

# Specifics of Mode Parameters Choice Under Twin Arc Welding of Fillet Welds

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**Abstract.** The present article covers the specifics of mode parameters choice under twin arc welding of fillet welds. The necessity of mode parameters adjustment at the second arc due to heated metal of the first arc was proven. The obtained correction indexes allow us to determine with satisfactory accuracy the mode parameters under given dimensions of weld joint.

## 1. Introduction

Application of twin arc welding allows us to significantly increase the performance of the process and widen technological capability of welding [1-2]. The article [3] covers the technology of twin submerged arc welding in separate melting pools with inclined electrode of H-beam circumferential seams, this technique allows us to eliminate all main weak points of underhand welding, i.e.: low productivity, unallowable deformations, difficulties of through penetration of a beam web.

The application of the proposed method requires strict choice of welding modes and the electrode shall be placed in a right position against the joint [4]. At the present time there is no data presented regarding the choice of weld modes and parameters under twin welding in separate melting pools with inclined electrode.

At the present moment there are only several known calculation methods of modes for twin arc welding [5-7]. But they are designed only for calculations of twin arc welding in one melting pool and do not consider inclined electrode.

## 2. Specifics of mode parameters choice for first arc

The present work covers distinctive points of welding mode parameters choice under twin arc welding of fillet welds in separate melting pools with inclined electrode.

At the first step we calculate mode parameters for the first arc regarding needed depth of penetration. For doing so:

2.1. Make a draught of weld joint (Figure 1). Based on the given algorithm we define the offset distance from a beam flange.

Geometrical construction of the offset distance shall be carried out according to the following algorithm:

1) Draw a fillet weld legs on the beam flange and beam web. Draw a line AB that forms the surface of a flat joint.



- 2) Draw a line DG mid-perpendicular to AB. But line AD shall be equal to line DB.
- 3) From A draw a line AOM with an angle  $\alpha$  to a beam web.
- 4) Through the cross of line DG and line AOM we draw an interval OF which is perpendicular to AOM. The resulting interval is the axis of weld.
- 5) The cross point of interval OF and a beam web defines the distance  $a$ , to which we shall move an electrode to obtain needed weld size.
- 6) To get a guaranteed overlap of joints, depth of penetration for the flange needed to be taken as  $0,7\delta c$ .
- 7) Accepting the form for depth of penetration– as a semi-ellipse, we can draw melding line  $a$ . So that axis of a semi-ellipse will be equal to intervals AO and OF.

2.2. According to Figure 2 and Equation 1 we identify the area of a metal under extension and we measure the total height of a joint and its width.

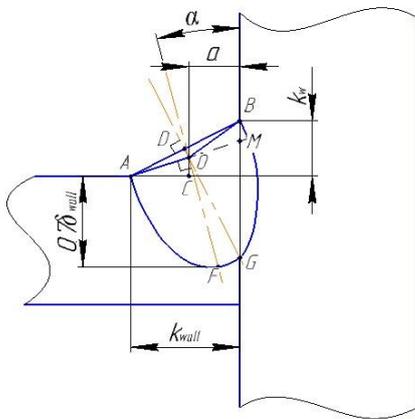


Figure 1 – Diagram to identify the distance «a»

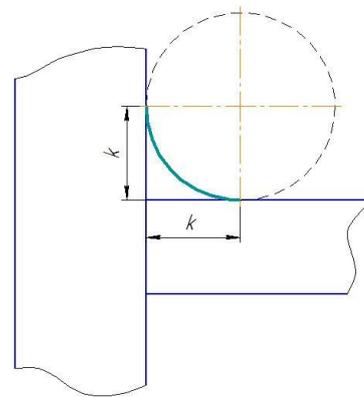


Figure 2 – Draught to identify the critical area of a metal under extension

The area of a metal under extension for a weld seam with not identical legs might be found according the equation:

$$F_y^{cr} = k_1 \cdot k_2 \cdot \left(1 - \frac{\pi}{4}\right), \quad (1)$$

where  $k_1$  and  $k_2$  – fillet weld legs, mm

2.3. We identify a calculated depth of penetration according to the following equation:

$$h_p = H - \frac{F_H}{0.73 \cdot e}, \quad (2)$$

where  $F_H$  – the area of a welded layer,  $\text{mm}^2$ ;

$H$  – the total height of a weld seam, mm;

$e$  – width of a weld seam, mm.

Under calculation of the joints with edge preparation or root opening – the area of a welded layer will include not only metal under extension but also the area of edge preparation or the area of a root opening.

2.4. Identify the range of a weld current

$$I_w = (80 \dots 100) h_p \quad (3)$$

From obtained range we choose approximate current rate.

2.5. Under chosen current rate we identify according to the following equation a welding arc voltage, needed for acceptable weld seam formation

$$U_a = 20 + \frac{0.05 \cdot I_w}{\sqrt{d_e}}, \quad (4)$$

where  $d_e$  – an electrode diameter, mm

2.6. Calculate the welding speed based according to the following equation:

$$V_w = \frac{A}{I_w}, \quad (5)$$

where  $A$  – a coefficient, that depends on the electrode diameter,  $A \cdot m/h$

Values of a coefficient  $A$  are given in Table 1.

