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MODERNIZATION OF THE EXTRUDER WORM IN ORDER TO IMPROVE THE QUALITY OF POLYMER PRODUCTS

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ABSTRACT

The research has developed a technical solution for enhancing the core of polymer particles in the extruder with the modernization of the worm. The essence of the modernization of the worm lies in the fact that the mixing section of the worm has radial pins, which will ensure more efficient preparation of melted recycled material. This is the reason for the modernization of the worm with the increased mixing of the material and the efficiency of the production of polymeric particles with an extruder.

KEYWORDS

Extruder, Worm, Polishing, Viscosity, Radial Pins, Mixing Section, Polymer Agents

CITATION

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Introduction.

The extruder is a universal equipment that is capable of processing a wide range of materials: rubber, plastics, ceramics, food, metals, etc. The extruder can be used to process various materials. This makes it indispensable equipment in many industries such as: construction, mechanical engineering, packaging, food industry, etc.

An extruder is a type of equipment used in manufacturing to create products by pushing materials through a die to shape them into the desired shape. The process involves feeding the material into an extruder, where it is subjected to high pressure and temperature. The material is then pushed through a special hole in the die to create a continuous profile. Their efficiency and precision in forming materials have made them a staple of modern production lines [1].

Extrusion is the process of obtaining products by squeezing material through a molding hole in the matrix [2].

The main advantages of the extruder are: ease of equipment maintenance, the ability to quickly produce a large number of products in a short period of time, profitability of manufacturing polymer products from prepared melt without waste and residues, etc.

The main disadvantages include: wear of the worm, heating of the body, constant monitoring of the process of converting granules into a finished melt, obtaining a heterogeneous melt, on which the quality of future products depends, etc.

In order to eliminate the last drawback of the extruder, a literary and patent search for the modernization option was performed, which helped to choose the modernization of the extruder.

The purpose of the article is to choose a way to improve the quality of polymeric materials in the extruder based on the modernization of the worm.

Features of the design and principle of operation of the extruder for the production of polymer products

Most methods of processing plastic masses involve the formation of products from raw materials that are in a viscous state. These are such methods as: injection molding, extrusion, pressing, calendering, etc. Some methods are based on the formation of the material in a highly elastic state, for example, vacuum forming, pneumatic forming. Methods of forming from solutions and dispersions of polymers, obtaining products by irrigation, pouring, etc. are also used.

Usually, at the temperature of the production room, the feedstock enters the feeding area in the form of granules or powder. Modern high-performance extruders are equipped with equipment for drying and preheating of raw materials up to 60–110 °C. During the processing of some polymers and plastics based on them (for example, PETF, PA-6, PA-12), ensuring low moisture content of raw materials is mandatory, since without this it is impossible to ensure a stable extrusion mode and high quality Products. The schematic diagram of the worm extruder is shown in Fig. 1 [3, p. 167].

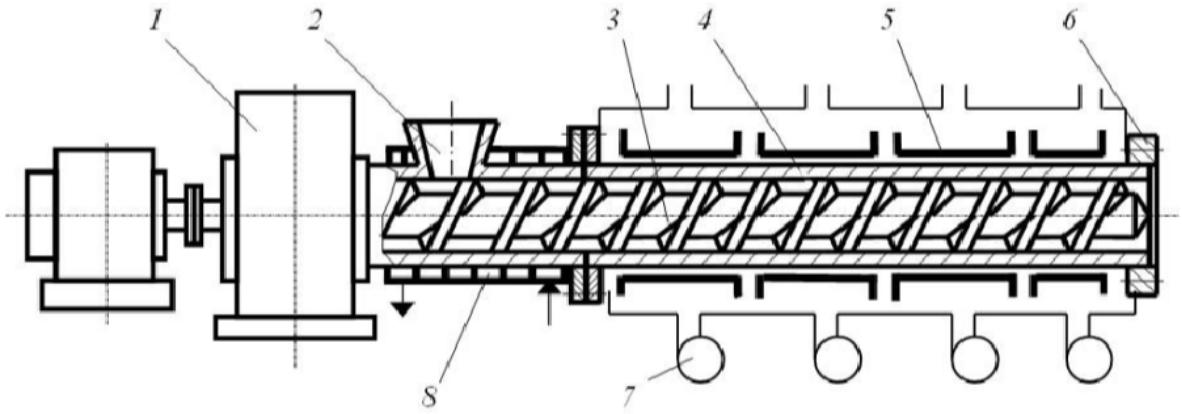

Fig. 1. Schematic diagram of a single-worm extruder:
1 drive; 2 - watering can; 3 - worm; 4 - cylinder; 5 - heaters; 6 - flange connection; 7 – fan; 8 – channels

