Automating of Process of Ultrasonic Welding of Thermoplastic Materials

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***Abstract* – The article discusses conception of automation of process of ultrasonic welding.**

***Index Terms* – Welding, ultrasound, automation.**

I. Introduction

POPULARITY OF thermoplastic materials increases every year. It is related to ease of processing, molding, gluing, etc. However, the manufacture of products of such materials usually is massive and requires the applying of automated tools of assembling and processing of them. One popular way of connecting of elements of thermoplastic materials is ultrasonic welding.

II. Factors Affecting On the Quality of Ultrasonic Welding of Products

Many factors determined by properties of material for making of welding workpieces, thickness of welding workpieces and quantity of ultrasonic energy entering into welding zone influences on the resulting quality of weld. That are material properties of which the welded components, the thickness of the welded parts and the amount of ultrasonic energy input. However, controlling parameters are amplitude of mechanical vibrations, force of pressing of welding tool to welded parts and time of ultrasonic action.

III. Overall Block Diagram of Welding Line Automated Control

Let's examine a general block diagram of controlling of automated welding process, shown schematically in Fig.1.

- The main components of automated welding line are :
- Display unit is designed for communication with the operator , allowing input of controlling information, information messages , etc.
- One or more ultrasonic generators.
- System of drive controlling that controls system of transfer of blanks and finished products and including drives (stepped motors or servo), mechanic of transfer system and a set of sensors monitoring the position of displacement system.
- Clamping system, providing compression of welding product between welding tools and supports. Clamping system usually consists of a mechanical guiding pneumatic drive providing a linear movement of welding tool or support, controlling element (valve), regulator of pressing force (with manual or electronic control) and sensors for monitoring of position of system of clamping and presence of welding products.

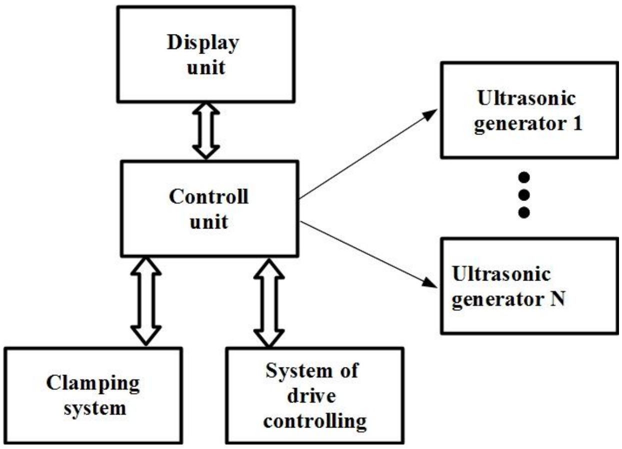

Fig. 1. Overall block diagram of automated welding line

Further only blocks directly associated with automation of process of moving and welding of products would be consider.

A. *Ultrasonic Generator of Welding Machine*

There are special requirements for ultrasonic generators using in automated welding lines. This is caused by the need of transmitting of information about the state of the ultrasonic generator to the controlling units (the error, modes, etc.), and also by the requirements to dynamic characteristics of generators for increasing of ultrasonic welding productivity.

To ensuring of temporal characteristics of welding process it is necessary to provide a high rate of rising of mechanical oscillations amplitude, and also stability of it during action.

A typical block diagram of the ultrasonic generator is shown in Fig.2.

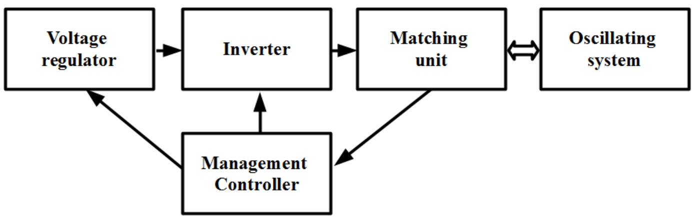

Fig. 2. Block diagram of the ultrasonic generator.

The main unit of the generator, influencing on the rate of rising of oscillations amplitude and on accuracy of retention of it during the welding process is a voltage regulator determining the output voltage of the inverter.

