

Ultrasonic Technology of Production of Unit-dose Pack With Guide Way of Spreads

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Abstract – The article presents the results of development of new type of unit-dose pack with special guide ways providing even laying of the spreads. The technology is based on ultrasonic welding. As a result of experimental studies we chose polymer materials for the production of soft unit-dose packs, proposed the method of process automation of its production and designed the construction of automated ultrasonic welding line.

Index Terms – Automated line, vibrating system, welding seam, polymer material, ultrasonic welding.

I. INTRODUCTION

MOST PART of branch of modern food industry occupies packaging equipment of foodstuff.

The packaging allows protect the foodstuff from the influence of ultraviolet, pollution, getting of microflora and moisture during transportation and storage.

At modern pace of life time for taking meal essentially decreases. That is why the customer buys portioned products in convenient single-service package.

In industrialized countries such type of package is widely used. It is paid much attention, as it is not only the method of product packaging, but also powerful instrument for product promotion.

In Russia the market of foodstuff in portioned packaging starts developing dynamically. Increase of demand for such products takes place not due to mass customers, but due to hotel lines, fast foods, airports, automobile companies and steamship line, flight catering area, tourist companies, health resort and sanitary institutions.

The main advantage of unit-dose pack is that up to the moment of consumption the product is hermetically sealed and there is no need to provide facilities for its storage (keep specified temperature and humidity regime).

Comfortable unit-dose pack is pleasant to the customer and makes easy accounting system for the administration; many companies prefer such offer method of several products.

II. PROBLEM DEFINITION

At present new type of soft unit-dose pack for the spreads, which is “steak” package combined with two firm polymer plates, is developed and applied [1] (see Fig.1).

The package after opening allows squeeze out spreads through the outlet in the form of the band (for example, butter on bread). At that there is no need to use knife for distribution of the spread.

At the development of new type of the package it is necessary to choose the materials for the production of package and propose the method of its junction.

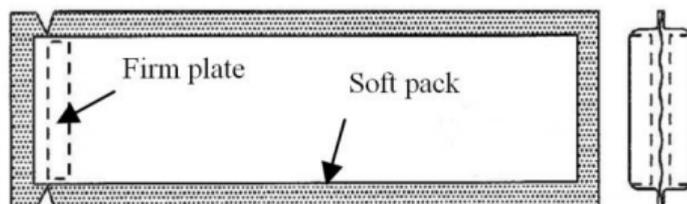


Fig. 1. Scheme of soft unit-dose pack.

To the package materials, which applied for the contact with foodstuff, rigid requirements are set. The dose-init pack for the foodstuff should be impenetrable for sunlight, moisture, oxygen, and also for bad microbes and inimical bacteria, which forward the development of mould.

Important requirement to the package materials is the preservation of the taste of the foodstuff. For the solution of this task the process of package production is being constantly improved; new types of multi-layer polymer films and methods of their joining are developed.

The main operation at the production of soft unit-dose pack is the junction of firm polymer plate with soft polymer film.

Traditional methods of joining such as thermal welding and gluing do not allow provide quality of this operation.

That is why; the task of present paper is the study of possibility to use intensifying action of ultrasonic vibrations for the junction of the materials different in their properties – elastic polymer film (package) and firm polymer plates at the production of soft unit-dose pack.

The final aim of the research is to determine the possibility and appropriateness of the application of ultrasonic welding at the production of soft unit-dose pack of the spreads.

For the achievement of formulated aim it is necessary to solve following special tasks:

- determine optimum conditions and modes of the ultrasonic welding of the package components;
- study influence of the form and material of the package components on quality and strength of the welding seam;
- develop offer on practical realization of the project of the ultrasonic machine (the scheme of the welding seam formation unit).

III. THEORY

The main advantage of soft unit-dose pack of new type is that it can be used by one hand.

So assumed size of the package at the product mass of 10 gr is:

- the length of the pack is 80 mm;

- the width of the pack is 20 mm;
- the width of the outlet is 2 mm;
- the length of the firm plates is 18 mm;
- the width of the firm plates is 3 mm.

At the production of the package (see Fig. 1) it is necessary to form linear step and continuous linear seams.

