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EXPERIENCES WITH AN OFFSHORE PIPELINE PROJECT FOR THE NORTH SEA (LANGELED)

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Abstract

This paper gives an overview about the Langeled Project, which will result in the longest offshore pipeline in the world. The Langeled 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 Langeled as the first pipeline bringing gas from Norway directly to the U.K.

The length of the pipeline is about 1200 km and close to 1 Million tonnes of steel pipe will be produced. For Langeled North the constant ID is 1016 mm (42"OD) and for Langeled South 1066 mm (44" OD). Wall thicknesses between 23.3 and 34.1 mm are required. The design of the pipeline is according to DNV standard OS F 101. The material grade is SAWL 485 IFD.

EUROPIPE supplied 835 km or 630,000 tons of pipe to the project. About 800 km were produced in Mülheim and the remaining portion, or 35 km in Dunkerque pipe mill. Pipe production started in April 2004 and finished in December 2005. Lots of around 30,000 t per month had to be shipped to Norway to receive corrosion and heavy coating. The paper will summarize the pipe production and the logistical challenges.

Introduction

The steady increase in the operating pressures of oil and gas pipelines and the pipe laying operations under extreme conditions in the offshore regions have led to increasingly severe property requirements for pipeline steels. Currently, some of the most stringent material requirements are those relating to pipelines for service in the North Sea. Today, not only greater wall thicknesses but also higher strengths are required. Further requirements are related to excellent toughness, good weldability and geometry with narrow tolerances. EUROPIPE continuously monitors the market requirements and tries to fulfil them by sophisticated research and development activities. Europipe was involved in all other major pipeline projects in the North Sea and from the Norwegian continental shelf, as shown in Figure 1. EUROPIPE was prepared to handle the order for the biggest offshore pipeline in the World.

Langeled Project

Figure 1. Major pipeline projects in the North Sea

The basis for Langeled is the development of the Ormen Lange gas field located at 1000m water depth outside mid Norway. The responsibility for the Ormen Lange and the Langeled development projects were given to Norsk Hydro as the operator. Statoil has the management of the Langeled pipeline project in cooperation with Hydro. For the line pipe supply, the first studies and technical clarifications started in 2001.

In 2002 a management meeting with STATOIL and EUROPIPE representatives took place, where the market situation and initial technical requirements were discussed. In early 2003 EUROPIPE prepared the commercial and technical offer, followed by several bid clarification meetings. In December 2003 EUROPIPE received the order to supply 835 km or about 630000t of the Langeled pipeline. The final approval to build the pipeline was given by the Norwegian Parliament, in April 2004.

Project Overview

The Langeled pipeline will transport dry gas from Nyhamna on the Mid West coast of Norway via the Sleipner platform in the southern Norwegian Continental Shelf to Easington on the East coast of England, see figure 2. The Langeled North is a 630km long 42"OD pipeline in grade SAWL 485 IFD (Similar to X70). 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 Langeled North has been designed with two different design pressures, 250 bars for the northern half and 215 bars for the southern half.

The Langeled South is a 550km long 44"OD pipeline, also in grade SAWL 485 IFD. The design pressure for Langeled South is 156 bars, requiring a wall thickness of 23 to 24 mm.

Including the coating, each pipe will have a weight of 15 to 25Metric Tonnes, dependant of the concrete coating thickness. All pipes are coated internally in order to improve the flow properties and thereby the capacity of the pipeline.

The transport capacity in the pipeline will be 70 MSCM/Day in Langeled South and 80 MSCM/Day for Langeled North.

The philosophy for the development of the Langeled project has been to maximise the use of well proven technology in order to reduce the development risk of the project. However, in a project of this magnitude there are still technical and execution challenges and risks. The main ones are;

a) Routing of the pipeline, specially related to third party blocks and installations. These discussions took nearly one and a half years to finalise.

b) Sub sea valve station to connect the Langeled to Sleipner field, including development of 42" ball valves for sub sea use. The main reason for this solution was to save building a new and separate riser platform in the area.

c) Installation of two 30" risers at the riser platform. These were the maximum size possible.

d) Landfall solution in Easington in order to account for the ongoing coastal erosion. A concrete lined mini tunnel was the selected solution through the coastal cliff. Ref. Figure 4.

e) Project logistics will ensure that all components of the project are available in time. A key issue for the logistics of such a project is related to the lay scenario, which forms the basis for the line pipe production and coating sequence. In addition, one should standardise the steel wall and the coating thickness to a maximum extent in order to keep a certain flexibility to change the lay sequence if necessary.

f) Safety related to all handling of heavy weight pipes. During the process of line pipe production, transport to the coating yard, coating internally and externally, transport to the intermediate storage area, transport to the lay vessels and handling on the lay vessel, each pipe will be lifted approximately 30 times.

