THE STUDY OF THE CURRENT DURING DOUBLE SPOT WELDING

Bogdan GEORGESCU[1], Dan Cătălin BÎRSAN[1]

[1]"Dunarea de Jos"" University of Galati
email: Bogdan.georgescu@ugal.ro

ABSTRACT

Spot welding is widespread across various manufacturing industries. During double spot welding, the welding current decreases due to the loss through the plate from the electrodes, and a part of the current is cut off by the source. In this paper, an equivalent electrical scheme is proposed and calculation relations for the branched currents are established. Following numerical calculations, the influences of different factors on the necessary welding current are established and technological recommendations are made to reduce current losses.

KEYWORDS: spot welding, aluminum alloy.

1. INTRODUCTION

Spot welding is widespread across various manufacturing industries, such as automotive, aerospace, or even domestic heating equipment production. In the examples mentioned, welding is done by robots. However, these robots must first be programmed and calibrated by human specialists to ensure optimal welding performance.

What problems appear? For the first spot, a specific welding current and set of parameters are required. At the second weld spot, part of the current is lost or shunted through the first spot, so the welding current or regime must be adjusted— increased.

In some cases, access from both sides is not possible, so we have to perform indirect spot welding.

Indirect welding (double spot) is also called welding from one side. It is applied in the spot welding of large assemblies when both electrodes are positioned on thesame side of the joint, which reduces the surface area covered by the transformer's secondary circuit, resulting in lower short-circuit impedance. This aspect represents an advantage in terms of the apparent power required for welding sheet metal of a certain thickness.

Double spot guns with a built-in transformer are used as shown in Fig. 1. For light operations (body repairs), we can replace the pliers with two electrodes that we press manually in the desired areas.
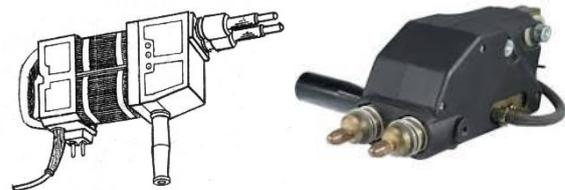

Fig. 1. *Double spot gun*

Depending on the position of the gun towards the direction of the joint and on its particularities, three welding alternatives are known as shown in Fig. 2.

a) Indirect welding with a single spot. It is used for welding sheets up to 2.5 mm thick. The welding current closes through the additional electrode with increased contact surface (Fig. 2a).
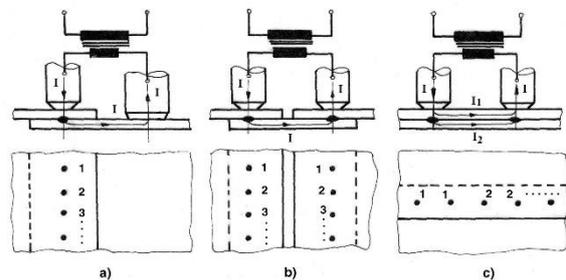

Fig. 2. *Indirect welding variants*

b) Double spot welding without a shunt. Due to the fact that two plates are welded to a third one, the entire current drawn by the transformer passes through the contact areas (Fig. 2b). It is used in the wagon building industry to weld sheets up to 2.5 mm thick on a rigid frame.

c) Double spot welding, with current shunting (Fig. 2c). The current is given by the transformer branches. One part, the I_1 shunt current, passes through the upper sheet without participating in the making of the welded joint, and another part, I_2, due to which the welding spots are formed, circulates through the surface of separation near the electrodes. When welding two plates of the same thickness and material, the I_1 shunt current is significantly higher than the I_2 welding current. This occurs because the electrical resistance along the I_1 path is lower and that of the I_2 current, which also passes through the contact resistances between the parts (Fig. 3a). To increase the amount of the needed welding current, it is recommended to use a copper support as in Fig. 3b. In this case the I_2+I_3 welding current will be higher than the I1 shunt current.

If the route in the upper plate is longer (Fig. 3c) or 2-3 times less thick than the lower plate (Fig. 3d), the copper support can be removed. The same thing is possible when welding sheets of the same thickness but from materials with very different electrical resistance, for example, stainless steel and carbon steel.
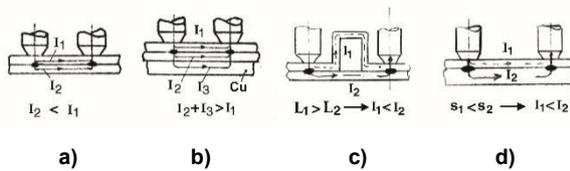