Table 1 – Values of coefficient  $A$

Electrode Diameter $d_e$ , mm	Values of Coefficient $A$ , $A \cdot m/h$
1.2	от $2 \cdot 10^3$ до $5 \cdot 10^3$
1.6	от $5 \cdot 10^3$ до $8 \cdot 10^3$
2.0	от $8 \cdot 10^3$ до $12 \cdot 10^3$
3.0	от $12 \cdot 10^3$ до $16 \cdot 10^3$
4.0	от $16 \cdot 10^3$ до $20 \cdot 10^3$
5.0	от $20 \cdot 10^3$ до $25 \cdot 10^3$
6.0	от $25 \cdot 10^3$ до $30 \cdot 10^3$

2.7. Identify the value of a heat input:

$$q_p = \frac{36 \cdot I_w \cdot U_a \cdot \eta_e}{V_w}, \quad (6)$$

where  $\eta_e$  - effective efficiency of a heat treatment of a surface by arc ( $\eta_e = 0.8 \dots 0.85$ );

2.8. Calculate a coefficient of a penetration form:

$$\varphi_p = k' \cdot (19 - 0.01 \cdot I_w) \cdot \frac{d_e \cdot U_a}{I_w}, \quad (7)$$

where  $k'$  - a coefficient that depend on the type of a current, its polarity and its density in electrode;

$\varphi_p$  - a coefficient of a penetration form.

Under current density  $j < 120 \frac{A}{mm^2}$  and DC welding on reverse polarity a coefficient  $k'$  is defined according to the equation:

$$k' = 0.367 \cdot j^{0.1925} \quad (8)$$

Under current density  $j < 120 \frac{A}{mm^2}$  and DC welding on direct polarity a coefficient  $k'$  is defined according to the equation:

$$k' = \frac{2.82}{j} \cdot 0.1925 \quad (9)$$

Under AC welding within all range of current density a coefficient  $k'$  equals 1.

Under current density  $j > 120 \frac{A}{mm^2}$  and DC welding on reverse polarity a coefficient  $k' = 0.92$ , on direct polarity -  $k' = 1.12$ .

Current density can be identified according to the equation:

$$j = \frac{4 \cdot I_w}{\pi \cdot d_e^2} \quad (10)$$

2.9. The actual depth of penetration under welding on chosen mode parameters is defined according to the equation:

$$h_p' = 0.076 \cdot \sqrt{\frac{q_p}{\varphi_p}} \quad (11)$$

2.10. Define the width of a seam according to the equation:

$$e_p' = \varphi_p \cdot h_p' \quad (12)$$

The value of an actual depth of penetration and an actual width of a seam should not differ from set values more than 5%. When the difference exceeds this 5% the mode parameters shall be adjusted and the calculation shall be carried out once more.

2.11. We define the wire feed speed based on the condition of an arc temperature balance according to the following dependency:

$$V_f = \frac{(I_w \cdot (U_{an} + \varphi) + I_w^2 \cdot \rho \cdot \frac{l_e}{F_e}) \cdot 36}{F_e \cdot \gamma_e \cdot \Delta h_e}, \quad (13)$$

where  $U_{an}$  – anode drop, B;

$\varphi$  – electronic work function, B;

$\rho$  – electrical resistivity of a metal at 300 °C, *microohm · cm<sup>2</sup> / mm* ;

$F_e$  – cross-section area of an electrode, cm<sup>2</sup>;

$\gamma_e$  – density of an electrode metal, g/cm<sup>3</sup>;

$\Delta h_e$  – enthalpy change of electrode metal at 300 °C, J/g.

2.12. Calculate an area of a deposited metal

$$F_d' = \frac{F_e \cdot V_f}{V_w}, \quad (14)$$

Obtained actual value of the deposited metal area shall not differ from set values more than 10%. When the difference exceeds this 10% the mode parameters shall be adjusted and the calculation shall be carried out once more.

2.13. Define actual height of reinforcement

$$g' = \frac{1.375 \cdot (F_d' - F_\Delta)}{e_p'}, \quad (15)$$

where  $F_\Delta$  – area of penetration, mm<sup>2</sup>

2.14. Define given depth of penetration according to the following equation:

$$h_p'' = h_p' + \frac{F_\Delta}{0.735 \cdot e_p'} \quad (16)$$

2.15. Calculate the height of a seam

$$H = h_p'' + g' \quad (17)$$

2.16. Draw a melting line. Form of penetration will be as semi-ellipse. Major semiaxis equals the height of a seam, and minor semiaxis equals half of seam width.

### 3. Specifics of mode parameters choice for second arc

To go to the next step we have to determine heating temperature of a metal under second arc. So that the distance between arcs will be in a range from 100 to 120 mm.

The initial temperature of a metal under the second arc we define according to the equations proposed by определяем по уравнениям Рыкалин NN.

