

The characteristic of 2205 duplex stainless steel and application in natural gas pipeline

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Abstract: 2205 duplex stainless steel (DSS) possesses favorable mechanical property and good corrosion resistance at the same time, and has been a new material and applied widely in petroleum, natural gas, ocean and chemistry industry etc from 1980's in some advanced countries and from 1990's in China. One natural gas headstream project possesses abundant natural gas and provides 80% of total quantity gas for West-East Pipeline Project. The project includes a 13 km length pipeline and a gas treatment plant that purify gas about $12 \times 10^9 \text{ m}^3$ every year. The Cl^- concentration in the water separated from gas is about 10%, and so the corrosion of medium is very violent to the pipeline. 2205 DSS material has been applied successfully to the project in 2004. This is the first time of such a mass of DSS material application in a project in China. The characteristic of 2205 DSS and application in natural gas pipeline project has been introduced in this paper.

Key words: duplex stainless steel; characteristic; application; natural gas pipeline

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1 Introduction

Ferritic-austenitic stainless steel, also referred to as duplex stainless steel (DSS) was found in 1920's, but it has not been widely used until 1970's because of some questions such as material, welding, heat treatment etc. As the progress of metallurgy technique, the finding of nitrogen element import role for DSS, the 2nd DSS has been developed in 1970's and the weldability has been improved. DSS start to be widely used in project from 1980's in some advanced countries and from 1990's in China. 2205 DSS is one of modern DSS and possess high mechanical properties and good corrosion resistance, and has been a new material and applied widely in petroleum, natural gas, ocean and chemistry industry etc. The DSS material used for the length of oil and natural gas pipeline exceeds 850 km at present all over the world, most of them is 2205 DSS^[1]. By investigating for material & welding and application experience in some natural gas pipeline, the characteristic and some key techniques of application have been introduced in the paper.

2 Property of 2205 DSS

2.1 Chemical composition

The main chemical compositions of 2205 duplex stainless steel (DSS) are Cr (about 22%, mass fraction), Ni

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(about 5%, mass fraction), Mo (about 3%, mass fraction) and N (about 0.15%, mass fraction). The role of each element, Cr and Mo promote to form ferrite, Ni and N stabilize austenite. N is a very strong austenite former and strongly promotes an austenitic structure. N increases the resistance to localised corrosion, especially in combination with Mo. N improves corrosion resistance too and plays important role for alloying in modern duplex stainless steel. Cr, Mo and N improve corrosion resistance of material, especially pitting and crevice corrosion resistance in containing Cl^- medium. Table 1 lists typical chemical composition value of 2205 DSS and requirement value of API SPEC 5LC "Specification For CRA Line Pipe".

Table 1 Typical chemical composition and standard requirement of 2205 DSS (mass fraction, %)

	C	Si	Mn	Cr	Ni	Mo	N
Typical value	0.02	0.38	1.45	22.0	5.5	3.0	0.16
Requirements of API SPEC 5LC	Max. 0.03	Max. 1.0	Max. 2.0	21.0–23.0	4.5–6.5	2.5–3.5	0.08–0.20

2.2 Microstructure

Generally, 2205 DSS is provided at the condition of solution annealed. 2205 DSS microstructure contains roughly equal amounts of ferrite (F, approximately 50%) and austenite (A, approximately 50%) in solution annealed condition, this is called phase balance, but it is not strictly equal in amount. Generally, less phase need to excess 30% at least. Less ferrite structure is better for weldability, plastic and toughness. The general standard requirement is 45 to 55 percent ferrite. Typical microstructure of 2205 DSS plate is shown in Fig. 1.

2.3 Mechanical property

Generally speaking, the strength of 2205 DSS is higher and toughness is lower than austenitic stainless steel; the strength of 2205 DSS is lower and toughness is higher than ferritic stainless steel and martensitic stainless steel. Two structures play important role for the mechanical properties of 2205 DSS. Ferrite structure provides high strength and austenite provides good toughness, and promotes forming fine grain structure. Therefore, 2205 DSS possesses favorable mechanical property and good corrosion resistance at the same time. Fig. 2 is the contrast of specified yield strength for different types of stainless steel.

