Contributions Regarding Plastic Materials Ultrasonic Welding used in Automotive Industry

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In the presented paper experimental results on welding polystyrene and optical elements are shown. On the basis of the obtained results on shearing-stretching and macroscopic analysis of the work pieces, conclusions are drawn regarding the weld when using ultrasonic welding process.

Key words: ultrasounds, welding, plastic materials

The ultra-acoustic system is the most important subgroup of an ultrasound processing installation due to the fact that it produces the welding, the concentration, the focusing and the glowing of the ultra-acoustic lamp within the working zone. The acoustic parameters (acoustic intensity, the acoustic energy density, the variation amplitude, the wave type, the variation frequency) and the mechanical parameters (the static pressure and the pressing force depending on the way it is projected and produced). The ultra-acoustic system used on ultrasound welding is formed by a piezo-ceramic group, a movement amplifier and a concentrator.

The ultrasound energetic concentrators must be calculated in such a way that they should work with each component and fulfill the following functions: to conduct ultrasound energy from the transducer to the place where the welding takes place, to concentrate and facilitate the ultrasound energy in the area, to increase the particles' speed value watching the enlargement of the work tool and at the same time the acoustic intensity, through their form they lead to a very diverse scale of welded constructions and to obtain different kinds of acoustic waves (longitudinal, transversal, of surface, of torsion, radial or combinations), to allow sustaining or fixing the entire acoustic system within the whole welding installation in the crucial plans.

Experimental investigation on polystyrene

During experimental research on polystyrene, main parameters established were: contact static pressure (daN/cm^2), generator power (P [W]) and welding time (t [s]). The frequency used was 24 kHz. The process outputs studies are: measurement of shearing-stretching force F used to break the welded structure, macroscopic and statistic analysis of the pieces [1, 5].

For setting the right parameters of the welding process, one parameter was varied while the others were maintained constant. It has to be known that one of the main factors influencing the process is the surface precision. A precise geometric form and a well prepared surface make the welding process easier and the welding structure much stronger. Contact surfaces of pieces can be different as form, but one of them must have at basis a prominence which fits along the length of the other pieces.

This prominence, also known as transducer for energy guiding, allows mechanical energy to be focused on the prominence surface, accelerating the heating and welding processes in the materials. One can also obtain a nice-looking welding on the outside.

Two panels were used during these experiments, one being in "V" prominence and the other one was plain. Panels have the following dimensions 46x15x2 mm (fig. 1).

Panels' length is half length of ultrasonic vibration wave on polystyrene, at a sampling frequency of 24 kHz. It was set that if the panel length is higher or equals half of the wave length, the vibration amplitude and the energy received will reach maximum values.

Prominence dimensions correspond to the most intensive melting in the shortest time.

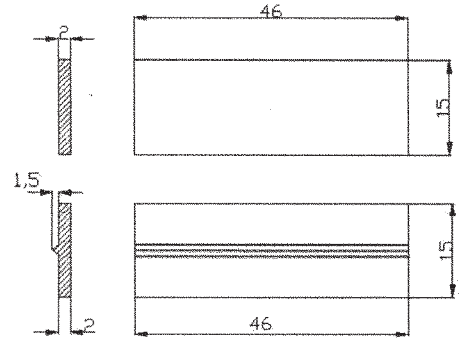

Fig. 1 Specimens geometry

It was observed, in the welding process of this type of panels, that there is a leaking tendency of melting material over the welded zone forming a burr. If the burr is useless, it is used in other types of constructions to avoid leaking of plastic material.

Melted material fills the space of few millimeters.

For welding, two pieces with two different thicknesses the contact surfaces have to be angled or rounded.

Parameters values and obtained results on shearing-stretching are shown in table 1. Static analysis of the obtained result allowed the elimination, from various reasons, of abnormal results on F (37*; 48*; 51*; 57*; 13*; 40*).

Variation of force F is shown in graphics built on measured values, in interaction with each of the three main parameters (fig. 3, fig. 4, and fig. 5).