The welding of the package consists of the following stages:

1. Welding of the firm plates to the polymer films.
2. Formation of side continuous linear welding seams.
3. Formation of transverse welding seam in front of the firm polymer plates.
4. Filling of formed pack with the spread.
5. Formation of transverse welding seam on the edge of the package.

As equipment for experimental studies we choose ultrasonic apparatus of series “Gimney-ultra” model AUS-0.4/22-OM developed at the “Center of Ultrasonic Technologies” ltd, Biysk and intended for the junction of structural articles and list materials by the method of continuous or step-by-step low-temperature welding (see Fig. 2).



Fig. 2. Apparatus of the ultrasonic welding of “Gimney-ultra” series, model AUS-0.4/22-OM.

The main technical features of the ultrasonic apparatus are shown in Tab. I.

TABLE I
MAIN TECHNICAL FEATURES OF THE APPARATUS OF
ULTRASONIC WELDING AUS-0.4/22-OM

Parameter	Value
Power, VA no more than	400
Frequency of ultrasonic vibrations, kHz	22±1.65
Power supply from alternating current line by voltage, V	220±22
Vibration amplitude of working tool, micron, no less than	40
Time of continuous operation, h	8
Maximum welding speed (at the thickness of the material of 200 micron), m/sec no more than	0.3

For the application as accessories at the carrying out of the experiments the welding anvils presented in Fig. 3, 4 were developed and produced.

Fig. 3 shows the appearance of the welding anvil for the production and welding on of the firm polymer plates. Fig. 4 shows the appearance of the welding anvil with polished surface for the formation of linear seams.

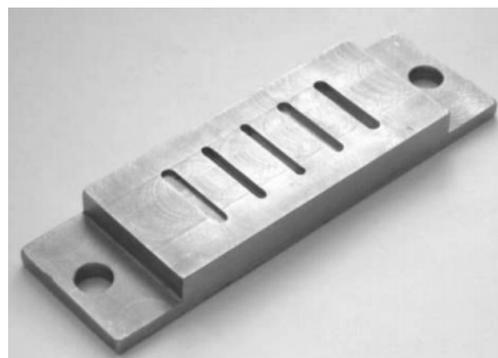


Fig. 3. Welding anvil for the production and welding on of firm polymer plates.

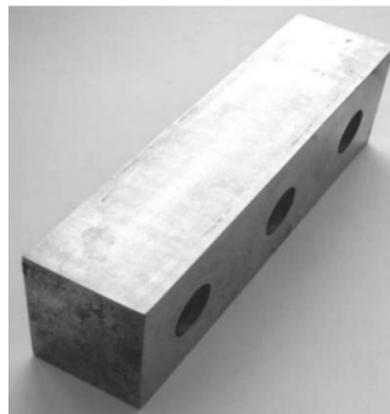


Fig. 4. Welding anvil for the formation of the linear seams.

On the welding anvil for the production and welding on of the firm polymer plates the slots of fixed length are made. The width and depth of the slots are performed different for the production and the welding on of firm polymer plates with various thicknesses.

IV. EXPERIMENTAL RESULTS

At the first stage of the experimental studies the choice of the materials for the package production (synthetic films and polymer materials for the production of firm polymer plates) were carried out.

For the production of the package the samples of synthetic films widely applied in food industry: two-layer (“duplex” – Danplex), three-layer (“triplex”– Danplex III), composition on the base of aluminum foil and polymer films, three-layer compositions on the base of paper and polymer films, PET were chosen.

For production of firm polymer plates we use polymer materials: polyethylene and polypropylene.

At the production of firm polymer plates the welding anvil (see Fig. 3) was used, in which slot the polymer material is pressed, the material was melted by the action of ultrasonic apparatus.

Fig. 5 shows the stages of production (formation) of the firm polymer plates.

The total cycle of formation of the firm polymer plate (time of formation + cooling time) does not exceed 1 second.

At the production of firm polymer plates by described above method melted material is shaped as a slot. At that high repeatability of their geometry is provided (see Fig. 6).

At the second stage of the experimental research we study influence of the form and material of the pack components on quality and strength of welding joint.

