

Effect of tempered bead techniques on maximum HAZ hardness for in-service pipeline welding

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Abstract. This research intends to investigate the main factors of tempered bead techniques affecting on maximum HAZ hardness for in-service pipeline welding. Tempering parameters to be considered are the overlap ratio, weld bead sequences, and subsequent welding processes. This research consists of two parts of experimental procedure. Firstly, critical HAZ hardness (> 350 HV) in the first weld bead was estimated using computational simulation. Secondly, welding experiments were conducted with tempered techniques. Experimental setup included the used material of API 5L Gr. B pipe steel with nominal size of DN 200, wall thickness of 8.18 mm, and water piping flow of 18.77 m³/hr. As a results, it suggested that the overlap weld ratio of 50% and 75%, weld bead sequences, as well as subsequent SMAW processes, were proficient of reducing significantly maximum HAZ hardness at the weld root. Nevertheless, in the case that the weld root was built up, maximum HAZ hardness was slightly changed with different weld bead sequences.

1 Introduction

In the oil and gas industry, a number of pipelines are widely used to transport natural gas or related products. Generally, welding is substantially employed for construction or maintainance. In this case, in-service welding plays an important role because this approach do not need to stop natural gas transportation in a main run pipe. Therefore, it is more benefit of saving production rate and income. However, there is issue to be noticeably considered such as the occurrence of hydrogen induced cracking (HIC). This crack typically occurs in a heat affected zone (HAZ). In practice, avoiding hydrogen induced cracking is undertake through reducing HAZ hardness. When HAZ hardness is lower than the critical value of 350 HV [1, 2]. Preheat or post weld heat treatment are alternative method to decrease HAZ hardness. Nevertheless, these methods are more difficult for in-service pipeline welding due to limitation of installation when the pipeline system is underground. As a result, tempered bead welding is practised to alleviate HAZ hardness.

As relevant researches[1-4], many studies have reported involving welding techniques to improve mechanical properties of the In-service welds such as Aloraier reported the change of metallurgical after post-weld heat treatment in repair welding using the temper bead technique. Mark Keeler had developed procedure to reduce the risk of burn through, blowout and HAZ Cracking. Likewise, Nicholas had studied and set Procedure qualification record (PQR) which used in In-service welding. However, there is no such woks focused

on welding procedure such as covering area of next weld bead ,weld bead pattern and different welding processes for next bead.

Consequently, this research intends to investigate the main factors of tempered bead techniques affecting maximum on HAZ hardness for in-service pipeline welding.

2 Experimental Works

In this work, In-service welding with tempered bead techniques was carried out. There were three (3) essential factors on maximum HAZ hardness to be investigated, namely overlap ratio, weld bead sequences, and subsequent welding processes.

2.1 Used Materials

Fillet welding was performed on a main pipe and a sleeve plate according to API5L Grade B seamless pipe material standard. Nominal pipe size of specimen was DN 200 Sch. 40 (219.8 mm outside diameter, 8.18 mm thickness). The sleeve plate of 8.18 mm thickness was employed. Chemical compositions of specimen was examined through optical emission spectrometer (OES) as shown in Table 1.

Table 1. Chemical composition of used material (wt%)

C	Mn	Cu	Ni	Cr	Mo	V
0.134	0.969	0.181	0.099	0.223	0.049	0.003

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Two (2) different welding processes were conducted, namely gas tungsten arc welding (GTAW) and shield metal arc welding (SMAW). As for GTAW, specimens were welded with a filler metal of ER70S-G according to AWS A 5.18, EWTH-2 tungsten electrode size of 2.4 mm in diameter, DCEN electrical polarity, argon shielding gas of 99.9%, as well as gas flow rate of 15 l/min. Meanwhile, SMAW was utilized with E7018 according to AWS A 5.5, electrode size of 3.2 mm in diameter, DCEP electrical polarity.

2.2 Methods

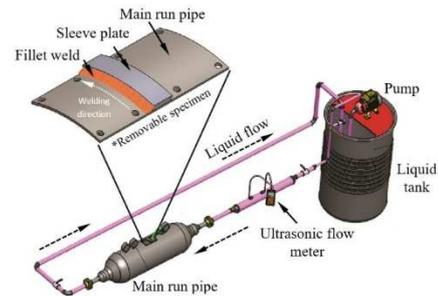
This work was divided into two steps. Firstly, heat input for a first weld bead with GTAW was estimated through computational simulation. Commercial PRCI program (Thermal Analysis Model for Hot Tap Welding V4.2) was utilized. Such heat input was used in order to achieve critical HAZ hardness value (over 350 HV). This could possibly lead to hydrogen induced cracking.

Secondly, actual welding experiments were carried out. Tempered bead techniques were employed to reduce the maximum HAZ hardness value of the first weld bead. Three (3) factors of tempered bead welding were investigated as follows; ratio of overlap weld, weld bead sequences, and subsequent welding processes. Utilized welding parameters were as given in Table 2.

