Effect of High Carbon Content in the Filler Metal on Room Temperature and High Temperature Mechanical Properties of Low Alloy Ferritic Cr-Mo-V Steel Weldments

By
Vivek Gupta and **V.K. Agarwal**
Quality Control
Central Foundry Forge Plant, BHEL
Haridwar

Synopsis :
To study the effect of high carbon content, a commercial heat of 1Cr1Mo1/4V steel welded with electrodes having specified and high carbon content were tested for room temperature mechanical properties and high temperature properties under two different postweld heat treatment conditions i.e. stress relieving and Quenching & Tempering.

The test results indicate that the hardnes and UTS values of weldments made with high carbon electrode are higher while imact values are lower as compared to that made with specified carbon electrode.The room temperature and high temperature properties obtained with high carbon electrode suggests that the effect of high Carbon in the electrode can be negated to a large extent by adopting to Quenching & Tempering as the post weld heat treatment.

1. INTRODUCTION :

Cr-Mo-V steels are widely used as economic low alloy materials for many of the parts of Steam Power Generating plants that operate at temperatures in the Creep range. From this group of materials, low alloy ferritic 1Cr1Mo1/4V steel in cast condition finds extensive application for components such as HP Inner , IP Inner, HP Outer, IP Outer, Interceptor Chest, LP Bypass, Emergency stop valve & control valve casings etc, because of its good castability, reasonable cost and high temperature strength. This steel is required to be welded often either insitu or during manufacture involving large amounts of weld deposits. To ensure good quality of the casting it is very much essential that the chemical composition and mechanical properties of the weldment should be compatible with that of the base metal. As the mechanical property is a function of Chemical composition and Heat treatment, the selection of electrode / filler metal is a very important criteria for achieving the desired compatibility with the base metal. As per the world wide practice the electrode being used for welding 1Cr1Mo1/4V steel bears the same composition as that of base metal except for Carbon, which is slightly lower in the electrode. For base metal carbon content specified is 0.15 - 0.20 and for electrode is 0.10 0.15.
This paper deals with the effect of higher carbon content (higher than the recommended) in filler metal on room temperature and High temperature properties of the weldment and Heat Affected Zone from a commercial pure 1Cr1Mo1/4V steel.

2. NEED FOR CARRYING OUT THE STUDY :

We have been procuring these electrodes with the following specified all weld metal chemical composition and mechanical properties A batch of electrodes was received with carbon content 0.178 %. With increased carbon it is expected that the hardness values in the weld will increase and the impact strength will go down. There is also a possibility of

2.1 Chemical composition of weld metal

C	S	P	Si	Mn	Cr	Mo	V
0.100	0.020	0.020	0.500	1.000	1.000	0.900	0.200
0.150	max	max	max	max	1.500	1.300	0.300

2.2 Mechanical Properties

YS/ 0.2 % PS N/mm², (min)	UTS N/mm² (min.)	%El l=5d (min)	%RA (min.)	Impact, J 2 mm 'V' notch at RT, min.
450	600	15	---	27

cracking in the weld. In order to know the extent to which the properties are affected this study was carried out. For the purpose we designated this particular batch of electrode having high Carbon content as **Electrode - H** and the batch with the specified carbon content as **Electrode O.**

3. MATERIALS :

The material used in this experiment was taken from a keel block of commercial purity 1Cr1Mo1/4V steel integrally cast in a MS Housing casting.

3.1 HEAT TREATMENT :

The three stages of heat treatment given to the casting originally is as follows :

(a) Homogenisation at 950°C for 6 hrs.

(b) Austenitising at 940°C for 4 hrs, quenching in water to a temperature of 250°C and then cooling in air.

(c) Tempering at 720°C for 6 hrs, and cooling in air.

4. EXPERIMENTS AND RESULTS:

4.1 Chemical Analysis :

The chemical analysis of the casting and electrodes are given in Table 1.

4.2 Welding :

The test assemblies / sets (4 Nos.) after edge preparation were welded separately. Two sets were welded with Electrode - O and two sets with Electrode - H by Shielded Metal Arc Welding (SMAW) process as per shop floor practice. The preheat and interpass temperature was 300-400°C.

Post Weld Heat Treatment :

After the welding was completed, the test assemblies were cooled slowly to room temperature under the cover of asbestos cloth. One set each welded with the two electrodes were subjected to stress relieving treatment by heating at a rate of 50°C to 690°C, holding at this temperature for 4 hrs and then cooling in the furnace. The other two sets were subjected to Quenching treatment by soaking at 950°C for 6 hrs and cooling in water to room temperature followed by tempering at 720°C for 8 hrs and cooling to room temperature.

