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INVESTIGATIONS OF WELD SEAM WIDTH VARIABILITY DURING SHIELDING GAS MIXTURE ARC WELDING

Variability of weld seam width during shielding gas mixture arc welding is experimentally investigated in the article. Adequacy of normal statistical distribution application to the variability of weld seam width with utilization of histogram, normal-probabilistic graph, Kolmogorov as well as Shapira-Wilk goodness-of-fit tests, and omega squared, is proved. [dx.doi.org/10.29010/082.9]

Ключевые слова: statistical distribution; weld seam width.

Introduction

Utilization of statistical methods permits to take into consideration the variability of controlled indices which is the main objective obstacle for the product quality requirements fulfillment. The variability may result in non-fulfillment of requirement connected with the item ability to operate, i.e. results in the defect originating. The more complex is technological process basis, the more is variability of the products quality with this process. Seam formation processes during arc welding have enough complex nature which includes physical-chemical, metallurgical and mechanical transformations. As a consequence, the weld seams are characterized by relatively high variability of the quality factors and this result in necessity to use the statistical methods for the indexes variability investigation.

Problem Statement

Determination of statistical law, which describes adequately the weld seam variability, permits to evaluate the welding process ability to fulfill requirements regarding the weld seam dimensions, to simplify the adjustment of welding equipment for specified welded joint dimensions, permits to determine the welding modes parameters range in which the weld seam variability is within the statistical error.

The work goal is the experimental investigation of the weld seam width variability and establishment of statistical law, which describes adequately this variability.

Main Part

The welded joint defects include the deviations from the established standards and technical requirements, which reduce the strength and operational reliability of the welded joints and may result in destruction of all the construction. According with ISO 6520-1:2012 "Welding and allied process. Classification of geometric imperfections and integrity in metallic materials — Part 1: Fusion welding", all welded joint defects are subdivided into six groups:

- cracks (100) - is a defect of welded joint in form of rupture in the weld seam and (or) in zones adjacent to it;
- pores (200) - cavities, filled up with gases;
- solid inclusions (300) - solid foreign substances of metallic or nonmetallic origin in weld seam metal;
- lack of penetration and incomplete fusion (400) - deepening along weld bed or incomplete fused surplus of incomplete fused metal;
- deviations of form and dimensions (500) - deviation of forms of the weld seam external surfaces or geometry of the joint from the value established;
- other defects (600).

One of the weld seam defects is the 513 defect - deviation of width from established value along the weld seam. Necessary values of weld seam widths are established by the designer on a base of appropriate requirements of standards.

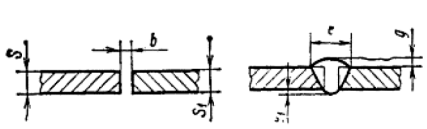
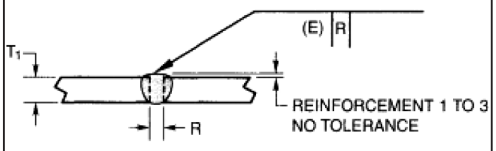
Experimental investigation of weld seam width variability is carried out by weld bed fusing onto the plate of 3×150×300 mm dimensions made of St3sp steel. Before the fusing the plate was scraped from rust and dirt. Electrode wire of Sv-08G2S (GOST 2246-70) trademark dia. 1.2 mm, 82% Ar + 18% CO_2 shielding gas mixture, Fronius VarioStar 2500 semi-automatic welding machine and ADG-502 welding tractor were used

Requirements formulated by intergovernmental and American standards regarding the seam dimensions onto 3 mm thickness main metal are in the Table 1.

During the experimental investigation the current strength was changed in the range of 150 - 190 A. For

Table 1

Requirements for welded joint according to the GOST 14771-76 and AWS – AWS D1.1/D1.1M:2010 [1,2]

Assessment criterion	GOST 14771-76	AWS - AWS D1.1/D1.1M:2010
Key	C2	B-P1a-GF
Graphical representation		
Welding process	Інп, Ін, Іп,Уп	SMAW, GMAW, FCAW
Thickness	S = 2.2–4 mm	T1 - up to 3 mm
Gap	B = 0–1.5 mm	R = 0 – 2 mm
Joint width	e < 8 mm	-
Convexity	g = 1.5 ± 0.5 mm	E = 1–3 mm
Convexity	G1 = 1.5 ± 1 mm	[E] = T1 - 1 = 2 mm

