

High Grade Line Pipe Submerged Arc Welding Technology

Science & Technology Management Department, CNPC

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CHINA NATIONAL PETROLEUM CORPORATION

High Grade Line Pipe Submerged Arc Welding Technology Promotes Oil and Gas Pipeline Construction!



China National Petroleum Corporation (CNPC) is a state-authorized investment agency and a state holding company. On July 1998, with the implementation of the Institutional reform of the State Council, CNPC was reorgnized to become an integrated oil company of cross-regions, crossindustries and cross-countries, it adopts modern enterprise system to realize the integrations of upstream and downstream operations, internal and external trade, production and marketing. CNPC's business covers six main sectors: oil and gas operations, petroleum engineering service, petroleum engineering construction, petroleum equipment manufacturing, financial services and new energy development. In 2014 CNPC produced 113.67 million tons of crude oil and 95.46 billion cubic meters of natural gas, while crude processing volume reached 150.2 million tons. The total revenue of RMB 2.730 billion with a profit of RMB173.4 billion had been achieved the same year.

CNPC was ranked 3th among the world's largest 50 oil companies and 4th in Fortune Global 500 in 2014.

CNPC strictly follows by the combined strategies of increasing resource capacity, expanding market shares and consolidating the international role, and persists in regarding technical innovation as a key framework to advance technological progress. To develop its core businesses, focuses will be placed on the solutions of key bottleneck technologies and key proprietary technologies. Thanks to continuously improving of the technical innovation system, optimizing the configuration of technological resources and strengthening the construction of strong talent teams, CNPC's technological creativity has been considerably upgraded. Consequently, a large number of technologies have been developed independently, with its own intellectual property.

The high grade line pipe submerged arc welding technology is one of representatives for major innovations of CNPC.

OFFERING ENERGY SOURCES, CREATING HARMONY

Introduction

Pipeline transmission is the most economic and safest mode of oil and gas transmission, and high pressure oil and gas transmission with high grade, large aperture and long distance has become the development direction of international oil and gas transmission.

The high grade line pipe submerged arc welding technology of CNPC is applicable to submerged arc welding of line pipes of \geq X70 steel grade and is characterized by high welding strength, good tenacity, fine appearance, high welding efficiency, etc.

The yield of high performance submerged air welded pipe products manufactured using this technology has exceed 5.00 million tons, and they are widely used in national major pipeline projects including West-East NG Transmission Line I, West-East NG Transmission Line II, West-East NG Transmission Line III, Shan-Jing Pipeline, China-Myanmar Pipeline, etc. In addition, they have also been used in foreign major oil and gas pipeline projects such as India "East-West NG Transmission" Project etc., so that China has become from a chaser into the top runner in the construction of world highperformance oil and gas pipeline engineering.





The high grade line pipe submerged arc welding technology consists of high robustness submerged arc welding wire technology, high speed submerged arc flux technology, welding seam toughening matching technology and high grade line pipe submerged arc welding process control technology.



Distribution of domestic and foreign products



High robustness submerged arc welding wire technology

Welding wire is one of the main welding materials for line pipes and its performance directly affects the strength, tenacity and quality of welding seams. Compared with common welding wires, the high robustness submerged arc welding wire has advantages such as high welding seam strength, good low temperature tenacity, low diffusible hydrogen content, etc.

The high robustness submerged arc welding wire technology is based on the robustness mechanism of complex alloys and microalloys involving Mn, Cr, Mo, Ti, V, etc. With the optimized welding process, welding seams form microstructures mainly including acicular ferrites, thus ensuring that welding joints have good strength and tenacity. The welding wire product manufactured with this technology has been awarded with multiple national invention patents.

The weld deposited Metal strength of the high robustness welding wires such as BG-H06H1, BG-H08C, etc., manufactured by the technology can reach over 540MPa, and the -20 °C Charpy impact energy over 80J. The tensile strength of the welding seams in the manufacturing of X70 and X80 welded pipes reaches over 570MPa (X70 steel grade) and 625MPa (X80 steel grade) respectively, and the -10 °C Charpy impact energy over 130J on an average level.



Welding wire finished product



Welding wire application site



Finished flux product



Flux application site

High speed submerged arc flux technology

During submerged arc welding, the main function of flux is to form slag, protect molten weld pool, clean welding seams, adjust welding seam composition and optimize welding seam forming quality. Flux has an important impact on welding process stability and welding seam quality.

In order to solve the difficult problems involving large welding seam tenacity fluctuation, bas process performance, low welding speed, etc. During high grade line pipe welding, the relation of flux slag series with welding usability and impact tenacity has been studied systematically, fluorine alkali type high speed submerged arc flux has been developed, and multiple national invention patents have been obtained.

