DUCTILITY OF WELDING JOINTS IN CK45 CARBON STEEL

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Gas Metal Arc Welding (GMAW) has received a lot of attention in recent years due to its many benefits, and is now applied in different industrials such car industry and ship building. It is expected that the GMAW parameters such arc voltage, welding current and welding speed severely affect mechanical properties of the welding joints. One of the most important mechanical properties that should be taken into consideration when designing is ductility of welding joint that can be determined by bending test. The purpose of this paper is an experimental investigation to determine the effect of robotic GMAW parameters on the ductility of welding joints in the CK45 carbon steel. The results clearly illustrate that the ductility of welding joints has a monotonic relationship to welding parameters.

Keywords: *Gas Metal Arc Welding, welding parameters, ductility, welding joint.*

Introduction Welding is one of the most applicable connection processes in industry [1]. Among many types of welding processes, Gas Metal Arc Welding (GMAW) is the preferred method for a wide range of ferrous and nonferrous metal parts [2, 3], due to high deposition efficiency and better welding quality [4, 5], low cost and high efficiency in joining process [6], high speed [7] and high productivity rate [8]. In this process, the heat for melting metals is generated by an electric arc between a continuous wire electrode and a weld pool. Such gases as carbon dioxide (CO_2), argon (Ar), helium (He) and their combinations, are used to protect the weld pool. In general, the GMAW process with CO_2 gas offers a cost-effective performance compared with other gases [9]. The automatic GMAW systems have multiple inputs, outputs, variables and performance [10]. The arc voltage, welding current, and welding speed are three important parameters for this process that can affect strongly the mechanical properties of the welding joint. The welding joint ductility is one of the most important factors that should be taken into consideration when designing structures. From what we know, a relatively little information is available on the mechanical properties of welding joints in medium-carbon steels. In this research work, an attempt is made to study the effect of robotic GMAW parameters on the ductility of welding joints in the CK45 carbon steel.

Materials and methods. A SOS Model DR Series ARK ROBO 1500 welding robot was applied for the automatic multi-pass GMAW process. Its key variables for this study were arc voltage, welding current and welding speed and the weld pool was properly protected against atmosphere by carbon dioxide (CO_2) gas. The CK45 medium carbon steel (DIN 1.1191 standard) in the form of plates with thickness of 10 mm and 30° beveled was used as a base material. To minimize the welding distortion, the plates were located in the jig fixtures before welding operations. The filler metal in the welding process was ER70S-6 (AWS A5.18 standard) wire electrode with 1 mm diameter and composition of 0.11C-1.63Mn-0.95Si-0.5Cu. After welding, the bending test specimens of 200×15×10 mm were prepared from the welding joints. Some of the bending test specimens and the base of this test are shown in Fig. 1. The three-point bending tests (type of face-bend and root-bend tests) were carried out at room temperature using

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a DARTEC testing machine under 15 kN force and with a testing rate of 0.1 mm/s in order to determine the elongation of the face and root of the weld in obtained joints.

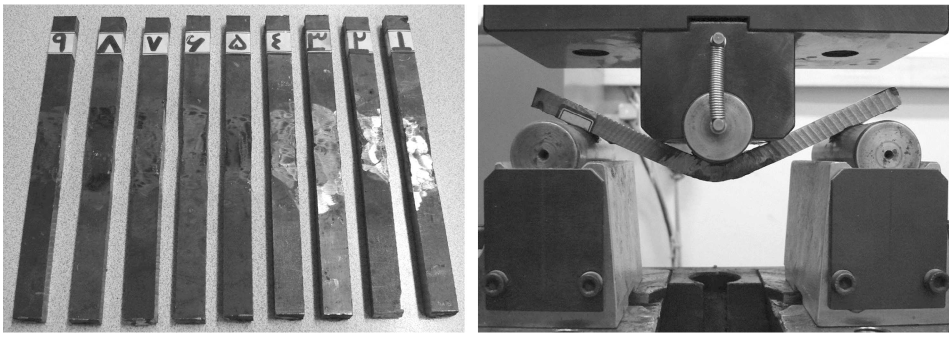

Fig. 1. Some of the bending test specimens and the base of this test.

Results and discussion. The effect of robotic GMAW parameters on the microstructure and strength of the weld metal in the CK45 carbon steel was studied in previous literature [11, 12]. The bending test results in this study are shown in Fig. 2.