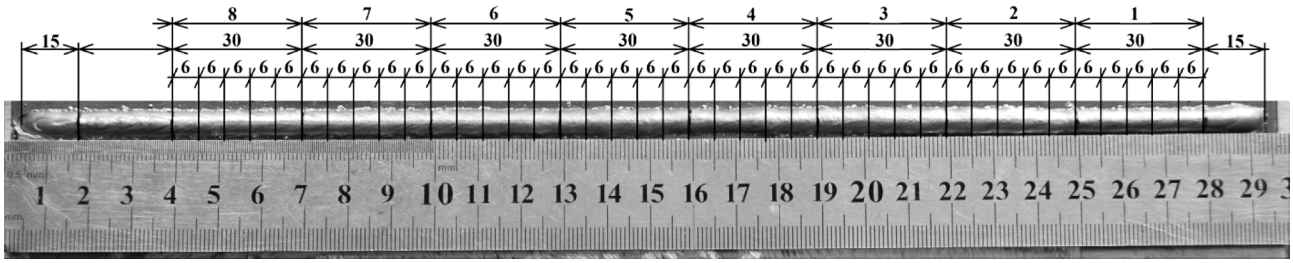


Fig. 1. Schematic view of weld seam width measuring

all welding current strength values investigated such process parameters as welding rate V_w = 6.2 mm/s, shielding gas flow rate q_r = 12 l/min, welding wire diameter d_{el} = 1.2 mm, electrode overhand l_{el} = 12 mm, were unchanged.

Variability of weld seam width was investigated by ШЦЦ-I-150-IP67 electronic slide gauge with 0.01 mm scaling factor in weld bed cross-sections formed under prescribed welding mode parameters (see Fig. 1).

Weld seam width refers to the quantitative continuous statistical evidence. Under non-changed welding conditions the weld seam width changes under the simultaneous action of great number of factors, that is evidence in favor of such fact that weld seam width changes by the normal distribution law [3 - 5]. Nevertheless, such statement is the hypothesis only, which needs the verification. The hypothesis of normality of weld seam width values distribution was checked by us. Graphical methods (histogram method and normal-probabilistic graphs method) and calculation methods (Kolmogorov criterion, Shapira-Wilk criterion, and omega squared criterion) were used.

In order to check the distribution normality by graphical methods the welding beds were fused under parameters of the first welding mode I_{w1} = 170-175 A, U_{nom} = 18.4 V, V_{w1} = 6.5 mm/s.

The histogram graphed using the experimental data for weld seam width variability is presented in Fig.2.

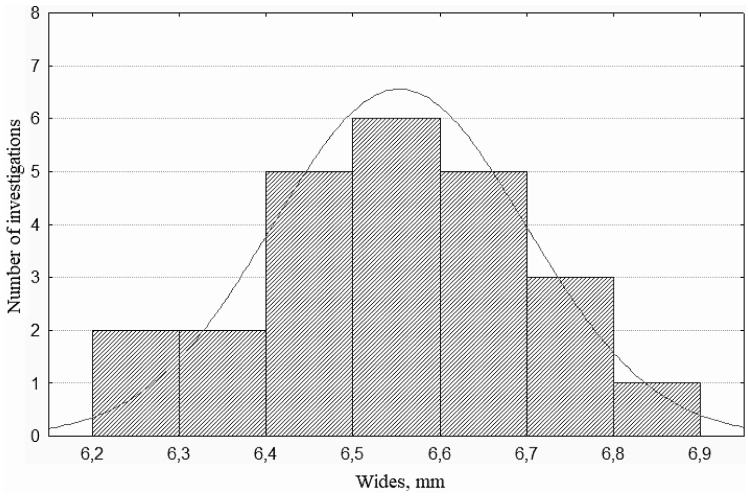


Fig. 2. Histogram of weld seam width variability:
1 - number of investigations; *2* - width, mm

