ABSTRACT—In article results of researches and development for a complete set of the packing machines, capable to provide are submitted at hermetic sealing liquid and loose raising dust products formation double cross-section sealing a seam by extent up to 360 mm in time, less than 1 second.

I. INTRODUCTION

LAST YEARS in the food-processing industry the increasing distribution is received with various ways and devices of packing of loose and liquid products. Their manufacture is carried out by various domestic and foreign firms: Bestrom (Russia), joint-stock company “Signal” (Russia), Braibanti (Italy), Bullez (Switzerland), ECL (USA), Ishida (Japan), Tetra-Pac (Sweden), Wagetechnic (Germany).

Packing in polymeric thermoplastic a film with vertical submission of a product has received the greatest distribution for loose foodstuff: groats, nuts, a flour, milk, sugar, sweets, chips, etc. Similar packing machines are used for packing liquid foodstuff: milk and dairy products, sauces and ketchups, etc. Used packing machines are arranged as follows.

In the top part of a packing machine it is established loading funnel with the device for regulation of quantity of an acting product, which by gravity and directing devices is allocated in special cylindrical capacity (a pipe forming a sleeve of a film). Concerning an external surface of a pipe the sleeve is formed of a polymeric film. Into structure of a packing machine enter: the tape drive mechanism, longitudinal and cross-section heat sealing devices. Before receipt of a doze of a product, drives of mechanisms of cross-section, longitudinal welding and the tape drive mechanism are included. Thus the longitudinal (vertical) thermal seam and the bottom cross-section (horizontal) thermal seam is formed, i.e. the plastic package for packing is formed. In beforehand generated package having vertical and horizontal seams, submit a portion of production, make welding top of a package (form the top cross-section seam), simultaneously forming a bottom of the following package. The knife separates a portion of the packed product (the hermetically sealed package) and a cycle repeats.

II. STATEMENT OF THE PROBLEM

Hermetic sealing of plastic packages at packing loose and liquid products consists in formation of a cross-section site for performance of a seam, compression of a package on this site before contact of internal surfaces of walls of a package with each other, realization of power influence on a material of a package before rise in temperature, sufficient for formation of a thermal seam.

In modern packing machines, depending on a kind of a used material, apply two various variants of realization of power influence:
- Thermal welding for fusible materials;
- Pulse welding for multilayered materials.

The basic difference of used variants that in the second the small surface heat sealing an element (for example, a wire between two edges of edges) with high resistance is used. Thus because of insignificant heat conductivity of elements they are quickly heated up and cool down. Besides reduction of duration of cooling of elements is influenced with application of water or air cooling, and for exception of adhesion of a packing material to an element, on last is rendered heat-resistant a layer of teflon.

In the first variant of realization of thermal welding heat sealing elements have the big working surface of contact, welding is carried out at smaller temperatures, at bilateral access and is more enduring.

Thermal welding provides reception of strong packing from polymeric materials. Its reliability and durability depends on a kind of a film, temperature heating, duration of contact of elements and effort of their compression.

Usually full cycle of heat sealing on automatic packing machines with high efficiency should last less than one second. Therefore time necessary for thermal welding of a film, defines the common speed of work of an automatic packing machine.

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However, alongside with the considered advantages, thermal hermetic sealing of plastic packages has the following essential lacks:

1. Does not provide high quality hermetic sealing of plastic packages at packing fine-dyrspersated and raising dust products (pepper, ground coffee, flour, plaster, etc.). It is caused by hit of particles of a dust in a zone of formation of a thermal seam and results to that on these sites the thermal seam is not formed and failed full hermetic sealing of a package. It results in losses of a part of a product at transportation and losses of its quality because of hit of atmospheric air and a moisture in packing;

2. Does not provide hermetic sealing of plastic packages at packing liquid viscous products (mayonnaises, creams, sauces and ketchups, etc.). It is caused by hit packing a product on a surface of walls of a film in a zone of formation of a thermal seam. On these sites the thermal seam is not formed and there is a thermal decomposition of a product. It results in reduction in quality of a product, losses at transportation and to losses of a packaging because of pollution of surfaces of packing;

3. At hermetic sealing plastic packages in case of packing liquid products (such as milk or juices) to provide reliable hermetic sealing probably under condition of exception of hit of a product on walls of a film in a zone of formation of a thermal seam. However, at such packing, simultaneously with pressurized a product (milk or juice) in a package pressurize unsterile atmospheric air which causes the accelerated defacement of a product. The obvious variant of exception of hit of unsterile air in a package by formation of a thermal seam on a liquid product at realization of the prototype is impossible.

