PRODUCTION OF HEAVY GAUGE PIPELINE STEELS WITH INTEGRATED WELDING SUPPORT

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Abstract

Modern steels for pipelines need to combine high strength with good toughness and excellent weldability. Furthermore higher steel grades and heavy gauges become more and more important and resistance to hydrogen induced cracking may also be required.

High class pipeline steels meeting the increasing demands can be produced in the hot rolling mills of ThyssenKrupp Steel in Europe and America. Wide experience regarding the production of pipeline steels for conventional and sour service in thicknesses up to 25.4 mm ensures top quality. The technical support of customers is of great importance: welding-related topics can be investigated in a new, well equipped welding laboratory.

Introduction

Contrary to public perception, ThyssenKrupp Steel is more than a supplier to the automotive industry. For nearly 50 years, the company has supplied hot rolled strip as well as plates for the production of pipes for pipelines. ThyssenKrupp Steel is capable of producing hot rolled strip for longitudinally and helically welded large diameter pipes for conventional and sour service.

The product range for pipeline steels as well as the capability for HIC and welding tests will be presented in this paper.

Production of Heavy Gauge Pipeline Steels in Europe and America

During recent years larger wall thicknesses and higher strengths have become inevitable market requirements. ThyssenKrupp Steel responded to these requirements with an upgrade of its hot rolling mill in Duisburg Beeckerwerth. Today, grades up to X80 or even higher with wall thicknesses of up to 25.4 mm can be produced in this hot rolling mill. Consequently the development of heavy gauge pipeline steels with improved toughness has been the focus for some time. The successful production of X70 in 23 mm with an alloying concept using the maximum niobium allowed according to the normative DIN EN 10208 was a first proof of the manufacturing capability. Nevertheless the improvement of X70 up to 25.4 mm is still in progress and parameters are continuously adapted in order to optimize the results. The current development activities are concentrated on leaner alloyed concepts and higher strength grades. First trials to produce X80 in 18.0 mm met all requirements. The widespread restriction of the niobium content in Europe required by DIN EN 10208 unfortunately complicates the development of high grade, heavy gauge pipeline steels with excellent toughness.

The new hot rolling mill in Mobile, Alabama, Figure 1, with an annual production of 4.3 million tons of carbon steel is equipped to produce heavy gauge pipeline steels as well. Most of the processed slabs are delivered from ThyssenKrupp Steel's new steelworks in Brazil. First trials in grades X42 to X70 with thicknesses up to 25.4 mm and X80 in 12.7 mm and 15.9 mm were successfully conducted. Even the mechanical properties of the grade X80 trial met all API 5L requirements on coil and on pipe – after pipe forming at Berg Pipe. Currently, the rolling parameters are adapted in order to improve the toughness requirements on heavy gauge coils. Another focal point is the adjustment of alloying concepts.

Table I shows an overview of the production possibilities in Europe and Alabama.

Figure 1. Hot rolling mill in Mobile (Alabama, USA).

Table I. API 5L Product Range for Pipeline Steels

Site	Grade	Thickness in mm (max.)	Width in mm (max.)
Duisburg	Grade B-X70 X80	25.4 18.0	2030 2030
Mobile	X42 – X70 X80	25.4 15.9	1855 1855

HIC-Resistance

For many years ThyssenKrupp Steel has been producing HIC resistant material for pipeline applications. High quantities of pipeline steels with resistance to hydrogen-induced cracking up to grade X70 can be produced and tested in Duisburg.

In order to be able to increase the testing capacity new facilities were installed during recent years. In the new testing laboratory coil samples, as well as pipe samples from our customers, can be tested.

Figure 2. Testing facilities for sour service grades.

Figure 2 shows some HIC-test and HSCC-test (hydrogen stress corrosion cracking) facilities in the new laboratory. The HIC-test is performed according to NACE TM0284. The crack evaluation of the HIC-samples can be done with a computer-aided ultrasonic testing device. In addition tests for hydrogen stress corrosion cracking, including a 4-point-bending test according to API5L/ISO 3183 and a constant load test according to NACE TM0177 Method A, can be performed in the laboratory in Duisburg.

Welding Support and Experience

Recently the development activities in pipeline steels at ThyssenKrupp Steel have been intensified. One of the investments was the expansion of the area of joining technology by setting up a welding laboratory which opened in July 2011. The laboratory is provided with gas and plasma cutting equipment and welding installations for submerged arc welding, gas-shielded metal arc welding and manual metal arc welding. The submerged arc welding system is shown in Figure 3. It can be used for single, twin and tandem arc welding as well as for narrow-gap welding.

