Studies and Development of Ultrasonic Welding Tools

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***Abstract* - The article is devoted to the development and the design of ultrasonic welding tools intended for the generation of lengthy seams by the press welding. We solve the problem of the formation of even distribution of vibrations radiating surface, which size exceeds half of the wave length of ultrasonic vibrations in the material of the tool. The dependence of distribution of vibration amplitude along radiating surface of welding tool on the shape and sizes of the tool are revealed. The possibility of the design of the tool with even distribution of vibration amplitude is confirmed by the results of experimental studies on the base of developed vibrating system with welding tool intended for the formation of 220 mm long welding seam.**

***Index Terms* – Ultrasonic welding tool, vibration amplitude, ultrasonic welding.**

I. INTRODUCTION

THE INCREASE of production processes and quality of ready articles is one of the main factors of the development of the industry. To provide all listed requirements it is necessary to have modern, effective and science-intensive technologies and equipment.

One of promising industrial application of ultrasound is ultrasonic welding. It is the method of the generation of permanent connection by the energy emitted in the contact zone of welded parts when passing ultrasonic vibrations through it.

At present ultrasonic welding equipment is presented by different variants; however the ultrasonic devices for stitch resistance press welding are in a great demand in modern industry. They have ultrasonic vibrating system as a working element with welding tool, which allows forming welding seams with the length of more than half of wave length in the tool material at single pressing. For the tool made of titanium alloy at the frequency of 20 kHz this size corresponds to 127 mm.

The necessity to generate lengthy seams at the connection of structural articles and list materials (for instance, geogrid), packaging of free-flowing and liquid products into bags made of polymer materials, producing of stationery, etc. causes the urgency of the design and efficient application of such working tools.

II. PROBLEM DEFINITION

For the formation of lengthy seams at the connection of the articles and materials there is a need to design working tools with radiating surface, one of the sizes (determining of the length of formed seam) exceeds half of the wave length of ultrasonic vibrations in the material of the tool and the other size (determining the width of formed seam) is less than half of the wave length of ultrasonic vibrations in the material of the tool.

At the development of such working tool they are made in the form of waveguide systems, which are plates of resonant size, intended to generate longitudinal vibrations during the operation process.

However, at the application of waveguide systems in the form of the plates, which longitudinal size is determined by the resonance frequency of the tool (it corresponds to half of the wave length at operating frequency of vibrating system) and the width (the length of formed seam) exceeds half of the length, vibrations of working tool of complex form appear, which differ from longitudinal vibrations. In this case complex vibration distribution, caused by interference of different modes of vibrations, occurs along radiating surface of the tool and it is impossible to provide even distribution of vibration amplitude along radiating surface.

At this reason solving of the task of providing vibration amplitude uniformity along radiating surface generated at the formation of seams by various length of the tool is a complex and multifactor problem.

Thus the aim of this study is to investigate the dependences of the distribution of vibration amplitude along the surface on different modifications of working tool shape and to use obtained data for the design of ultrasonic vibrating system for seam press welding.

III. DESIGN OF THE PLATE BAR

It is known, that in order to achieve even vibration amplitude several methods of the shape modification of the plate (adding of slots, holes, local changing of the thickness, adding of mechanical filters) are used in practice.

At the same time during the first stage of the development it is necessary to suggest and apply welding tool, which form at further modification provides the generation of vibrations with amplitude, that it is sufficient for the formation of qualitative welded joint. As it is evident from the papers on the theory and practices of the ultrasonic welding [1] this value is about 38…42 µm.

As the vibration amplitude of the active element – piezoelectric transducer is limited (it is generally 5…10 µm), to obtain required value of the amplitude it is necessary to use additional strengthening units in the structural scheme of vibrating system. Working tool itself should also provide certain amplification coefficient.

Thus, the shape of working tool should be the following, that in its cross-section it should be a transformer of vibrational speed – a concentrator. For the design of concentrating form we use calculation procedure described in detail in [2].

As a result of the calculations the profile of the cross-section is formed, it is shown in Fig.1.

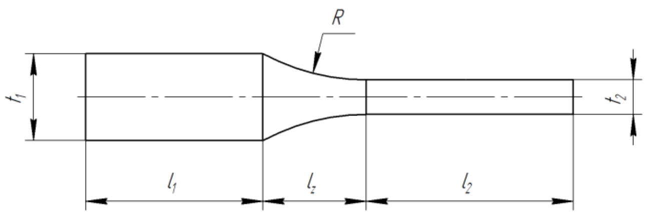

Fig. 1. The profile of the cross-section of welding tool

Welding tool is made by the method of profile pressing-out in given width. Value t_1 is determined by the width of titanium plate used for blanking and it normally equals to 20 mm. Output width t_1 is determined by required amplification coefficient and in the most cases it equals to 8 mm. At the calculation of values l_1, l_z, l_2 the rate of ultrasonic vibration propagation equals to 4950 m/sec (for titanium alloy), calculated resonance frequency corresponds to 22000 Hz.