The produced BG-SJ101H1 high speed submerged arc flux is used in manufacturing of X70 and X80 welded pipes; at high welding speed (1.7m/min), welding seams have good process performance and stable quality. In addition the tensile strength of the welding seams reaches over 570MPa (X70 steel grade) and 625MPa (X80 steel grade) respectively, and the -10° C Charpy impact energy over 130J on an average level.

Welding seam toughening matching technology

According to the composition, structure and performance features of high grade pipeline steel and on the basis of ensuring strength matching of welding seams with base metal, adjust the alloy elements in welding seam metal depending upon the metallurgical reaction of base metal, welding wire and flux in the molten weld pool, optimize welding seam structure, refine welding seam crystal grains, purify crystal grains and grain boundaries, and make welding seams have high strength and tenacity.



(After welding seam toughening, the tensile strength of welding seam is increased by 96MPa, and the impact energy by 72J) Application effect of X80 pipeline steel welding seam toughening technology

High grade line pipe submerged arc welding process control technology

For the line pipes with different steel grades, pipe diameters and wall thicknesses, study and design different bevel shapes and the relation of weld line energy with welding seam energy, optimize the key process parameters such as welding current, voltage, welding speed, etc., and ensure that steel pipe welding joints obtain good integral performance. In addition, the welding speed has been increased from 1.3m/min to 1.7m/min, and the production efficiency is increased by over 30% in line pipe manufacturing.







Welding bevel and bevel tracking

3 TYPICAL CASES

> 3.1 Comprehensive application in projects such as West-East NG Transmission Pipeline Project etc. to ensure the construction of national major energy channels

With this technology, CNPC has manufactured high performance X70 and X80 line pipes and their performance reaches international advanced level, thus filling up the gap in China. The manufactured



"The First Pipe" of West-East NGTransmission Line I

X70 ϕ 1016×14.6~17.5mm, ϕ 1067×15.9mm and X80 ϕ 1219×18.4mm submerged arc welded pipes are widely used in domestic major oil and gas transmission projects such as West-East NG Transmission Project, China-Myanmar Pipeline, Central Asia Pipeline, Shan-Jing Line, etc., totaling over 4.00 million tons. This has greatly guaranteed the need of national engineering construction, reducing CO₂ emission and promoting the development of national green economy.



Transportation of the First Train of Steel Pipes for West-East NG Transmission Line III

Application of high	arade line	pipe submera	ed arc welding	ı technoloav iı	1 maior pipelines
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No.	Pipeline name	Steel grade	Specification (mm)	Welding wire name	Welding wire consumption (t)	Flux name	Flux consumption (t)
1	West-East NG Transmission Line I	X70	φ 1016 × 14.6/ φ 1016 × 117.5	BG-H08C	711	BG-SJ101G	813
2	West-East NG Transmission Line II	X80	φ 1219 × 18.4	BC-H06H1/ BG-H08C	6769	BG-SJ101H1	10900
3	West-East NG Transmission Line III	X80	φ 1219 × 18.4	BC-H06H1/ BG-H08C	4724	BG-SJ101H1	5399
4	Central Asia Pipeline	X70	ϕ 1067 × 15.9	BG-H08C	2100	BG-SJ101G	2400
5	India Pipeline	X70	ϕ 1219 × 17.2	BG-H08C	427	BG-SJ101G	488

3.2 Winning the bid for major overseas pipeline projects and showing the strength in the industry

CNPC stood out from the competition among many foreign famous steel pipe companies and successfully

won the bid for India "East-West NG Transmission" $X70 \phi 1219 \times 17.2 \text{mm}$ Pipeline Contract with over 600000 tons, thus gaining foreign exchange of 0.537 billion USD. The contract becomes the largest single international steel pipe contract of CNPC, and the product quality has been highly appraised by the Owner.



Schematic of India East-West NG Transmission Pipeline Total length: 1244km

Shipping of the First Ship of Steel Pipes for India East-West NG Transmission Line





CNPC has National Oil and Gas Pipe Engineering Research Center. It has excellent and advanced scientific research equipments, can meet the needs of research on oil and gas steel pipeline material design technology, process control technology, testing and evaluation technology, tubular product application site engineering service technology, etc., and provides a powerful guarantee to the development of new products and technologies.





MTS 250kN dynamic and static testing machine can be used to carry out mechanical property test involving pipeline steel breaking tenacity, CTOD, material fatigue, etc. The tensile force sensing and measurement accuracy of the testing machine can reach ISO 0.5 grade.



MTS 250kN dynamic and static testing machine



Hydrostatic pressure burst field test and detection equipment



Hydrostatic pressure burst pipe

The hydrostatic pressure burst field test and detection equipment can be used to carry out hydrostatic pressure burst testing of welded pipes at different pressures (50~130MPa), test the circumference variation ratio during steel pipe burst and evaluate the integral performance of steel pipes.

The flux laboratory can develop flux and carry out process experiments on raw material mixing, dry mixing, granulation, sintering, etc. The mixing ratio of each component of flux raw material is optimized according to the impact of each component of flux raw material on welding process performance and welding seam mechanical property.