B. Thyristor Regulator of Voltage

The scheme is simple thyristor regulator of voltage is shown in Fig.3. Rectified supply voltage is applied to the thyristor with the diode bridge. Depending on the duration of the opening of the thyristor voltage action time (half-wave part) charging the capacitor C has change. Thyristor automatically closes when the voltage drops to zero. Thus, the thyristor controlling signal must be synchronized with the beginning of the half-wave of supply voltage. In this method of control, pulses inevitably take place on the output of controlling circuit. To suppress of these pulsations it is necessary to increase the capacity of the output capacitor C. Acceptable ripple amplitude is achieved at the capacity of the output capacitor of order of hundreds of microfarads (100 – 500 uF) [1].

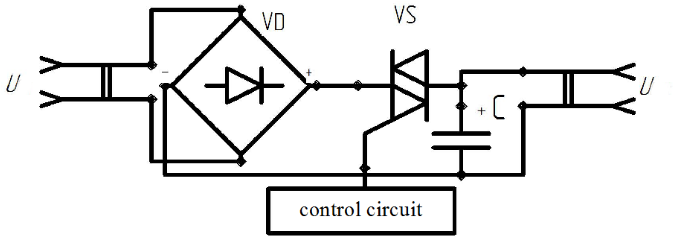

Fig. 3. Scheme of thyristor regulator

This scheme of using in practice thyristor has a number of disadvantages, the main of them is lowest rate of changing of output voltage. Limiting factor is the emergence of large pulsed currents at accelerated charging of capacitor C with maximum voltage. Second drawback is inability to control the rate of decrease of output voltage of circuit. Wherein velocity of control determines by the time constant of discharging of capacitor C and by the magnitude of the acoustic load . Since the capacity of using capacitor is sufficiently high (100 - 500 uF) , the rate of decrease of the output voltage is low.

C. Buck Converter Voltage Regulator

Buck converter, schematically shown in Fig.4 has much less shortcomings than traditional thyristor regulator. When it work velocity also depends of the output capacitance, but as buck converter operates at a higher frequency (tens of kHz) compared with thyristor converter (100 Hz), this capacity of required capacitor has much smaller nominal value (as it was shown in a practice, for the apparatus of 150 W it is enough of electrical capacitance of not more than 5 - 10uF). [1,5]

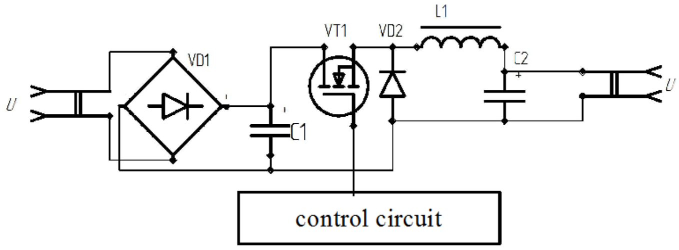

Fig. 4. Scheme of buck converter voltage regulator.

For optimum performance, it is desirable to supply stable DC voltage on input of buck converter. Therefore, for improving of operational characteristics of ultrasonic generator it is desirable to replace a conventional rectifier by the electronic power factor correction (PFC), for avoiding ripples of consuming current, reducing of electromagnetic interference in a power grid, and also stabilizing voltage of buck converter.

D. Positioning System

For forming of qualitative weld it is necessary to provide even distribution of ultrasonic energy on the entire area of formed seam. This only can be achieved with a uniform and stable clamping. To ensure a stable and uniform clamping it is necessary accurate positioning of welded product on a support providing by positioning system.

Various moving mechanisms uses to ensure the transportation workpieces in a welding zone and also to remove finished product from the welding zone. There are various kinds of conveyors or rotors may be used. In smaller installations, typically stepper motors are used, allowing to form systems without feedback, which simplifies the design and reduces the cost.

Despite the using of stepper motors in movement system for accurate positioning of products in the welding zone there are some additional sensors. This allows to compensate inaccuracies taking place in process of manufacturing of transport mechanism. Block diagram of a drive control system is shown in Fig.5.

