

Optimization of Submerged Arc Welding Heat Affected Zone Toughness in X-120M line Pipe Steel

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Received: 16 December 2011 Accepted: 4 January 2012 Published: 15 January 2012

Abstract

In view of the ever-increasing demand for energy and ever increasing operating pressure of line pipe, it is very essential to develop high strength steel and production technology for manufacturing the line pipes of high strength of level to X-120M. Recent experiments show that the grade (X-80M) with respect to grade (X-70M) could give investment cost saving of pipe line construction project. if we use X-120M steel line pipes, the cost saving is much higher. Therefore, economic transport of gas from remote sources is an important consideration in today's global economic environment. To solve these challenges, a high strength grades, large diameter line pipe of X-120M strength level through J-C-O-E technique has to be developed. The J-C-O-E longitudinal double submerged arc welding (LDSAW) of X-120M line pipe has major challenge to establish the toughness for heat affected zone (HAZ) at the X-120M strength level, as the SAW welding is high heat input welding process. So the maintaining the strength and toughness at the strength level of X-120M of heat affected zone (HAZ) is very critical as the cooling rate is very high.

Index terms— X-120M, LDSAW, HAZ, CTOD, toughness, heat input, macro hardness.

1 Introduction

Heat affected zone (HAZ) is the portion of the base metal (Plate Material) lying next to the fusion line of longitudinal double submerged arc weld (LDSAW), which has not been melted but whose mechanical properties or microstructures have been altered by the heat of the welding. The HAZ is subjected to a complex thermal cycle (sudden heating followed by rapid cooling), in which all temperatures from melting range of the steel down to mere warming involved, and therefore HAZ consists of series of graded structures.

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and ever increasing operating pressure of line pipe, it is very essential to develop high strength steel and production technology for manufacturing the line pipes of high strength of level to X-120M. Recent experiments show that the grade (X-80M) with respect to grade (X-70M) could give investment cost saving of pipe line construction project. if we use X-120M steel line pipes, the cost saving is much higher. Therefore, economic transport of gas from remote sources is an important consideration in today's global economic environment. To solve these challenges, a high strength grades, large diameter line pipe of X-120M strength level through J-C-O-E technique has to be developed. The J-C-O-E longitudinal double submerged arc welding (LDSAW) of X-120M line pipe has major challenge to establish the toughness for heat affected zone (HAZ) at the X-120M strength level, as the SAW welding is high heat input welding process. So the maintaining the strength and toughness at the strength level of X-120M of heat affected zone (HAZ) is very critical as the cooling rate is very high. In this paper the heat input for LDSAW process has been optimized with respect to the toughness down to -20 0 C in HAZ of X-120M strength level. The effect of varying level of heat input in increasing order from minimum heat input of LDSAW process

has been studied with three wire tandem system of submerged arc welding system. The experimental procedure at varying level of heat input has been established similar to line pipe welding except line pipe formation. The testing performed on test coupons are charpy V-notch testing, crack tip opening displacement (CTOD), Vicker's macro hardness testing. The said tests for all level of heat input established the optimum level of heat input for toughness of X-120M in the HAZ of LDSAW weld down to -20 0 C.

