EXPERIMENTAL RESEARCH ON ULTRASONIC WELDING OF MATERIAL COMBINATIONS COPPER-COPPER

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Abstract: This paper presents the optimum ultrasound welding parameters of copper sheets using static analysis methods results and microscopic structural analysis. Also it get the conclusion that weld formation it’s produced after the plastic deformation process of metals because the action of ultrasonic energy in the joint area.

KEYWORDS: Ultrasounds, Optimum technology, Copper

1. THEORETICAL CONSIDERATIONS

Ultrasonic welding of metallic materials is part of the processes of welding pressure in solid shape. Energy required for welding is introduced in welded components, the challenge of combining vibrations instead, with an appropriate frequency ultrasound (16 × 10³ … 10¹⁰ Hz), welded components are pressed with a normal force on their surface contact.

The simultaneous action of vibration and pressing force producing oscillating tension in the neighboring areas of contactless. This leads to slip and friction between the two components soldered, to expel oxides and impurities from the surfaces in contact, thus remain, easier hardware implementation of metal ties of the two components. In area a-a a welding point formed whose size depends on the time of welding (penetration is 50…400·10⁻³ mm). Area b-b , where the metal particles vibrate, is 2…3 more then in area a-a. [1],[3].

Processes occurring in ultrasonic welding of metallic materials must be understood as a series of phenomenals, which influence each other: development of heat and pressing superficial surface layers under the action of pressing and of friction; plastic deformation; hardening and recrystallization; diffusion and micro-welding continues training between those two welded metals. The most important part of an ultrasonic welding equipment is the ultraacoustic system. It contains the transducer, acoustic concentrators and tool.

In general, the choice of welding parameters it’s made from table, diagrams or nomograms. The chosen values of parameters represents just one starting point, because for each material and welding equipment type it sets optimal parameters of welding regime only experimentally.

In most cases the quality of welded joins is estimated metallographic way by determining the shearing-traction force \( F \), needed to break the join of two welded bars.

The statistic analysis of the results presumes the calculation of the following measures[1]:
- the medium value of the traction break force \( \overline{F} \), that is calculated with the relation:

\[
\overline{F} = \frac{1}{n} \sum_{i=1}^{n} F_i
\]  
(1)

- the corrected dispersion \( s^{-2} \), with:

\[
s^{-2} = \left( \frac{1}{n-1} \sum_{i=1}^{n} (F_i - \overline{F})^2 \right)^{-1} 
\]
\[
\bar{s}^2 = \frac{1}{n-1} \sum_{i=1}^{n} (F_i - \bar{F})^2
\]
- the corrected medium square deviation \( \bar{s} \), with:
\[
\bar{s} = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (F_i - \bar{F})^2}
\]
- the variation coefficient \( W \), with:
\[
W = \frac{\bar{s}}{\bar{F}} \cdot 100\%
\]
where: \( F_i \) is the tested value; \( n \) - number of measurements.
To exclude the result of a reject we use the student criterion:
\[
t = \frac{F_j - \bar{F}}{s}
\]
where: \( F_j \) is the tested value (the highest or the lowest in the \( n \) measurements); \( \bar{F} \) - the medium value of the traction break force.

To verify the hypothesis that two random medium values \( \bar{F}_1 \) and \( \bar{F}_2 \) belong to the same real value, first the „F” test is used:
\[
F = \frac{s_1^2}{s_2^2}
\]
and then the „t” test, under the form:
\[
t = \frac{\bar{F}_1 - \bar{F}_2}{s} \sqrt{\frac{n_1 \cdot n_2}{n_1 + n_2}}
\]
where: \( \bar{F}_1, \bar{F}_2 \) are the studied medium values; \( n_1, n_2 \) – the number of experiments where \( \bar{F}_1, \bar{F}_2 \) were determined; \( \bar{s} \) - the corrected medium square deviation, calculated as such:
\[
\bar{s} = \sqrt{\frac{f_1 \cdot s_1^2 + f_2 \cdot s_2^2}{f}}
\]
where: \( f_1=n_1-1; f_2=n_2-1; f=f_1+f_2=n_1+n_2-2 \) are the degrees of freedom.

2. EXPERIMENTAL RESULTS

To obtain high quality joints is sufficient degreasing copper specimens [1,2,3]. The samples were also determined optimum values of force and time pressure welding conditions: \( f = 21.6 \) kHz frequency and amplitude of the oscillation of the tool \( a_0 = (2,5 - 4,9) \times 10^{-2} \text{mm} \). Geometrical form of the active part is represented in Fig.1.