LSM 700 laser scanning confocal microscope

Impact fracture

LSM 700 laser scanning confocal microscope is the most advanced scanning confocal microscope at present. The microscope is designed with the originally created laser path and has 405nm laser path. The microscope is used mainly in the analysis of microstructure, fracture shape and dimple depth of pipeline steel and also quantitative analysis of surface crack and surface roughness. The digital welding testing equipment is used mainly in single-wire, two-wire and multi-wire (3~6 wires) spiral/longitudinal submerged arc welding process tests with different wall thicknesses (max wall thickness 50mm), different steel grades (X42~X100) and different pipe diameters (maximum pipe diameter 1422mm), thus providing technical support to industrialized production of steel pipes.



Digital welding testing equipment



Enterprise qualification

CNPC firstly obtained the quality management system certificate approved by API in the same

industry in China and has DNV certificate and laboratory certificate (CNAS certificate) issued by China National Accreditation Service for Conformity Assessment.



Standards

Responsible for drafting 4 national petroleum tubular product standards such as GB/T 9711 Petroleum and natural gas industries—Steel pipe for



pipeline transportation systems, etc. and 17 industrial standards and translating and converting 3 sets of international standards.



Patents

CNPC has totally 10 national patents in high grade line pipe submerged arc welding technology field.

No.	Patent No.	Name	Туре
1	ZL 200510022707.3	Fluorine alkali type sintered flux with high welding speed and high tenacity	Invention patent
2	ZL 200610104968.4	Sintered flux manufacturing technology	Invention patent
3	ZL 200610145593.6	Submerged arc welding wire for pipeline steel	Invention patent
4	ZL 200810005040.X	Submerged arc welding wire with high strength, high tenacity and high welding speed for high grade pipeline steel	Invention patent
5	ZL 200810017525.0	Submerged arc flux with high strength, high tenacity and high welding speed for pipeline steel	Invention patent
6	ZL 201010110747.4	High-strength submerged arc welding wire for pipeline steel	Invention patent
7	ZL 200410073353.0	Submerged arc welding material for high grade pipeline steel	Invention patent
8	ZL 200710017201.2	Submerged arc welding material for high grade pipeline steel	Invention patent
9	CN101549445.	Submerged arc welding material for X80 pipeline steel and its preparation method	Invention patent
10	CN101549445.	Submerged arc welding material for X80 pipeline steel and its preparation method	Invention patent

6 EXPERT TEAM

CNPC has a professional oil and gas tubular product technology R&D team, which has 94 employees enrolled, including 74 ones with master degree and technical title of middle class or above. 20 technical experts who enjoy great popularity at home and abroad have been invited. Special products can be developed and a complete set of technical solutions can be provided as needed by customers.



Academician of the Chinese Engineering Academy, professor level senior engineer, Ph.D. candidate supervisor. He has taken charge of development over 10 new materials. He has proposed and set up the discipline field "Petroleum Pipe Engineering". 23 achievements of which he took charge of were awarded with provincial and ministerial science and technology advance prizes. 7 monographs and over170 papers written by him have been published at home and abroad. Tel: 010-84922751 Email: lihl@tgrc.org



Yang Zhongwen Senior technical expert, professor level senior engineer. He has taken charge of completing over 10 scientific research projects including national "863" projects and CNPC's major special scientific research projects. He has drafted and translated over 20 international standards, national standards and industrial standards. 17 papers written by him have been published. He has obtained 17 patents. Tel: 0917-33988470

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Bi Zongyue	Senior technical expert, doctor, professor level senior engineer. He has taken charge of or participated in completing over 10 major scientific research projects. 1 monograph and over 30 papers written by him have been published. He has formulated and revised 5 national and industrial standards. He has obtained 10 provincial and ministerial prizes and over 20 patents. Tel: 0917-33988475 Email: bsgbzy@cnpc.com.cn
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Senior technical expert, senior engineer, master student supervisor, "Thee-Qin Talent" of Shaanxi Province. She has participated in completing over 10 major scientific research projects. Over 10 papers written by her have been published. She has obtained 6 provincial and ministerial prizes and 8 patents. Tel: 0917-33988455 Email: bsgnh@cnpc.com.cn TRAINING AND SERVICES

Training

In order to let customers understand the manufacturing standards for line pipe products more comprehensively, CNPC can train customers in the standards such as API Specification for Line Pipe, GB/T 9711 Petroleum and natural gas industries— Steel pipe for pipeline transportation systems, etc. more perfectly.

Services

Depending upon the perfect testing and inspection equipment of National Engineering Technology Research Center for Petroleum and Natural Gas Tubular Goods, experienced technology teams and CNAS and CMA qualifications, CNPC can provide customers technical services involving mechanical property testing of tubular products, structure analysis, corrosion test, technological research, etc. and the best after-sales services round the clock.





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