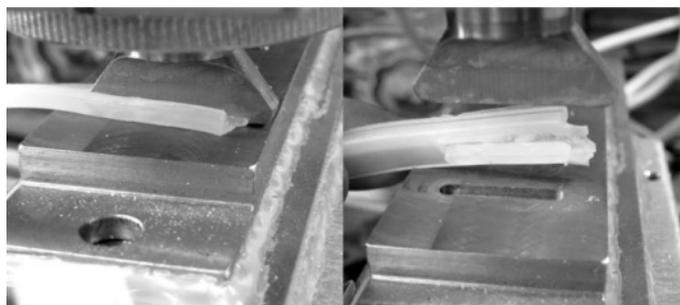


Fig. 5. Method of production of firm polymer plates.

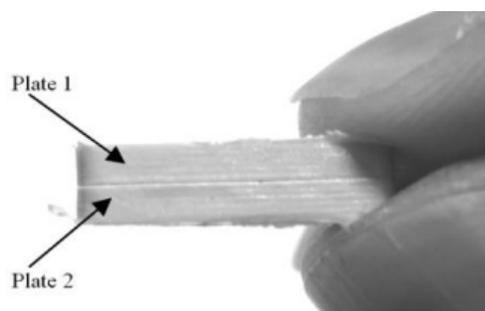


Fig. 6. Firm polymer plates.

At the strength test of the package welded by ultrasound the strength of the package sealing and quality of welding of firm polymer plate to the package material were controlled (see Fig. 7).

As a result of carried out researches it was determined, that all package materials of one type are welded safely with each other. The strength of obtained welding seams exceeds required strength for the unit-dose pack of the spreads. The most strength of the welding seam has polymer film for packaging of mayonnaise (doypack type) on the base of PETF.



Fig. 7. Results of welding of firm polymer plate to the material of the pack.

Many tests on selection of the material of the polymer plate show the possibility to use polypropylene and polyethylene.

Both these materials permit contact with the foodstuff and are safely welded with considered polymer films.

At the same time it should be noted, that firm polymer plates made of polypropylene have more hardness in comparison with the plates made of polyethylene.

It was determined, that after welding the plates made of polyethylene leave small parts of polyethylene in the form of dust around the plate to be welded.

That is why the most suitable material for the production of the firm plates is polypropylene.

The best strength indices of welding of the firm polypropylene plate are provided by the combination on the base of PET at the width of the polymer plate of 3 mm and more (the more the width is, the stronger the welding seam is). The time of welding on of the firm plate to the polymer film does not exceed 0.3 sec the vibration amplitude of no less than 40 micron.

The speed of the polymer film welding on the base of PET by continuous linear seam with the width of 4 mm by the ultrasonic device is no less than 20 cm/sec.

Fig. 8 shows the appearance of formed soft unit-dose pack.



Fig. 8. Appearance of formed soft unit-dose pack.

V. DISCUSSION OF RESULTS

Carried out studies show appropriateness and efficiency of application of the ultrasonic equipment for the production of soft unit-dose pack.

According to achieved experimental results and analyzing all essential factors it is possible to recommend implementation of ultrasonic apparatuses at the productions concerned with the packaging [6,7].

During the experiments it was determined, that the best material for the production of the firm polymer plates is the polypropylene. The best strength indices of welding on of firm polypropylene plate are provided with polymer film on the base of PET at the width of polymer plate of 3 mm and more.

During welding on of firm polymer plates it was determined extrusions of melted material of firm polymer plates (see Fig.9).

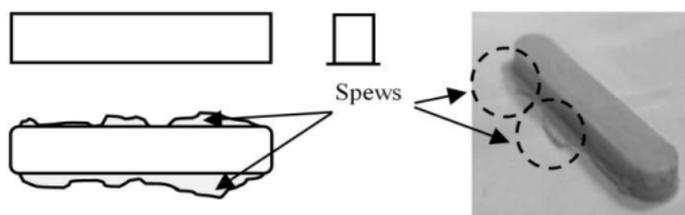


Fig. 9. Firm polymer plate after welding.

The extrusion of melted material from the welding zone is caused by the fact, that the surface of the firm polymer plate contacting with the polymer film is flat.

To exclude extrusion of melted material from the welding zone on the surface of firm polymer plate contacting with the polymer film the stress concentrators (see Fig.10) were made.

