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Microstructure and Property Analysis of X80 Pipeline Steel Joint

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Abstract

With the development of pipeline engineering, long distance pipeline construction is more and more extensive, high strength and high steel grade pipeline steel has been rapidly developed. Nowadays, X80 pipeline steel welding technology is widely used in domestic pipeline engineering. In order to ensure the safe use of the pipeline more efficiently, this paper discusses the welding process and chemical composition characteristics of X80 pipeline steel, the microstructure and properties of the welding zone under the microscope and the reliability of X80 pipeline steel.

Keywords

X80; Welding; Microstructure.

1. Introduction

Pipeline transportation is mainly used in the transportation of oil and natural gas. As an uninterrupted means of transportation, it is one of the important modern transportation modes.

Pipeline steel is a kind of hot rolled coil or wide plate used in the manufacture of oil and natural gas pipeline and container. The development of pipeline steel has gone through a long process. With the development of oil and gas industry, the performance requirements of pipeline steel are getting higher and higher. In the fierce market competition, all the oil companies in the world are constantly looking for ways to reduce costs and improve benefits. In pipeline projects, reducing wall thickness can reduce steel consumption, while high pressure transport can reduce pipe diameter without changing the volume of transport. The X80 pipeline steel was developed against this background. It is estimated that the replacement of X70 steel with X80 steel in the same pipeline construction project can save 8%-12% of the pipe cost and 3%-12% of the total project fund under the condition of the same conveying pressure and pipe diameter, and significantly improve the economic benefits [1].

2. Welding process of X80 pipeline steel

Combined with China national petroleum corporation "X80 grade pipeline steel tube hot heat pipe technology research" on the analysis of the research abroad on X80 grade pipeline steel technology development and application and the identified on the basis of mechanical properties and toughness etc standard, according to our country's development of grade X80 pipeline steel rolled hot-rolled coil and the spiral seam submerged arc welding pipe and straight seam submerged arc welding pipe mechanical properties, toughness test results put forward our country X80 grade pipeline steel hot-rolled coil, coil made of spiral seam submerged arc welding pipe and straight seam submerged arc welding pipe mechanics properties and toughness index. For the first time made the domestic X80 steel (Φ 1016 mm x 7.9 mm) welding process plan: E7010 electrode root welding + E9018 - G hot welding and covering welding electrode, a qualified welding joint can be obtained. For the qualified welding process scheme for X80 steel pipe made in Japan is: JM58 wire STT semi-automatic root welding +E10018-G filler cover welding. The fuzzy random comprehensive evaluation method was

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used to evaluate the welding process of X80 grade pipeline steel with the two-stage comprehensive evaluation model.

Shi Tingshen[2] et al. combined two welding processes, laser welding and arc welding, respectively investigated the influence of welding current, laser power, welding speed, optical wire speed, optical wire spacing and other parameters on the weld formation process of X80 pipeline steel. The experimental results show that:

(1) When the laser-MIG composite welding method is used to weld X80 high strength pipeline steel, the welded joint with good appearance and internal forming can be obtained. The laser plays a certain role in stabilizing the flow and pressure of MIG arc, and greatly reduces the welding spatter.

(2) In a suitable current range, the welding depth of composite welding can be increased to a certain extent compared with laser welding, and up to 5 times higher than that of single MIG welding. At the same time, the weld width also increases with the increase of laser power.

(3) Composite welding can better reflect its advantages in high-speed welding, under the conditions of this test, the same weld fusion

Compared with laser welding, composite welding can greatly improve the welding speed .The laser defocus has a great influence on the depth of the composite welding, and the maximum depth of the composite welding can be obtained when the defocus is -2 mm.

3. Microstructure and properties of X80 pipeline steel

X80 pipeline steel is a new generation of special pipeline steel developed on the basis of X70 pipeline steel by adopting pure purification, fine crystallization metallurgy, micro-alloying and controlled rolling and cooling processes. From the perspective of chemical composition (see Table 1), the composition design of X80 steel adopts the low carbon - manganese - niobium - titanium alloy system. According to the different thickness of the plate, an appropriate amount of Mo, Cu, Ni and other alloy elements are added to improve the strength and toughness.

Table 1. Toughening composition of X80 pipeline[3]

Steel types	C	Si	Mn	P	S	Mo	Ni+Cr+Cu	Nb+V+Ti
X80	0.05~0.07	0.25	≤1.80	0.01	0.001	≤0.35	≤0.50	≤0.15
standard of API 5L	≤0.08	≤0.40	≤1.85	≤0.02	≤0.004	≤0.35	≤0.50	≤0.15

Zhang Lily[4] et al. with thermal simulation technique, mechanical performance testing means and microscopic analysis method, on the second line of west-east gas pipeline engineering in X80 pipeline steel and its welding heat affected zone, the organization of the heating pipe bending and mechanical properties were studied systematically, and aims to explore the mechanism of strong toughness of X80, establish process - the organization - the relationship between the performance and ensure that the second line of west-east gas pipeline engineering with safety reliability of X80 grade pipeline steel. The results show that the main microstructure of X80 pipeline steel includes polygonal ferrite, quasi-polygonal ferrite, granular bainitic ferrite and bainitic ferrite. The results show that the X80 pipeline steel with low alloy content can achieve high strength and toughness through advanced TMCP technology. It is also shown that the traditional Mo pipeline steels and the newly developed high Nb pipeline steels both have excellent strength and toughness matching characteristics by taking full advantage of the comprehensive functions of grain refinement, segregation, dislocation and phase transformation strengthening, which meet the technical requirements of the second line of West-to-East Gas Pipeline Engineering in China. The effects of welding process parameters and peak temperature of secondary thermal cycle on microstructure and properties of X80 steel were also studied. The experimental results show that X80 coarse-grain heat affected zone (CGHAZ) has low toughness value. Under the conditions of medium and low welding heat input (10kJ/cm-25kJ /cm), the toughness of X80 welding coarse-grain zone is better, and the toughness of X80 welding coarse-

