MECHANICAL STRENGTH OF THE WELD METAL IN CK45 CARBON STEEL

H. R. GHAZVINLOO, A. HONARBAKHSH-RAOUF

Department of Materials Engineering, Semnan University, Iran

Gas Metal Arc Welding (GMAW) has received much attention over the recent years and has many beneficial applications in industry. Arc voltage, welding current and welding speed are three independent variables for this process that can affect the mechanical properties of the weld metal. One of the most important mechanical properties of the weld metal is its yield strength and ultimate tensile strength. Therefore, this study is focused on the strength of the weld metal in CK45 carbon steel welded by robotic GMAW process in different conditions. The results clearly illustrate that the strength of the weld metal has a monotonic relationship to welding variables.

Keywords: *Gas Metal Arc Welding, welding variables, strength, weld metal.*

Welding process plays an important role in manufacturing industries. There are more than 100 processes within welding technology [1]. The gas metal arc welding (GMAW) is a fusion-welding process having wide applications in industry [2] in which a continuous wire electrode and a shielding gas are fed through the nozzle of a welding gun [3]. An electric arc is generated between a wire electrode and a weld pool. Gases are used to shield the weld pool, and flow through the nozzle of the welding torch. These gases are argon (Ar), helium (He), CO_2 and their mixtures [4]. The GMAW has got wide applications in industries due to the advantages such as high reliability, all position capability, low cost, high productivity, high deposition rate, ease of use, absence of fluxes, cleanliness and ease of mechanization [2]. The robotic welding process has more advantages than the conventional manual process, since the quality of the weld is more consistent, the process speed is higher compared with manual, there is less waste and a reduced cost [5]. The strength of the weld metal is one of the most important factors that should be taken into consideration when designing. The high strength of the weld metal ensures its acceptable resistance to failure during various loading. The arc voltage, welding current, and welding speed are important parameters for GMAW that affect the weld metal strength. From what we know, the relatively little information is available on the mechanical properties of the weld metal in medium-carbon steels. In this research work, an attempt has been made to study the effect of robotic GMAW parameters on the weld metal strength in the CK45 carbon steel.

Materials and methods. The CK45 medium-carbon steel (according to DIN 1.1191 standard) in the form of a plate with 20 mm thickness was used as a base material, and the ER70S-6 (AWS A5.18 Classification) wire electrode with 1 mm diameter was used as a filling metal. At first, each plate was beveled 30° to provide single-V-groove butt joint configuration with 60° groove angle. To minimize welding distortion and deformation, the plates were located in the jig fixtures before welding operations. The GMAW welding operations in this work were performed by means of a SOS Model DR Series ARK ROBO 1500 welding robot and the weld pool was protected by CO_2 shielding gas. The chosen welding variables for this study were arc voltage, welding

Corresponding author: H. R. GHAZVINLOO, e-mail: Hamid.Ghazvinloo@gmail.com

current and welding speed, and the multipass welds were used to join the base materials. After welding process, the cylindrical tensile test specimens of 5.64 mm in diameter and 28 mm gauge length were extracted from the weld metals. Some of welding coupons and tensile test specimens extracted from the weld metals are shown in Fig. 1. The tensile tests were carried out at room temperature using a 20 KN capacity DARTEC testing machine and a testing rate of 0.25 mm/s in order to evaluate the mechanical strength of the weld metals obtained in the different conditions.