For macroscopic analysis of welded structures three representative specimens were prepared (7, 8 and 9 as shown in table 1. Welded work pieces are constrained to the following operations:

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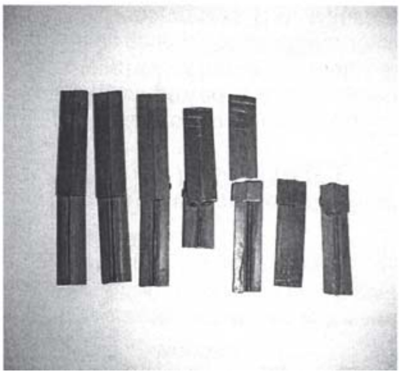


Fig. 2. Welded work pieces submitted to stretching

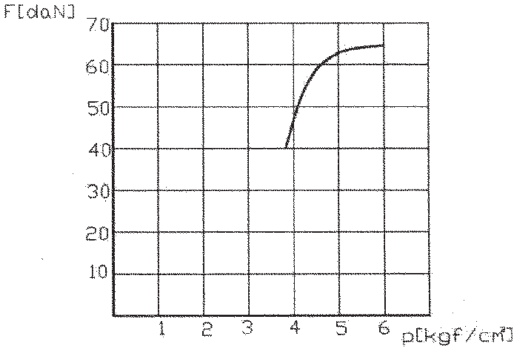


Fig. 3. Static pressure influence on weld resistance (t=3s;P=ct)

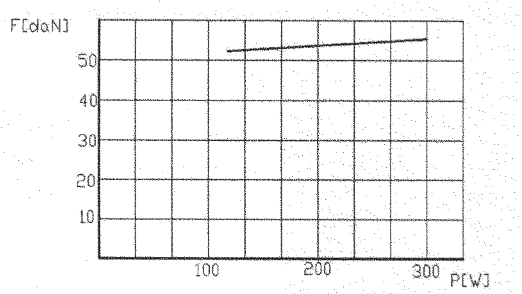


Fig. 4. Power influence on weld resistance (t=3s;P=5 daN/cm ^{2})

- cutting through welded area;
- wet sanding with abrasive paper no. 280, 400, 500, 600 (a dry abrasive paper will lead to local heating and structural changes in material)
- polishing with water-imbued velvet and no. 3 alumina, three hours each;
- chemical solution attack with the following composition: 30 mL anol, 50 mL formic acid; 20 mL alcohol; process time was 1-2 min at solution temperature of 60°C.

Afterwards it could easily be seen the separation line between the two pieces and also the joint shape.

The work piece no.8, where the proper parameters were used, had a good weld.

At work piece no.7, with welding time just one second, the "V" prominence did not penetrate the lower panel resulting in a low resistance welding structure. This is, of course, due to the insufficient welding time.

On work piece no. 9 the static contact pressure used was daN/cm^2 and a welding time of 6 s, "V" prominence penetrated too much the lower panel resulting in a defective weld with the shape of a hole which obviously led to a weaken structure.

The influence of the welding parameters on the welded structure can be estimated using the previously obtained results.

Table 1
VALUES OF THE WELDING PARAMETERS AND THE RESULTS OBTAINED IN THE SCISSORING-TRACTION

No	Pres. level [daN/cm^2]	Po wer [W]	Time [s]	Breaking force on shearing-stretching [daN]		
				1	2	3
1	5	200	3	52	51	37*
2	5	250	3	54.5	51.5	48*
3	5	300	3	55.5	55	54.5
4	3.8	250	3	41	39	51*
5	5	250	3	62	64	57*
6	6	250	3	56.5	69	64
7	5	250	1	21	13*	27
8	5	250	3	56	40*	53.5
9	5	250	6	58	57	60

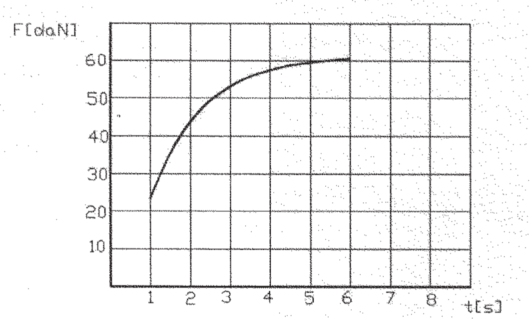


Fig. 5. Time influence on weld resistance (p=5 daN/cm, P=250W)

Influence of static-contact pressure on weld quality

Pressure level is an essential parameter of the welding process because the process takes place only after an acoustic contact between the work pieces and concentrator.

Analyzing the picture representing the force variation with pressure, it can be observed that at low values of pressure (about 3.8 daN/cm^2), the lowest values of the breaking force are encountered, this fact showing once again that a weak acoustic contact leads to ultrasonic oscillations damping and with that the decreasing of mechanical energy transmitted to pieces. Somewhere around 5 daN/cm^2 breaking force has mean values, but this value of pressure correlated with proper values of the other welding parameters leads to a strong welding structure and also a nice-looking one. For the mentioned value of the static pressure the acoustic contact is very good, the energy transmitted to the work pieces is at its optimum value, which leads to a high quality welding structure without big burrs or marks on surfaces. Increasing the value over 5.5 daN/cm^2 it results an increased tensile strength, but also an improper aspect of welded pieces (like burrs or marks).