The project requires two lay seasons, and therefore it was logical to finalise Langeled South first, in order to start gas export from October 2006. Langeled North will start up October 2007.

The size and timing of the project is a challenge in itself for line pipe production and delivery, requiring steady supply over two years.

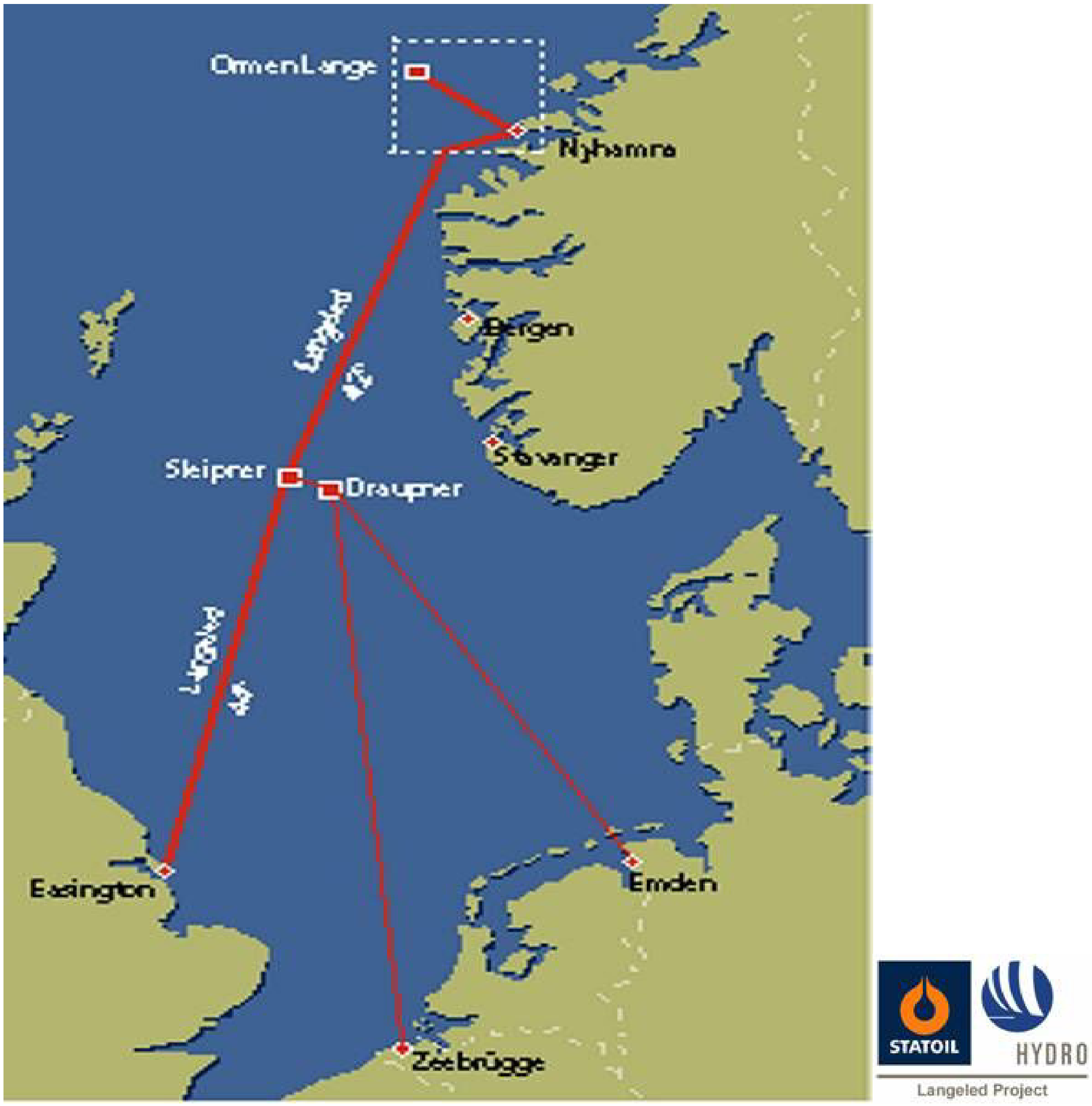

Figure 2. Langeled Pipeline route

Figure 3. LB200 lays pipe near Sleipner platform summer 2005

Figure 4. Langeled Landfall at Easington.

Line Pipe Production Logistics

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

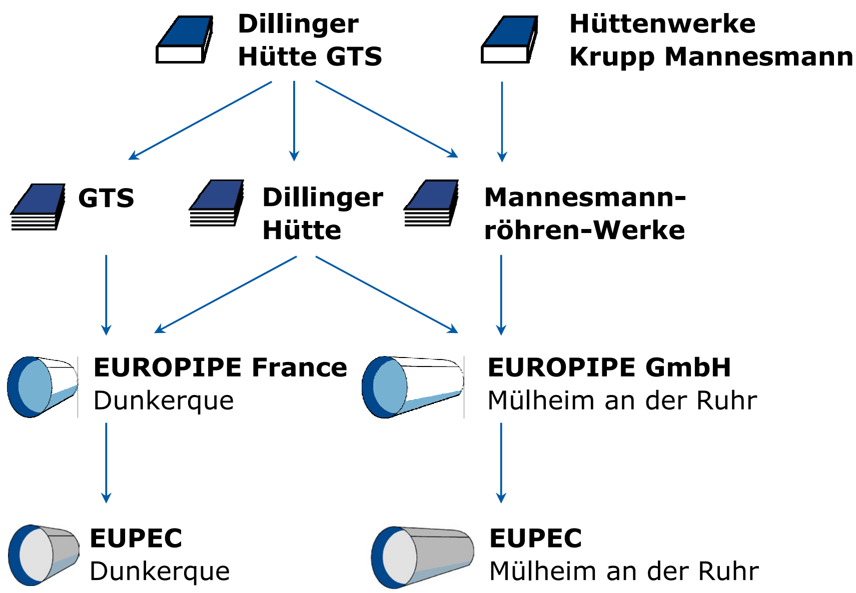

Figure 5. Material flow of the Langeled order

Dillinger Hütte (DH) delivered slabs to their plate mills in Dillingen (DH) and Dunkerque (GTS) where the plates were rolled. Hüttenwerke Krupp Mannesmann (HKM) cast 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 Langeled North was internally coated in the EUPEC coating yard in Mülheim, while external corrosion and concrete coating application was performed in Farsund, Norway.

For Langeled 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 Langeled North (29.1 to 34.1 mm) were solely manufactured in Mülheim because of the higher forming forces required. 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 (Table I).

