

# Effect on property of HIC-Resistance of vessel steel of PWHT

Xinyu Zhao<sup>1,2</sup>, Yang Zou<sup>1,2</sup>, Liye Qin<sup>1,2</sup>, Yanchun Lv<sup>1,2</sup>

<sup>1</sup> Plate Technology Department, Shougang Research Institute of Technology, Beijing 100043

<sup>2</sup> Beijing Engineering Research Center of Energy Steel, Beijing 100043

xyz1076@sina.com

**Abstract.** Post-Welding Heat Treatment (PWHT) is usually taken after welding and joining of vessel steel, which effects the mechanical and Hydrogen Induced Cracking (HIC) resistance property of vessel plates. Simulating PWHT experiment was taken to research on the effect on mechanical property and HIC-resistance of PWHT of vessel plates. Some conclusions can be summarized as following. Comparing with the normalizing samples, the tensile strength of the samples after PWHT with holding time of 2h, 6h and 20h decreases by 27MPa, 44MPa and 47MPa. Ductile Brittle Transition Temperature (DBTT) of the normalizing samples was almost close to those of the samples after PWHT. But the impact energy of samples at 0°C increased with rise of PWHT holding time. And the hardness of samples decreases with rise of PWHT holding time. As shown in morphology structure, the precipitation of carbonide increases with the rise of holding time of PWHT, which decreases the strength and hardness of samples and raises the impact energy. But PWHT has a little effect on HIC-Resistance, which means PWHT don't deteriorate property of HIC-Resistance of vessel plates severely.

## 1. Introduction

PWHT is a heat treatment method in order to improve the mechanical property and structure and relief the residual stress of welding joint, which is kind of stress relief annealing. A part or component is heated to a special temperature with a special heating rate and maintained to be a fixed time and then cooled in furnace with very low cooling rate.

An amount of reports had been published about the research on effect on mechanical property of PWHT through simulating method in Lab <sup>[1]-[6]</sup>. Also the effect of the PWHT on the HIC-Resistance property had not been investigated sufficiently. The simulating PWHT in laboratory was taken to research on the effect of PWHT on HIC-Resistance of vessel plates in this paper.

## 2. Experimental procedure

The samples with a chemical composition, given in table 1, were prepared. And the samples conform to the requirements provided by criterion that Yield Stress (YS)  $\geq 220\text{MPa}$ , Tensile Stress (TS)  $\geq 415\text{MPa}$ .

**Table1** Chemical composition

C	Si $\leq$	Mn $\leq$	P $\leq$	S $\leq$	Alt $\leq$	Nb+V+Ti $\leq$	Mo $\leq$	Cu $\leq$
0.12%-0.18%	0.45%	1.50%	0.01%	0.003%	0.05%	0.1%	0.1%	0.1%

The industrial manufacturing procedure of samples is BOF-LF-RH-CC slab-TMCP. Then 4 samples were cut to normalize in laboratory. After that 3 samples of these were heat treated by PWHT.

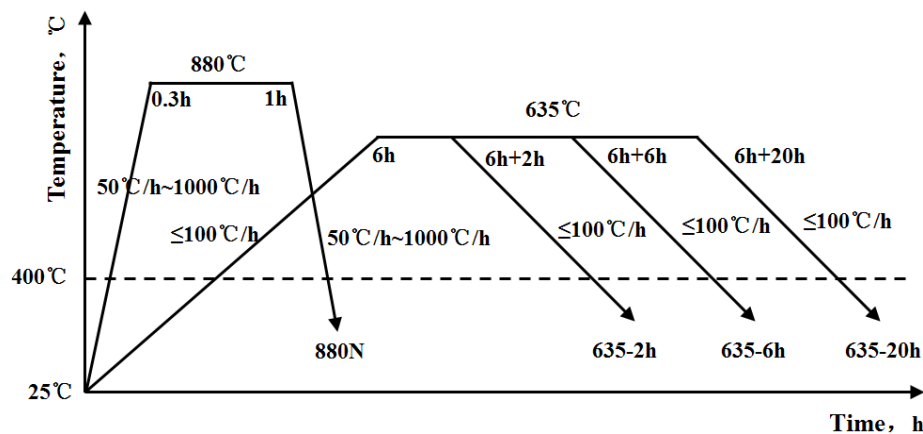


The samples, with a thickness of 37.7mm, were heat treated in table 1. The sample code, given in table, is the abbreviation of samples with different heat treatment and different holding time.

