

HIGH-PRODUCTIVITY A-TIG WELDING

VISOKOUČINSKI A-TIG POSTUPAK ZAVARIVANJA

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Ključne riječi: A-TIG postupak zavarivanja, aktivirajući topitelj, probe zavarivanja

Key words: A-TIG welding process, surface-active flux, welding trials

Sažetak: U ovom radu se obrazlaže usporedba konvencionalnog TIG postupka zavarivanja i visokoučinskog A-TIG postupka na temelju rezultata dobivenih praktičnim probama zavarivanja. Naznačene su također i primjene A-TIG postupka zavarivanja. Eksperimentalni dio rada je upotpunjen objašnjenjem fizikalne podloge A-TIG postupka zavarivanja uz korištenje aktivirajućeg topitelja, koji u suštini povećava penetraciju, tj. brzinu zavarivanja.

Abstract: The paper deals with a comparison of the conventional TIG welding process with the high-efficiency A-TIG welding process made on the basis of results obtained in practical welding trials. Applications of A-TIG welding are indicated as well. The experimental part of the paper is accompanied also by an explanation of the physical background of A-TIG welding using surface-active fluxes, which essentially increase fusion penetration, i.e. welding speed.

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1. INTRODUCTION

TIG welding is used when nice appearance and high quality of welds are required. In this process the arc is burning between a non-consumable tungsten electrode and a parent metal. The shielding gases most often used are the inert gases argon and helium or their mixtures. The main disadvantages of the process are poor penetration, considerable sensitivity of the weld pool to the state of the parent metal, and low productivity. In order to increase the efficiency and productivity of the TIG welding process, the process variant using activating fluxes is getting established. The so-called A-TIG process comes from "Active Flux TIG". The increases in penetration depth and welding speed in arc welding with a tungsten electrode can be accomplished by adding surface-active elements, the shape of welding current, and use of some oxidizing gas mixtures such as Ar-O₂ and Ar-CO₂ [1, 2, 3]. A-TIG welding is a process, in which, due to arc constriction and a modified melt flow in the weld pool, the penetration in the parent metal is considerably deeper than in the conventional TIG welding process. A combination of the deeper penetration and higher welding speeds increases the efficiency of the welding process concerned.

The first trials of A-TIG welding date back to the 1960s when at the Paton Institute the deposition of an active flux on the surface of a parent material, i.e. in TIG welding of titanium, was carried out. A thin layer of the active flux was deposited on the parent metal. A portion of the flux evaporated during welding and reacted with the weld pool. In addition to favourable weld properties, deeper penetration than in conventional TIG welding was observed.

A-TIG welding knew its renaissance in the past seven years, both in the field of research and applications. The present paper summarizes some practical findings obtained in a R&R project, performed in co-operation with the Varstroj company from Lendava, titled "Further advancement of TIG welding devices for new technologies".

2. WELDING TRIALS

Surfacing on 5 mm thick austenitic stainless steel was accomplished with TIG welding using argon (100 %). Welding was carried out on a welding test bench so that constant welding speed and torch position during welding were provided. A digital inverter-welding machine, type OTC DT 300P, was used for the purpose.

A case of an activating-flux deposit on the parent metal is shown in Fig. 1 whereas the welding parameters referring to four different cases, including weld images, are shown in Table 1.

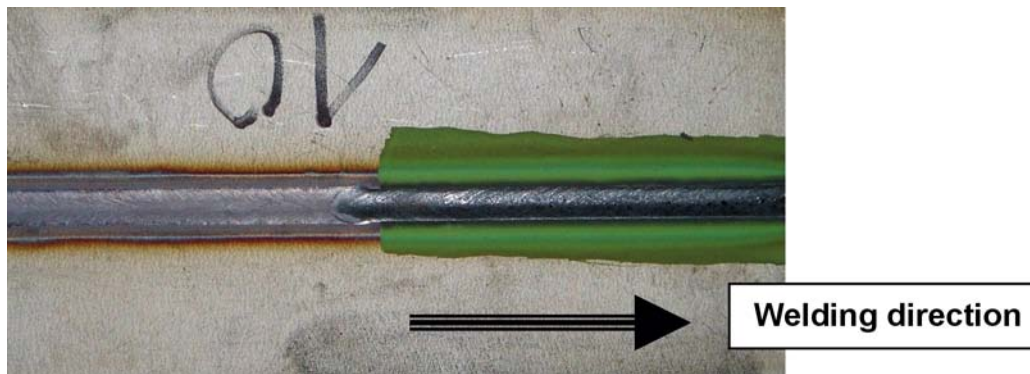


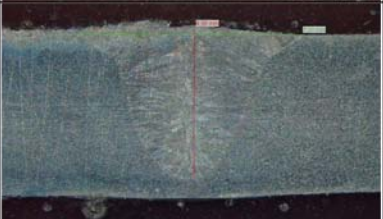



Fig. 1. Case of activating-flux deposition on parent metal – a nice transfer from the zone without flux to the one with flux is clearly visible in the middle.

