DOI 10.26886/2414-634X.1(37)2020.4

UDC: 621.384.3:621.791:615.462-035

WELDING PROCESS AND FEATURES OF MICROSTRUCTURE OF WELDED JOINTS OF BIOPOLYMERS

V. Talanyuk,

https://orcid.org/0000-0001-6302-0306

A. Shadrin, PhD of Engineering Sciences*,*

M. Iurzhenko, Doctor of of Engineering Sciences,

https://orcid.org/0000-0002-5535-731X

N. Korab, PhD of Engineering Sciences,

M. Menzheres

E. O. Paton Electric Welding Institute of the NAS of Ukraine, Kyiv, Ukraine

Polymers and biopolymers in particular are increasingly used in various sectors of the economy and more recently biopolymers replace traditional polymers in many applications. The problem of polymeric materials recycling can be solved by designing products that will be easy to recycle. In fact, biodegradation is the consistent breaking of chemical links of a polymer molecular chain under the action of microorganisms. Destroying a polymer, bacteria, fungi or algae use the remnants of its molecules as a source of vital organic compounds as well as energy. Usually biodegradation occurs in an aqueous or humid environment during the process of composting. Bioplastics wastes, like fallen leaves or other organic waste, are stacked on soil and gradually converted into environmentally friendly material. The ability of a polymer to biodegrade mainly depends on the chemical composition of its macromolecule chain. It must be heterocyclic and should include biodegradable chemical groups. The chain should not include fragments consisting of more than five CH_2 *groups in sequence. The breakdown of the molecular chain is facilitated by* *the presence in its structure of bulk substituents of hydrogen atoms with a sufficiently large volume. It is also possible to include in the chain of natural organic groups such as starch, cellulose, urea and the like. In this work, the samples were formed by pressing of the polyhydroxybutyrate (PHB) powder under the following temperature conditions: the powder heated up to 40°C was poured into the mold and heated without pressure for 1-2 min. After that it was kept under pressure for 12-15 min., and then it was heated up to 175°C for 3-5 min. According to the experimental data, it was found that with increasing of the pressing temperature internal stresses appeared in the specimens, and defects such as cracks occurred upon cooling. Under lower pressing temperatures, the powder was not completely melted and according to, the samples had a non-homogeneous microstructure.*

Therefore when welding the temperature of the heater was set at 220-240°C, the upset pressure - 0.1 MPa. The warm-up time was varied within 30-40 seconds to determine the optimum conditions of weld formation.

It was confirmed that PHB material is a brittle material with high fluidity when melted. In the welded joints, flash rollers are usually formed with the melt spreading over the sample surface. The flash has a small height almost equal on the both sides of the welded joint.

Keywords: biodegradable, polyoxyalkonoates, thermoplastic polymer, bioplastic.

Polymers and biopolymers in particular are increasingly used in various sectors of the economy and more recently biopolymers have been replacing traditional polymers in many applications. The problem of recycling polymeric materials can be solved by designing products that will make their further processing easy [1].

The design and selection of materials should be implemented taking into the account of the final stage of their life cycle. That could be done by indicating the method of decomposition, recycling or disposal. Plastics allows us to create a variety of packaging forms, have greater protective properties than traditional packaging materials.

Biopolymers are high molecular weight natural compounds that are the structural basis of all living organisms and play a decisive role in the processes of life [2]. In fact, biodegradation is the consistent breaking of chemical links of a polymer molecular chain under the action of microorganisms. Destroying a polymer, bacteria, fungi or algae use the remnants of its molecules as a source of vital organic compounds as well as energy. Usually biodegradation occurs in an aqueous or humid environment during the process of composting [3]. Bioplastics wastes, like fallen leaves or other organic wastes, are stacked on soil and gradually converted into environmentally friendly material. The ability of a polymer to biodegrade mainly depends on the chemical composition of its molecule [4].