The experimental set up as shown in Figure.1 was accomplished in accordance with API 1104 Annex B. This means that a sleeve plate is attached to a main run pipe to form a circumferential fillet weld lap joint, as well as 5G uphill position as illustrated in Figure.1(a). Meanwhile, water flows in the main run pipe during welding. The water flow rate of 18.8 m³/hr. (Methane flow rate of 41.5 MMSCFD) was set up in order to obtain the convective heat transfer same as in-service natural gas pipelines[5].

2.2.1 Ratio of Overlap Weld

After experimental setup as mentioned earlier, GTAW process was performed. The influence of overlap weld ratios as illustrated in Figure.2 on HAZ hardness was investigated. That is to say, 1st weld bead was overlay welded by 2nd weld bead in the different percentages of overlap weld, namely 25%, 50%, and 75%. Welding parameters was employed as given in Table 2. Then, maximum HAZ hardness at the root weld pass was examined.



(a) Schematic of in-service pipeline welding



(b) Experimental setup of in-service pipeline welding

Fig.1 Experimental Set Up

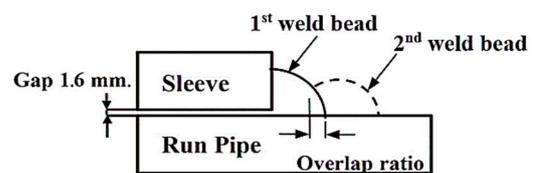


Fig.2. Overlap Weld Ratio

Table2. Utilized welding parameters for experiments

Variables \ Conditions	Overlap Weld		Weld Bead Sequences			Subsequent Welding Process			
	1 st bead	2 nd bead	1 st bead	2 nd bead	3 rd bead	1 st bead	2 nd bead	3 rd bead	
Process	GTAW		GTAW			GTAW	GTAW	SMAW	SMAW
Voltage (Volts)	150	200	150	200	150	200	150		
Current (Amps)	10.4	12.4	10.4	12.4	10.4	12.4	26.6		
Travel Speed	7.75	7.53	7.75	7.53	7.75	7.53	12.19		
Heat Input (kJ/mm)	1.2	2.0	1.2	2.0	1.2	2.0			

Note. Heat Input(kJ/mm) = (Current x Voltage x 60) / (Travel Speed x 1000)

2.2.2 Weld Bead Sequences

HAZ hardness at the root weld pass was influenced through the thermal energy during welding. Therefore, two (2) different formations of the weld sequences were conducted in order to obviously determine maximum HAZ hardness. The weld sequence of type A and type B were illustrated as Figure 3. GTAW process was employed in entire procedure. In addition, severe HAZ hardness was considered that located on whether the sleeve plate or the run pipe.

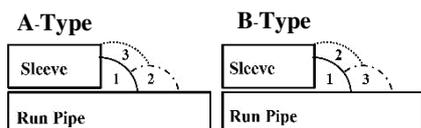


Figure 3. Types of Weld Bead Sequence

2.2.3 Subsequent Welding Processes

In this case, the effect of different welding procedures on HAZ hardness was studied. Two (2) patterns of subsequently different welding processes were carried out, namely 1st weld bead was built-up with GTAW and then followed with SMAW as exhibited in Figure 4.

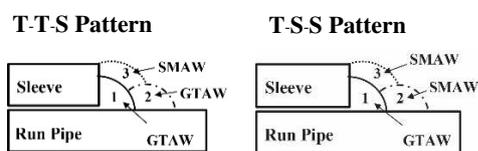


Figure 4. Different welding procedures

2.2.3 Hardness Measurement

After completed welding, each welded specimen was cut into 3 test pieces. Later on, those test pieces were grinded, polished and etched with Nital Acid 2%. Optical microscopic (Leica DM-2500M) was used so as to examine a sound weld. Besides, Maximum hardness in the HAZ area of coarse-grained region at the root weld pass was measured with micro-vickers hardness tester (Matsuzawa MMT-X3). Measuring procedure was operated in accordance with ASTM E384-11 as shown in Fig 5. Five indentations were pressed on individual area of HAZ. Measuring interval point was given as 0.2 mm from a fusion line, an indent spacing of 0.5 mm with applied load of 500 gram, as well as hold time of 10 seconds.

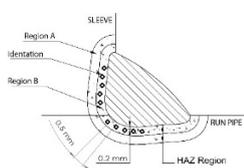


Figure 5. HAZ Hardness Measuring Procedure

3 Results and Discussion

3.1 Heat input to induce critical HAZ hardness

First step, welding parameter like a heat input for 1st weld bead was approximately calculated by commercial PRCI program. As the results, it exhibited that the critical heat input of 1.18 kJ/mm (30 kJ/in) was suggested in order to obtain critical HAZ hardness of 388.1 HV. However, maximum HAZ hardness of 323.1 HV at the run pipe was attained in the actual welding. This welding condition was utilized for 1st weld bead in entire experiments.

3.2 Effect of Overlap Weld Ratio

The effect of tempering welds was considered through overlap ratio. Fig. 6 represents the cross section appearance of different overlap weld ratios. It exhibited entire sound welds. Furthermore, Fig. 7 presents the comparison of maximum HAZ hardness in each overlap ratio between 25%, 50%, 75%. It revealed that HAZ hardness at the root weld pass decreased when using overlap ratio of 50% and 75%. However, it was found that the hardness was not significantly different.