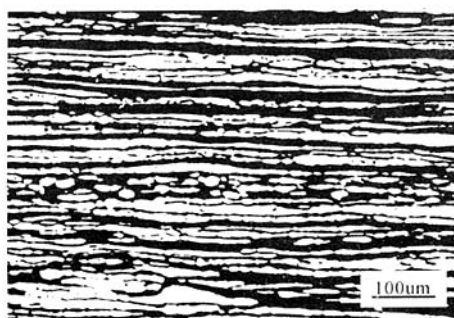


Fig. 1 Typical microstructure of 2205 DSS plate

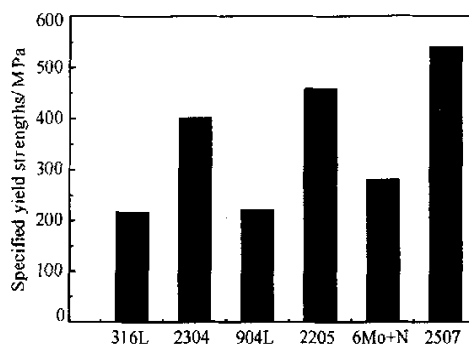


Fig. 2 Specified yield strength for different types of stainless steel

2.4 Corrosion resistance

Corrosion resistance is the most important properties for stainless steel. Chemical composition and duplex microstructure determine that 2205 DSS possesses favorable corrosion resistance. Super-low Carbon, high content Chromium and Molybdenum make it have high resistance for general corrosion, intergranular corrosion, pitting and crevice corrosion. Duplex microstructures make it high strength, so make it have good resistance for stress corrosion cracking. Critical pitting temperature (CPT) of 2205 DSS is about 40°C in 6% FeCl₃ solution, but 316 L is only about 20°C. This shows that 2205 DSS has better resistance for Cl⁻ pitting than 316 L. 2205 DSS has also good corrosion resistance in H₂S containing medium^[2].

2.5 Weldability

2205 DSS has best proportion of ferrite to austenite (each is about 50 percent) and make use of Nitrogen as alloy element, make sufficient austenite structure can be reformed in heat-affected zone (HAZ) when welding. Less expansion and higher heat conductivity compared to austenitic stainless steels, and duplex microstructure make 2205 DSS have less hot crack tendency and less distortion. Approximately 50 percent austenite microstructures make it has less cold crack tendency than low-alloy steel. Generally speak, 2205 DSS has good weldability, not need preheat before welding and not need heat treatment after welding^[3,4].

3 2205 DSS application in natural gas pipeline

One natural gas headstream project possesses abundant natural gas and provides 80% of total quantity gas for West-East Pipeline Project. The project includes a 13 km length pipeline and a gas treatment plant that purify gas about $12 \times 10^9 \text{ m}^3$ every year. The Cl⁻ concentration in the water separated from gas is about 10%, and so the corrosion of medium is very violent to the pipeline. 2205 DSS material has been applied successfully to the project in 2004. This is the first time of such a mass of DSS material application in a project in China. Welding is the most important work for the natural gas pipeline construction, especially for this material which procedure is complex and difficult. The gas pipeline project has been constructed successfully at the end of 2004 by 5 months hard working.

3.1 Preparation work

This is the first time of 2205 DSS used in natural gas in China. Scientific research corporation which service for the project has done many tests and research works for material, welding, structure and properties. The characteristic of material & welding, inspection & test technique and welding technique had been mastered by research for the material.

There were many size of pipe (min. $D 33.4 \text{ mm} \times 3.4 \text{ mm}$, max. $D 508 \text{ mm} \times 19.1 \text{ mm}$) in the project. 12 welding procedure specification (WPS) have been prepared according to welding investigation, 12 welding procedure qualification (WPQ) have been done. 6 welding procedures have selected used for the project. Table 2 and Table 3 are the main conditions and results of one welding procedure qualification. Fig. 3 is the microstructure of welds and HAZ of the qualification.