It must be heterocyclic and include biodegradable chemical groups. The chain should not include fragments consisting of more than five CH_2 groups in sequence [5]. The breakdown of the molecular chain is facilitated by the presence in its structure of bulk substituents of hydrogen atoms with a sufficiently large volume. It is also possible to include in the chain of natural organic groups such as starch, cellulose, urea and the like [6].

In the present work the samples were formed by pressing of the PHB powder in the following temperature regime: the powder heated up to 40°C was poured into the mold and heated without pressure for 1-2 min. After that it was left under pressure for 12-15 min., and then it was heated up to 175°C for 3-5 min. According to the experimental data, it was found that with increasing of the pressing temperature internal stresses appeared in the specimens, and such defects as cracks have occurred upon cooling. At reduced pressing temperatures, the powder was not melted completely and according to, the samples had a non-homogeneous microstructure.

Fig. 1 PHB powder.

The weldability and properties of the welded joints of PHB were investigated on the plate specimens made by thermal extrusion of a polymeric powder material. In a round metal mold heated up to 40 ° C it poured a measured amount of PHB powder and heated it for 12 minutes in the free state and for 3 minutes under pressure. Then the powder form was heated to 175 ° C and kept under pressure for one minute.

It was experimentally found that with the mold temperature increasing the molded samples had internal stresses, which subsequently led to the formation of cracks. At lower temperatures the powder was not completely melted and a non-homogeneous weakened microstructure was formed during the pressing in the samples.

After cooling down the disc-shaped specimens were received (3-4 mm thick and 25 mm in diameter); rectangular specimens 45 to 50 mm wide were cut out of these discs.

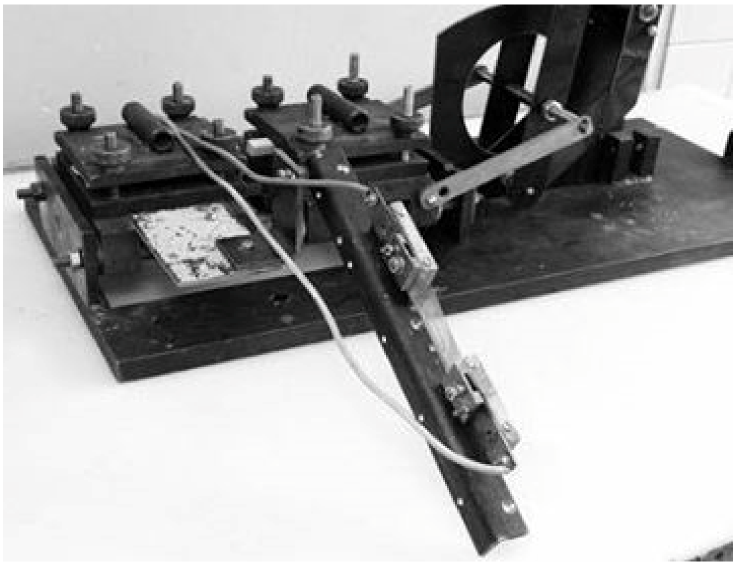

Fig. 2. Experimental device for heated tool butt welding.

The weldability of samples from PHBs was investigated on an experimental device for heated tool butt welding (Fig. 2). The heated tool was a thin plate or stainless steel mesh heated by the transmission of electric current. Experiments with the compression of PHB raw materials have shown that this polymer reacts poorly to overheating to temperatures above 220°C.

Therefore the welding temperature was set at 200 - 210°C, the upset pressure - 0.3MPa. The warm-up time was varied within 30 to 40 seconds to determine the optimum conditions for the weld formation.

The PHB material proved to be a brittle material with high fluidity when melted. In the joint welds, flash are formed with the melt spreading over the specimen surface (Fig. 3). The flash rollers had a small height, almost the same on the both sides of the welded joint.