Besides at realization of traditional thermal welding it is impossible to provide the control of parameters over a zone of formation of a thermal seam (for example, temperature on border of connected materials or the moment of transition of materials on border in viscous-plastic a status). Absence of the control does not allow to influence operatively process, to optimize time of hermetic sealing at deviations of geometrical and technological parameters from norm, and also at change of a material of a packing film or its thickness.

The revealed lacks of used thermal welding cause impossibility of its application at packing fine-dyrspersated raising dust and liquid products.

In this connection there was a necessity for creation of a simple and effective way of the welding, allowing to provide hermetic sealing plastic packages at packing all kinds of products, including loose and liquid and to develop the specialized equipment for practical realization of a new way.

III. ULTRASONIC STEP-SEAM PRESS COLD WELDING OF THERMOPLASTIC POLYMERIC MATERIALS

The carried out analysis of functionalities of various ways of hermetic sealing, with reference to packing in polymeric thermostatic a film with vertical submission of a product, has allowed to offer as the power influence, capable to solve a task in view - ultrasonic high-amplitude influence i.e. a method ultrasonic low-temperature weldings [1].

To advantages of ultrasonic welding materials concern:

1. Sufficiency of access by the working tool through which power influence to a surface only is carried out by one of connected details, with an opportunity of allocation of the maximal energy on border of connection of this detail with another [2].

2. An opportunity of welding without preliminary preparation of connected surfaces (removal of liquid and firm pollution) and applications of special additives, accomplishing a role adding material.

3. The opportunity of tight connection at temperatures, is lower than temperature of fusion and decomposition of materials of a packing package.

4. Time of reception of qualitative welded connection does not exceed shares of second.

Thus, only ultrasonic welding is capable to remove lacks of thermal hermetic sealing of plastic packages from various thermoplastic films at packing loose and liquid products, increase of productivity of process at simultaneous reduction of power inputs. Besides ultrasonic welding allows to provide the continuous control of parameters of process and optimization of power and time influence.

At hermetic sealing a package by ultrasonic welding formation of a cross-section site for performance of a seam carry out two surfaces - a clamping rod and the working ending of ultrasonic oscillatory system. Power influence on a material of a package carry out ultrasonic fluctuations with frequency 22 … 44 kHz and amplitude from 20 up to 150 microns, depending on thickness of a material of a package, before translation of a material in visco-plastic a status. During ultrasonic influence register the parameter of ultrasonic influence describing a degree of transition of a material in visco-plastic a status. On size of this parameter establish time necessary and sufficient for formation of a tight seam.

Thus, ultrasonic oscillatory system move in the direction of a clamping rod before formation of a backlash which size establish to equal thickness of a film of a package, reduce ultrasonic influence and maintain without decrease in effort in the compressed status connected surfaces before transition of a material from visco-plastic statuses and stabili-
zation pressurizing a seam [4]. Process of formation pressurizing a seam is explained by Fig. 1.

Fig. 1. The circuit of formation cross-section pressurizing a seam ultrasonic welding.

In the top part of a packing machine it is established loading funnel 1 with the device for regulation of quantity of an acting product. The packaged product 2 by gravity and directing of funnel 1 is distributed in special cylindrical capacity 3 (a pipe forming a sleeve of a film). Concerning an external surface of a pipe 4 the sleeve is formed of a polymeric film. Formation of a sleeve is carried out with the help of the tape drive mechanism 5 and longitudinal heat sealing devices 6. Before receipt of a dose of a product, drives of mechanisms of the cross-section welding 7 including ultrasonic oscillatory system 8 and electronic generator having it 9 are included. The mechanism of cross-section welding provides compression of a package 10 on a site of formation of a seam with 11 two surfaces - a clamping rod 12 and the working ending 13 ultrasonic oscillatory systems 8 before contact of internal surfaces of walls of a package with each other. After compression of a package electric fluctuations of ultrasonic frequency from the generator 9 move on piezoelectric elements of oscillatory system 8. There is a transformation of electric fluctuations in mechanical ultrasonic, they amplify the concentrating device and are entered in a film of a package on a site of formation of a seam. Power influence on a material of a package is carried out by ultrasonic fluctuations with amplitude from 20 up to 150 microns, depending on thickness of a film of a formed package before translation of a material in visco-plastic status. Ultrasonic oscillatory system at formation of a seam move in the direction of a clamping rod before formation of a backlash which size establish to equal thickness of a wall of a package during ultrasonic influence.