**Table 2** Experimental scheme

	Sample code	Sample thickness	Heat treatment	Temperature	Holding time
Sample 1	880N	37.7mm	Normalization	880°C	1h
Sample 2	635-2h	37.7mm	PWHT	635°C	2h
Sample 3	635-6h	37.7mm	PWHT	635°C	6h
Sample 4	635-20h	37.7mm	PWHT	635°C	20h

The thermal histories of normalization and PWHT are given in Fig. 1. The normalizing temperature is 880°C and the heating and cooling rate ranged from 50°C/h to 1000°C/h. Then the simulating PWHT process in labrotory is that a sample was thrown into heat furnace with temperature 25°C and heated to a uniform temperature, 635°C in this experiment. Also the sample was held with a special holding time at this temperature for a period of time and then cooled in the heat furnace. The heating rate is not larger than 100°C/h. Then the holding time are 2h, 6h and 20h respectively. After that the cooling rate is not larger than 100°C/h.



**Fig. 1** Thermal histories of heat treatment

The HIC test experiment is accordance with criterion of NACE 0284. And the solution A provided by the criterion is taken in the experiment. Finally three ratios of Crack Length Ratio (CLR), Crack Thickness Ratio (CTR) and Crack Sensitivity Ratio (CSR) were got<sup>[7]</sup>. A HIC-Resistance Index (HRI) was proposed to estimate the property of HIC-Resistance. And

$$\text{HRI} = \max((\text{CLR})/15, (\text{CTR})/5, (\text{CSR})/2)$$

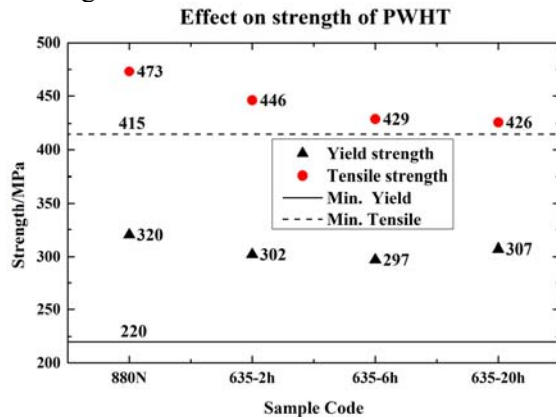
Then in case of  $\text{HRI} > 1$  the property of HIC-Resistance of plate is not standards-compliant. Otherwise, in case of  $\text{HRI} \leq 1$  the property is standards-compliant.

### 3. Results and discussion

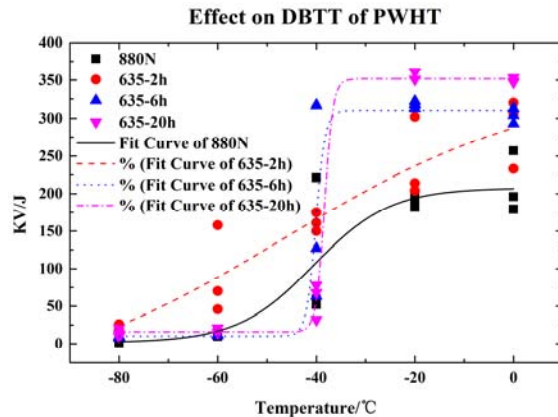
The effect on strength of PWHT is given in Fig.2. As shown in figure, the strength of the sample after simulating PWHT, comparing with normalizing sample, decreases with rise of holding time. The YS of normalizing sample is 320MPa. But the YS of the samples after simulating PWHT, comparing with normalizing sample, decreases by about 20MPa. The YS of the samples after simulating PWHT with different holding time ranges from 297MPa to 307MPa. At the same time TS of normalizing sample is 437MPa. But TS after simulating PWHT samples significantly decreases with rise of holding time. TS decreases by 27MPa 44MPa and 47MPa, corresponds with the holding time of 2h, 6h and 20h respectively.