In order to fulfil delivery of pipes in time, a big amount of testing 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 II) 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 15 pipes/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 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. The high amount of Charpy testing made the final release in time to a challenge. A more simplified test programme should therefore be discussed for future projects of this size.

Table I. Pipe Transport Figures (*estimated figures*)

	Langeled South		**Langeled North**			**Sum**
Diameter:	44"OD		42"OD			
Wall Thickness	23.3 mm	24.0 mm	29.1 mm	33.3 mm	34.1 mm	
Wagon Loads	2,107	2,049	*3,931*	4,106	2,210	14,572
Trains	85	81	*157*	164	88	575
Vessels	17	17	*25*	26	14	99

Table II. Number of Specimens (italics: estimated figures)

	Langeled South		**Langeled North**			**Sum**
Diameter:	44"OD		42"OD			
Wall Thickness	23.3 mm	24.0 mm	29.1 mm	33.3 mm	34.1 mm	
No. of Pipes	13,302	10,290	15,861	16,569	8,979	
No. of Heats	581	446	922	1,070	605	
Tensile (3)	1,743	1,338	*2,766*	3,210	1,815	10,872
CVN Sets (9)	5,229	4,014	*8,298*	9,630	5,445	32,616
CVN Spec (27)	15,687	12,042	*24,894*	28,890	16,335	97,848
Hardn. Indent.(30)	17,430	13,380	*27,660*	32,100	18,150	108,720