Microalloying technique [1] and dynamic accelerated cooling process after controlled rolling were applicable to develop low composition parameter (Pcm) high grade line pipe steel which is required for prevention of cold cracking in girth welding. The HAZ toughness was improved by adding small amount of titanium ('Ti'). The hardenability of boron ('B') treated new type of steel was considered by using the effective 'B' contents calculated equilibrium as free 'B'. The effect and its mechanism of 'B' [2] addition to steel containing fine 'Ti₂O₃' particles on toughness improvement of HAZ in large heat input welding process has been studied. The formation of intergranular ferrite (IGF) in HAZ is promoted and HAZ toughness is improves markedly after large heat input welding by adding 'B' in steel containing 'Ti₂O₃'. While 'B' segregates of gamma (?) grain boundaries suppresses nucleation of grain boundaries alpha(?) ferrite, 'B' at gamma (?)/Ti₂O₃ interface doesn't suppress nucleation of IGF from 'Ti₂O₃' because of 'B' absorption into 'Ti₂O₃'. Consequently fine IGF nucleation is accelerate by the effect of both 'Ti₂O₃' and 'B' so that refining of HAZ microstructure and improvement of HAZ toughness are achieved even after large heat input welding process. The CGHAZ has been studied [3,4] for different steel composition like carbon with Al-Si and Al, Si-face, Al-free, 'Si' and 'Nb' alloyed. The above combination did not make much difference but the difference made by the reduction in the carbon percentage to improve low temperature toughness of HAZ is appreciable. The matrix microstructures [5] are also reported to have a strong influence on HAZ toughness. In bainitic and mertensitic steel the austenite grain transform to lath structure, the lath structure occurs in bundles or packets with low range boundaries between the laths and large misorientation occurs across packet boundaries. In such structures the packet width is the main microstructural features controlling cleavage crack propagation. It was reported that the ductile-brittle transition temperature is a logarithm function of the inverse square root of the product of the pocket diameter. The presence of M-A phase is the dominate factor for determining the toughness of intercritically cooled coarse grain (ICCG) HAZ. The evaluation of the mechanical properties [6,7] for the base metal and the weld together with field weldability were carried out for X-80M TMCP steel plates. The steel has a bainite microstructure and has excellent To establish the toughness of heat affected zone (HAZ), number of test coupon has been made from V-Nb-Ti-B microalloyed steel with low Pcm plate of API-5L, X-120M. The steel plate used in this study has been produced through TMCP and accelerated cooled process to achieve the strength, toughness and weldability the level of X-120M with bainitic microstructure. The welding of the test coupons has been carried out by the combination of gas metal arc welding (GMAW) and double submerged arc welding (DSAW) processes. The root pass weld (Continuous tack weld) by GMAW and the final welding were completed with three wire tandem submerged arc welding (SAW) technique by one pass from first side opposite to the root run and second pass on the root weld side of the test coupons. The welding procedure has been made to maintain the minimum HAZ, optimum cross penetration, defect free elliptical weld pool shape, competitive epitaxial dendrite growth in the weld. The test coupon assembly is shown in figure # 02 (a) having (2800 mm X 300 mm X 14.3 mm) with double-Y joint geometry as shown in figure # 02 (b). The heat input of GMAW kept constant as shown in the table # 02. The different heat put levels of test coupons is shown in the figure # 03. After first pass of SAW welding, the test coupons were allowed to cool down room temperature to achieve the fast cooling rate. arrestability to unstable ductile fracture. With lowered 'Si' content the HAZ fusion line show excellent toughness. Fracture mechanics [8] test results reveals that the weld joints are affected the mechanical and metallurgical heterogeneity in welds. It was exhibited that the CGHAZ corresponds to potential local brittle zone in welds which controls the initiation brittle fracture. It was claimed that strength overmatching of weld metal was not always beneficial, because the HAZ toughness was decreased with increasing the degree of strength overmatching of weld metal. This is due to the constraint effect of the overmatching weld metal. The overmatching weld metal elevates the local stress in the HAZ which facilities fracture initiation in the HAZ. Recent investigation on structural significance of low toughness HAZ showed no implication on the integrity [9,10]. It is therefore recommended that the existing procedures for defining and testing HAZ toughness are reconsidered under consideration of the actual loads, the defect probability and incorporating the size of the local brittle zone (LBZ), also their significance on the structural integrity.

3 II. Materials and Experimental Methods

4 Results and Discussion

a) Evaluation of Heat Affected Zone (HAZ)

The test coupon welded with different heat input level as shown in the table # 03, the HAZ of each test coupon is shown in figure # 04 was evaluated for non destructive examination (Visual Examination, X-ray examination and manual ultrasonic examination) and destructive examination (charpy V-notch test. Fracture toughness 'CTOD), Vickers macro hardness (HV 10) testing and light microscopy.

5 b) Visual Examination

All the samples welded at different heat input have been visually inspected for any visual defects as per AWS specification AWS -B1.11 (Guide for visual examination of welds) and API-5L. All the welded samples has no defect such as undercut and under fill is observed except the test coupon # L-1, H-2 and H-3, having very high convexity weld bead, which is beyond the acceptance level of the line pipe standards/ specifications.

6 c) Manual Ultrasonic Examination

The test coupons welded at different heat input have been scanned by manual ultrasonic as per ASME Section-V and API-5L. The test coupon # L-1 was having indication along the entire length and test coupons # H-2 and H-3 were having two indications each. Rest of coupons was having no significant indications.