Figure 3. Submerged arc welding system.

The welding of pipeline steels has been an important recent topic. The experience gained with welding investigations to provide advice for our customers helped to start up the new welding laboratory. Some of these investigations will be presented here. Currently, the weldability of pipeline steels with higher niobium contents, considering the limitation in the European standard is being investigated.

Welding Process Simulation [1]

To evaluate a pipeline steel, the characteristics of the heat affected zone (HAZ) of a welded joint are of great importance. In many cases, the toughness of the HAZ is inferior to the parent metal. Trials to simulate the welding process by heat treatment for grade X70 pipeline steels were performed in order to check whether this simulation is adequate to estimate the weldability and the resulting toughness. The temperature cycles of the welding process were replicated via rapid induction heating and controlled cooling using a Gleeble 3500 System. Charpy V-notch blanks were used for the trials and finished to produce test samples after the simulation. To allow the use of these blanks in the Gleeble system, an adaptation of the clamping tools was necessary. Figure 4 shows the Charpy-V-notch blanks in the Gleeble System and a schematic blank indicating the area of the simulated HAZ measuring approximately 12 mm.

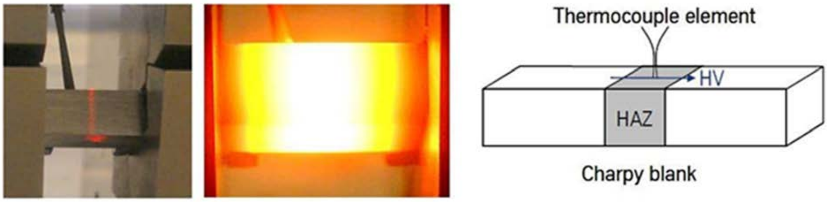

Figure 4. Charpy blank in the Gleeble system with the resulting HAZ.

With the Gleeble System, various temperature cycles can be simulated. For this simulation, two coarse grain cycles with a maximum temperature of 1350 °C and a cooling time t8/5 of 20 s or 50 s respectively were chosen. Additionally two double cycles with a maximum temperature of 1350 °C in the first cycle (t8/5 20 s and 50 s) and a second cycle at a temperature of Ac1+20 K were simulated. The comparison of three pipeline steels with different chemical compositions,

Table II, led to the impact toughness means shown in Figure 5.

Table II. Chemical Composition of the Steels Used for the Simulation

	C	Si	Mn	P	S	Others
Alloy 1	0.08	0.38	1.64	0.014	0.001	Nb, V
Alloy 2	0.08	0.39	1.57	0.015	0.001	Nb, Ti
Alloy 3	0.06	0.26	1.77	0.018	0.003	Nb, Mo, Ni

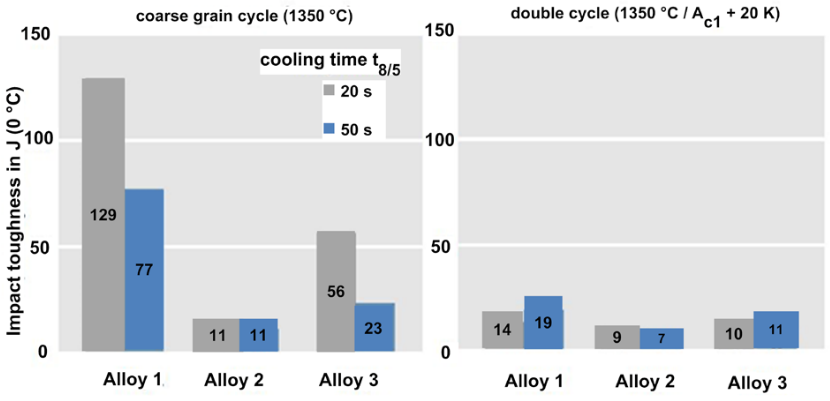

Figure 5. Impact toughness values (0 °C).

Figure 5 shows that the double cycle resulted in extremely low toughness values compared to the coarse grain cycle. Thus the coarse grain cycle seems to be more realistic to evaluate the weldability of pipeline steels. Nevertheless it can be assumed that the toughness of real weld seams is better. This assumption will be verified in future trials.