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grain zone is worse because of high welding heat input. When the peak temperature of the secondary thermal cycle is in the (α+γ) two-phase region (800°C), X80 has the lowest toughness, showing local embrittlement in the critical coarse grain zone (ICCGHAZ) of welding. The main causes of welding embrittlement are the coarsening of grains and the formation of thick carbon-rich M-A elements during the welding thermal cycle.

Han Chen[5] et al. took X80 pipeline steel with low carbon and high Nb as the research object, and analyzed the microstructure and precipitated two-phase particles of the steel. The results show that the microstructure of steel produced by HTP is mainly acicular ferrite, and most of the precipitates are irregular compound precipitates formed by round Nb(C,N) attached to square Ti N particles with high thermal stability. Reducing the N content and adjusting the Ti/N ratio can increase the content of Nb in solid solution and give full play to the role of high Nb content.

Zhang Mingxuan [6] et al. carried out microstructure analysis, mechanical properties, impact and hardness tests on the welded joint samples of X80 pipeline steel by adopting gas shielded welding and automatic welding (process 1) and gas shielded welding and automatic semi-automatic welding (process 2). The macrostructure morphology and structure of welded joints under different process conditions were obtained as follows:

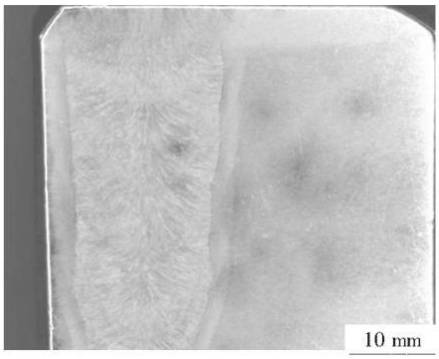

Fig. 1 Microstructure morphology of welded joints when process 1 is used [6]

As can be seen from Figure 1, the welded joint is mainly composed of base metal, heat-affected zone and weld seam containing columnar crystal.

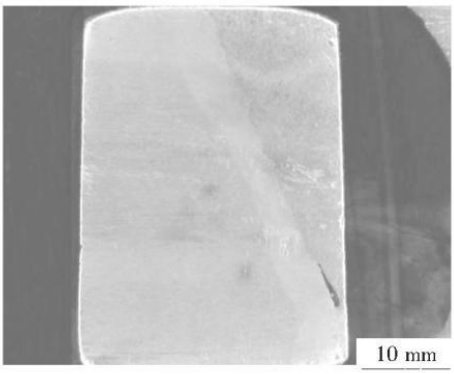

Fig. 2 Macrostructure Morphology of Welded Joints Using Process 2 [6]

As can be seen from Fig. 2, cracks exist at the junction of the bottom weld zone and the fusion zone of the welded joint.

In the end, it is considered that the tensile strength and impact toughness of the welded joint obtained by gas shielded welding and automatic shielded semi-automatic welding are better.

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4. Reliability study of X80 steel

Cui Yi[7] et al. simulated the whole process of producing X80 grade pipeline steel by continuous casting and rolling process through the real-time production method of laboratory steelmaking, continuous casting and direct rolling, and studied the reliability of X80 grade pipeline steel produced by continuous casting and rolling process by optical microscope, scanning electron microscope (SEM), transmission electron microscopy (TEM) and other methods. Results show that the mainly acicular ferrite organization of grade X80 pipeline steel various performance indexes can meet the standard requirement of API 5 l, high strength, high toughness and good welding performance, as well as in the resistance to oil, natural gas and hydrogen sulfide stress corrosion cracking ability and can meet the needs of the oil and natural gas in practical engineering.

Zhang Shuai[8] et al. made a comparative analysis of the microstructure, dislocation morphology and precipitation equality of X80 pipeline steel produced by different processes through optical microscopy and transmission electron microscopy. Combined with the mechanical properties test, the influence of X80 microstructure on mechanical properties was studied. The results show that the grain size of acicular ferrite, the distribution of precipitated phase, the dislocation density and the dislocation morphology have obvious effects on the strength, toughness and brittle transition temperature of the material. The X80 pipeline steel with good comprehensive mechanical properties is obtained by the comprehensive strengthening methods of solid solution strengthening, fine grain strengthening, dislocation strengthening and precipitation strengthening.

5. Summary

(1) X80 pipeline steel is the most widely used high strength pipeline steel in the world. Its strength, toughness and welding performance can meet the requirements of domestic long distance pipeline engineering application.

(2) Weld zone is a very important part of the steel pipe of X80 pipeline. Welding process parameters such as welding current, welding rate, welding voltage, welding layer number and welding wire composition directly affect the performance of the weld zone.

(3) The X80 steel pipes with different diameters and wall thicknesses adopt matching welding materials and reasonable process respectively, which can ensure the safe use of pipes more efficiently.

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