Experimental study of the ultrasonic welding effects in the metal joint microstructure

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Abstract. In this article will present the technology parameters effects in the case of thin copper sheets joining with agree of the material science theory and metalworking rules-based executed experiments. Known the dislocation theory of the ultrasound energy influence in the case of the metal working. The ultrasonic welding technology uses the ultrasound effect for increase the metal formability because the joint established by high-frequency vibration and pressing. The ultrasonic welding is a solid-state welding technology in which detectable the high-frequency vibration caused friction effected warming in the joint and the heat-affected zone. The established heat accompanied by plastic deformation can cause Changement in the joint microstructure as a function of the established heat, the heat transfer coefficient and the plastic deformation degree of the used metal. The relationship is founded between the experimented metal thin sheets welded joint mechanical properties, microstructure and the welding parameters. The joint mechanical and microstructural properties experimented by Vickers hardness test and visual inspections.

1. Introduction

The joining of thin metal sheets is a requirement of the industry. A lot of electrical boxes (Faraday cage) made from aluminium, copper or both thin sheets because of the high electrical conductivity under suitable strength and ductility.

The base theories of the researches were, the softening and the hardening of metals under ultrasound load, introduced by Blaha and Langernecker [1, 2] and another one A. Rusinko's studies of the plasticity and creep of metals [3, 4]. These studies complete the basic knowledge of the enhancement of the metals cristal structure under ultrasound effect. The scientific explanation of the mechanical properties and microstructure of the ultrasonic welding process established metal joint needs the knowledge of several factors to consider [2]. Strength of materials is influenced by the interaction between dislocation and impurities [5] investigated by different methods.

Well understood the recrystallization phenomenon of the metals. Even that in the case of the cold worked and heated (over recrystallization temperature) pure metals the result grain size depends on the cold working rate and the heat treating time [6, 7]. This heat-treatment by the recrystallization phenomenon cause softening of the metal and the changing in the grain size. During the ultrasonic welding as the function of the friction and the ultrasonic energy the temperature of the joint increase widely. The established heat and plastic deformation cause dynamic recrystallization in the joint means annealing and decrease the hardness and strengths [8]. The ultrasonic vibration, the plastic deformation
and thermal activation mechanism effect also modification of the dislocation dynamics. The acoustoplasticity is metal formability under a high-frequency ultrasound vibration [9]. The ultrasonic vibration enhances the activation energy and along with the plasticity and formability of the metal.

2. Material and welding processes
The used commercially pure copper (C1020) sheet (0.5 mm thickness) with the cold-rolled condition. The chemical composition of the used copper shown in Tab.1 and the mechanical properties are shown in Tab.2. The welded copper plate test samples of 60 mm in length and 16 mm in width (Fig. 2.).

| Table 1. The used aluminium in wt% rest is Cu % |
| S  | As  | Pb  |
|---|---|---|
| 0,1 | 0,01 | 0,01 |

| Table 2. Mechanical properties of the test material |
|---|---|---|
| Used metal | $F_{p0,2}$ (MPa) | HV$_{0,2}$ |
| Copper, C 1020-H065 | 240-300 | 66,8 |

Ultrasonic welding of thin sheets was made by Branson Ultraweld L20 instrument. The used frequency was 20 kHz. The applicable pre-pressure (TP) and welding pressure (WP) are between 10-80 Psi, maximal Power is 4 kW. For the welding, it needs to select the following welding parameters; welding time $t$ (s), amplitude A ($\mu$m) maximum 60 $\mu$m pre-pressure TP (Psi), welding pressure WP (Psi).

3. Results and discussion
The ultrasonic welding of the samples was made by amplitude 46 $\mu$m and 37 $\mu$m under welding time 1,5 s and 2,2 s and TP=24 Psi, WP=24 Psi standard. The Vickers hardness test was made with 20 g load, under 15 s. The hardness test results of the welded joint and the reference hardness (used copper without welding) shown in Fig.8. The ultrasonic welding friction established heat was detected by temperature indicating crayon between 550-680 °C. In the case of the pure copper ($T_{\text{melting}}=1085$ °C) the welding temperature is over than the recrystallization temperature. The joint microstructure under plastic deformation in this temperature has a dynamic recrystallization process. The microstructure of the welded joint shown in Fig. 3-7. In all picture is shown orderly grains, deformation or texture can not detect.

Figure 1. Ultrasonic welding instrument

Figure 2. Setup of the welded sample
Figure 3. Without welding 66.8 HV

Figure 4. A=46 µm, t=1,5 s, 73.2HV

Figure 5. A=46 µm, t=2,2 s, 73.9 HV

Figure 6. A=37 µm, t=1,5 s, 76.6HV

Figure 7. A=37 µm, t=2,2 s, 76 HV

Figure 8. Hardness as a function of the distance from the welded joint center point

Welded joint hardness as a function of the weding time and amplitude

| Welding amplitude | Hardness (HV 20/15) |
|-------------------|---------------------|
| 37 µm             | 78                  |
| 46 µm             | 76                  |

Copper hardness

Hardness as a function of the welding time
4. Conclusions

I. It can predict that if the used amplitude is minimum 37 $\mu$m and the welding time is minimum 1.5 s (TP=WP=24 Psi) under the ultrasonic welding the joint microstructure temperature will be higher than the recrystallization temperature.

II. I confirmed, in accordance with the literature, that the ultrasonic welding in the case of the used amplitude between 37-46 $\mu$m under 1.5-2.2 s welding time cause dynamic recrystallization and hardness Changement in the welded joint.

III. The welding affected dynamic recrystallization cause suitable microstructure in the joint (higher tensile strength and hardness).

IV. It can predict on the base of the research results and the cited references, that the welded joint hardness depends on the welding parameters.

V. The welding time determines the ultrasound effect quantity namely on the base of the acoustoplasticity theory and the experimental results of this research it can conclude that the avaible mechanical properties of the joint depend at.

The future research plan to find the relationship between the mechanical properties and the welding parameters, and optimize the welding parameters to earn the wanted mechanical properties.

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