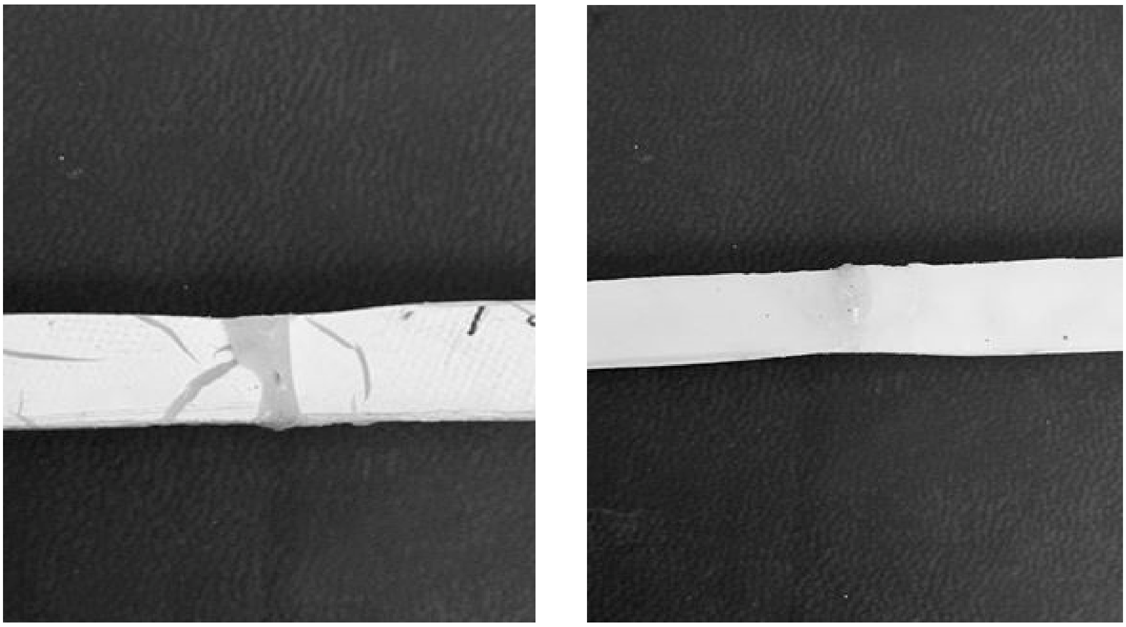

Fig. 3 butt welds of specimens with PHB.

In the process of welding, when the specimens were heated up for 20 - 30 seconds, fragments of unmelted material were observed on the grate (Fig. 3, left), in some areas formed in the weld, which reduced the strength of the welded joint.

With the heating time increasing to 50-60 seconds, the optimal butt welds were formed, with the uniform flash rollers. The longitudinal section of the specimens shows a weld of almost the same size in the vertical plane, which indicates uniform heating of the polymer material. The seam consists of a fairly homogeneous material with a changed structure of a darker color compared to the main polymer material.

Fig. 4. PHB welded specimens and with insufficient melting.