7 d) X-rays Examination

The test coupons welded at different heat input have been exposed to the X-rays as per ASME Section-V and API-5L. The test coupon # L-1 was having lack of penetration (LOP) along the entire length and test coupons # H-2 and H-3 were having slag inclusions. Rest of coupons was having no significant defect as per API-5L. Hence the test coupon L-1 was discarded from further investigation in the present study. The results of Vicker's macro hardness test showing the general trend of increase in hardness but confusing. The Vicker's hardness measurement is on macro scale and might not able to pin point hard and soft structures. In light microscopy the microstructure at HAZ shows good fusion between parent metal and weld without any micro-defects. Immediate after fusion line, coarse grain HAZ was seen, microstructure at coarse-grained HAZ shows mixture of lower transformation products with carbides. At fine-grained HAZ microstructure comprises of uniform grains of lower transformation products with carbides. The only difference is the size of phases (grains) and percentage of carbide, martensite and ferrite contents. As the level of heat input increases the grain grows proportionally and the percentage of the carbide and martensite is increasing. The test coupon # L-1-A Micrographs shows Bainitic type ferrite and lath type ferrite along with coarsened precipitates in the ferrite matrix of HAZ. As the heat input increases the Bainitic type ferrite and lath type ferrite starts decreasing i.e. more coarsened type structure. The above observation is also supported by data of mechanical testing namely CVN and CTOD.

The result of various tests shows the trend of different properties the heat input level corresponding to the test coupon number 'L-1-A' showing the best results for toughness as the target values of heat affected zone (HAZ). From the above study, it was found that the heat input level named "L-1-A" produce the minimum HAZ and highest toughness level and appropriate hardness.

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1 2 3 4 5 6

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²© 2012 Global Journals Inc. (US) 2012 July each Heat Input Transition temperature CVN values are shown in the figure # 06. CGHAZ is shown in the figure # 05. The results of the

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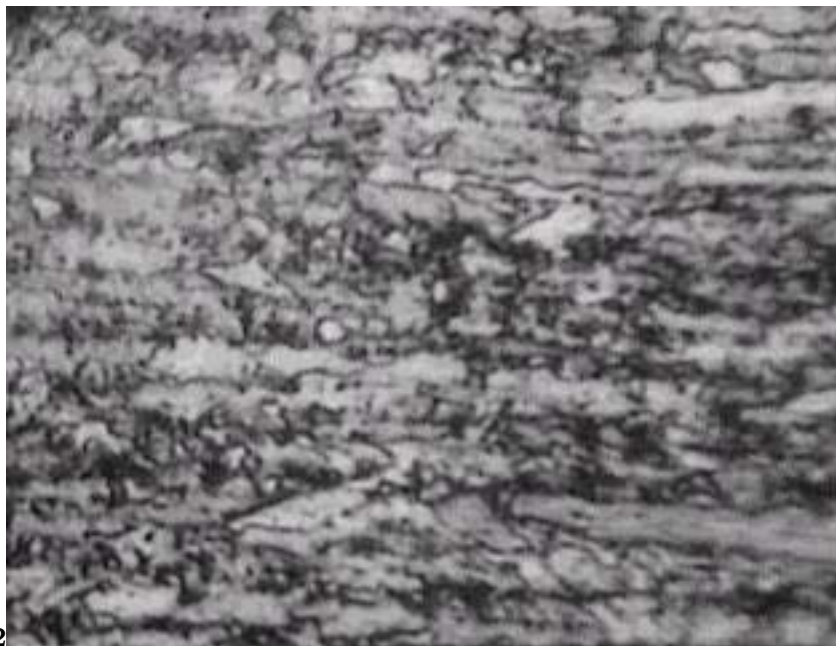
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Figure 1:



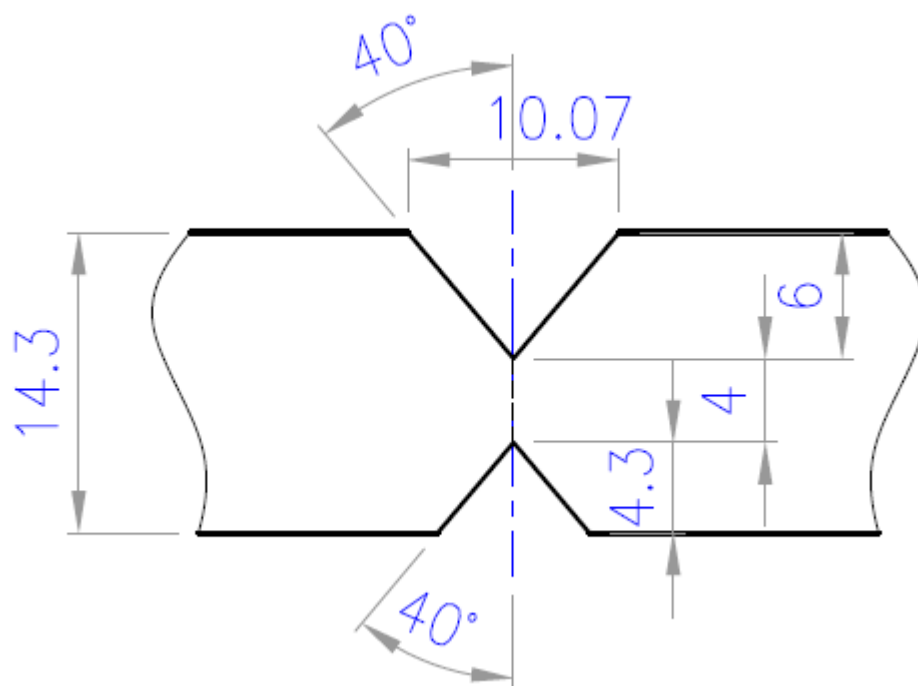
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Figure 2: Figure 2 (



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Figure 3: Figure 3 :



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Figure 4: Figure 5 :Figure 6 :

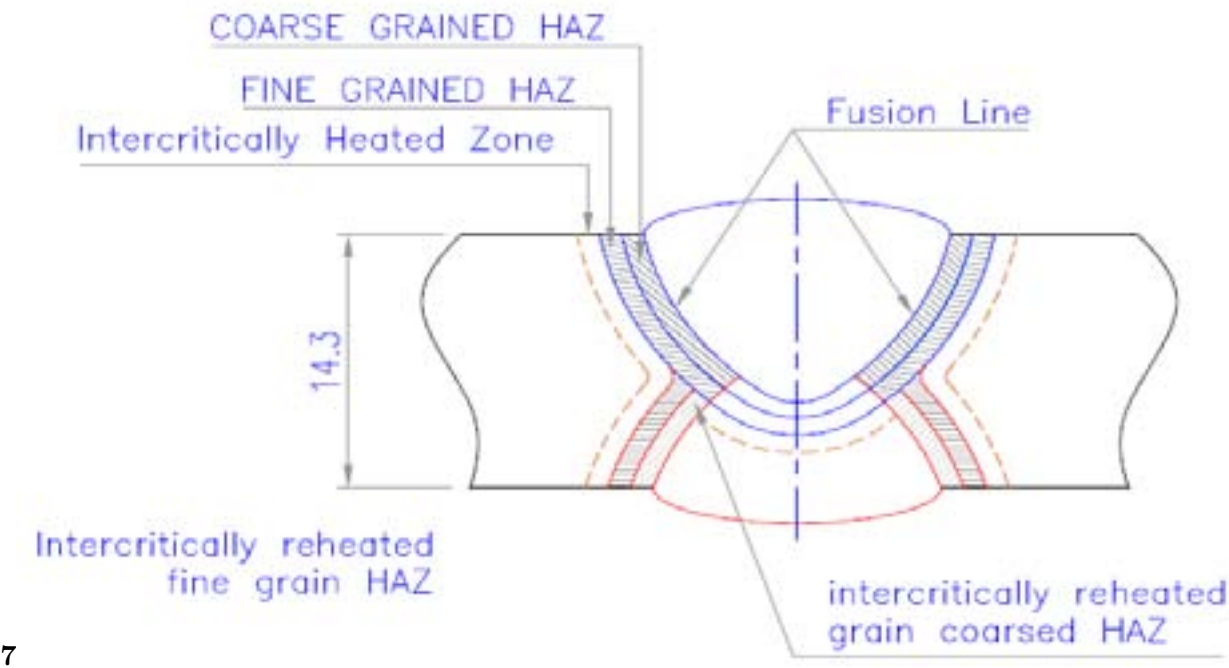


Figure 5: Figure 7 :