Table 1

Case	I (A)	v _v (cm/min)	Flux	f (Hz)	d _{obl} (mm)	I _b /I _p (A)	Weld image
1	204	20	/	/	2	-	
2	204	20	/	300	2	100/300	
3	204	20	yes	/	2	-	
4	204	20	yes	300	2	100/300	

In the first case, surfacing was carried out without the application of flux. The welding current amounted to 204 A and welding voltage to 12 V.

In the second case, high frequency DC welding with a frequency of 300 Hz and with ratios $\frac{I_b}{I_p} = \frac{100A}{300A}$ and $\frac{t_b}{t_p} = \frac{50}{50}$ was used. It could be noticed that the weld-face width slightly reduced and the penetration depth slightly increased. The differences are perceivable but minimum.

In the third case, an activating flux, type EWI SS-7, containing titanium, silicon and chromium three-oxide was used. Surfacing was carried out with the same welding parameters as in the first case. The weld face got somewhat narrower whereas the penetration increased by almost three times.

In the fourth case, the activating flux was used in welding with a pulsed current shape having a frequency of 300 Hz, a ratio of the values $\frac{I_b}{I_p}$ was $\frac{100A}{300A}$, and a ration $\frac{t_b}{t_p}$ equalled $\frac{50}{50}$, similarly as in the second case. Due to the effect of arc constriction, in comparison to the previous case, further narrowing of the weld face and penetration increase may be observed.

3. ANALYSIS OF WELDING RESULTS

An analysis of TIG welding with pulsed control of the process and of high-efficiency A-TIG welding was made. In the context of expanding the spectrum of pulsed welding (conventional pulsed welding, modulated pulsed welding, the use of lower and higher frequencies resp.), the events in the welding arc and weld pool were studied. In pulsed welding the following findings are important:

- Pulsed welding at frequencies of 10 Hz or lower can be used to control heat input into the parent metal,
- Pulsed welding at higher frequencies (100 Hz or higher) produces the arc constriction and increases the arc stiffness, which, in turn, produces a more concentrated arc energy,
- Pulsed welding at higher frequencies, of which the signal is modulated with a pulsed shape of a signal of lower frequency, permits the control of heat input into the parent metal and simultaneous control of the weld pool; consequently, the weld is clean, nice and suitably wavy (the waviness of the weld face depends on the frequencies of the modulation signal of lower frequencies).

3.1 Low-frequency pulsed TIG welding

Properties of low frequency pulsed welding are as follows:

- a) Good penetration with a lower heat input
- b) Smaller deviations of welding parameters
- c) Good control of the weld pool even if we are slightly out of position
- d) Easier welding of thinner materials
- e) Easier welding of materials of different thickness

The main feature of the pulsed welding process is that the same weld can be obtained as in conventional DC welding with a considerably lower heat input. In the course of the pulsed value of the current a suitable fusion penetration is achieved rapidly. Before the heat input can get too high, the pulse will transfer to a considerably lower, basic value. In this time the parent metal, i.e. the weld pool, will get cooler to such a degree that the cycle of the pulsed current value can be repeated. Such a limited heat input permits a welder to have an essentially better control of the weld pool although he may be out of position or welding two materials of different thickness.

With this type of pulsed welding the following are to be set:

- Pulsed current value (it is usually higher than the current value with DC welding),
- Basic current value (it is usually considerably lower than the pulsed current value),
- Pulse frequency, and
- Pulsed-current time (usually set in % of the total signal period).

In practical applications pulsed welding is mostly used in a frequency range from 0,5 Hz to 20 Hz, and pulsed-current duration from 20 % to 80 %.

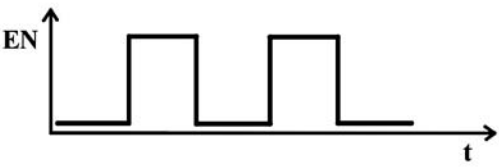

3.2 High-frequency pulsed TIG welding

As already mentioned, pulsed welding at higher frequencies (100 Hz or higher) produces the arc constriction and increases the arc stiffness, which produces a more concentrated arc energy. Questions, however, appeared what the frequency of the welding process concerned and the regulation of the basic and pulsed currents should be.

It was found that the actual frequencies ranged between 100 and 300 Hz, and ratio $\frac{t_b}{t_p}$ was $\frac{50}{50}$, since the role of the high-frequency pulsed welding is merely to constrict the arc, which will produce a narrower and nicer weld face and give a slightly deeper fusion penetration.

In Table 2 the case of low-frequency and high-frequency pulsed-current signals is given.

