

Research and Evaluation of x80 HSAW Line Pipe

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Abstract. This paper gives an introduction to the application research and the quality status of X80 HSAW pipe. The line pipe specification was analyzed combining with the properties of the practically manufactured pipe in this paper. It's shown that the pipe manufactures have established the steel design process for X80 pipes and the pipeline designers have been developing the design method of high-pressure gas pipelines with X80 line pipe. The YS before and after forming is compared with the strength obtained by the burst test and it is found the strength obtained from the burst test is higher than that obtained from the small specimen. This paper systematically analyses the mechanical properties of X80 SSAW pipe.

Introduction

The demand to oil & gas has improved dramatically with the economic rapid growth. It is predicted the demand to oil & gas will double in the future 10~15 years. The pipeline has developed greatly in the last 40 years as an economic, safe and an uninterrupted transmission method. The oil & gas pipelines in the world are now more than 2.3×10^6 km in length and they grow at a speed of $2 \times 10^4 \sim 3 \times 10^4$ km yearly. China has constructed the Shaan-jing, Se-ning-lan, Lan-cheng-yu and West-east pipelines in the last 10 years. It is predicted about 1000×10^4 t of steel will be used for oil & gas pipelines in China in the future 10~15 years.

The important trend for pipeline construction is the pipe selection of large diameter and high steel grade with high operation pressure. The construction expense can be greatly reduced with high pressure and high strength steel. The highest pressure is 6.3 MPa in 1950~1960, 10 MPa in 19870~1980 and 14 MPa in 1990. The design and operation pressure has reached 15 MPa~20 MPa recently and some project even consider higher pressure. With the higher pressure used the higher strength steel is needed. X52 is used in 1960's, X60~X65 is used in 1970's, X70 is more popularly used in recent years, and X80 is used now. The pipeline constructed and under construction as X80 is about 2000 km (2nd West-east pipeline not included).

X80 Steel Pipe Development and Its Application Research

"Combine Development and Application together" principle is used in the development of X80 line pipe. Application research on X80 steel pipe includes: microstructure and performance study on X80; fracture control study on high strength line pipe; optimization of site welding technique and the selection of welding consumables; bend site cold forming fabrication technique and its control parameter; fittings fabrication and its quality control technique of X80 grade; safety and reliability analysis and its evaluation on X80 pipeline, etc..

In the research of microstructure and performance of X70 in the West-east pipeline project[1], the structure of acicular ferrite was recommend; the influence of specimen sampling methods was studied on the determination of YS in X70, X80 line pipe tensile test, the combination of the performance properties was also studied in the high strength line pipe.

Abnormal fracture occurs in DWTT test on the high strength line pipe. There is no further description on how to determine the DWTT shear area in API RP 5L3 and this brings difficulty in the

actual production inspection. DWTT abnormal fracture research on X70, X80 line pipe has obtained some achievement since X70 line pipe production in West-east pipeline project, as the classification of the abnormal fracture, fracture process analysis and fracture SEM analysis. The achievement on the DWTT abnormal fracture research has been incorporated in the line pipe specification as 2nd Shaan-jing, liaison between West-east and 2nd Shaan-jing and the test part of X80 pipeline.

In determination of the arrest toughness for the West-east pipeline project, the predicted data by BMI empirical method was multiplied by CVP/CV100, this is much conservative. TGRC proposed the M parameter to predict the arrest toughness of high strength line pipe and the verification on the West-east pipeline project and the test part of X80 pipeline obtained good result. TGRC has carried out the research on CTOA (Crack Tip Opening Angle) as the arrest toughness, the research on the fracture dynamic propagation, fracture arrest prediction method and relevant software development.

Chemical Composition Design and Mechanical Properties of X80

Research on X80 line pipe in China started in 1999 and breakthrough was made at that time: different sizes of X80 steel coil, plate and line pipe were experimented and manufactured. Recently for the engineering application the steel plate and hot coil of X80 are developed by several steel companies as per the requirement of X80 specification of 2nd West-east pipeline project. HSAW pipe and LSAW pipe of OD 1219mm are conform to the requirement of X80 specification.

As the 3rd party TGRC has monitored the manufacturing processes and evaluated the line pipe quality by test. The test results show the quality of the line pipes manufactured in China domestic is comparable with that of the abroad. The level and capability of the steel making, plate / hot coil rolling and pipe welding can satisfy the commercial mass production.

To guarantee the site weldability of the X80 line pipe, Ceq is required to be not more than 0.46%, and the typical chemical composition of X80 is as in the Table 1.