4.4 Post Weld NDT :

All the welded sets were subjected to ultrasonic and radiographic tests and were found to be free from defects.

4.5 Mechanical Testing :

The room temperature mechanical properties of the welded assemblies have been determined and the results are given in Table 2. High temperature properties of the weld joint are given in Table 3.

5. Discussion

i) No cracking was observed either in the weldment or in HAZ in the plates welded with the high carbon electrode (Electrode H) as apprehended. However it may be noted that these plates were welded in free condition i.e. without any restraint, but the actual jobs are being invariably welded under some amount of restraint.

ii) Hardness values observed in the weld and HAZ as per Table 2.3 are well within the specified range (305 BHN max) for the plates welded with Electrode H. However in stress relieved condition the hardness in the weld is significantly high as compared to the base metal hardness (184 BHN). This high variation in the hardness may act as a metallurgical notch.

In quench and tempered condition hardness values in the weld and HAZ are quite compatible with the base metal.

The hardness values in the weld, as anticipated, are higher in Electrode H in both conditions of post weld heat treatment as compared to Electrode O.

iii) Though the UTS values (as per Table 2.2) , as envisaged, are higher in Electrode H in both conditions of post weld heat treatment as compared to Electrode O, still the values are well within the specified limits (590 780 N/mm²).

Similarly the impact strength , as envisaged, is lower than in Electrode H in both conditions of post weld heat treatment as compared to Electrode O, still the values are meeting the requirement (27.0 J min.). However it may be noted that the values obtained for Electrode H in stress relieved condition are very marginal.

iv) The stress rupture samples of weld joint made with Electrode-H for both the post weld heat treatment conditions have achieved the expected rupture life (1000 hrs) at 550°C and 170 N/mm² stress and still not yet broken even after completing 2160 hrs.

6. Conclusion

Considering the room temperature and high temperature properties obtained with high carbon electrode **Electrode H ,** it can be said that the effect of high Carbon in the electrode can be negated to a large extent by adopting to Quenching & Tempering as the post weld heat treatment.

7. Scope for future work

i) It is recommended that the effect of restraint on the cracking tendency of weldment made with the high carbon electrode should be studied further.

ii) The high temperature properties of all weld samples made with Electrode H may also be determined.

Table 1 : Chemical composition of test plate and electrodes

Material	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	V
Test plate	0.165	0.410	0.720	0.016	0.012	0.060	0.250	1.320	0.930	0.230
Electrode - O	0.130	0.370	0.960	0.012	0.005	0.020	---	1.300	1.020	0.210
Electrode - H	0.178	0.500	1.000	0.014	0.008	---	---	1.450	0.990	0.210

Table 2. : Room temperature Mechanical Properties

2.1 Base metal properties

YS, N/mm²	UTS, N/mm²	%El	%RA	Impact, J 2 mm 'V' notch	Hardness (BHN)
440	608	23.4	67	40,38,32	184

2.2 Weld Joint Properties

Material / HT	UTS, N/mm²	Location of Fracture	All weld Impact 2 mm 'V' notch, J	HAZ Impact 2 mm 'V' notch, J
Electrode - O SR	655 , 673	BIW	40,55,68	46,64,72
Electrode - H SR	668,669	BOW	24,32,32	120,120,94
Electrode - O Q & T	596 , 598	BIW	202,204,216	204,204,216
Electrode - H Q & T	660,668	BIW	182,184,202	164,180,194

BIW – Broken Inside Weld
BOW – Broken Outside Weld

2.3 Hardness of the Weld Joints (BHN)

Material / HT	Weld	HAZ
Electrode - O SR	234,237	270,275
Electrode - H SR	290,295	280,272
Electrode - O Q & T	190,196	202,205
Electrode - H Q & T	220,218	229,234

Table 3. : High Temperature Properties

Stress Rupture Properties at 550 °C and 170 N/mm² stress

Material / HT	Rupture Life of Weld Joint (hrs)
Electrode - O SR	1000 *
Electrode - H SR	2160 *
Electrode - O Q & T	1000 *
Electrode - H Q & T	2160 *

Expected Stress rupture life of base metal at 550°C and 170 n/mm² stress is 1000 hrs