Amplitude of the oscillation measurement tool \( a_0 \text{Fig.2} \) has been established through the pressing force needed for welding copper samples (2444 N). For values greater than his magnitude is practically ascertained.
Using the pressing force $F_D = 2444 N$ and welding times $t=0.5 \, s$, $3 \, s$, $8 \, s$ and reproducible values were obtained resistance welding points (Table 1)

<table>
<thead>
<tr>
<th>Time of welding (N)</th>
<th>$\bar{F}$ (N)</th>
<th>$\bar{\sigma}^2$ (N)</th>
<th>$\bar{\sigma}$ (N)</th>
<th>$W$ (%)</th>
<th>$n$</th>
<th>Degree of deformation in the welded zone %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>950</td>
<td>1734</td>
<td>41.6</td>
<td>4.38</td>
<td>15</td>
<td>11.4</td>
</tr>
<tr>
<td>3.0</td>
<td>1400</td>
<td>1650</td>
<td>40.6</td>
<td>2.9</td>
<td>16.6</td>
<td></td>
</tr>
<tr>
<td>8.0</td>
<td>1478</td>
<td>2058</td>
<td>44.3</td>
<td>3.0</td>
<td>37.2</td>
<td></td>
</tr>
</tbody>
</table>

Tensile strength of base metal $F_{MB} = 1932 \, N$
It is found that weld strength depends on the number of welded areas (microwelds) of the welding point (Fig. 3, 4, 5, 6).

With increasing welding time increases the number and size of these zones increases weld strength. Thus the tensile strength increases from 47% of the base metal strength for t = 0.5s, 72% for t = 3s to 76% for t = 8s. Of these statistically significant increases in resistance.

Dependence of tensile strength and welding time, for different values of the pressing force is represented in Fig. 7. With increasing welding time from 3s to 8s increases the degree of plastic deformation apruvelor welded area, which leads to lower their section in this area, making them unusable. From these considerations it follows that the optimal welding time is t = 3 - 4s.

Strength of welded joints depends on the size of the pressing force $F$ (Fig. 8). In example, for t=3s and $F_p = 600 - 4292 N$ finds that from 600 N to 2444 N obtain a marked increase of tensile strength $\frac{F}{p}$, and from 2444 N to 4294 N the changing of $\frac{F}{p}$ is not significant statistically speaking. Physical sense of this reality is that the greater the downforce than the better conditions are created for the destruction of oxide layers, hence creating a greater number of welded parts.
Fig. 7 Dependence of tensile force $F$ during welding $t$.

Fig. 8 Dependence of breaking traction force $F$ pressing force $F_p$

Fig. 9 The variation of the $H_{VM}$ micro grid irregularity.
In addition, increasing pressure increases the degree of plastic deformation, which produces undesirable phenomenon—weakening of the weld section. As such the value $F_p = 2400 - 2700 \, N$ provide optimum conditions for obtaining quality welds.

The measured values of microhardness (Fig. 9) show that for $t = 0.5s$ and $3s$, hardening occurs in the joint as a result of plastic deformation of metals, which takes place when the joints are made. For higher welding speeds ($t=8s$) there is a decrease in the concentration of defects and recrystallization. Ultrasonic welding plant used for welding, is represented in Fig.10.
3. CONCLUSIONS

On ultrasonic welding of metallic materials, vibrations produced by magnetostrictive transducer and amplified by acoustic concentrators are transmitted at the join by a parallel plan with the contact surface. The simultaneous action of vibration and pressing force is producing oscillating tension in areas neighboring the contact. This leads to sliding between the two welded components at the expel of the oxides and impurities from the surfaces in contact, following such the achievement of metal connections of the two components;

The processes occurring in ultrasonic welding of metallic materials should be understood as a series of phenomena, which influence each other: development of heat and pressing superficial layers under the action of pressing and friction, plastic deformation, hardening and recrystallization, diffusion and formation of micro welds between the two components of the joint;

Almost all materials and metal alloys can be welded with ultrasound, but the procedure is not always the most economical. In each case, the optimal welding parameters are established experimentally;

Ultrasonic welding process is already applied industrially in the electrical industry to manufacture miniaturized components of different types of electrical contacts. The components that lead electrical power made of different materials, such as aluminum, copper, silver must be well welded along with calibrated thin wire with high power density.

REFERENCES

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