Comparing with X70 steel the chemical composition of X80 is adjusted, the microstructure is optimized with even small M/A colony and much even distribution[2]. X80 steel with different chemical composition exhibits different mechanical properties by evaluating the pipes from different companies. Further study on the relationship among chemical composition, microstructure and performance can obtain X80 line pipe with optimized microstructure and performance by proper process control.

The typical tensile property of X80 line pipe is shown in Table 2. The line pipe shows enough strength and toughness, and the weld tensile also shows enough strength, which can satisfy the requirement of engineering application.

For X80 line pipe, FATT50<-60°C, FATT85<-45°C. The Charpy absorbed energies of X80 pipe are as 385J, 137J and 151J at -10°C for the pipe body, weld and HAZ.

Table 1 - Typical chemical composition of X80 steel (wt%)

C	Si	Mn	P	S	Cr	Mo	Pcm	Ceq
0.05	0.24	1.76	0.012	0.001	0.140	0.280	0.19	0.46

Table 2 - The typical tensile property of X80 line pipe

YS(MPa)	TS(MPa)	Elongation(%)	YS/TS	Weld TS(MPa)
635	700	23	0.91	770

Table 3 - Charpy impact test result of X80 (-10℃)

Position	CVN(J)				SA(%)			
	Single		Ave		Single		Ave	
Pipe Body	380	392	382	385	100	100	100	100
Weld	157	127	126	137	78	69	67	71
HAZ	163	173	118	151	98	100	70	89

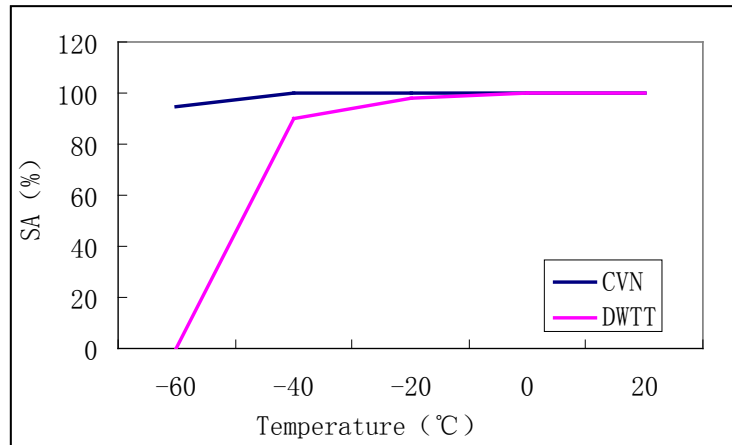


Fig.1. Charpy impact and DWT transition Curve

Yield Strength of X80 Pipe and Hydrostatic Burst Test

To measure the yield strength of pipe, which is standard value in stress base design to pressure, test specimens have to be flattened. This flattening process decreases yield strength due to Bauschinger effect. On the other hand no flattening is needed for L-direction tensile test or rode bar specimens. To determine the accurate tensile properties of line pipe is very important to judge both pressure containment capacity and strain capacity.

The manufacture process for pipe forming generates work hardening. This is an advantage to keep high strength in pipe, which is a control factor of pressure containment capacity of line pipe.

Pipe line steel with acicular ferrite structure has behavior of continuous yield, having higher effect of Work hardening. Work hardening by pipe forming can repair Bauschinger effect.

It be found in tensile test of X80 pipe, Yield strength measured by flattened rectangle specimen is lower than round bar specimen. There is a 50MPa fall between flattened rectangle specimen and round bar specimen. Comparison of yield strength between X80 pipe and coil shown in Figure 2, there is a 54MPa increase in average after forming (rectangle specimen for coil, round bar specimen for pipe). Pressure containment capacity of line pipe is the first priority to design pipelines. Tensile strength in circumferential direction has been adopted successfully to evaluate the pressure containment capacity of line pipe.

Burst pressure exceeds measured tensile strength of X80. Results of Hydrostatic burst test shown in Figure 3.

Yielding of pipe is another concern to confirm pressure containment capacity. By relation between internal pressure converted to circumferential stress and volume change are plotted, predicted yield strength of X80 pipe exceeds measured yield strength by round bar specimen. By the results (shown in Figure 4) of Hydrostatic burst test of X65, X70 and X80 pipe, yield strength of pipe have increase trend as the strength level increase.