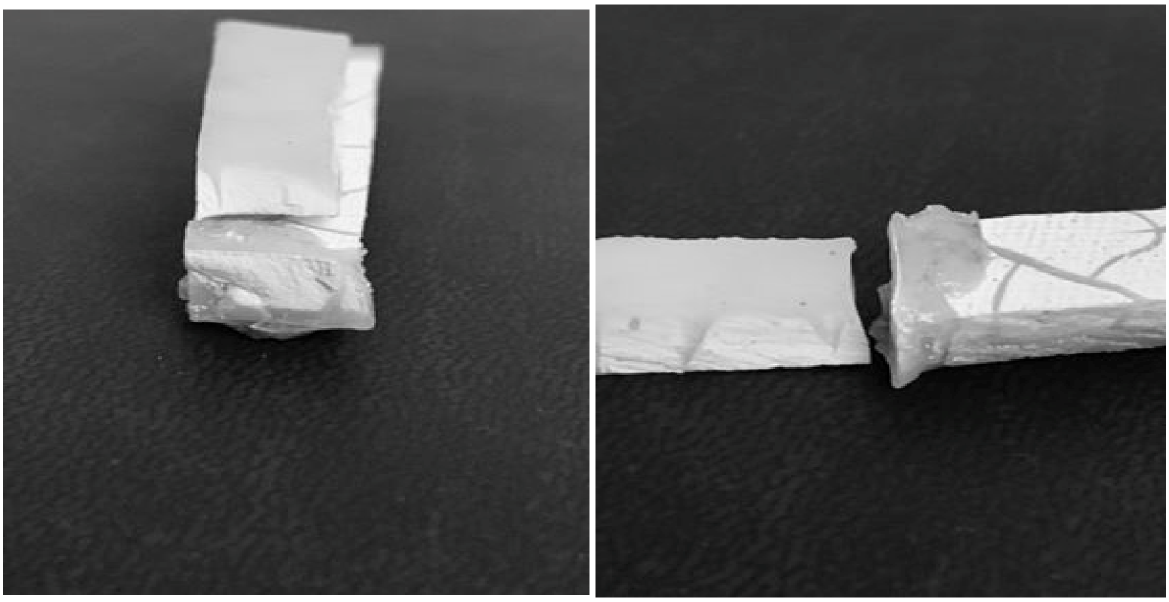

Fig. 5. PHB welded specimens destroyed during the tensile tests.

The tensile tests have shown that the distortion of the optimum welds occurs in the basic material near the thermal impact zone (Fig. 5). The fragile nature of the material is visible on the fracture surfaces, the fracture occurs with the separation of individual fragments and layers of material of the samples. Thus, the PHB polymeric material, although having poor elastic properties, demonstrates good weldability with a heated tool.

Conclusions.

Therefore, due to the significant environmental damage caused by the use of conventional polymers, it is advisable to replace them with biopolymers. After all, their properties, as already mentioned, have no significant differences. Also, it is more appropriate to use biodegradable materials that have less negative impact in the packaging. The main chemical compounds that make biodegradable plastics are starch, polylactic acid, polyhydroxyalkanoates, cellulose and lignin. In this work, we investigated the welding features of the two most commonly used biodegradable polymers – polyhydroxybutyrate. When vacuum packing is used, there is a need for a strong welded joint. A solution to this problem is described in this article.

References:

1. Sudesh K., Maehara A., Gan Z., Iwata T., Doi Y. (2004). Direct observation of polyhydroxyalkanoate granuleassociated-proteins on native granules and on poly(3- hydroxybutyrate) single crystals by atomic force microscopy. Polymer Degradation and Stability, 83, 281–287 DOI: 10.1016/S0141-3910(03)00273-8.
2. Khanna S., Srivastava A. K. (2005). Recent advances inmicrobial polyhydroxyalkanoates. Process Biochemistry, 40, 607–619 DOI: 10.1016/j.procbio.2004.01.053.
3. Jacquel N., Lo C-W., Wei Y-H., Wu H-S., Wang S. S. (2008). Isolation and purification of bacterial poly(3-hydroxyalkanoates). Biochemical Engineering Journal, 39, 15–27 DOI: 10.1016/j.bej.2007.11.029.

4. Ramsay J. A., Berger E., Voyer R., Chavarie C., Ramsay B. A. (1994). Extraction of poly-3-hydroxybutyrate using chlorinated solvents. Biotechnology Techniques, 8, 589–594 DOI: 10.1007/BF00152152.
5. Jiang X., Ramsay J. A., Ramsay B. A. (2006). Acetone extraction of mcl-PHA from Pseudomonas putida KT2440. Journal of Microbiological Methods, 67, 212–219 DOI: 10.1016/j.mimet.2006.03.015.
6. Yu J., Chen L. X. L. (2006). Cost-effective recovery and purification of polyhydroxyalkanoates by selective dissolution of cell mass. Biotechnology Progress, 22, 547–553 DOI: 10.1021/bp050362g.

Citation: V. Talanyuk, A. Shadrin, M. Iurzhenko, N. Korab, M. Menzheres (2020). WELDING PROCESS AND FEATURES OF MICROSTRUCTURE OF WELDED JOINTS OF BIOPOLYMERS. Innovative Solutions in Modern Science. 1(37). doi: 10.26886/2414-634X.1(37)2020.4