The charpy impact tests were taken at the position of 1/4 thickness direction. And tests were conducted at 0°C, -20°C, -40°C, -60°C and -80°C. The effect on DBTT of PWHT is given in Fig.3.

As shown in figure, DBTTs of the normalizing and PWHT samples are all approximately  $40^{\circ}\text{C}$ , whatever the holding time is 2h, 6h or 20h. But Charpy impact energy of  $0^{\circ}\text{C}$  increases with a rise in the holding time.

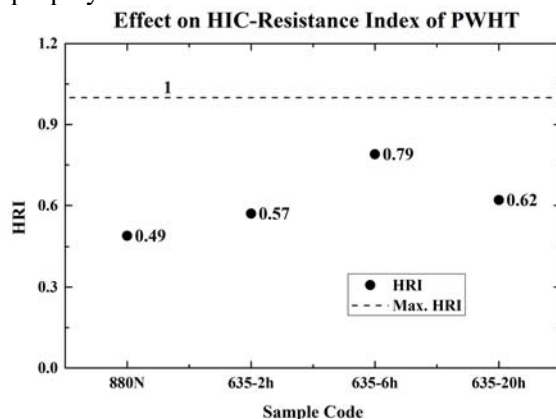


**Fig.2** Effect on strength of PWHT

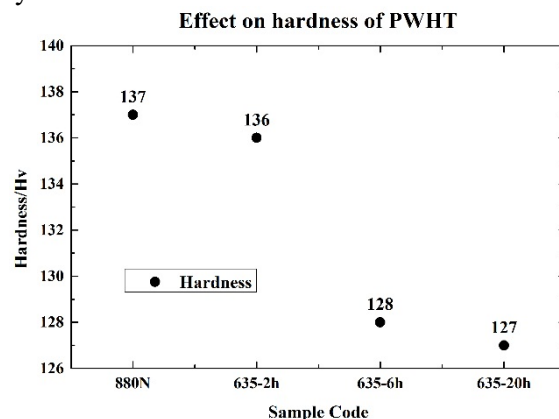


**Fig.3** Effect on DBTT of PWHT

The effect on HRI of PWHT is given in Fig. 4. As shown in figure, the HRI has a little increase with a rise in the holding time. But all HRIs are under the Max HRI, which means PWHT don't deteriorate the property of HIC-Resistance of vessel steel severely.