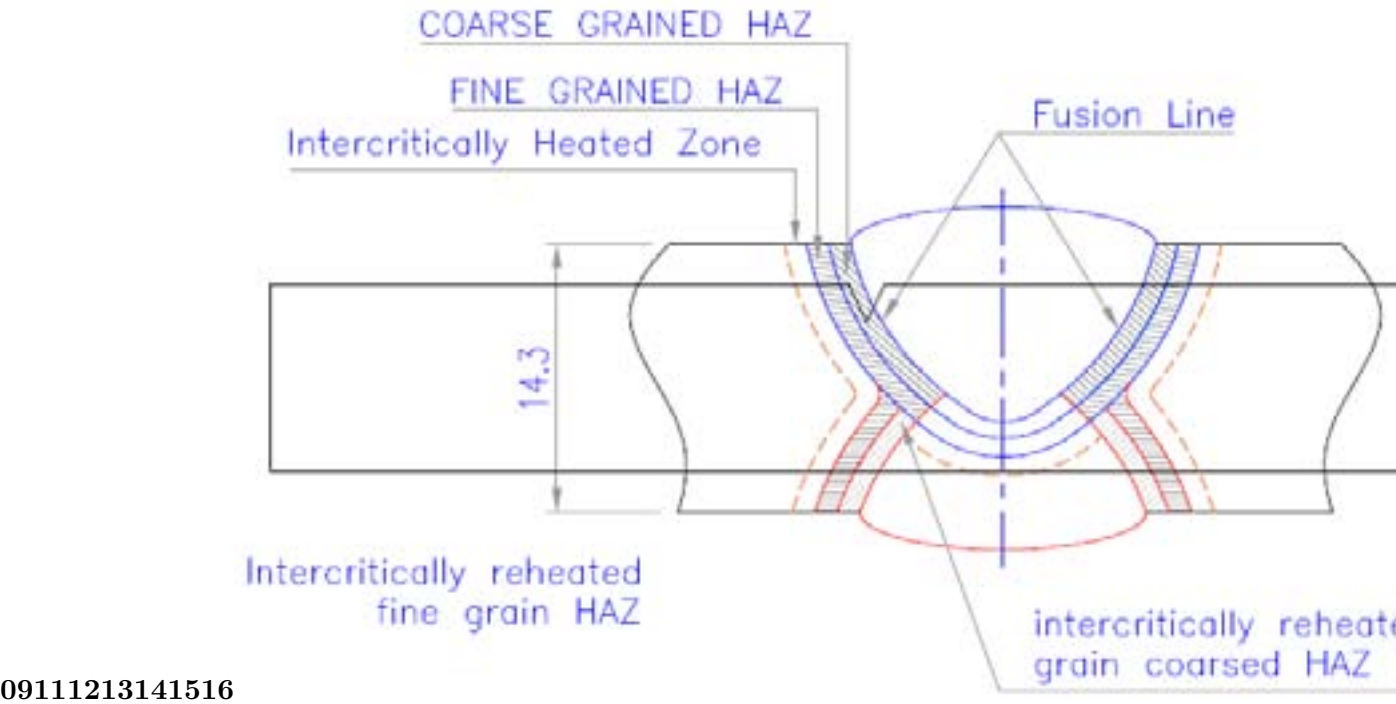


Figure 6: Figure 09 :Figure 11 :Figure 12 :Figure 13 :Figure 14 :Figure 15 :Figure 16 :

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Element	C		Si	Mn	P	S	Cr	Ni	Mo	Al	Cu
Wt. (%)	0.065	0.290		1.950	0.012	0.005	0.170	0.040	0.130	0.042	0.021
Element	Ti		V	Nb	Ca	N	B	Al/N	Nb+V+Ti	Pcm	CE
Wt. (%)	0.012	0.001		0.042	0.001	0.002	0.004	21	0.055	0.211	0.454

[Note: Figure 1 : Bainitic Microstructure of X-120M Steel Plate]

Figure 7: Table 1 :

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Current	Voltage	Speed	Heat Input	Shielding	Flow Rate	Wire Diame- ter
(A)	(V)	(m/min.)	(kJ/mm)	Gases	(lpm)	(mm)
190	21	0.6	0.48	CO 2	15	1.2

Figure 8: Table 2 :

.1 Acknowledgement

I am grateful to Prof. N L Singh (Department of Physics, M S University of Baroda -392 002, India) for his endless support and encouragement during this study. I acknowledge the support from Welspun Gujarat Stahl Rohren Ltd. India.

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