Research Regarding Capacitor Discharge Stud Welding with Tip Ignition on Galvanized Thin Sheets

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Abstract. Arc stud welding is a widely used welding process used to fix joints like studs, screws, pins, or similar elements on a wide variety of products. The process is mainly characterized by simplicity, high welding productivity, very good welding joint quality, low cost price, easy welding equipment and easy to handle, flexibility. The process successfully replaces other assembly methods such as: threaded assembly, riveting, classic arc welding or pressure welding and soldering. The paper proposes to establish welding technology for M5 x 35 mm steel stud with tip ignition and electric charge stored in capacitors on thin galvanized steel (s <1 mm thick). The main problem of welding galvanized steel is vaporization of zinc on the surface of the sheet which produces pores, splashes and very toxic fumes. This vaporization produces also the corrosion hazard in the surface of the sheet. Welding technology will be applied to joint stud on the cover of an air filter.

1. Introduction

The principle of stud welding with tip ignition is relatively simple. The stud is initially fixed by the welder operator in the elastic muff of the special welding torch and positioned on the surface of the workpiece. By pressing the torch trigger, the welding current passes through the stud producing the heat of the tip stud. By easy lifting and for a short time the stud on the surface an electric arc is primed that produces the melting of the stud tip and the local melting of the piece. At the interruption of the electric arc, the stud is pushed by a relatively small force, by means of a spring placed in the head of the torch, in the welding pool, and by joining and solidifying the common bath results the welded joint [1].

Depending on the spring arc mode, the duration of the welding time, the type of metal bath protection, the type of the source, the arc stud welding process can be performed in several variants. For this application is of interest arc stud welding with tip ignition and electric charge stored in capacitors [2]. The particularities of this welding process are:
- The diameter of the stud \( d_b = 3...10 \text{mm} \);
- Welding current: \( I_s \leq 5000 \text{A} \);
- Welding time: \( t_s \leq 10 \text{ms (1 .. 3 ms)} \);
- Electric arc and welding pool protection: It does not require protection;
- Minimum thickness of the workpiece: 1/10 of the diameter of the stud (\( s_{\text{min}} = 0,6 \text{mm} \));
- Stud material: carbon steel, high alloy steel (stainless steel), aluminum or brass on metal surfaces.

Due to a penetration depth of only 0.1 mm, the welding of the studs by this process leaves no trace, staining or deformation even on galvanized or painted surfaces on the opposite side of the sheet even at small thicknesses.

Figure 1 shows the principle of arc stud welding with tip ignition and electric charge stored in capacitors.

![Figure 1. The principle of arc stud welding with tip ignition [1].](image)

2. Welding parameters

In the case of arc stud welding, the quality of welded joints depends decisively on the correct setting of welding technology, more precisely the choice of technological welding parameters and less the skill of the welding operator. This is explained by the fact that the welding takes place in a very short time (usually less than 1.5 s), and the process takes place without the intervention or the participation of the welder operator.

The main technological parameters in arc stud welding are the welding current (I_s) and the welding time (t_s), which act on the power of the electric arc, respectively on the welding energy, with implications of welding pool volume, the penetration, the degassing or the danger of defects occurrence in the weld joint [6].

The determination of the main technological parameters of welding can be done by using empirical relations presented in table 1 [6].

| Welding current | I_s = 80\_d_b | For stud diameter < 12 mm |
|-----------------|----------------|--------------------------|
| I_s (A)         | I_s = 90\_d_b | For stud diameter 12–25 mm |
| Welding time t_s (s) | t_s=0.04\_d_b | For all stud diameters |

Arc welding of studs can be carried out both in direct current and in alternating current. Continuous current is preferred for increasing the arc stability. In alternating current, the arc blow is eliminated. When direct current welding is used, direct polarity is preferred which provides easier priming of the electric arc [3].

An important technological aspect in the welding of studs is the danger of a strong arc blow that can affect the quality of the weld joint.

