Influence of wire feeding speed, welding speed and preheating temperature on hardness and microstructure of weld of RQT 701-British steel produced by FCAW

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Abstract

FCAW (flux-cored arc welding) is an arc welding process widely used in different industries to join the metals and alloys. The present study focuses on the effect of FCAW-G process parameters on the hardness and microstructure of weld in RQT 701-British steel having 5 mm thickness. In this study, effects of wire feeding speed, welding speed and preheating temperature were investigated. Different samples were produced by employing wire feeding speed of 4.5, 6 and 7.5 m/min, welding speed of 30, 45 and 60 cm/min and preheating temperature of 200, 300 and 400°C. After welding process, brinell hardness (HB) test was performed on weld metal and the micro-structural evolution of weld was analyzed by optical observations of the weld cross sections. Results were clearly illustrated that change in process variables has significant effect on hardness, grain size and phases transformations in weld metal.

Keywords: FCAW, RQT 701-British steel, welding parameters, hardness, microstructure, heat input

1. Introduction

The gas-shielded flux cored arc welding (FCAW-G) process has been in use for approximately 40 years (Welding handbook, 1991). This process uses a consumable electrode, like the gas metal arc welding (GMAW) process, except the electrode is tubular and filled with flux, in addition to metal powders, instead of being solid (Widgery, 1994). Recent studies indicate (Ibrahim & Shehata, 1999; Ibrahim & Shehata, 2000; Sadek et al., 2001) that FCAW has a number of advantages over the common welding techniques available that use solid wires such as manual metal arc welding (MMAW) and gas metal arc welding (GMAW). Ghazvinloo et al. (2010) studied on effect of arc voltage, welding current and welding speed on fatigue life, impact energy and bead penetration of AA6061 joints produced by robotic MIG welding. The effect of FCAW-G parameters on weld width and tensile properties of weld metal in low carbon steel was also investigated (Ghazvinloo & Honarbakhsh-Raouf, 2010). Effect of FCAW process parameters on duplex stainless steel clad quality was researched by Kannan & Murugan (2006). Mostafa & Khajavi (2006) optimized welding parameters for weld penetration in FCAW process. During the past 20 years significant progress has been made in understanding the solidification behavior of welds and the evolution of microstructure (Badheshia et al., 1985; Van der Eijk et al., 1998). However, nearly there exists no information regarding to the welding researches on microstructure evolution and hardness changes of RQT 701-British steel joint in the available literatures especially for RQT 701 welded joint produced by FCAW method. The present work is aimed to the evaluation of the wire feeding speed, welding speed and preheating temperature effect on hardness and microstructure behavior of welded joints produced of a high strength quenched and tempered steel.

2. Materials and methods

The base material used in this investigation was RQT 701-British steel, 5mm in thickness with composition in weight percentage and mechanical properties as given in Table 1 and 2. FCA welding operations were performed by means of a WOD-E 1595 Model DK Series ARK ROBO 1350 welding robot. One hundred percent CO_2 was used as shielding gas to protect weld pool in this study. In addition, flux cored wire of 1.6 mm diameter (AWS classification E70T5) as filling metal was employed on FCAW machine.

Table 1. *Chemical composition of base metal*

Element	C	Si	Mn	P	S	Cr
Wt. (%)	0.165	0.36	1.22	0.018	0.011	0.19
	Mo	Ni	Cu	Ti	Al	
	0.14	0.24	0.15	0.03	0.015	

Table 2. *Mechanical properties of base metal*

Min yield strength (MPa)	Tensile strength (MPa)	Min elongation (%)	Min average impact energy (J)	Min Individual Impact energy (J)
693	795	18	27 @ -45°C	20 @ -45°C

The fixed parameters during welding were tabulated in Table 3. The chosen welding parameters for this study were wire feeding speed, welding speed and preheating temperature. These parameters and limits employed were given in Table 4.

Table 3. *Fixed parameters during welding*

Parameter	Limit/Type
Cylinder pressure (bar)	135
Cylinder outlet pressure (L/min)	15
Nozzle opening (mm)	12
Electrode stick out (mm)	15
Arc length (mm)	4
Nozzle-to-work distance (mm)	18
Arc voltage (V)	23
Welding current (A)	140
Droplet transfer	Spray transfer mode
Number of weld pass	4 passes

Table 4. *Welding parameters and limits*

Parameter	Symbol	Unit	Limits
Wire feeding speed	W.F.S	m/min	4.5, 6 & 7.5
Welding speed	S	cm/min	30, 45 & 60
Preheating temp.	T_p	°C	200, 300 & 400

After welding process, brinel hardness indentations were made using a 15.63 kgf on the weldments cross section in accordance with ASTM E10 guidelines. For characterizing of weld microstructure, weld surface was removed from each combination and grounded through 200–1000 mesh using grinding papers and then polished. The samples were etched in 2% Nital solution in methanol for 4 s. In the present work, optical examination of samples was performed using an AU DIC microscope. All experiments were carried out at Semnan University in Iran during 2009.