To calculate the temperature after the first arc passing we accept the following model of a heated field (Figure 3):

a) we consider a heat input as a combination of two processes:

- 1) heating of an edge of web with focused point source with wattage  $q_{\text{CT}}$ ;
- 2) heating a flange with with focused point source with wattage  $q_{\text{П}}$ .

Values  $q_w$  and  $q_{\text{web}}$  depend on the angle of inclination of an electrode and ration of thickness between web and flange. The fraction of a heat input for the flange according to the recommendations presented in work [8] shall be calculated based on the following equation:

$$k_{\text{web}} = 0.374 \cdot \sqrt{\frac{\delta_w}{\delta_{\text{web}}}}, \quad (18)$$

Then the fraction of a heat input for the web might be calculated according to the following equation:

$$k_w = 1 - k_{\text{web}}, \quad (19)$$

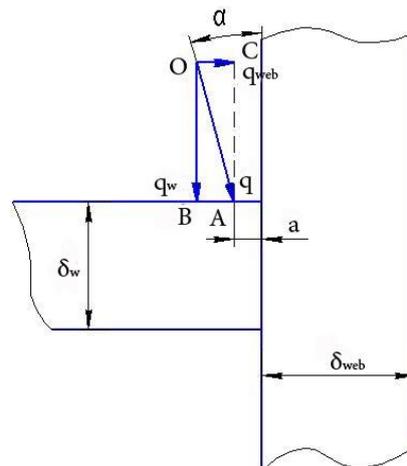


Figure 3 - Scheme of a heat input from the first arc

After calculation of a temperature of a metal under the second arc we define mode parameters for the second arc.

The second arc shall provide needed legs of a seam and its formation with graded junction to the main metal.

To calculate mode parameters for the second arc we need to make a draught of a weld joint with indication of a seam from the first arc so that we can draw a leg to a flange and following the scheme, given above, define the offset distance of an electrode to the web for the second arc.

The calculation of weld modes and parameters of a seam shall be carried out according to the same scheme as we used for the first arc with allowances made for heating of a metal by the first arc. For doing so we shall find current load according to the following equation:

$$I_w = B \cdot (80 \dots 100) h_p \quad (20)$$

where  $B$  – a coefficient that represents the influence of a heating by the first arc -  $B = \sqrt{\frac{\Delta T_2}{\Delta T_1}}$

To identify the depth of penetration we need to use the following equation:

$$h = \sqrt{\frac{\Delta T_1}{\Delta T_2}} \cdot 0.076 \cdot \sqrt{\frac{q_p}{\varphi_p}} \quad (21)$$

#### 4. Conclusion

Carried experimental accuracy check of mode parameters with the given recommendations showed acceptable repeatability (within 10%) of calculated results and parameters of actual weld seams. As can be seen from the above the recommendations given in the present article might be used for calculation of mode parameters under twin welding of fillet welds in separate melting pools with inclined electrode.

#### References

- [1] Kuanfang He: Ethernet solutions for communication of twin-arc high speed submerged arc welding equipments / Kuanfang He, ZhuoJie Zhang, Jun Chen, Qi Li // Journal of computers 2012 (12) 3052-3059
- [2] Cho D.-W. Analysis of the flux consumption and metal transfer for tandem submerged arc welding process under iso-heat input condition / Cho D.-W., D.V. Kiran, S.-J. Na // Welding Journal 2015 (94) 396-401
- [3] Chechulin U.B.: Совершенствование технологии сварки поясных швов двутавровых балок [*Improvement of welding technologies under welding of circumferential seams of H-beams*] / Chechulin U.B, Melnikov A.U., Sjukaev G.M., Kozhuhkar A.F., Shumyakov V.I. // Welding and Diagnostics: Abstracts from reports presented at scientific and technical conference. – Ekaterinburg, 2011 145-150.
- [4] Buzorina D.S.: Расчет параметров режима многопроходной механизированной сварки в защитных газах для получения качественных сварных соединений [Calculation of mode parameters of mechanized multi-pass welding in protective gases for quality of welded joints]. Welding and Diagnostics, 2014 (3) 13-17.
- [5] Попков А.М.: Расчет параметров режима двухдуговой сварки угловых и стыковых швов [*Mode parameters calculation under twin arc welding of fillet and butt-joint seams*]. Welding International, 1998 (7) 3-5.
- [6] Melnik S.S.: Многодуговая автоматическая сварка стальных корпусных конструкций под флюсом АН-66 [*Multiarc automatic submerged arc welding of steel housings of AN-66*] / Melnik S.S., Ksenz N.D., Kukhareenko V.V.: Welding International, 1984 (8) 37-38.
- [7] Попков А.М. Методика расчета параметров режима сварки тавровых соединений с неравнокатетными угловыми швами [*Calculation method of mode parameters for T-joints with not identical legs for the fillet joints*]. Welding International, 2002 (12) 3-4.
- [8] Belchuck G.A. Распределение тепла между элементами таврового соединения при дуговой сварке [*Distribution of heat within elements of T-joint under twin arc welding*]. Welding International, 1959 (5) 13-15.