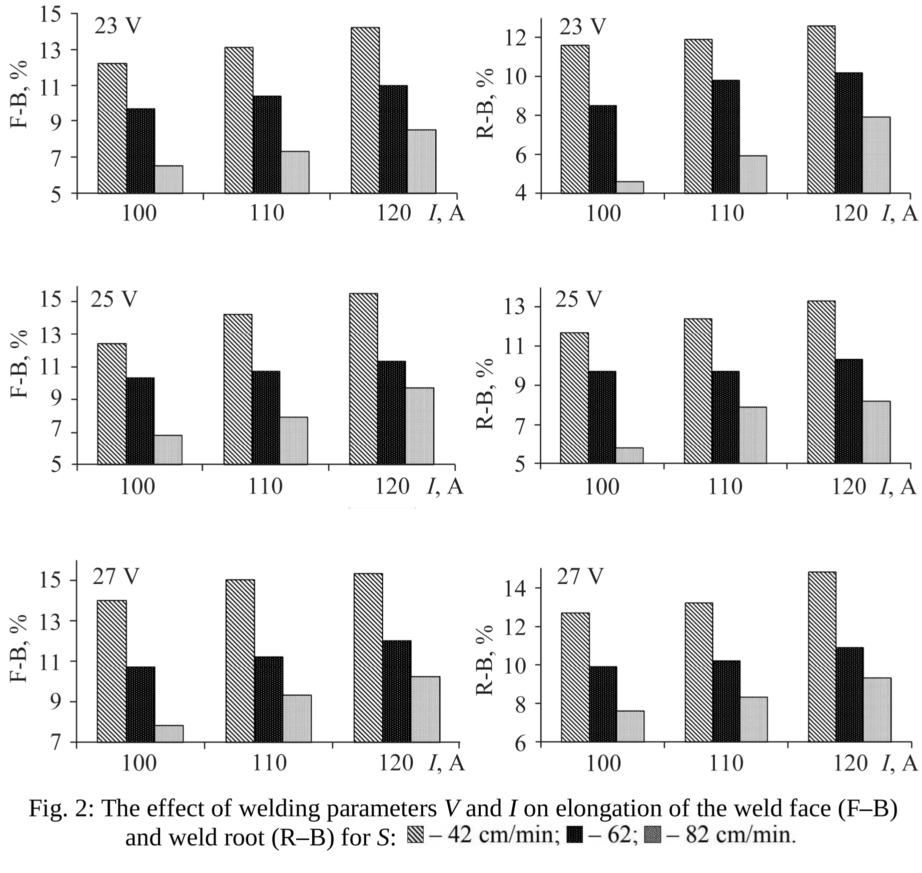

Fig. 2: The effect of welding parameters *V* and *I* on elongation of the weld face (F–B) and weld root (R–B) for *S*: ▨ – 42 cm/min; ■ – 62; ▩ – 82 cm/min.

As shown in the Figure, an increase of arc voltage V from 23 to 27 V led to an increase in elongation in the weld face and root, and the average increase in elongation of the face and root was ~1.4% and ~1.5%, respectively. The effect of welding current on welding joints elongation was similar to the arc voltage but this effect was a few stronger in comparison with the arc voltage. An increase in the welding current *I* from 100 to 120 A led to an increase in elongation of the weld face and root, and the average increase in elongation in the face and root was ~2% and ~1.8%, respectively. Whereas, the effect of welding speed on the elongation of welding joints was reverse to two previous ones. The elongation of welding joints decreased with increase of the welding speed *S* from 42 to 82 cm/min, and the average reduction in elongation of the face and root was ~5.7% and ~5.4%, respectively. According to the results of this study, the effect of welding speed on of the welding joints elongation was stronger than the arc voltage and welding current. The effect of welding parameters on the ductility of welding joints can be associated with microstructural changes in the weld metal. The changes in the welding parameters result in the change in the welding heat input. Heat input increases with increasing arc voltage, welding current or decreasing welding speed. 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 a given weld metal. The cooling rate is a primary factor that determines the metallurgical structure and mechanical properties of the weld metal [13]. When the cooling rate increases the resulting martensite volume fraction in the weld metal also increases, whereas the volume fraction of retained austenite and tempered martensite in the weld metal decreases due to the lower heat input. Also the probability of grain coarsening in the weld zone is lower.

Therefore, variation of the heat input will typically affect the mechanical properties and metallurgical structures of the weld metal [13]. Finally, the results illustrate that the welding joints ductility has a monotonic relationship to the welding parameters. It means that the ductility of welding joints either increases or decreases thoroughly with increasing the welding parameters.

CONCLUSION

A change in arc voltage, welding current and welding speed value affects the welding joints ductility. However, the severity of these effects is not equal, and welding speed has the most severe effect among the welding parameters. The effect of the welding parameters on the welding joints ductility can be associated with the microstructural changes of the weld 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 a 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 ductility of the welding joints has a monotonic relationship to the welding parameters. It means that the ductility of welding joints either increases or decreases thoroughly with increasing the welding parameters.

РЕЗЮМЕ. Електродугове зварювання металів у газі (GMAW) останнім часом привертає особливу увагу через низку переваг і застосовується в різних галузях промисловості, зокрема, в автомобіле- та кораблебудуванні. Очікується, що параметри GMAW такі, як напруга і струм зварювання, а також його швидкість, сильно впливають на механічні властивості зварних з’єднань. Однією із найважливіших характеристик, яку слід враховувати на стадії проектування, є пластичність зварного з’єднання, яку можна встановити випробами на згин. Експериментальними дослідженнями виявлено вплив параметрів GMAW на пластичність зварного з’єднання у вуглецевій сталі CK45. Отримані результати чітко ілюструють монотонну залежність між параметрами зварювання і пластичністю зварного з’єднання.

Ключові слова: *газове електродугове зварювання металів, змінні параметри зварювання, міцність, зварювання металу.*

РЕЗЮМЕ. Электродуговая сварка металлов в газе (GMAW) в последнее время привлекает особое внимание по ряду преимуществ и применяется в различных отраслях промышленности, в частности, в автомобиле- и судостроении. Ожидается, что параметры GMAW такие, как напряжение и ток сварки, а также ее скорость, сильно влияют на механические свойства сварных соединений. Важной характеристикой, которую следует учитывать на стадии проектирования, является пластичность сварного соединения, которую

определяют испытаниями на изгиб. Экспериментальными исследованиями выявлено влияние параметров GMAW на пластичность сварного соединения в углеродистой стали CK45. Полученные результаты четко иллюстрируют монотонную зависимость между параметрами сварки и пластичностью сварного соединения.

Ключевые слова: *газовая электродуговая сварка металлов, сменные параметры сварки, прочность, сварка металла.*

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