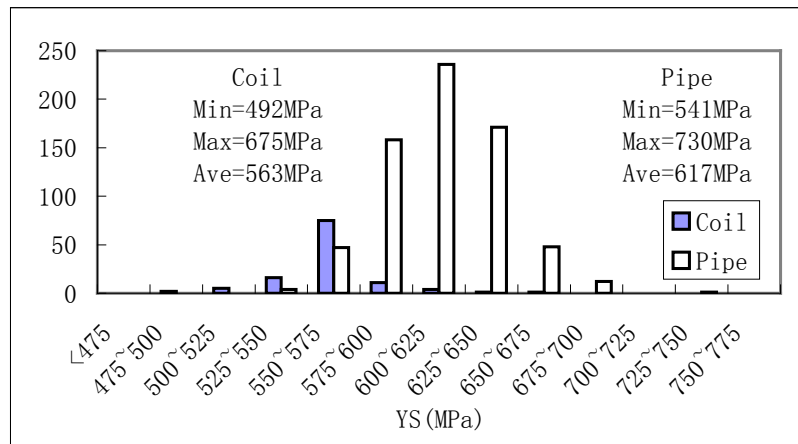


Fig.2. Comparison of yield strength between X80 pipe and coil

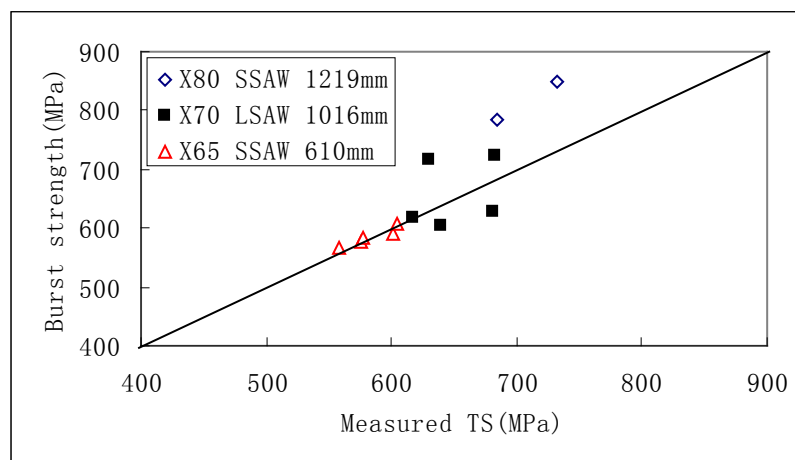


Fig.3. Hydrostatic burst Strength on X65, X70 and X80 pipe

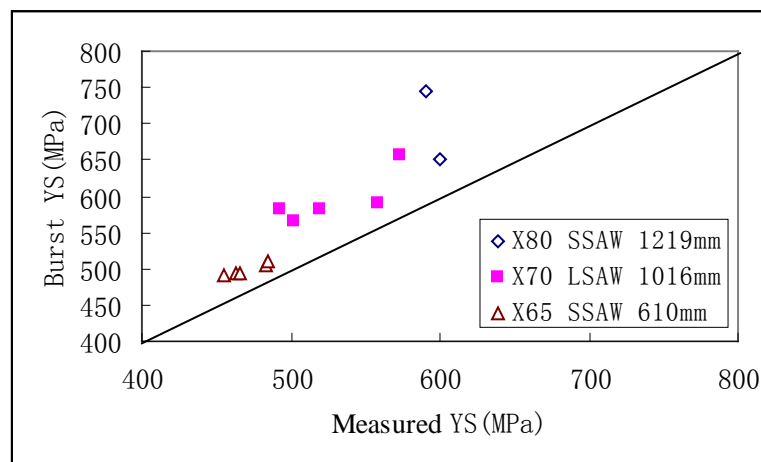


Fig.4. Hydrostatic burst yield Strength on X65, X70 and X80 pipe

Quality of X80 HSAW Pipe for Mass Production

To mass production of X80 1219mm×18.4mm SSAW pipe, chemical composition and manufacture process have been controlled strictly, Mechanical properties of X80 1219mm×18.4mm SSAW pipe are conform to API Spec 5L[3]. For yield Strength of mass production has a average value of 617MPa.

For Charpy V-notch toughness of mass production of X80 1219mm×18.4mm SSAW pipe at temperature of -10℃, there are average value of 328J, minimum value of 122J and maximum value of 491J in pipe body. There are average value of 157J, minimum value of 68J and maximum value of 421J in weld seam. There are average value of 205J, minimum value of 70J and maximum value of 486J in HAZ.

Conclusions

Mechanical properties of X80 1219mm×18.4mm SSAW pipe are conform to API Spec 5L. There is a obviously increase for yield strength of X80 pipe after forming. The yield strength measured by hydrostatic burst test for full scale size pipe are higher than small size tensile specimen. For testing materials in grades higher than X70, it is recommended that the specifications should prescribe the use of a transverse round bar specimen in order to determine the pipe properties correctly. The gauge diameter of the round bar specimen should be as larger as possible.

References

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