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CALCULATION OF THE RADIUS OF TRANSITION OF THE WELD TO BASE METAL OF ALUMINIUM ALLOY WELDED JOINTS

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The objective of the work was establishing a mathematical dependence between the radius of the weld transition to base metal and ratio of weld height to its width in butt welded joints of aluminium alloys. During investigations, the authors used the published data on geometrical dimensions of butt joints of aluminium alloys of the second, fifth, sixth and seventh series to DSTU ISO 209-1:2002 made by consumable and nonconsumable electrode argon-arc welding, as well as consumable electrode pulsed-arc welding. When plotting the sought dependencies, regression analysis was conducted with application of MathCAD system. An analytical formula was obtained in the form of a polynomial with fractional powers to determine the radius of weld transition to base metal, as a function of the ratio of reinforcement height to its width on the joint face side. It is found that the proposed formula can also be recommended for determination of the radius of transition of the weld back bead to base metal. 19 Ref., 3 Tables, 2 Figures.

Keywords: *butt welded joint, aluminium alloys, gas-shielded welding, weld geometry, radius of weld transition to base metal, back bead, regression analysis*

Stress concentration in a zone of transition from weld to base metal is one of the main factors determining fatigue resistance of welded joints [1]. The experience shows that stress concentration shall be taken into account not only at vibration loading, but also at static loading and impact, when brittle fracture is possible [2]. Besides, stress concentration can be a reason of crack formation in process of heat treatment [3], which is used for welded joints in order to eliminate residual stresses and deformations [4].

The dominant effect on a level of stress concentration in welded joint has a radius of weld transition to base metal r [5]. The procedures of measurement of this radius is very labor-consuming and present known difficulties [6], therefore determination of its relationship with height h and width g of reinforcement of butt weld, which are relatively easy for measurement, considerably simplifies and accelerates practical calculations of strength and durability of welded structures.

Dependencies of such type were earlier obtained for steels [7]. However, a value of transition radius and parameters of weld convexity depend, in particular, on mode of welding and thermophysical properties of metal being joined [8, 9]. Therefore, acquiring of such dependencies for joints of aluminium alloys, obtained using arc welding processes, is still relevant today.

Table 1. Geometry parameters of butt welded joints of aluminium alloys

No.	Alloy	Welding method	Thickness δ, mm	Transition radius r, mm	Reinforcement height h, mm	Reinforcement width g, mm	Source
1	1915T	MIG	1.7–2.0	2.65	0.30	7.60	[10]
2	AD33T1	MIG	6.0	1.32	1.39	21.20	[11]
3	AMg2M	MIG	1.45	1.27	0.80	8.18	[12]
4	AD33T1	MIG	6.0	1.13	1.67	16.90	[11]
5	AD33T1	MIG Pulse	6.0	1.10	1.73	17.40	[11]
6	AD33T1	MIG Pulse	2.0	1.01	1.23	7.20	[14]
7	AMg6	MIG Pulse	2.0	1.00	1.10	9.05	[13]
8	AMr6	MIG Pulse	6.0	0.75	2.55	18.20	[12]
9	1915T	MIG	1.7–2.0	0.51	1.30	6.80	[10]
10	AMg6	MIG Pulse	2.0	0.55	1.34	6.59	[14]
11	D16T	MIG Pulse	2.0	0.54	1.15	5.20	[13]
12	D16T	MIG Pulse	2.0	0.39	1.19	5.33	[14]
13	1915T	MIG	1.7–2.0	0.24	1.60	6.00	[10]
14	1915T	MIG	1.7–2.0	0.20	2.15	6.20	[10]

Note. Metal inert gas welding — MIG; tungsten inert gas welding — TIG; Pulse metal inert gas welding — MIG Pulse.

Table 2. Relationship of height to width of reinforcements of butt welded joints and corresponding to them values of transition radiuses from weld to base metal

No.	*h*/*g*	Transition radius *r*, mm
1	0.039	2.65
2	0.066	1.32
3	0.098	1.27
4	0.099	1.13
5	0.100	1.10
6	0.171	1.01
7	0.122	1.00
8	0.140	0.75
9	0.191	0.51
10	0.203	0.55
11	0.221	0.54
12	0.223	0.39
13	0.267	0.24
14	0.347	0.20
Note. Numbers correspond to numbers in Table 1.		

In course of several decades the Department of strength of welded structures of E.O. Paton Electric Welding Institute has been carrying the measurements of profiles of butt welded joints of aluminium alloys of different series to DSTU ISO 209-1:2002, made by different gas-shielded arc welding methods (Table 1).

Based on discrete data the computer assisted design system MathCAD provides the possibility to plot a regression dependence of one value from another in form of n-power polynomial, where *n* is the positive integer [15]. However, application of integral indices at small number of terms of the polynomial provides low accuracy of approximation, since in the considered case (Table 2) *h/g* relationship takes the values differing from each other almost by order. Therefore, the dependence of radius of transition from the weld to base metal on *h/g* parameter is reasonable to seek in form of the polynomial with fractional powers [7]:

$$r\left(\frac{h}{g}\right)=\sum_{i=0}^{n}a_i\left(\frac{h}{g}\right)^{\frac{i}{2}}, \qquad (1)$$

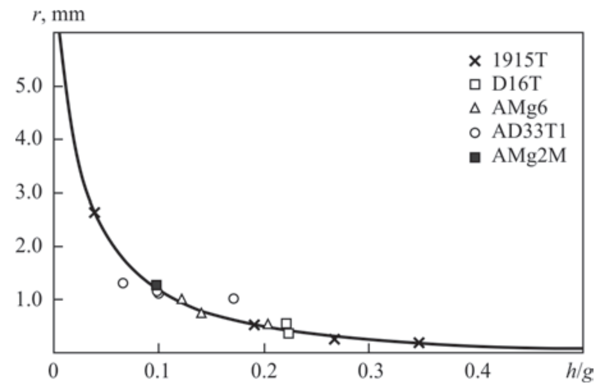

Figure 1. Dependence of transition radius from weld to base metal on relationship of height to width of reinforcement and calculation curve on equation (2) for butt joints of aluminium alloys made by gas-shielded arc welding

where a_i is the coefficient of regression function.