IV. Studies of Amplitude Distribution Depending on Various Modification Methods of Plate Form

For the correction of the sizes of the cross-section obtained at the stage of the design of the plate bar and for the studies of amplitude distribution along the surface of the tool it was proposed to apply direct finite element method. At that the development of 3d models of welding tools was realized by solid-modeling CAD system and the results of calculations were exported to the system of finite element modeling.

One of the most common methods of plate modification is slot adding. They are used to break a bond between the parts of planar waveguide allowing them to vibrate in mode, which is closed to the longitudinal one [3]. During the studies of influence of vibration distribution along vibrating surface such parameters as slot width, slot height and the distance between them were varied.

At the first stage the tool with radiating surface of 150 mm was chosen for the studies. The results of computer modeling at various parameters of the plate are presented in Tab. I. Amplitude uniformity was estimated as the ratio of vibration amplitude at the border of the waveguide to the amplitude in the center of the waveguide. If the ratio is more, than vibration amplitude is more uniform.

TABLE I
THE RESULTS OF MODELING OF WELDING TOOL WITH THE WIDTH OF 150 MM

Slot width, mm	Distance between the slots, mm	Amplitude ratio
5	40	0.15
7	40	0.51
6	40	0.77
8	40	0.47
9	45	0.25
10	45	0.37
11	30	0.30
12	35	0.60

As it follows from the data given in the table, the highest uniformity is achieved, when the width of the slot is 6 mm and the distance between them equals to 40 mm.

At next stage we studied the influence of slot height on the vibrations distribution of radiating surface of welding tool.

The slot width was 6 mm (as the experiments with other sizes of slot width showed worse results), the slot height varied from 40 to 60 mm. The data of the calculations are given in Tab. II.

TABLE II
THE RESULTS OF MODELING OF WELDING TOOL WITH THE WIDTH OF 220 MM

Slot height, mm	Distance between the slots, mm	Amplitude ratio
50	40	0.15
55	40	0.51
60	40	0.8
45	40	0.47
40	40	0.25

As it is evident from presented table the most even vibration amplitude is achieved, when the height of the slot is 60 mm.

V. Experimental Studies

According to the results of computer modeling of the tools various in size we designed the ultrasonic welding tool of 220 mm wide with the slots, which size was optimum regarding to proposed calculation procedure.

For making the experiment radiating surface of the plate was divided into the zones with nine points, at which the amplitude was measured repeatedly (Fig.2).

The measurements of system amplitude were carried out by piezoelectric receiving transducer with dry point contact [4] at power supply of ultrasonic vibrating system from low-voltage generator.

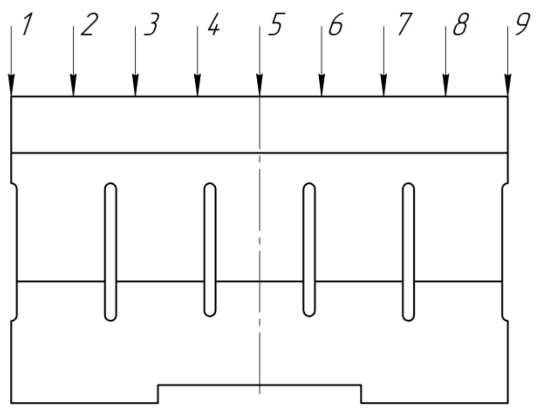

Fig. 2. Measurement points of vibration amplitude

Obtained results are given in Tab. III.

TABLE III.
THE RESULTS OF MEASUREMENTS

Point number	1	2	3	4	5	6	7	8	9
Amplitude	2.2	2.2	2.4	2.6	3.0	2.6	2.4	2.2	2.2

As it is evident from the results of measurements the ratio of the amplitude on the border to the amplitude in the center was about 0.7, at that it is observed symmetric distribution relative to the center of the waveguide. Given results of measurements correspond to the results obtained by computer modeling of distribution of vibration amplitude along radiating surface.

VI. CONCLUSION

Carried out studies of the dependences of distribution of vibration amplitude along the surface at different modifications of working tool shape allowed to reveal the conditions, at which even distribution of amplitude can be provided, and design practical constructions of working tools for seam pressing welding.

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