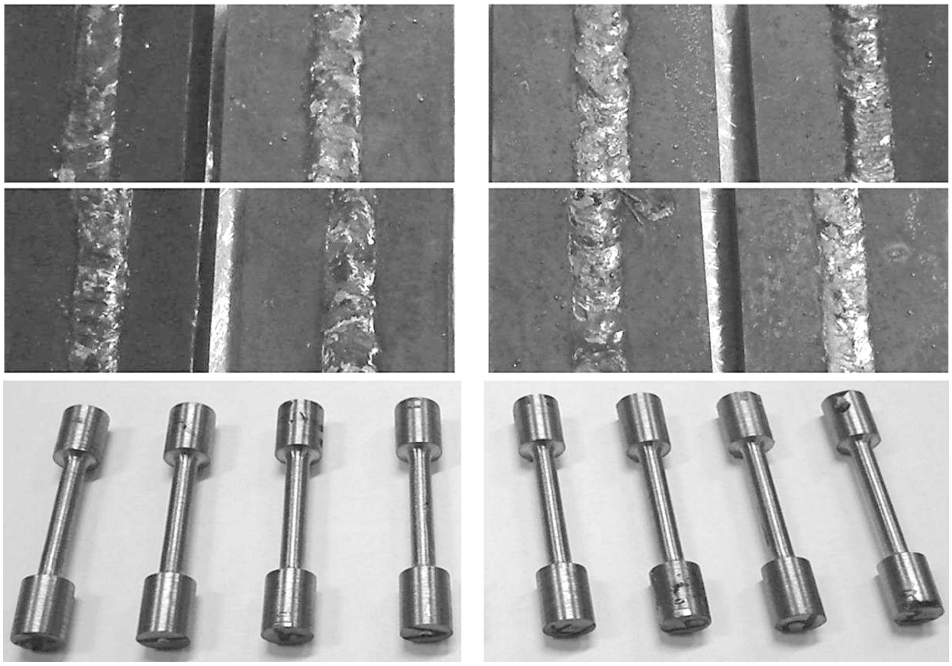

Fig. 1: Some of the welding coupons and tensile test specimens extracted from the weld metals.

Results and discussion. The effect of robotic GMAW parameters on the microstructure of the weld metal in the CK45 carbon steel was studied in previous literature [6]. The tensile test results obtained in this study are shown in Fig. 2. As shown in the Figure, an increase of arc voltage from 23 to 27 V led to a decrease of yield strength (YS) and ultimate tensile strength (UTS) of the weld metal, and the average reduction in YS and UTS was ~12.5 and ~14 MPa, respectively. The effect of welding current on the weld metal strength was similar to arc voltage but this effect was stronger compared to arc voltage. An increase of welding current from 100 to 120 A led to decrease of the YS and UTS of the weld metal, and the average reduction in the YS and UTS was ~18 and ~24 MPa, respectively. Whereas, the effect of welding speed on the weld metal strength was reversed to two previous ones. The YS and UTS of the weld metal increased with increasing of welding speed from 42 to 82 cm/min, and the average increase in the YS and UTS was ~61 and ~79 MPa, respectively. According to the results of this study, the effect of welding speed on the weld metal strength was about 5 times more than the arc voltage effect and 3 times more than the welding current effect. The effect of welding parameters on the weld metal strength can be associated with microstructural changes in the weld metal. Welding heat input increases with increase in arc voltage or welding current, and decrease in welding speed. On the other hand, the heat input is an important parameter that affects the cooling rate of the weld metal. When heat input increases, the cooling rate decreases for the given weld metal. The cooling rate is a primary factor that determines the metallurgical structure and mechanical properties of the weld metal [7]. When the cooling rate is increased, the resulting martensite volume fraction in the weld

metal increases, whereas the retained austenite volume fraction decreases, the volume fraction of tempered martensite in the weld metal decreases due to the lower heat input, and the probability of grain coarsening in the weld zone is lower. Therefore, the change in the heat input will typically affect the mechanical properties and metallurgical structures of the weld metal [7]. Finally, the results illustrate that mechanical strength of the weld metal has a monotonic relationship to the welding parameters. That means: the mechanical strength of the weld metal either increases or decreases thoroughly with increasing the welding parameters.