Due to the very short welding time and process without the participation of the welder operator, it is not possible to control the arc blower by operator intervention as can be done with the classic manual welding. It is therefore necessary to take additional measures to reduce or avoid the magnetic arc blow [4].

The most important measure to avoid the magnetic arc blow is the use of symmetric workpiece connection, knowing that the arc blow always manifests in the opposite direction to the workpiece contact, figure 2 [6].
In this way new welding sources are provided with two workpiece connections. Positioning of the torch is also very important in this case, in order to cancel the magnetic arc blow, the torch should be oriented perpendicularly to the joining.

3. Technological aspects of galvanized sheets welding
The main problem is vaporization of zinc on the surface of the sheet which produces pores, splashes and very toxic smoke. Welding process can also produce the corrosion of the sheet in the surface area because the zinc is burned from the surface [2].

MAG welding can be done in CO$_2$ or gas mixtures Ar + CO$_2$, and with a welding speed of less than 20 cm / min by comparison of steel sheets welding. Oxy-fuel welding is applied at thicknesses below 3 mm and has the disadvantage that the zinc layer is destroyed on a very large area. Manual metal arc welding can be done at low welding speed recommended, high opening of joints, oscillation of the electrode and the use of slag electrodes that slowly solidify to allow the pore out of the welding pool. TIG welding does not apply because vaporization of zinc causes electric arc instability by coating the tungsten electrode with zinc oxide [6].

Regardless of the process used, it is recommended that at welding to have ventilation to remove smoke (zinc oxide).

For welding studs there are mainly 3 welding processes as follows:
- drawn arc stud welding with ceramic ferrule or shielding gas;
- short-cycle drawn arc stud welding;
- capacitor discharge drawn arc stud welding or capacitor discharge stud welding with tip ignition [6].

Starting from the particularities of these processes and the characteristics of the given application, it results that the possible welding process to be applied is capacitor discharge stud welding with tip ignition.

Characteristic of this process are the shape and dimensions of the fusible tip having a cylindrical shape with a diameter of 0.5-0.75 mm and a length of less than 1 mm. The welding process can be applied to the stud with a diameter between 2 and 10 mm.

4. Experimental research
Research has been done to establish the welding technology of capacitor discharge stud welding with tip ignition for M5x35mm studs on thin sheets (s <1 mm thick) covered by galvanizing. The suitable welding technology from a qualitative point of view will be applied to the welding of studs on the air filter cover.
The difficulty of stud welding in this case is determined by the following:
- low thickness of the sheet \( s = 0.75 \text{ mm} \) leading to the danger of penetration of the workpiece during the welding process;
- coating the sheet by galvanizing with a thin layer of zinc leading to the danger of material expulsion and pores in welding area due to zinc evaporation;
- absence of information in the literature on welding of galvanized thin sheets by capacitor discharge stud welding.

For welding the stud, it is necessary before marking the welding spot on the surface of the workpiece. This operation can be done by drawing with the vernier caliper or by using a jig. This marking is presented in figure 3 and 4.

In the first case it is observed that the location of the stud is determined by a line, and in the second case it is marked by a point obtained by plastic deformation using a pointing device.

The first marking method is simple but has the disadvantage of scratching the piece and removing the zinc layer which can lead to local corrosion in time, respectively the wrong positioning of the stud over the drawing as a result of sliding the stud on the piece when the torch is fixed. The second method eliminates the disadvantages presented above because the tip of the stud is guided in the local plastic deformation that appears on the piece.

The disadvantage of this method is that plastic deformation can lead to changing the welding process conditions by reducing the length of the electric arc. This can lead to influencing the quality of the welded piece, therefore the application of this method should avoid a local plastic deformation with a depth greater than 0.1 - 0.15 mm.

4.1 Verification of welding technology
Manufacturers of capacitor discharge stud welding equipment give technological recommendations regarding the capacitor loading voltage depending on the diameter of the stud, respectively the capacity of the capacitor. Capacitor capacitance differs from one equipment manufacturer to another. Therefore, a welding technology recommended by a manufacturer cannot always be applied to welding equipment of another manufacturer because it would lead to different welding energies. Also recommendations are valid for welded steel stud on the not galvanized sheet.