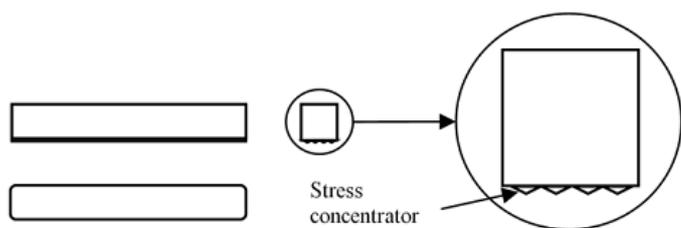
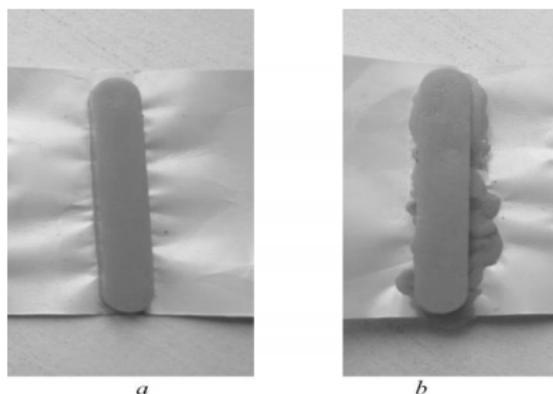


Fig. 10. Firm polymer plate with the stress concentrators.

Fig. 11 shows the results of welding on of the firm plates with the stress concentrators and without them.



a – with stress concentrator; *b* – without stress concentrator

Fig. 11. Result of welding on of the firm plates.

From Fig. 11 it is evident, that qualitative welding on of the firm plates can be without extrusion of the material from the welding zone.

The results of experimental studies allow determine, that ultrasonic apparatus with vibration amplitude of the working tool of no less than 40 micron and power of no less than 400 VA [5] is sufficient for the realization of stated tasks.

The ultrasonic apparatus of series “Gimenez-ultra” model AUS-0.4/22-OM developed in the “Center of Ultrasonic Technologies”, Biysk and intended for the junction of structural articles and list materials by the method of continuous or step-by-step low-temperature ultrasonic welding corresponds to all mentioned above criteria.

At the application of ultrasonic apparatus of series “Gimenez-ultra” model AUS-0.4/22-OM welding speed of the polymer film on the base of PET by continuous linear seam of 4 mm wide is no less than 20 cm/sec, time of welding on of the firm polypropylene plate to the polymer film on the base of PET is no more than 0.3 sec.

VI. SUGGESTION ON PRACTICAL REALIZATION OF THE PROJECT OF ULTRASONIC WELDING UNIT

From the analysis of characteristic features and nuances of welding of the soft unit-dose pack determined during the experiments we can formulate following recommendations for the construction of the unit of welding seam formation in the automatic packaging line with the application of ultrasonic apparatuses [2] – [4]:

1. The package should be formed from two polymer bands wound on the independent drums.

2. For welding on of the firm polymer plates, formation of lengthy seams, traverse seams there is a need in independent sets of the ultrasonic equipment.

3. It is necessary to produce the hermetic case of vibrating system with air-forced cooling from compressed-air network, as the packaging of foodstuff is realized, and they can get into the vibrating system and damage it.

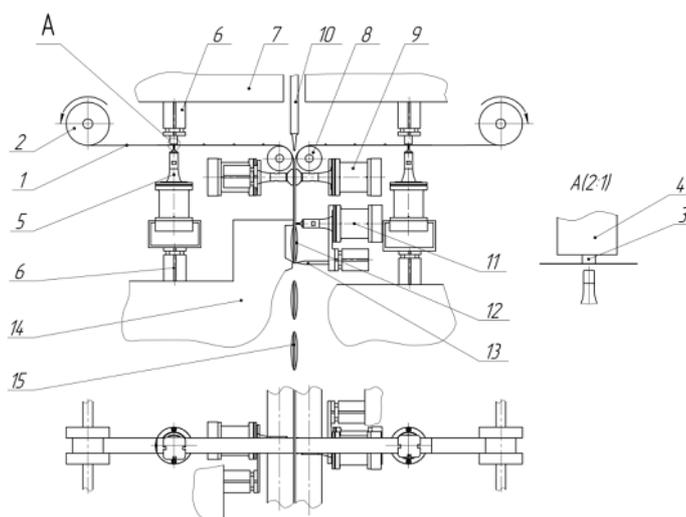
4. To increase productivity of the line of welding on of the firm polymer plates the formation of traverse seam and segmentation of sealed pack should be performed synchronously in one operation.