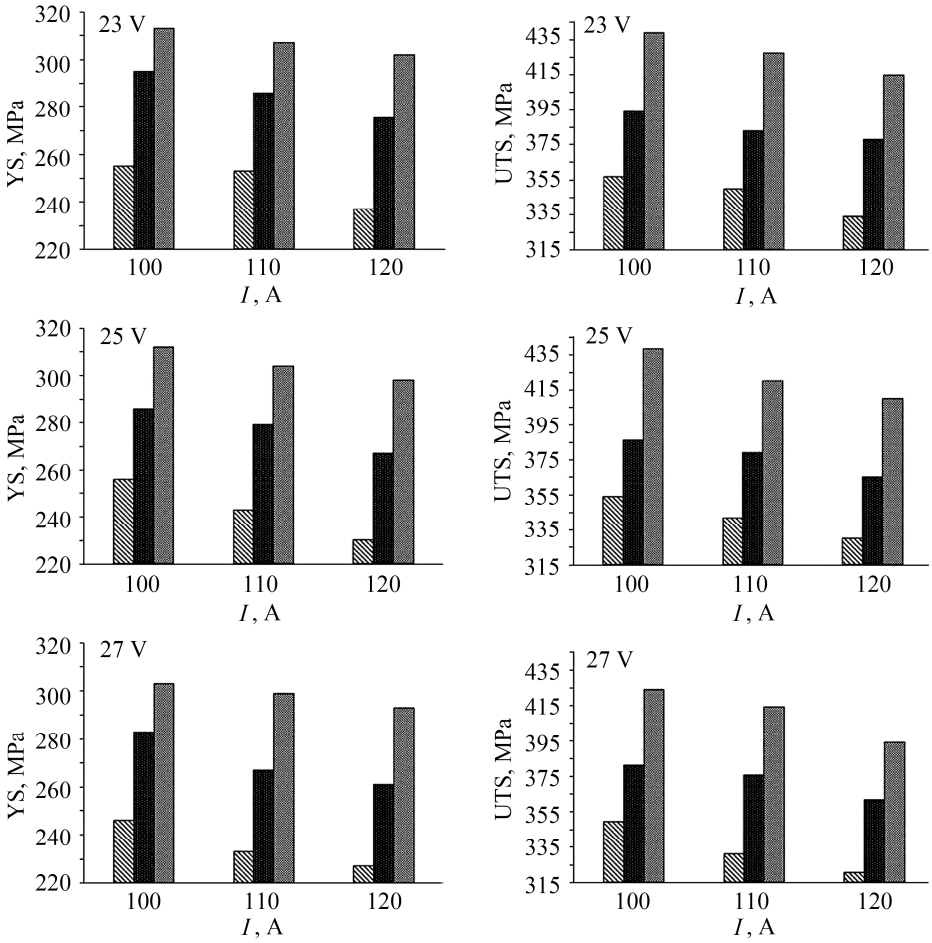

Fig. 2: The effect of welding parameters on the weld metal strength:
▨ – 42 cm/min; ■ – 62; ▩ – 82 cm/min.

CONCLUSION

A change in arc voltage, welding current and welding speed value affects the strength of the weld metal. However, the severity of these effects is not equal, and welding speed has the most severe effect on the weld metal strength among the welding parameters. The effect of welding parameters on the weld metal strength can be associated with the microstructural changes of this zone. The heat input is an important parameter that affects the cooling rate of the weld metal. When heat input increases, the cooling rate decreases for the given weld metal. The cooling rate is a primary factor that determines the final metallurgical structure and mechanical properties of the weld metal. The results of this study illustrate that mechanical strength of the weld metal has a monotonic relationship to the welding parameters. That means that the mechanical

strength of the weld metal either increases or decreases thoroughly with increasing in the welding parameters.

РЕЗЮМЕ. Останнім часом особливу увагу приділяють електродуговому зварюванню *Gas Metal Arc Welding* (GMAW), яке успішно застосовують у промисловості. Напруга і струм, а також швидкість зварювання є незалежними параметрами, які впливають на механічні властивості металу зварного з'єднання. Одними з найважливіших механічних характеристик є його границі міцності та плинності. Проаналізовано міцність металу зварного шва вуглецевої сталі СК45, виконаного роботизовано методом GMAW за різних умов. Результати досліджень демонструють, що міцність металу шва монотонно залежить від змінних параметрів зварювання.

Ключові слова: *газове металеве дугове зварювання, змінні параметри зварювання, міцність, зварювання металу.*

РЕЗЮМЕ. В последнее время особое внимание уделяют электродуговой сварке *Gas Metal Arc Welding* (GMAW), которую успешно применяют в промышленности. Напряжение и ток, а также скорость сварки являются независимыми параметрами, которые влияют на механические свойства металла сварного соединения. Одними из наиболее важных механических характеристик являются его границы прочности и текучести. Проанализировано прочность металла сварного шва углеродистой стали СК45, выполненного роботизированно методом GMAW при разных условиях. Результаты исследований показывают, что прочность металла шва монотонно зависит от переменных параметров сварки.

Ключевые слова: *газовая металлическая дуговая сварка, переменные параметры сварки, прочность, сварка металла.*

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