Table 2

TYPE OF SIGNAL	CURRENT SHAPE IN PULSED WELDING	PURPOSE OF CONTROL - EFFECT
Pulsed DC signal of lower frequencies (0.5 to 20 Hz)		> <u>control of heat input</u> > all-position welding
Pulsed DC signal of higher frequencies (100 Hz to 300 Hz)		> <u>arc constriction</u> > welding of thin sheets > welding together of workpieces of different thicknesses

3.3 A-TIG welding and welding trials

As already mentioned, the mode of increasing fusion penetration and welding speed in arc welding with a tungsten electrode can be achieved by adding surface-active elements. This is the A-TIG welding process. Practical trials showed that with the same welding speed the penetration increased from 1.71 mm to 4.98 mm, which is almost by three times. Certainly, it is possible to use with the A-TIG welding process welding speeds three times higher in order to obtain the same penetration. In any case the process concerned permits a efficiency three-times higher than in conventional TIG welding. It is also important that practically the same power sources may be used. In A-TIG welding the arc will get concentrated and the flow of the weld pool will change, which depends on the surface-tension gradient. The temperature dependence of the surface tension can be modified by certain chemical elements, the so-called surface-active elements, such as oxygen (O), sulphur (S), titanium (Ti), selenium (Se), antimony (Sb), tellurium (Te), and similar.

The literature reviewed and our own findings confirm the fact that the welding result is mainly affected by two factors, i.e.:

- The change of the Marangoni flow resulting from a change of the surface-tension gradient $\gamma = \frac{\partial \sigma}{\partial T}$ and
- The effect of arc constriction.

With negative values of γ , the cooler marginal weld-pool zones show a higher surface tension than the weld-pool centre; therefore the flow is directed from the inside to the outside,

which creates a wide and shallow weld pool. With the materials having a positive γ , the weld-pool flow is directed from the margins towards the centre, which will produce, using the same parameters, a narrower and deeper weld pool [4]. Figure 2 shows Marangoni flows depending on the surface-tension gradient.

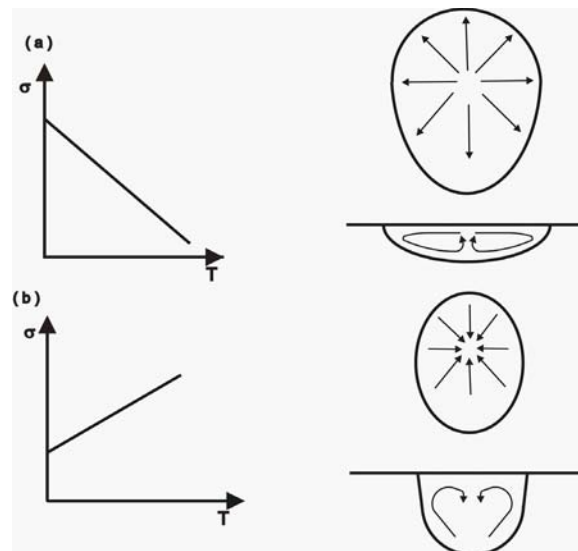


Fig. 2. Marangoni flow in weld pool for: a) $\gamma < 0$ and b) $\gamma > 0$.

In A-TIG welding we noticed a slightly increased arc voltage, which was found also by C. Dong and S. Katayama [5], Fig. 3. This means that the fields of arc characteristics in A-TIG welding are slightly raised in comparison to conventional TIG welding, but not as much as to essentially affect the welding parameters. This means that with the A-TIG process the same welding machines can be used as with conventional TIG welding. In pulsed high-frequency welding, however, only modern electronic welding sources shall be used [6].

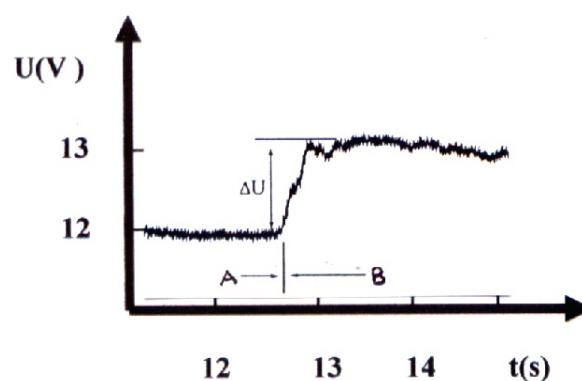


Fig. 3. Time variation of welding voltage; A – without active-flux deposition, B – with active-flux deposition.

4. CONCLUSIONS

The results of the welding trials described in the paper show that the application of the activating fluxes can essentially increase the fusion penetration in TIG welding (approximately by 300 %). A single bead is sufficient to obtain full penetration in surfacing of 5 mm thick austenitic steel using a current of 240 A. Even better results in terms of penetration were obtained with the active fluxes combined with high-frequency (between 100 Hz and 300 Hz) pulsed welding since in this case the effect of arc constriction increased. With the application of the fluxes, the welding voltage slightly increased, but not by more than 1 V. The A-TIG welding process does not require particular dynamic characteristics of the welding machine used; therefore, the existing welding sources will be sufficient.

The increased efficiency achieved with A-TIG welding offers new possibilities of application of TIG welding in the field of automation. The fluxes being commercially available and their price being acceptable, it is expected that A-TIG welding will get established in our countries as well. We hope the present paper will be a contribution to this end.

5. REFERENCES

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