only a few pipes showing ovality values larger than 3 mm. Additionally to the low absolute value also the shape of the pipe ends is very consistent. Figure 13 is characteristic for the appearance of the pipe ends.

Conclusions

This paper describes the main manufacturing steps for longitudinal submerged arc welded large diameter line pipe essential to serve the increasing requirements of offshore applications. Consistent quality control starting in the steel plant and continuously going through all subsequent production steps is the basis for high quality. Special attention is paid to the pipe forming, the welding process and its control as they are of essential importance for the intrinsic pipeline safety.

Production results of recent orders for offshore projects with challenging requirements such as thick wall pipe for North Sea, production of sour service line pipes and tendon pipes are presented to give an impression about actual market developments and to describe the corresponding EUROPIPE solution. The three examples show how specific demands like severe sour service acceptance criteria, narrow ranges for mechanical properties and dimensional tolerances are reliably fulfilled in time even for very large order quantities.

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