3. Results and discussion

Experiments with different wire feeding speed, welding speed and preheating temperature combinations were performed and the hardness value was measured for all cases. The results were shown in Figs. 1-3. In continue, for analyzing the effect of process parameters on microstructural evolution of weld, the flux cored arc welded specimens were exposed to metallographic investigations. The metallographic results were illustrated in Figs. 4-7.

Figs. 1-3 showed clearly that increasing in wire feeding speed from 4.5 to 7.5 m/min and welding preheating temperature from 200 to 400 ^{0}C decreases the hardness of weld metal but the weld hardness gradually increases with increasing the welding speed from 30 to 60 cm/min. The change in weldments hardness to welding parameters can be related to the microstructure behavior, including phases transformations and grain size of weld metal. These microstructural changes have been shown in Figs. 4-9. The change in arc welding parameters results in the variation in welding heat input. Since, the amount of heat input influences on cooling rate of the weld therefore varying the heat input typically will affect the microstructure properties of weld. With increasing wire feeding speed, welding current also increases in GMAW and FCAW process which it results in increasing welding heat input while with increasing welding speed, welding heat input decreases. When heat input increases, the cooling rate decreases for deposited weld metal and in multipass welds increases the volume fraction of tempered martensite phase and increases grains coarsening of the microstructure of weld zone. Increasing welding preheating temperature has a similar effect to wire feeding speed on cooling rate. Preheating before welding process decreases cooling rate of weld so decreases the weld hardness.

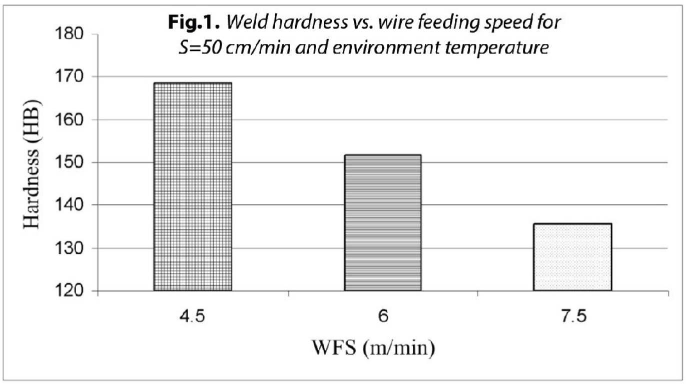


Fig.1. *Weld hardness vs. wire feeding speed for S=50 cm/min and environment temperature*

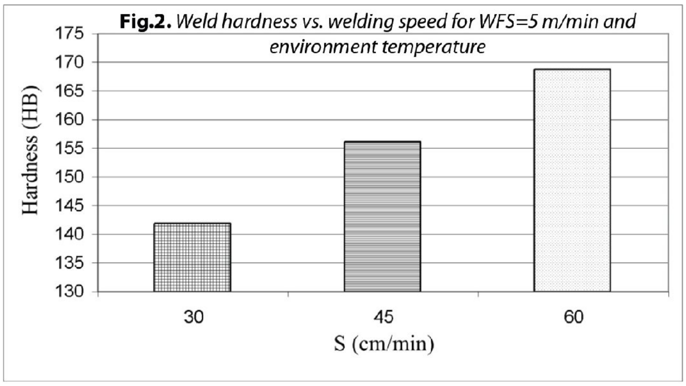


Fig.2. *Weld hardness vs. welding speed for WFS=5 m/min and environment temperature*

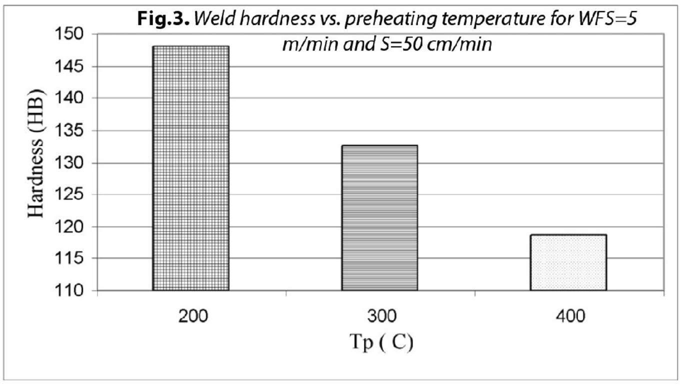


Fig.3. *Weld hardness vs. preheating temperature for WFS=5 m/min and S=50 cm/min*

Fig.4. *Grain size of weld metal for S=50 cm/min, environment temperature and wire feeding speed (a) 4.5, and (b) 7.5 m/min, 1000×*