Thus the bottom cross-section (horizontal) thermal seam, i.e. pressurize a plastic package with the packed product is formed. The knife separates a portion of the packed product (a package with a product) and the cycle repeats [5].

For practical realization of ultrasonic hermetic sealing plastic packages it is necessary to develop the specialized equipment.

The basic, not solved till now, technical problem not solved till now, at practical realization of ultrasonic welding for hermetic sealing all types of packing packages (width up to 350 mm) creation of oscillatory system with the working ending in length 350 … 360 mm and width, sufficient for simultaneous formation of two seams (in pressurized and formed packages) in time, less than 1 second is.

Besides for practical realization of the site of ultrasonic welding in structure of packing machines it is necessary to solve some technical problems, not realizing till now:
- To develop the site of fastening and the site of a clip of ultrasonic oscillatory system. The site of fastening should provide minimal damping of ultrasonic oscillatory system and an opportunity of integration in various packing machines. The site of a clip should provide a uniform clip of a film to a surface of the working tool with constant static pressure
- For maintenance of an electric feed of oscillatory system it is necessary to develop the electronic block the generator of ultrasonic fluctuations and the block of automatic control providing work of the electronic generator in an optimum mode.
- For maintenance of effective ultrasonic influence to define optimum values of amplitude of fluctuations and efforts of a clip, and also to develop the specialized clamping rod.

IV. DEVELOPMENT OF EQUIPMENT FOR ULTRASONIC STEP-SEAM PRESS COLD WELDING

The basic efforts, at creation of the ultrasonic equipment, have been directed on development of the special ultrasonic oscillatory system, capable to provide formation of a welded seam in length of 360 mm and width not less than 12 mm for simultaneous formation of two seams.

The ultrasonic oscillatory system is executed under the two-half-wave constructive circuit and unites two half-wave piezoelectric converters and the resonant half-wave concentrator of mechanical fluctuations having the working ending of the special form [6]. (Fig. 2.)

Piezoelectric converters are executed under the constructive circuit of converter Lanzhevena and will consist from consistently placed and acoustically connected among themselves a resonant re-
reflecting overlay, piezoelectric elements and a working overlay. Distinctive feature of the developed converters is displacement of piezoelectric elements aside a reflecting overlay concerning a zone of the maximal mechanical pressure and a minimum of mechanical fluctuations. It has allowed to raise electro-acoustic factor of transformation and to execute the site of fastening of the converter on a working overlay in a zone of a minimum of mechanical fluctuations. Accommodation of the site of fastening of the converter in a zone of the minimal ultrasonic fluctuations has provided minimal damping ultrasonic oscillatory system at fastening in the case and the maximal amplitude of fluctuations of a radiating surface of a working overlay. Besides presence of such site of fastening has allowed to offer a special design of protective cases on which surface there is flanged connection connection for installation in various types of packing machines (Fig. 2) and excluding transfer of ultrasonic fluctuations on elements of a packing machine.

The concentrator of ultrasonic fluctuations (Fig. 3,4.) has forming fluctuations (a surface of connection with piezoelectric converters) and radiating surfaces of the rectangular form of the identical longitudinal size (length), and the relation of their cross-section sizes determines factor of amplification of the concentrator. For maintenance of the maximal factor of amplification and reduction of limiting mechanical pressure the concentrator is executed under the circuit half-wave in steps - the radial concentrator.

The geometrical sizes of the concentrator are chosen from a condition of maintenance of the maximal factor of amplification in such a manner that lengths of sites of the concentrator with the various cross-section sizes and length of radial transition between them correspond to the sixth part of length of a wave of ultrasonic fluctuations in a material of the concentrator, and the sizes of smooth transition are chosen from a condition

\[ R = \frac{4L_z^2 + (D_1 - D_2)^2}{4(D_1 - D_2)} \]

where \( L_z \) - length of smooth transition, \( D_1 \) and \( D_2 \) are the cross-section sizes of forming and radiating surfaces of the concentrator.

The sizes of the concentrator at designing oscillatory system are chosen from a condition of the optimum coordination with piezoelectric converters on frequency at creation of static pressure upon the working ending at realization of welding.