Research was carried out with a HBS KES 2100 equipment. This source has a capacitor capacitance of 88 000 \( \mu \text{F} \). Following the calculations resulted 100 V of a capacitor voltage.

Figure 5 shows the welded stud appearance following bending technological test [5].
It is to be noticed that the welded stud resistance is adequate, since the stud has been bent at an angle greater than 60 degrees, without detachment of the stud and without cracks. With this technology were made welds on 0.75 mm thick galvanized sheet [5].

Four weldings were made using different capacitance loading voltages (figure 6), respectively two ways of marking the welding place by drawing or plastic deformation as shown in figures 3 and 4.

![Image](image-url)

**Figure 6.** Welded studs with different capacitor loading voltages; 1- 100V; 2-100V; 3- 115V; 4-130V.

The test voltage for the first two studs was 100 V following the influence of the marking method on the stud welding quality. The studs were tested by bend according to ISO 14555 [5]. No major qualitative differences are observed regarding the influence of the marking method on the resistance of the welded point. However, in both situations the melting does not occur on the entire section of the stud.

This may lead to the conclusion that in the case of a galvanized sheet, a higher loading voltage is necessary. Therefore studs 3 and 4 were welded with 115V or 130V. We notice the beneficial effect of increasing the voltage by increasing the tear section of studs.

These tests lead to the conclusion that the stud welding on the finished product is recommended to use a capacitor loading voltage of 130 V.

Experimental investigations continued on samples of 0.75 mm galvanized sheet using Soyer BMS 8H source. The welding quality has been checked for different values of the capacitor loading voltage corresponding to the voltages of 90 V, 115 V, 130 V and 150 V. The appearance of the welds is shown in the figure 7.

In order to highlight the influence of the capacitor loading voltage on the welding resistance, initially 90 V and 115 V voltages were used, characterized by insufficient energy for an M5 stud. This is observed following the technological torque test when weld failure (figure 8). Increasing the voltage at 130 V, respectively 150 V determines the best quality of the welded point because the welding has broken off the sheet without failure.

![Image](image-url)

**Figure 7.** The appearance of the welds.

**Figure 8.** Torque test of the welds.

After the attempts made on the galvanized sheet were welded studs on the air filter cover trying different welding technologies.

The charging voltage used for welding on galvanized sheet of 115V, 130V turns out to be inappropriate when welding on the air filter cover, partial welding of the stud is observed. From the analysis it was found that the cover of the sheet was made by galvanizing and the cover of the air filter...
was made by thermal zinc coating. The result is that in the case of zinc galvanizing, the thickness of the zinc layer is much smaller and more uniform than in the case of thermal coating.

5. Conclusion
Welding technologies have been made with welding installations from different companies were implemented, namely the KES 2100 equipment from HBS and the Soyer BMS-9 welding equipment. Welding technologies proposed by experimental research are:
- for the KES 2100 installation, optimal welding technology was 135 V and capacitor capacitance 88 000 μF;
- for the Soyer BMS-9 installation, optimal welding technology was 160 V and capacitor capacitance 66 000 μF;
- the two welding technologies are equivalent in terms of energy stored in the capacitor, the differences being determined by the capacity of the capacitors in the two installations, namely 88 000 μF at the HBS installation and 66 000 μF at the Soyer installation. In both cases, the accumulated energy is 800 J.

The appearance of welded studs on the finished product is shown in figures 9 and 10.

Figure 9. The appearance of the welded studs on the air filter cover. Figure 10. Stud appearance after avoiding coating with oxide.

From the analysis of the tests it can be seen that capacitor discharge stud welding with tip ignition for M5x35mm studs on the surface of the air filter with results corresponding to the quality, resistance and aesthetics being the only welding process possible to apply for such an application. In addition, it is noted that it has been solved to avoid covering the area adjacent to the stud with oxide (figure 10).

6. References
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