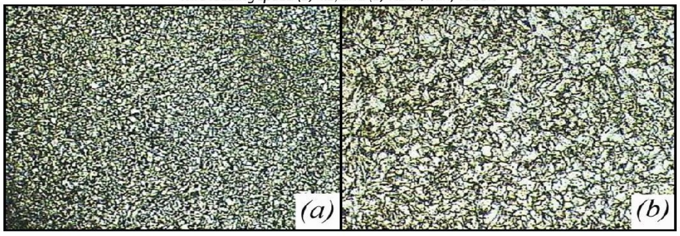


Fig.5. *Grain size of weld metal for WFS=5 m/min, environment temperature and welding speed (a) 60, and (b) 30 cm/min, 1000×*

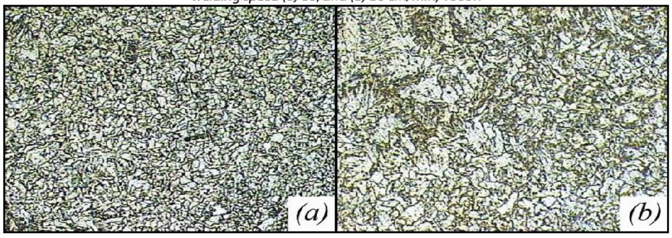


Fig.6. *Grain size of weld metal for WFS=5 m/min, S=50 cm/min and preheating temperature (a) 400 and (b) 200 C, 1000×*

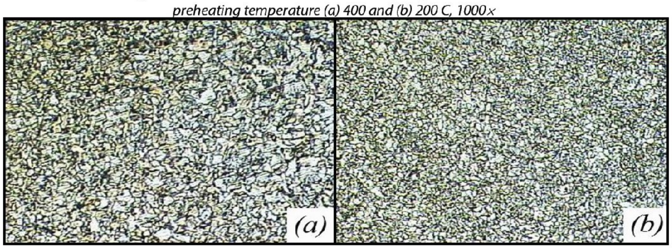


Fig.7. *Phases arrangements of weld metal for S=50 cm/min, environment temperature and wire feeding speed (a) 4.5 and (b) 7.5 m/min, 1000×*

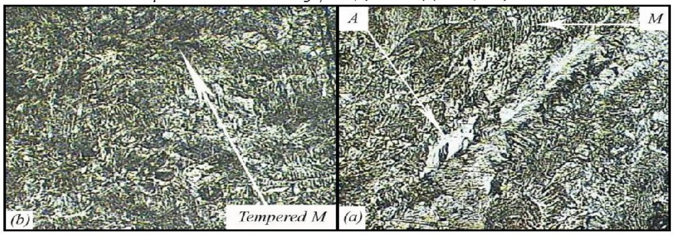


Fig.8. *Phases arrangements of weld metal for WFS=5 m/min, environment temperature and welding speed (a) 60, and (b) 30 cm/min, 1000×*

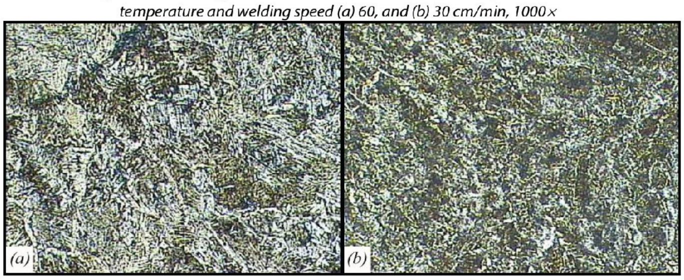
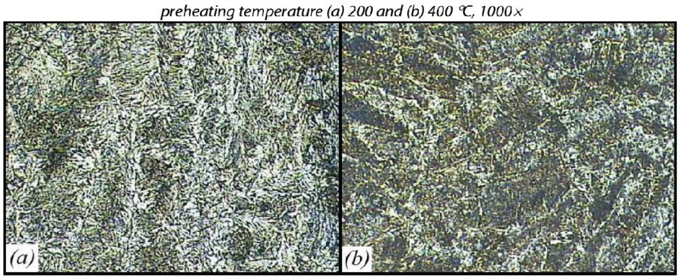


Fig.9. *Phases arrangements of weld metal for WFS=5 m/min, S=50 cm/min and preheating temperature (a) 200 and (b) 400 ℃, 1000×*



4. Conclusions

According to the results obtained from robotic FCA welding applied to RQT 701-British steel:

(1). Heat input is increased with increasing wire feeding speed but increasing in welding speed decreases the welding heat input. When heat input increases, the cooling rate decreases for deposited weld metal and in multipass welds increases the volume fraction of tempered martensite and increases grains coarsening of the microstructure of weld zone.

(2). With increasing the wire feeding speed or preheating temperature, brinell hardness of weldment decreases but effect of welding speed on hardness is reversed to other parameters. When welding speed increases the weld hardness also increases.

5. Acknowledgement

The authors would like to thank of Oghab Afshan Industrial & Manufacturing Company for the financial support and Semnan University for all the facilities. Mrs. N. Shadfar from R&D Dep. of Oghab Afshan Co. is also thanked for her cooperation during this research.

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