The working ending of the concentrator (welding tip) has two flat surfaces in the size 360x5 mm for simultaneous formation of two seams and a groove for moving the knife separating pressurized package at packing of products.
material (factor of Poisson) in the concentrator through grooves are executed. Researches of influence various under the form and the sizes of grooves (Fig. 4) have allowed to establish, that the maximal effect of elimination of the parasitic fluctuations caused by deformations of all concentrator, is reached at performance of through grooves in width of 5-6 mm through the distances equal to the sixth part of length of a wave of ultrasonic fluctuations in a material of the concentrator.

- For excitation of fluctuations of a forming surface two piezoelectric converters are used. As a result of researches the optimum arrangement of piezoelectric converters on a forming surface of the concentrator of ultrasonic oscillatory system as it is submitted on Fig. 5 has been established.

As a result of the lead researches and practical realization of the offered new technical decisions the ultrasonic oscillatory system which has provided distribution of amplitude of fluctuations on a surface of the working tool, Fig. 4 is developed. Such distribution of amplitude of fluctuations has been chosen in connection with necessity of formation reliable pressurized seam on four layers of a film located on edges of a package and two layers by other part of a package. For this reason regional zones of the working ending of oscillatory system make fluctuations with the amplitude equal of 45 microns. On all other radiating surface the amplitude of fluctuations remains practically to a constant and makes on less than 30 microns.

For an electric feed of piezoelectric ultrasonic oscillatory system the electronic block (Fig. 6.) including except for the generator of electric fluctuations of a ultrasonic range the block of the control and automatic control by process of welding has been developed and made. For maintenance of work of the electronic generator in structure of packing machines management of the generator by means of interface RS-232 from a personal computer is stipulated.

The electronic generator is executed under the circuit of the bridge inverter and for automation of process of welding is supplied with a regulator of amplitude of fluctuations of a radiating surface of oscillatory system and system of automatic maintenance of frequency of the generator to resonant frequency of oscillatory system at all possible changes of temperature parameters of ultrasonic oscillatory system and the properties, welded polymeric materials during reception of a welded seam.

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of fluctuations of the working ending of oscillatory system up to 45 microns.

Fig. 9. The research stand of ultrasonic welding.

Technological process of hermetic sealing of packing packages is submitted on Fig. 1 and Fig. 7. All cycle of reception of connection borrows from 0,5 till 1,0 seconds depending on thickness and a material of a film used for packing.

The opportunity of creation pressurizing seam is caused by that the polymeric material used for packing, is characterized by high absorption of energy of ultrasonic fluctuations that provides fast translation of a material of a film in visco-plastic condition. Diffusive the processes proceeding under action of ultrasonic fluctuations of high intensity, provide mutual penetration of materials each other at temperatures smaller temperatures of fusion of a material.

As during ultrasonic welding the temperature of a welded seam is lower than temperature of fusion of the material, welded materials are not exposed to thermal decomposition with allocation of harmful substances, and qualitative tight connection is provided.

For creation of identical conditions of a clip along all radiating surface of oscillatory system the special elastic clamping rod which form is shown on Fig. 8 has been developed and made.

The absorbing covering is applied for increase in absorption of energy of ultrasonic fluctuations in thermoplastic film of a package on a surface of the clamping rod, executed of the several layers of fiber glass fabric covered with a layer of teflon, a welded material excluding sticking to a substrate.

V. CONCLUSION.

In result conducted researches and development the specialized ultrasonic equipment for a complete set of the packing machines, capable to provide is created at hermetic sealing liquid and loose raising dust products formation double cross-section pressurizing seam by extent up to 360 mm in time, less than 1 second.

At creation of the equipment the following technical problems are solved:
- The ultrasonic oscillatory system consisting from half-wave piezoelectric of the converter is developed and is step - the radial concentrator, providing sufficient for formation pressurizing seam amplitude and its distribution along all radiating surface in length of 360 mm and width 12 mm;
- The unit of fastening of the ultrasonic oscillatory system, providing minimal damping, excluding transfer of fluctuations and an opportunity of integration to various packing machines is developed;
- The technical decisions are developed, allowed to create unit of welding on the basis of a special clamping rod, to create the research stand (Fig. 9) and to define technological parameters and modes of welding.

REFERENCES

[3] The patent of the Russian Federation under the application № 2004135854 Way of hermetic sealing of plastic packages at packing loose and liquid products