From the esthetic point of view it is very important to obtain a nice welding aspect with this welding process.

Influence of powder on weld quality

Figure 4 presents a linear increasing resistance of welded structure with power.

The conclusion drawn is that an increased mechanical power transmitted to the pieces leads to a better welding resistance.

An increasing power correlated with maintenance of the other parameters at their optimal values does not change in a great manner the welding structure resistance.

Influence of time on weld quality

From figure 5 it can be noticed that lower values of time (about 1 second) lead to a low welding structure resistance even if correlated with optimum values of the other parameters.

Here, temperature in welding zone is very important. If the time is short temperature will be at low values. At low temperatures, thermoplastics turn into solids, which oppose deformations due to the particles micro moves and to crystalline domains (stability of form).

Due to this fact, welding will not be completed; partial material melting and improper penetration of "V" prominence will result. A three seconds welding time will result in good welding resistance. This is because once one increases the temperature, micro Brownian movement also increases and the intermolecular connections decrease. During this period of time, the temperature is reached in such a way, so that hydrogen mollecules break and melting begins on a larger crystalline area, so one can obtain a good welding structure.

Choosing a welding time of 6s brings an excessive temperature leading to destroyed plastic material and to the appearance of gas holes. In this case, the welding resistance decreases. The welding time, when the other parameters are used at their optimum values, is three seconds.

Regarding the machining of welded structure, following experimental setup correlated with experts opinions, conclusions can be drawn as follows.

At low temperatures material acts like a guide and oppose deformations. When heated, Brownian moves in the material increase and chemical connections decrease. Increasing once again the temperature, the internal capacity of the molecules internal is increasing also, being obtained a plastic yield domain of the material.

Exceeding a certain temperature, chemical valence forces are overcame and the material becomes plastic. At the same time melting of first crystalline area appears.

At a continuously increasing of the temperature value, molecular moves become so strong and the last resisting chemical valence connections break. It also gets to molecular destruction and even cracking in liquid phase. The welding temperature of thermoplastic materials was set between lip temperature and destroying temperature.

$$199^0 C < \theta_s < 210^0 C \qquad (1)$$

Thermal energy at the welding spot, meaning material heating, is due to molecular frictions. It is presumed that Brownian moves leading to chemical valence breakings, main and secondary ones, are the thermal energy source.

When applying static pressure, free chemical valences of the materials get closer enough to form chemical bonds. Partial divided molecules reintegrate once again. Pressure also determines crowding and fragmentation of surface molecules whose free chemical valences were tied through O_2 connection type during heating. Oxidization of plastic heated materials is the proof of free connection forces existence. They connect again through material leaking.

Research on vehicle optical elements

Figure 6 shows the components of one vehicle optical elements: two parts made of ABS and one part made of steel, representing a composite material [15-17].

Figure 7 presents a different type of vehicle optical elements, made of ABS.

In figure 8 concentrators for ultrasonic welding of vehicle optical elements are shown. Front face of concentrators must have a proper geometry according to welding pieces outlines.

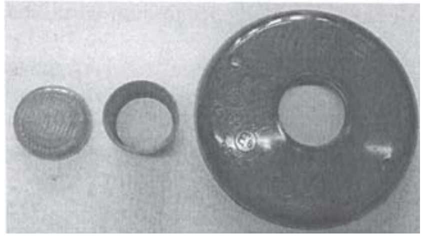


Fig. 6. Vehicle optical elements: 1,2 – components (composite material) made of ABS; 3 –steel component