Table 2 Main welding condition of WPQ of D508×15.9 pipe girth welds

Welding process	Filler metal	Protect gas	Groove	Position	Heat input E/(kJ·cm ⁻¹)
TIG for 2 root pass SMAW for filler and cap pass	AVESTA 2205 AVESTA 2205-PW	Torch gas: Ar+1.5% N ₂ Back gas: Ar+5% N ₂	Single V	45°Fixed (6G)	8-20

Table 3 Main results of WPQ of D508×15.9 pipe girth welds

Tensile strength R_m /MPa	Side bend (90 mm, 180°)	Impact energy at -40°C CVN/J		Microstructure	Pitting corrosion	
		Welds	HAZ			
766	No Crack	41.5, 43.5, 45.0	155, 103, 115	Welds and HAZ are F + A. No intermetallic precipitations in welds and HAZ. The F proportion is 35% - 50% in welds and 50% - 65% in HAZ.	No pitting corrosion occur in specimens surface after 24 h at 22°C, 6% FeCl ₃ solution.	
763						
737		43.0, 40.0, 40.0	112, 155, 90.0		Average corrosion rate of 3 specimens: 1.57, 1.57, 0 mg · dm ⁻² · day ⁻¹	
752						

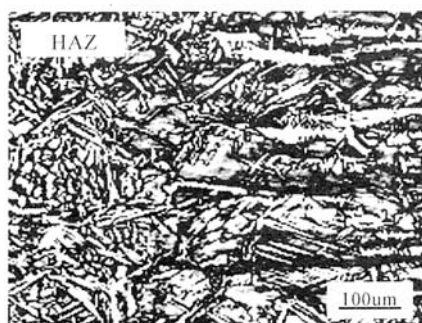
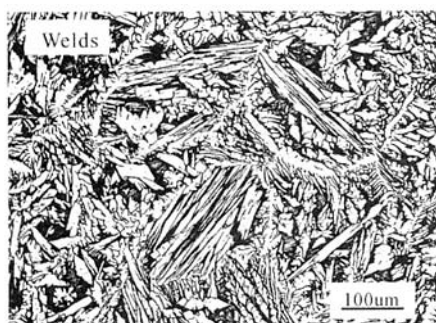


Fig. 3 Microstructure of welds and HAZ

Welder training and qualification have been done before pipeline welding. About 50 personals 128 items have passed examination after two months training. Differing from others general material welding and considering the characteristic of pipeline field welding, this project welding and construction have much specific requirements in weldment prepared, process control, handle technique, etc. Especially, how to do back protect, how to control heat input, how to control oxygen content in back gas, etc. Discipline of welding and construction have been established and used to the project.

3.2 Field construction

2205 DSS is used for the pipeline and the plant inside tubes. The project was constructed by two companies which has abundant experience for pipeline, inspected and supervised by professional corporation which have qualification certificate. Two construction companies provide experienced welders and erectors for the project, and equip with excellent equipments of welding & fixing and tool of cleaning & grinding, etc. Construction companies had bought gas protect equipment from abroad and made protect equipment by himself, also bought oxygen concentration measurement instrument which may measures 10 ppm oxygen. Construction process was supervised strictly by professional corporation, the technique requirement and discipline have been carry out, thereby the quality has been assured. Participators of the project put quality as the first and regard quality as their lives. The welding works have been finished by 5 months hard working. The 96 percent welds pass nondestructive examination at one time that is enough high for this material in field condition, this assured the progress and quality of the project.

4 Conclusion

(1) 2205 DSS possesses favorable mechanical property and good corrosion resistance, and has wide purposes in petroleum, natural gas, ocean and chemistry industry etc.

(2) 2205 DSS is a new material and has much characteristic, thereby some key techniques such as

process, welding, heat treatment, etc. must be respected when applying.

(3) The project has been finished successfully based on scientific organizing and intense quality consciousness. Abound techniques and experiences of this sort material used for construction natural gas pipeline have been accumulated.

References

- [1] Wu J, Jiang S H, Han J N, et al. Duplex Stainless Steel[M]. Beijing: Metallurgy Industry Press, 1999, 1—6, 31—48.
- [2] China Society for Corrosion. Localised Corrosion of Metal[M]. Beijing: Chemical Industry Press, 1995, 277.
- [3] China Society for Mechanical Engineering. Welding Handbook(Welding of Material)[M]. Beijing: Chemical Industry Press, 1995, 303—309.
- [4] Zhang W Y, Hou S C. Weldability and Filler Metal of Duplex Stainless Steel[J]. Welding Technology, . 2004, 33 (1): 40—42.