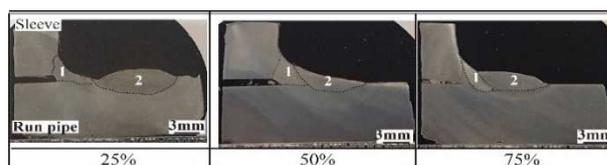


Figure 6. The weld cross sections due to the different overlap ratios

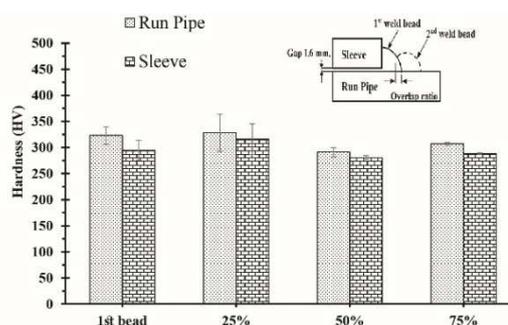


Figure 7. Max. HAZ hardness in each overlap ratio

Moreover, HAZ hardness between Run pipe and sleeve was not different.

3.3 Effect of Weld Bead Sequences

In order to investigate the different formations of the weld sequences affecting HAZ hardness, Fig. 8 represents the weld cross sections of type A and type B weld sequence. As the results, it exhibited that maximum HAZ hardness reduced consistently with increasing the number of weld

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beads, namely reducing from 323 HV to 260 HV (run pipe A-Type) and reduce to 265 HV (run pipe B-Type). And also the maximum HAZ hardness occurred at the run pipe in all cases. However, comparing between the weld bead sequence of type A and type B indicate that these tempered techniques were not obviously different as shown in Fig.9.

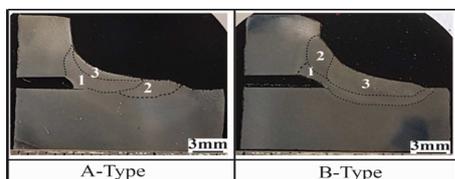


Figure 8. Cross-Sectional Welds Due to Bead Sequences

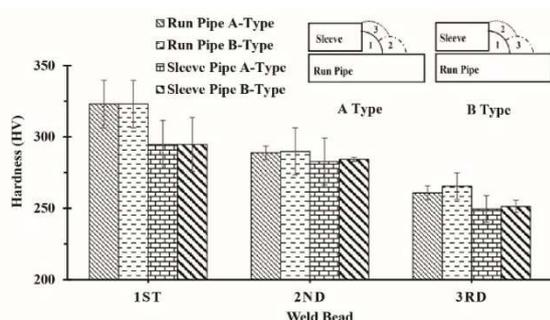


Figure 9. Max. HAZ Hardness in Different Weld Sequences

3.4 Effect of Subsequent Welding Processes

In this case, critical HAZ hardness at 1st weld bead was thermally tempered by different welding processes. Fig. 10 represents cross-sectional welds due to T-T-S pattern and T-S-S pattern procedure.

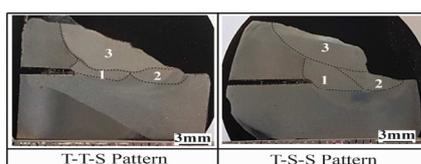


Figure 10. Cross-sectional welds due to different welding processes

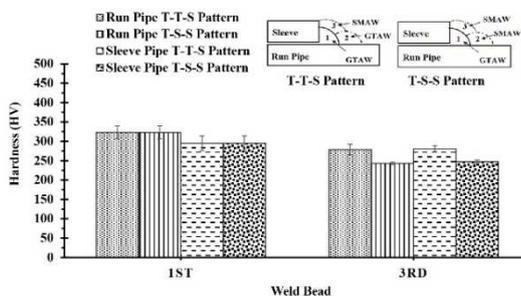


Figure 11. Max. HAZ Hardness in Different welding procedures

It was found that subsequent SMAW process was able to produce larger fusion zone. Especially, critical HAZ hardness of 1st weld bead dropped remarkably with T-S-S

pattern. Maximum HAZ hardness reduced from 323 HV to 279 HV (run pipe T-T-S Pattern) and reduced to 243 HV (run pipe T-S-S Pattern)

4 Conclusion

This research describes the effect of tempered bead techniques on maximum HAZ hardness for in-service pipeline welding. The outstanding investigations can be summarized as follows.

- 1) As the experimental results, it was found that the overlap weld ratios of 50 %and 75% was able to significantly reduce critical HAZ hardness.
- 2) In the case that critical HAZ hardness reduced with increasing the number of weld beads, the different types of the weld bead sequences was insignificantly influenced.
- 3) As for subsequent welding process, it was suggested that SMAW process should be subsequently employed to built-up on 1st weld bead. This procedure was able to obviously reduce the maximum HAZ hardness at the root weld pass.
- 4) When comparing maximum HAZ hardness between the run pipe and the sleeve plate, maximum HAZ hardness always occurred at the root weld pass on the run pipe.

Acknowledgments

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5 References

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