<u>Cold Cracking Susceptibility [2]</u>

Experience with different test methods to evaluate the cold cracking susceptibility after arc welding such as the CTS-test, the Tekken test and the WIC-test exist at ThyssenKrupp Steel. These tests, in particular the WIC-test, are complex and time consuming. Carbon equivalents can be used to classify the cold crack susceptibility of steels by a simple calculation. Common carbon equivalents are the CEIIW from the International Institute of Welding and the PCM according to Ito-Bessyo. The latter is more appropriate to estimate the weldability of modern pipeline steels because the detrimental effect of carbon is highlighted. On the basis of extensive examinations of the cold crack susceptibility the CET was developed at ThyssenKrupp Steel, Equation 1. This carbon equivalent is part of European and national standards such as the EN

1011-2, the SEW 088 and the DVS 0916.

$$CET = C + \frac{Mn+Mo}{10} + \frac{Cr+Cu}{20} + \frac{Ni}{40} \qquad (1)$$

For steels with relatively high alloy contents preheating may be necessary to avoid cold cracks after arc welding. Some years ago ThyssenKrupp Steel developed a software support for welding called ProWeld which can be obtained on a CD-ROM free of charge, Figure 6. The program is based on the cooling time t8/5 and the CET concept. It can be used to calculate different carbon equivalents, the preheat temperature and other parameters for welding.

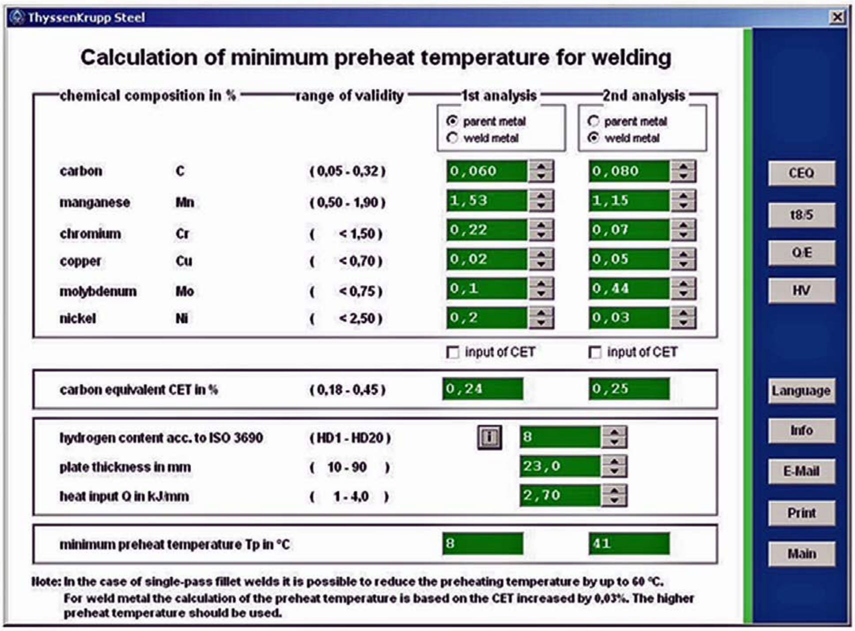

Figure 6. ProWeld: Calculation of the minimum preheat temperature for welding.

<u>Welding Consumables [3]</u>

In cooperation with the leading welding filler metal producers two trials with different weld metals have been conducted in order to recommend the appropriate welding consumables for the submerged arc welding of the pipeline steel grades X60-X80. So as to determine the influence of the consumables on the weld metal strength, toughness and HIC resistance systematic experiments will be carried out in the new laboratory.

Current Welding Trials

Since the opening of the new welding laboratory, modern alloying concepts with higher niobium contents are tested. An example of the current trials is the submerged arc welding of a grade X70 pipeline steel with a thickness of 23 mm produced as hot rolled coil. Table III indicates the chemical composition of this steel.

Table III. Chemical Composition of the Test Plate (Heat Analysis)

C	Si	Mn	P	S	Σ Cu, Cr, Ni, Mo	Σ Nb, Ti, V
0.06	0.29	1.53	0.013	0.002	< 0.6	< 0.1

The calculated carbon equivalent CET for this concept is 0.24. The carbon equivalents CEIIW and PCM calculated according to the normative API5L are 0.39 and 0.17 respectively. According to the Software ProWeld preheating is not necessary for the submerged arc welding of this steel.

For the tandem arc welding of the plates a double-V seam preparation with root faces was used. The parameters for the welding process were chosen to be in line with real production conditions using S2Mo wire electrodes (AWS A 5.23: EA2) with a diameter of 4 mm and an aluminate basic welding flux. The first pass was welded without preheating and the second pass at an increased interpass temperature which also led to an increased cooling time t8/5. The welded joint and the microstructures in the different areas are shown in Figure 7.