Accuracy in use of the first eight terms of the approximating series with integral indices is lower than when using the first five terms of such series with fractional powers.

Besides, in the considered case the function described by high power polynomial is not monotone in the investigated interval of change of *h/g* relationship from 0 to 0.5.

Using the first five terms of approximating series (1) allowed getting the function

$$r\left(\frac{h}{g}\right)=9.215-53.22\left(\frac{h}{g}\right)^{1/2}+127.05\left(\frac{h}{g}\right)-143.43\left(\frac{h}{g}\right)^{3/2}+62.74\left(\frac{h}{g}\right)^{2}, \qquad (2)$$

which demonstrates a strict monotone decrease in the interval of change of *h/g* relationship from 0 to 0.5 and does not have inflections in this interval (Figure 1).

The separate interest is the transition radius from weld to base metal on the root side of butt welded joint, since the maximum level of stress concentration

Table 3. Geometry parameters of root side of butt welded joints of aluminium alloys

No.	Alloy	Welding method	Thickness δ, mm	Transition radius *r*, mm	Reinforcement height *h*, mm	Reinforcement width *g*, mm	*h*/*g*	Source
1	AD33T1	MIG Pulse	6.0	0.76	1.38	7.90	0.175	[11]
2	AD33T1	MIG Pulse	6.0	0.72	1.38	7.80	0.177	[11]
3	D16T	MIG Pulse	5.0	0.52	1.03	4.51	0.228	[12]
4	AMg6	MIG Pulse	6.0	0.51	1.29	4.38	0.295	[11]
5	1915T	MIG	1.7–2.0	0.45	2.30	7.60	0.303	[10]
6	AD33T1	MIG Pulse	2.0	0.37	1.37	4.70	0.291	[14]
7	1915T	MIG	1.7–2.0	0.31	1.40	5.10	0.275	[10]
8	D16T	MIG Pulse	2.0	0.31	1.20	3.75	0.320	[13]
9	AMg6	MIG Pulse	2.0	0.31	1.10	3.72	0.296	[14]
10	AMg6	MIG Pulse	1.5	0.30	0.56	2.33	0.240	[12]
11	D16T	MIG Pulse	2.0	0.26	0.97	3.50	0.277	[13]
12	1915T	MIG	1.7–2.0	0.18	1.20	4.50	0.267	[10]
13	1915T	MIG	1.7–2.0	0.07	2.00	5.40	0.370	[10]

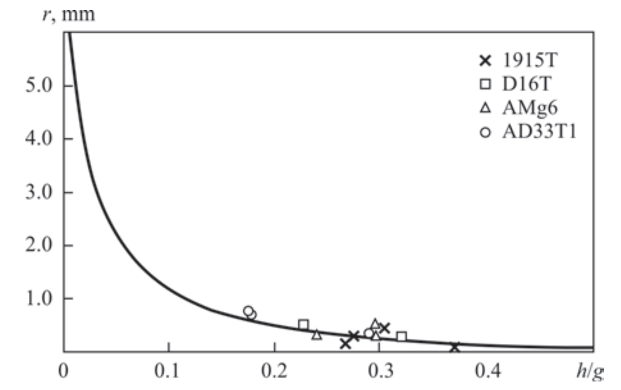

Figure 2. Dependence of transition radius from weld back bead to base metal on relationship of height to width of weld reinforcement and calculation curve on equation (2) for butt joints of aluminium alloys made by gas-shielded arc welding

at specific relationships of dimensions occurs close to back bead [16].

The processes of deformation of face and root surfaces of weld pool under effect of gas-dynamic arc pressure are significantly different [17]. Besides, in order to eliminate metal burn-through and provide quality formation of back side of the weld there is use of removable backing forming elements [18].

Geometry parameters of root convexity are virtually determined by dimensions of groove of forming backing [14, 19]. At that it is unkown whether the determined connection is preserved between the transition radius from the weld root part to base metal with relationship of height to width of the back bead.

The experimental measurements [10–14] showed that the same as on the face side, the radius of transition from the weld root part to base metal rises with decrease of relationship of height to width of back bead (Table 3).

The experimental points (Table 3) give sufficiently accurate description of the calculation curve (Figure 2), therefore, formula (2) can be recommended for determination of the transition radius from weld to base metal on face as well as root side of butt joints of aluminium alloys of different alloying systems made by gas-shielded arc welding methods.

Conclusions

1. The data from different authors on experimental measurements of the transition radius from weld to base metal in butt joints of aluminium alloys made by gas-shielded arc welding methods were collected and arranged.

2. A functional dependence of fillet radius of the weld with base metal from relationship of height to width of weld reinforcement on face side of butt welded joint was obtained by means of regression analysis of discrete experimental data using computer assisted design system MathCAD.

3. Further analysis showed that the obtained dependence can also be used for calculation determination of fillet radius of the weld back bead with base metal on the root side of welded joint through relationship of height to width of back bead.

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