Mechanical Properties

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. micro structural 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 cast 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 were reached safely with one chemical composition, but several optimized Thermo-Mechanical-Control Process (TMCP) rolling concepts were required. The thicker wall required a more stringent accelerated cooling after rolling of the plates. The chosen composition is given in table III. With this concept the properties of strength, toughness, weldability and fabricability are comfortable met.

Table III. Mean Chemical Composition (weight %)

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

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 phosphorous 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.

Table IV. Results on 44"OD x 23.3 and 24.0 mm and 42"O.D. x 29.1, 33.3 and 34.1 mm W.T., SAWL 485 IFD line pipe production for the Langeled project

Mechanical Properties	Mean Value	Mechanical Properties	Mean Value
Yield strength $R_{t0.5}$ (MPa)		Yield strength $R_{t0.5}$ (MPa)	
Transverse	522	Transverse	513
Longitudinal	515	Longitudinal	520
Tensile strength R_m (MPa)		Tensile strength 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

Mechanical Properties Thinner Wall Mechanical Properties Heavy Wall

As can be seen from the data given in the above tables, 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 the transverse direction is about 20 MPa higher.

Comparing the tensile test values obtained by rectangular straightened or cylindrical samples shows that there is no pronounced differences. Moreover, they are within the same distribution (see Figure 6). This phenomenon was not observed before since the so-called Bauschinger effect usually led to significant difference in the yield strength. Whether this feature is due to the alloying concept employed with its particular rolling parameters or whether it is due to the sampling of the cylindrical test piece that samples merely the midwall location due to the curvature of the pipe, has not been investigated.

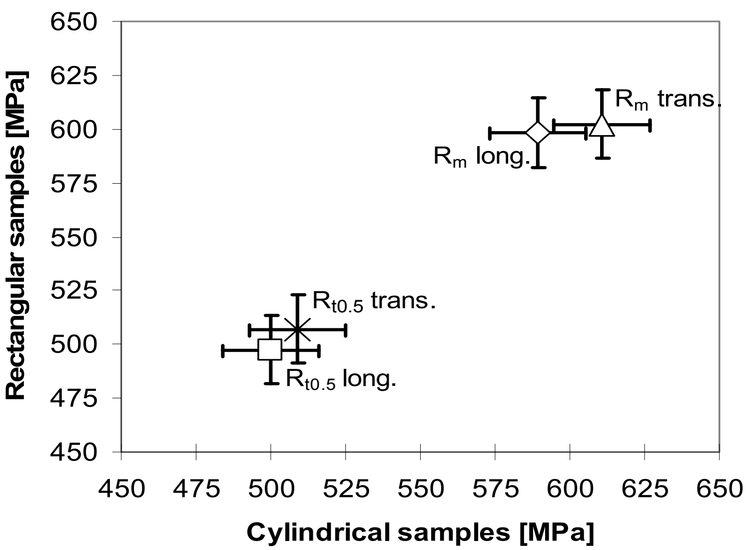

Figure 6. Comparison of cylindrical and rectangular samples for 42"OD x 33.3 mm W.T., SAWL 485 IFD

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 CVN temperature transition curve (Figure 7) and the Batelle Drop Weight Tear Test (BDWT test) (Figure 8) for the heavy wall material.