Fig. 3. *Variants of welding with current shunting*

2. ESTABLISHING THE CALCULATION RELATIONSHIP

For this study, we will consider the situation in Figure 4a, with the welding of two steel plates on a copper support, for which we can establish the equivalent circuit plan from Figure 4b.
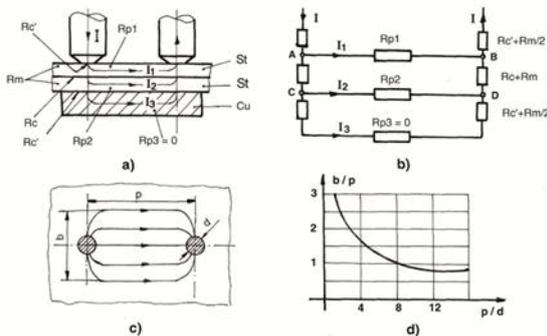

Fig. 4. *Elements of the circuit plan*

The resistances R_c, R'_c, R_m, and R_p interfere in the welding circuit.

R_c – electrical contact resistance between welding components. It can be calculated with the known formula:

$$R_c = \frac{K}{F^x} \qquad (1)$$

R'_c – electrical contact resistance between the electrodes and the welding plates. Considering the contact resistance for copper as negligible, it will be:

$$R'_c = \frac{R_c}{2} \qquad (2)$$

R_m – electrical resistance of the metal under the electrodes. It can be calculated in a simplified way; if we consider the metal cylinder restricted by the tip of the electrodes, with the formula:

$$R_m = \frac{\rho \cdot l}{A} = \rho \frac{\rho 4S}{\pi d_e^2} \qquad (3)$$

In reality, this resistance is much lower, and it has to be corrected with the following factors:
-$K_1 = 0.4...0.8$, to take into account the actual current passing section which is larger than the surface of the electrodes;
-$K_2 = 0.75...0.85$, to take into account the even more pronounced scattering of the current due to the heating of the material. It will preferentially pass through the side areas, colder, compared to the heated central area, with the higher resistivity.
R_p – the inherent resistance of the material between the electrodes:

$$R_p = \frac{\rho \cdot l}{A} = \rho \frac{p}{b \cdot s} \qquad (4)$$

To calculate its resistance, we need to know the width "b" of the current's passing area from one electrode to another (Fig. 4c). This depends both on the pitch of the point "p" and on the contact diameter, as in Figure 4d [3].

Due to the very low resistivity of copper, we can neglect its own resistance ($R_{p3} \approx 0$).

From the electric circuit, considering the welding current $I_s = I_2 + I_3$, it will result:

$$U_{AB} = I_1 \cdot R_{p1} = I_s \cdot R_{ACDB}$$

so the ratio between the welding current and the shunt current will be:

$$\frac{I_s}{I_1} = \frac{R_{p1}}{R_{ACDB}} \qquad (5)$$

where:

$$R_{CD} = \frac{(2R'_c + R_m)R_{p2}}{2R'_c + R_m + R_{p2}} \text{ and} \qquad (6)$$

$$R_{ACDB} = 2R_c + 2R_m + \frac{(2R'_c + R_m)R_{p2}}{R_c + R_m + R_{p2}} \qquad (7)$$

3. EXAMPLE OF NUMERICAL CALCULATION

To study the influence of different factors on this ratio, we will consider a concrete case of welding steel sheets with S = 1 mm, d_e = 5 mm, p = 7…12 daN/mm², F = 140…240 daN, resulting:

$$R_m = K_1 K_2 \frac{\rho 4S}{\pi d_e^2} = 4,9 \ \mu\Omega \qquad (8)$$

$$R_c = \frac{5 \cdot 10^{-3}}{(140...240)^{0,75}} = 125...83 \ \mu\Omega \qquad (9)$$

$$R'_c = \frac{1}{2}(R_{cOL} + R_{cCu}) = \frac{1}{2}R_c \qquad (10)$$

Considering the distance between the electrodes (the pitch of the points) p = 40 mm, from the graph in Fig. 4d, it gives us b = p and we will have:

$$R_p = \rho \frac{1}{A} = \rho \frac{p}{b \cdot s} = \frac{\rho}{s} = \frac{0{,}12}{10^{-3}} = 120 \; \mu \; \Omega \quad (11)$$

Analyzing these values, we notice that R_c and R_p are comparable in size, while R_m can be neglected. The final calculation result:

$$\frac{I_s}{I_1} = \frac{R_{p1}}{2R_c + \frac{R_c \cdot R_{p2}}{R_c + R_{p2}}} = \frac{R_{p1}(R_c + R_{p2})}{2R_c(R_c + R_{p2}) + R_c \cdot R_{p2}} \quad (12)$$