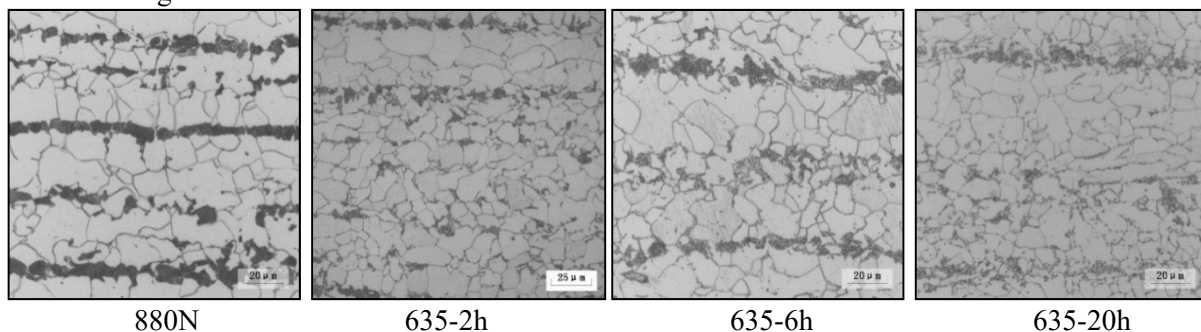


**Fig.4** Effect on HRI of PWHT



**Fig.5** Effect on hardness of PWHT

The effect of hardness of PWHT is shown in Fig. 5. As shown in figure, hardness of the samples after simulating PWHT, comparing with normalizing samples, decreases apparently, especially with a rise in holding time.



**Fig.6** OM images of the effect on morphology structure of PWHT

The OM images of the effect on morphology structure of PWHT are given in fig.6. As shown in figure, the microstructures of 4 samples were all composed of ferrite and pearlite. Moreover more dot-like carbonides could be found on pearlite of simulating PWHT samples comparing with normalizing samples. Then the content of pearlite of the samples after simulating PWHT decreases because of

precipitation of carbonides, which decreases the strength and hardness but increases the toughness of the samples after PWHT. However the carbonides don't deteriorate the HIC-Resistance of the samples significantly.

#### 4. Conclusions

PWHT is usually taken after welding and joining of vessel steel, which effects the mechanical and HIC resistance property of vessel plates. Simulating PWHT experimental process was taken to research on the effect of PWHT on mechanical property and HIC resistance of vessel plates. Some conclusions can be summarized as following.

1) The strength of the samples after PWHT, comparing with normalizing samples, decreases with a rise in holding time. And TS of samples after PWHT with holding time of 2h, 6h and 20h, comparing with TS of normalizing samples, decreases by 27MPa, 44MPa and 47MPa.

2) The DBTTs of normalization and PWHT samples are approximately 40°C, which means PWHT don't change the DBTT no matter how long holding time is. But the impact energy of 0°C increases with a rise in holding time of PWHT.

3) The hardness of PWHT samples decreases with a rise in holding time.

4) More dot-like carbonides could be found on pearlite of simulating PWHT samples comparing with normalizing samples. Then the content of pearlite of the samples after simulating PWHT decreases because of precipitation of carbonide, which decreases the strength and hardness but increases the toughness of the samples after PWHT. But PWHT has little effect on HRI, which means PWHT don't deteriorate property of HIC-Resistance of vessel plates severely.

#### References

- [1] WANG J, LU H, MURAKAWA H. Mechanical Behavior in Local Post Weld Heat Treatment (Report I): Visco-Elastic-Plastic FEM Analysis of Local PWHT (Mechanics, Strength & Structure Design)[J]. Transactions of JWRI, 1998, 27(1): 83-88.
- [2] Guozheng Zhang, Feng Zhao. Research on Post weld Heat Treatment for Steel Pressure Vessel [J]. Industrial heating, 2013,01:66-68.
- [3] Ravi S, Balasubramanian V, Nasser S N. Influences of post weld heat treatment on fatigue life prediction of strength mis-matched HSLA steel welds[J]. International journal of fatigue, 2005, 27(5): 547-553.
- [4] Mitchell D R G, Moss C J, Griffiths R R. Optimisation of post-weld heat treatment of a 1.25 Cr-0.5 Mo pressure vessel for high temperature hydrogen service[J]. International journal of pressure vessels and piping, 1999, 76(4): 259-266.
- [5] WANG Z, CHEN W. Local Post Weld Heat Treatment on Site for Pressure Vessel of Large-diameter and Thicker Wall [J][J]. Petro-Chemical Equipment, 2010, 1: 015.
- [6] Stout R D. Postweld heat treatment of pressure vessel steels[J]. Weld. Res. Coun. Bull., 1985 (302): 1-14.
- [7] NACE TM 0284. Standard Test Method—Evaluation of Pipeline and Pressure Vessel Steels for Resistance to Hydrogen Induced Cracking, 2003.