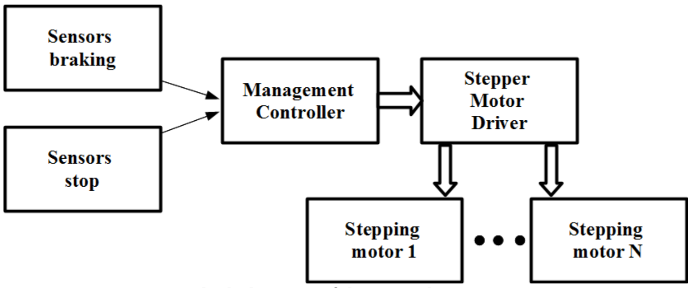

Fig. 5. Block diagram of the control actuators unit.

As it follows from the block diagram control actuators unit consists of a controlling microcontroller, stepper motor driver and the corresponding sensors determining position of moving system. Sensors of braking report about approaching of workpiece to weld zone wherein it takes place beginning of a gradual declining of rate of movement for improving of accuracy of positioning the product at a stopping.

E. Clamping System

For ensuring of effective input of ultrasonic vibrations in welding material, and obtaining of high-quality of weld joint it is necessary to ensure a good acoustic contact between welding pieces and working tool of radiator of ultrasonic vibrations. For this it is necessary to provide normalized pressure of working tool to the welding product. Pneumatic equipment enabling creation not only a uniform and stable clamp but and characterizing by simple adjustment of this effort meets requirements that can provide such conditions.

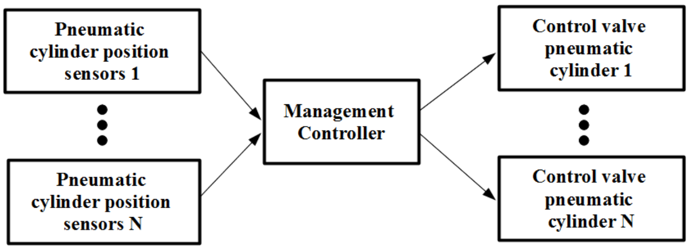

Fig. 6. Block diagram of the control system of a clip.

Clamping control unit (see Fig.6) consists of a controlling microcontroller, control valves and position sensors of pneumatic cylinders. Information obtained from the position sensor of pneumatic cylinders is used for determining of presence of welding products, determining of erroneous situation and as a signal of transition to the next step.

F. Control Algorithm of the Welding Line

Process of performing of weld joint in automated welding lines consists of the following major steps:

1. Installing of workpieces of welding product.
2. Transporting of workpieces in the welding zone.
3. Clamping of workpieces
4. Ultrasonic impaction.
5. Exposure of stabilization time weld joint
6. Transporting of welded product in zone of discharging of finished products.

IV. EXAMPLES OF IMPLEMENTATION OF WELDING LINES

In view of discussed above concept it was developed and implemented a few welding lines intended for different products of thermoplastic materials.

Fig.7 shows the appearance of a line for joining of two half-spheres of thermoplastic material with diameters from 10 mm to 50 mm by low temperature ultrasonic welding.

Fig. 7. Line for connecting of two half-spheres.

Presented line consists of a mechanism for moving and clamping [2,3,4] (with two parallel transport streams), two set of ultrasonic welding equipment (generator and UOS), and also control unit supervising the entire process of formation of weld joint. Feature of line is a system of transferring of conveyor type implemented by pins mounted on the conveying chains.

Line for joining of two half-spheres of thermoplastic materials of the same diameter (Ø38 mm, Ø30 mm, Ø25 mm) by ultrasonic welding is shown on Fig.8.

Fig. 8. Line for joining of two half-spheres of thermoplastic materials.

Presented line consists of conveying rotary mechanism with grips for welding workpieces, pressing mechanism and two ultrasonic welding set. Feature of this line is the ability of welding of workpieces, capturing during the installation, moving and feeding in the welding zone with using of outer surface of the product.

Another type of developed weld line is shown on Fig.9. In this line there is no movement of welded workpieces, but it take place moving of welding tool performing stepping welding of workpiece along contour.


Fig. 9. Line for stepping welding along contour

Created welding line for packing (blistering) of various products and articles consists of welding support (table) with indention for lower part of welding workpiece, a welding tool displacement system providing positioning of spot welds along the contour of welding product, clamping system, and one set of welding equipment.

V. Conclusion

Presented in the article concept of automated lines making is allowed to develop and implement automated lines for welding of products with different shape and size with using different properties of thermoplastic materials with productivity up to 2500 pieces per hour.

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