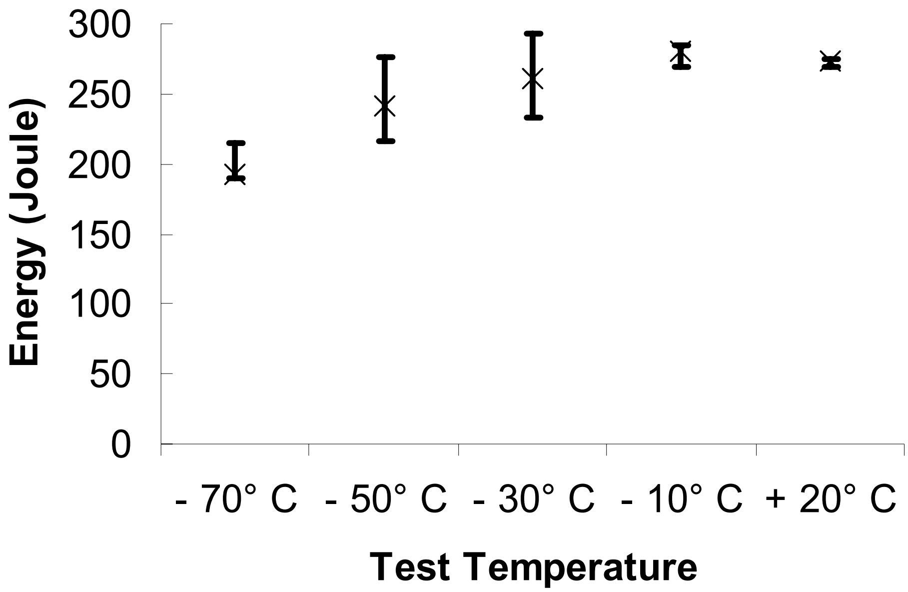

Figure 7. CVN temperature transition curve for 42"OD x 33.3 mm W.T., SAWL 485 IFD

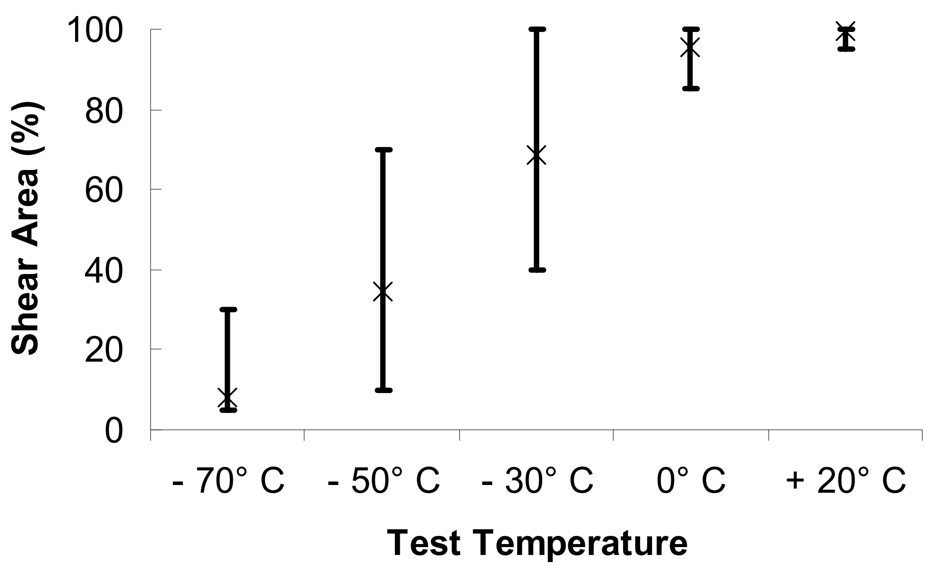

Figure 8. BDWT temperature transition curve for 42"OD x 33.3 mm W.T., SAWL 485 IFD

In the course of the production, the base metal chemistry was 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 such a big order successfully.

Conclusions

Since the Statpipe project in 1985, STATOIL and Norsk Hydro have had continuous and fruitful co-operations with pipe producers to improve the properties and weldability of line pipe steels. The chemistry, plate rolling and pipe production have been optimized over the years, giving improved mechanical properties, dimensional tolerances and far better welding characteristics. One important change has been the reduction in Carbon content to about 0.08% today.

EUROPIPE is a reliable supplier of pipe for the North Sea and worldwide. The Langeled Project is a further example, how a pipe manufacturer has to solve technical and logistical challenges.

The whole order was supplied successfully and within the agreed time frame.

In the meantime EUROPIPE has supplied in total about 2.3 Mill. t of steel pipe to STATOIL. That was only possible with the excellent support of our related steel plants, plate mills, coating yards and shipping companies and the good project management together with our partners in Norway.