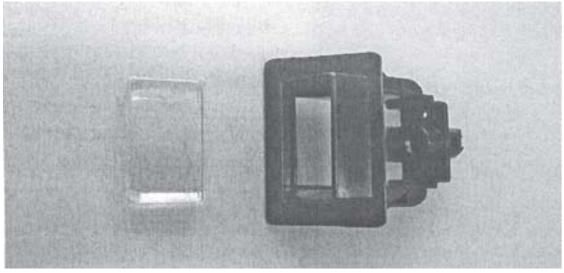


Fig. 7. Vehicle optical elements made of ABS

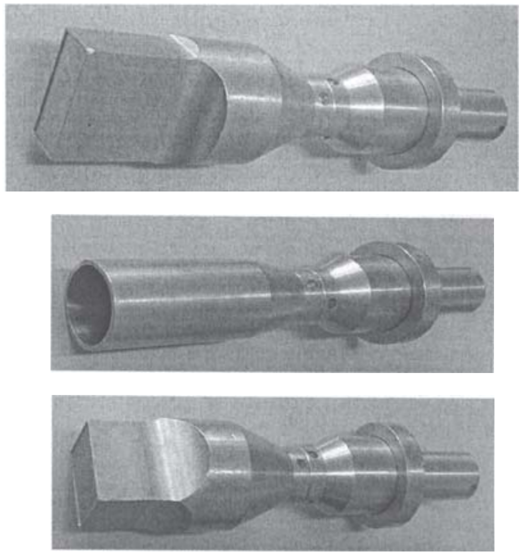


Fig.8. Concentrators used to weld vehicle optical elements

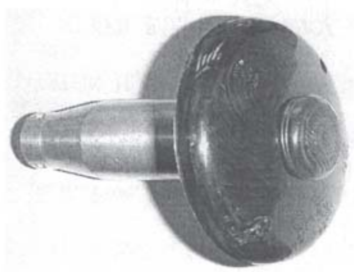


Fig. 9. Vehicle optical elements during welding process

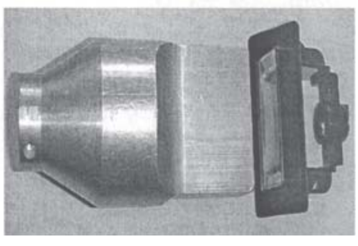
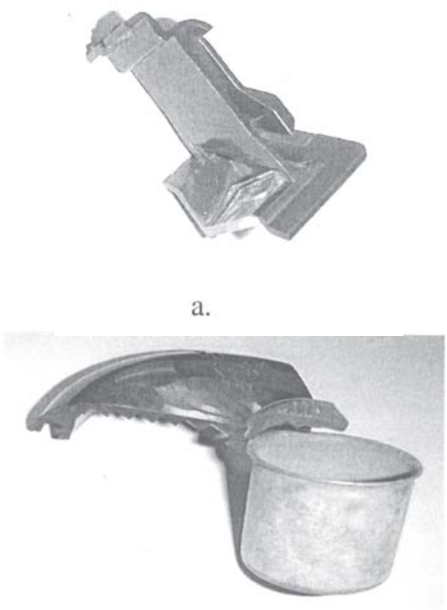


Fig. 10. Vehicle optical elements during welding process



a.

b.

Fig. 11 Ultrasonic welding of vehicle optical elements
a.– first type; b – second type

In the figure 9 are presented the elements during the welding process (acoustic concentrator pressing the plastic elements).

Figure 10 displays same type of cue light as in figure 7 during welding process.

Figure 11 (a- type one element, b - type two element) shows ultrasonic welding for vehicle optical elements previously presented .

Figure 12 a, b show welded work pieces for the two types of cue lights.

Parameters used for the cue lights welding:

-work piece material – duralumin;

-welding frequency – 20 kHz;

-BRANSON welding equipment – 400 W/20 kHz;

-welding time: 0.55 seconds;

welding pressure: 2 bar.

Conclusions

Ultrasonic welding process can be used on composite materials with very good results.

Experimental research on polystyrene and cue lights revealed the influence of welding parameters on welding quality and allowed conclusions to be drawn regarding the making of the weld.

There is an interdependence between welding parameters, optimal welding regime being experimentally determined for each material and equipment separately.

Some aspects regarding the subject were discused in [18-24].

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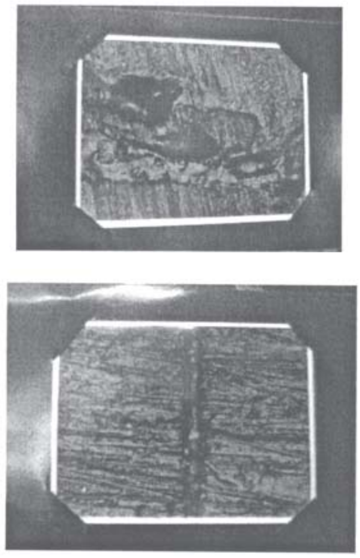

a

b

Fig. 12 Welded work pieces submitted to shearing-stretching
a.- one section; b – second section

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