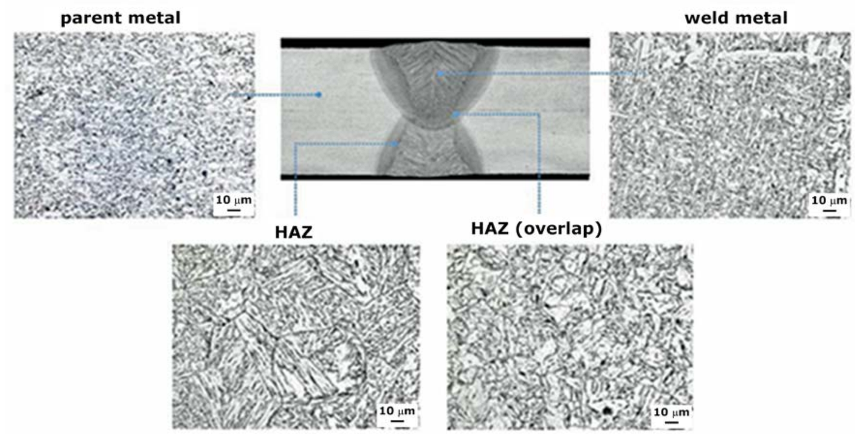

Figure 7. Welded joint with microstructures.

The mechanical properties of the welded joint and the parent metal were examined by hardness, tensile and impact testing. The results of the hardness tests are illustrated in Figure 8.

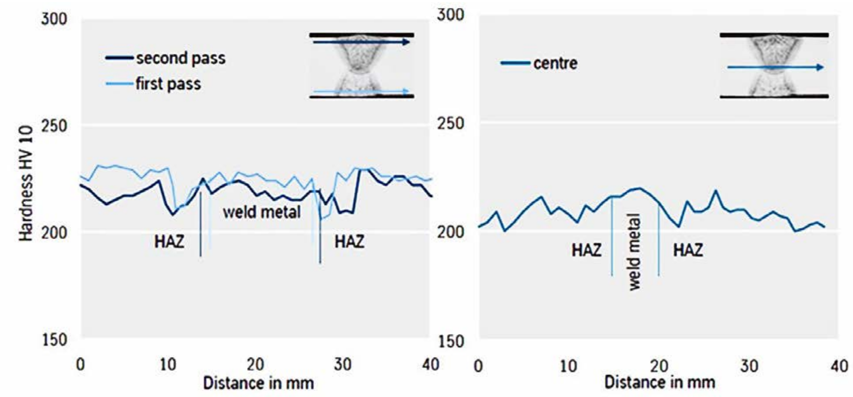

Figure 8. Hardness in the weld area.

The hardness values for the weld metal, the HAZ and the parent metal are at the same level and significant hardness peaks do not occur. The tensile strengths, between 640 and 681 MPa for the weld and the parent metal, met the requirements of a grade X70 steel. The excellent results of the impact toughness tests (Charpy V-notch) can be seen in Figure 9.

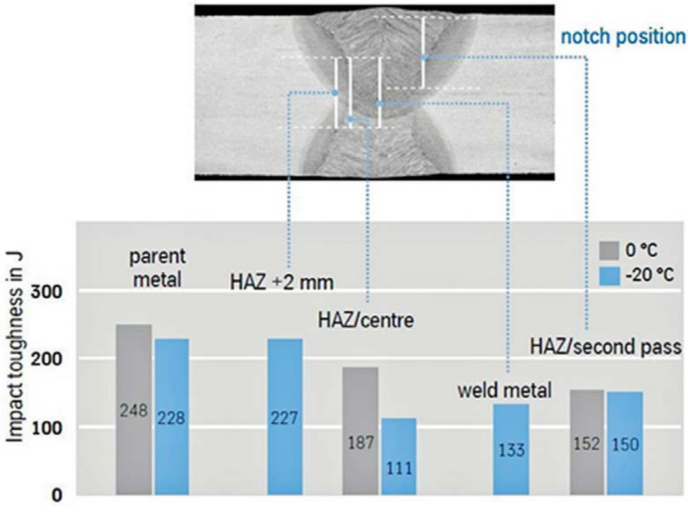

Figure 9. Impact toughness in the weld area (0 °C and -20 °C).

These results indicate that good welding properties during the production of helically welded pipes can be expected for this steel. More examinations with varying alloying contents and different welding parameters are currently being carried out.

Summary

This paper provides information about:

- The product range regarding pipeline steels at the production sites of ThyssenKrupp Steel.
- The experience with the production and testing of HIC-resistant steel grades.
- The new welding laboratory.
- Welding tests and the conclusions drawn concerning:
    - Simulation of the welding process.
    - Cold cracking susceptibility.
    - Welding consumables.
- The software ProWeld.
- Current welding trials and first results regarding the excellent weldability of newer alloying concepts containing increased niobium.

References

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