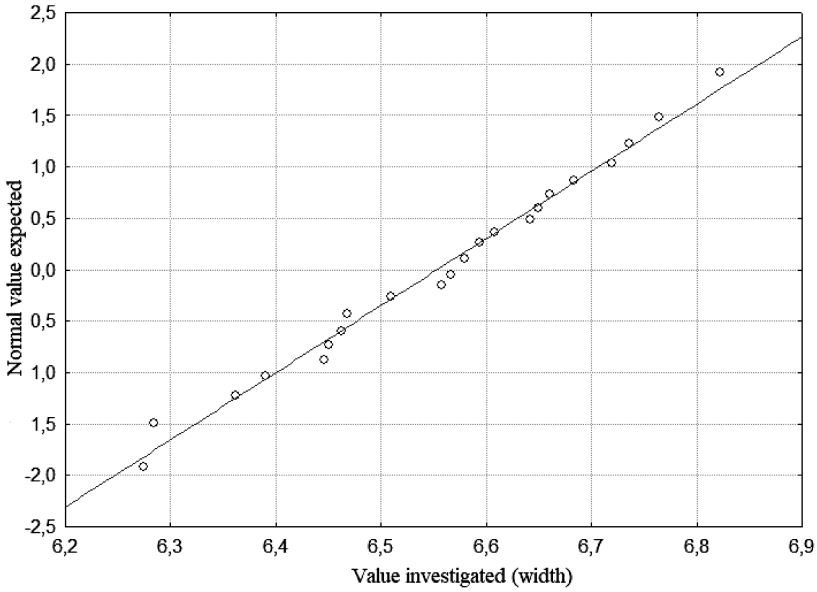


Fig. 3. Normal-probabilistic graph:
1 - normal value expected; *2* - value investigated (width)

The histogram obtained is close to symmetrical one and fits in normal distribution curve (shown by red color).

The data under which the histogram is plotted down are transferred on normal-probabilistic graph (see Fig. 3).

Points on the graph are situated near the line corresponding to the normal distribution (red color). Thus, both graphic methods show that the distribution normality hypothesis is verified.

For additional verification of distribution normality hypothesis the calculation procedure by goodness-of-fit criterion is used by us. Data for seam width under the first welding mode are supplemented with data under the second welding mode I_{w2} = 150-155 A, U_{nom2} = 16.6 V, V_{w2} = 4.98 mm/s and data under the third welding mode I_{w3} = 185-190 A, U_{nom3} = 20.8 V, V_{w3} = 9.7 mm/s. Results of calculations under Kolmogorov and Shapira-Wilk criterions, as well as under omega squared criterion, are in the Table 2.

According to the calculation results, at all current strength values the weld bed width has normal distribution law. At I_w = 170-175 A under Shapira-Wilk criterion only, the hypothesis of distribution normality is faulty. Because all other methods brought the positive result, the hypothesis of statistical distribution of weld seam width values for this current strength is not rejected.

Conclusions

It is demonstrated, that under arc welding in 82% Ar + 18% CO_2 shielding gas mixture in the range of welding current values 150 - 190 A, the variability of weld seam values is described adequately by the normal distribution law.

It is advantageous to concentrate further investigations on investigation of changeability of other quality factors of weld seams.

Nomenclature

I_w – welding current strength;
U_{nom} – voltage nominal drop onto welding arc;
V_w – velocity of welding wire feed.

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Table 2

Calculation methods of normal distribution adequacy checking

Calculation criterion	Criterion condition	Criterion statistics	150…155 A	170…175 A	185…190 A
Kolmogorov criterion	$D_{calc} < D_{tabl}$	D_{tabl}	0.909	0.909	0.909
		D_{calc}	0.815	0.7833	0.509
Shapira-Wilk criterion	$W_{calc} > W_{tabl}$	W_{tabl}	0.916	0.885	0.885
		W_{calc}	0.993	0.7672	0.968
Omega squared criterion	$\omega^2_{calc} < \omega^2_{tabl}$	$\omega^2_{tabl(\alpha = 0,05)}$	0.126	0.126	0.126
		ω^2_{calc}	0.113	0.118	0.028
Total			3	2	3

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ДОСЛІДЖЕННЯ ЗМІНЮВАНОСТІ ШИРИНИ ЗВАРНОГО ШВА ПРИ ДУГОВОМУ ЗВАРЮВАННІ У СУМІШІ ГАЗІВ

В роботі експериментально досліджена змінюваність ширини зварного шва при дуговому зварюванні у суміші захисного газу. З використанням гістограми, нормально-імовірнісного графіку, критеріїв згоди Колмогорова, Шапіра-Уілка, омега квадрат доказана адекватність застосування нормального статистичного розподілу до змінюваності ширини зварного шва. [dx.doi.org/10.29010/082.9]

Ключові слова: статистичний розподіл; ширина зварного шва.

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