CONCLUSIONS

A. Considering the welding of equal thicknesses of the same material, with equal electrical resistances R_{p1} and R_{p2}, the ratio I_s/I_1 will be influenced by the factors:
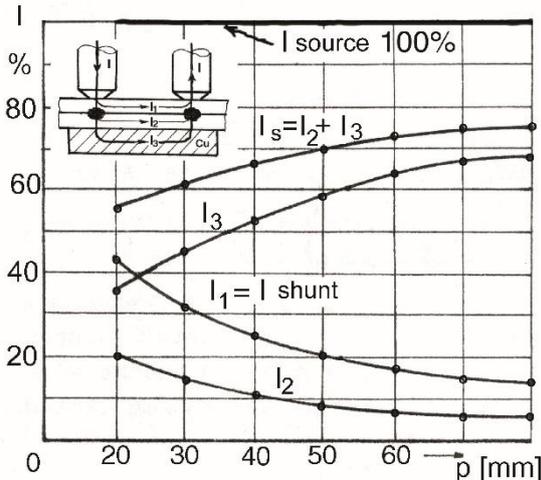
a) the size of the inherent resistance R_p; the welding current Is increases with it; the increase of R_p is obtained with the reduction of the b/p ratio (Fig. 4d), as a minimum distance between electrodes p ≥ (8…12) de is required.

b) the size of the contact resistance, R_c, in comparison with the inherent resistance, influences the reduction of the welding current as shown in Table 1. The reduction of contact resistance is favourable to the desired distribution of the currents, so it is necessary to clean the surfaces.

Table 1. *Editing The influence of the contact resistance on the welding current*

R_c/R_p	0.25	0.5	1.0	2.0
I_s/I_1	1.4	0.75	0.4	0.25

c) the distance between the electrodes (increasing R_p) influences the distribution of the currents through the components, as in Figure 5. We can see that we get a maximum welding current for a pitch greater than 70...80 mm.

Fig. 4. *The influence of the pitch on the distribution of currents*

B. Considering the welding of different thicknesses, the inherent resistances will be inversely proportional to the component thicknesses. For when $R_c = 2 R_{p2}$, the data presented in Table 2 will result. The thickness inequality favours the welding process, only if the thinner sheet is arranged towards the electrodes. Due to the drastic reduction of the welding current, it is not possible to obtain the points if $s_1 > (2…3) \cdot s_2$.

Table 2. *The influence of sheet thickness on the welding current*

$\dfrac{s_2}{s_1} = \dfrac{R_{p1}}{R_{p2}}$	0.25	0.5	1	2	3
I_s/ I_1	0.18	0.37	0,75	1.5	2.25

C. In the case of materials with different thermophysical characteristics, the ratio of the inherent resistances also changes:

$$\frac{R_{p1}}{R_{p2}} = \frac{\rho_1}{\rho_2}$$

with the same result presented above. Therefore, the welding process is favored when access is made from the sheet with lower electrical conductivity, rather than from the one with higher conductivity.

REFERENCES

[1] **Mandal, A.-K., Kumar, R., Kumar, B., Rani, D.**, *Probing the effect of pre- and post-heating in resistance spot welded multi-material system through response surface methodology*, International Journal of Advanced Manufacturing Technology,139, 2025, pag. 5025 - 5042;

[2] **Khaleel, H. H.**, *Fatigue and impact properties of single and double resistance spot welding for high-strength steel used in automotive applications*, International Journal of Advanced Manufacturing Technology, 2023;

[3] **Shiri, S.,** *Resistance spot welding of DH1200 using short pulses (single-pulse and double-pulse),* International Journal of Lightweight Materials and Manufacture, 2025;

[4] **Lee, H. T., Chang, Y. C.**, *Effect of Double Pulse Resistance Spot Welding Process on 15B22 Hot Stamped Boron Steel*, Metals, 10, 2020, pag. 1279 –1298;

[5] **Soomro, I. A., Pedapati, S. R., Awang, M.**, *Double Pulse Resistance Spot Welding of Dual Phase Steel*, Materials, 2021;

[6] **Feizollahi, V., et al.,** *Factors affecting weld quality in resistance spot welding (including multi-pulse effects)*, *Sci Rep* **15**, 30012, 2025;

[7] **Wei, Y.**, *Double Pulse Process of Resistance Spot Welding*, Steel Research International, 2025;

[8] **Janardhan, G.**, *Failure mechanism of resistance spot-welded DP600 steel*, MaterialsToday Proceedings, Vol. 59, 2022, pag.1666 - 1671;

[9] **Görtan, M. O.**, *Effect of Double-Pulse Strategy on the Expulsion Formation and Peak Loads During Resistance Spot Welding of Dissimilar Thickness Ultra-High Strength MS1500 and Mild DD11 Steels*, HJSE (Harran Journal of Engineering), 2025, vol. 12, issue 1, pag. 51 – 58.