5. It is necessary to provide control system of the presence of welded firm polymer plate at specified position of the band. At the absence of welded firm polymer plate on the specified position of the band (depletion of the hutch of the half-finished products of firm polymer plates, their jamming in the feeding unit or failure of the welding apparatus) the line should be stopped to avoid the output of defective products and the operator should be informed about the error.

On the base of listed above recommendations following structural scheme of the unit of welding seam formation for the production of unit-dose pack of the spreads (see Fig. 12) is proposed.

The unit of welding seam formation operates in following way: at the broaching of polymer bands 1 wound on the drum 2 the cyclic stop is performed, during which simultaneous welding on of the firm polymer plates to polymer bands, formation of traverse seam and segmentation welded pack are carried out.

The unit of welding on of the firm polymer plates to the polymer band 1 consists of the ultrasonic vibrating system 5, welding anvil 4, pneumocylinder displacement of the welding anvil 6 and guide-plate 3. In the moment of stop in the welding reciprocal anvil 4 the firm polymer plate should be fixed. The displacement cylinder of the welding anvil 6 presses welding reciprocal anvil 4 to the working ending of the ultrasonic vibrating system 5. The ultrasonic action (welding) is carried out. The displacement cylinder of the welding anvil 6 takes aside the welding anvil 4 from the working ending of the ultrasonic vibrating system 5.



1 – band; 2 – drum with wound band; 3 – guide plate; 4 – welding reciprocal anvil; 5 – ultrasonic vibrating system of the plate welding; 6 – displacement pneumocylinder of the welding anvil; 7 – upper base of the device; 8 – bypass roller of the band; 9 – ultrasonic vibrating system of the traverse seam; 10 – dosing unit of the product; 11 – ultrasonic vibrating system of traverse seam welding; 12 – pack-half-finished product; 13 – cutting knife; 14 – lower base of the device, passive anvil of welding and cutting; 15 – ready pack.

Fig. 10. Scheme of the unit of welding seam formation.

For the formation of traverse seam and segmentation of welded pack with the help of the pneumocylinder the ultrasonic vibrating system of traverse seam welding 11 and cutting knife 13 are pressed to the passive anvil of welding and cutting 14. Then ultrasonic action (welding) is realized. The pneumocylinder takes aside the ultrasonic vibrating system of the traverse seam 11 and the cutting knife 13 from the passive anvil of welding and cutting 14. The cutting knife 13 divides in half welding seam obtained by the ultrasonic vibrating system of the traverse seam 11 at the previous stop cycle.

At the formation of traverse seams polymer films 1 are pressed between the ultrasonic vibrating system of traverse seam welding 9 and metal passive anvil made in the form of the roller and sliding surface. The ultrasonic vibrating system of traverse seam welding 9 pauses in the moment of stop cycle (welding on of the plates, formation of traverse seam and segmentation of the pack).

To avoid the detachment of the welded firm polymer plate from the polymer band in the construction of the unit of welding seam formation the bypass roller of the band 8 is provided. The more is the radius of the bypass roller of the band 8, the less is the risk of detachment of welded firm polymer plate from the polymer band.

Thus for the construction of the unit of welding seam formation it is necessary to use 5 sets of ultrasonic apparatuses of series "Giminey-ultra" model AUS-0.4/22-OM (or more powerful), 4 pneumocylinders with additional pneumatic equipment.

VII. CONCLUSION

Carried out studies demonstrate efficiency and appropriateness of the application of ultrasonic equipment for the production of soft unit-dose pack.

Following specific tasks were solved:

- optimum conditions and modes of the ultrasonic welding of pack components were determined;
- the influence of the form and material of pack components on the quality and strength of the welding seam was studied;
- suggestions on practical realization of the project of the ultrasonic machine (the scheme of the unit of welding seam formation) were developed.

The results of experimental studies show that for the realization of stated tasks it is sufficient the application of the ultrasonic apparatuses with vibration amplitude of the working tool of no less than 40 micron and power of no less than 400 VA, which allow construct the unit of welding seam formation in the automatic transfer line.

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