The polymer granules enter the loading funnel 2 of the extruder. The material is then transported along the cylinder 4 by the worm 3, which rotates from the drive 1. Due to the appropriately designed geometry of the worm, the polymer is compressed, melted, homogenized and under a certain pressure enters the extrusion head. The head is attached to the cylinder by means of a flange connection 6. The air contained in the spaces between the granules, is squeezed out by compacting the granules through the loading funnel 2. The heat required for melting is supplied mainly from the drive, the mechanical energy of which, due to dissipation in the volume of the formed melt (viscous friction), is converted into heat. Part of the energy is supplied from heaters 5 placed on the surface of cylinder 4. It should be noted that in some cases the heat of dissipation exceeds that required for melting and homogenization, and therefore it is possible to remove its excess. This is done through cooling by means of fans 7. In some cases, liquid cooling is also used. The extruder supply zone is cooled by water supplied to channels 8 to prevent premature melting [3, P. 167].

Mixing is one of the most important methods of preparation of polymer compositions, which is designed to obtain a mixture of the main polymer and various ingredients and significantly improves the properties of the material and products from it. The resulting mixture must be homogeneous in physical and chemical properties and have an even distribution of ingredients over the entire volume of the mixture. Due to the fact that the ingredients are often introduced into the main polymer in agglomerated form, the mixing process may be accompanied by simultaneous dispersion. In practice, the process of mixing polymeric materials is carried out as a result of the force on the system, however, in principle, it is possible to carry out the mixing process as a result of molecular diffusion – provided that the sizes of polymer particles and particles of ingredients are comparable, as well as with a low viscosity of the polymer medium.

In industry, it is common to mix polymers in the liquid phase (when the main polymer is in a liquid state), mix solid bulk materials and mix viscous plastic masses. For mixing in a liquid state, pneumatic, hydraulic and mechanical methods are used. For mixing bulk materials, in addition to pneumatic and mechanical methods, the gravitational method is used. For mixing viscous non-Newtonian systems, only a mechanical method is usually used, which ensures an intense mixing effect. In mixing equipment, the mixing process can occur both continuously and periodically (cyclically) [3, P.100].

To modernize the extruder, it was decided to modernize the worm, as one of the most important elements, the design of which most of all affects the mixing efficiency and quality of polymer products.

Materials and research methods for the choice of the option of upgrading the extruder worm for the manufacture of polymer products

In order to ensure the improvement of the quality of polymer products, a literature and patent review of options for the modernization of the worm was carried out.

As a result of the literary and patent search and analysis of options for upgrading the extruder design, several interesting technical solutions with the modernization of the worm were selected. Let's consider them in more detail to choose the most appropriate technical solution to improve the quality of polymer products.

In the paper [4], a design of an extruder with a worm is proposed, which is equipped with mixing elements in the form of cams. Also, in the housing, the pins installed with the possibility of reciprocating movement in the radial direction are equipped with elastic elements. These elastic elements are installed with the possibility of contact of their end surface with the cams. In this proposed design, due to the continuous contact of the pins with the cams and the corresponding reciprocating The movement of the pins during the rotation of the worm with cams occurs an intensive change in the direction of movement of the particles of the material components in the interval between the body and the mixing elements. This will contribute to obtaining high-quality polymer products in the extruder.

The source [5] discusses the improvement of the extruder based on the use of rotating elements located within the worm cutting. At the same time, the rotating elements are made longitudinal with cylindrical end sections, which are located in the grooves of the ridges of adjacent turns of the worm cutting. Also, the middle part of at least one rotating element is made with a cross-section, which is different from the round one. This design provides a pulsating effect of such a rotating element on the processed material and increases the mixing and dispersing capacity of the extruder as a whole.

In the source [6], the design of a single-worm extruder is proposed, which contains a hollow body with a worm with a mixing section at its end section. The mixing section of the worm is equipped with radial pins and is made hollow with the possibility of placing the mandrel of the extrusion head in it. A mandrel in cross-section at the location of the radial pins is made of a non-circular shape, for example, in the form of an ellipse, hypocycloid, epicycloid or Cassini oval. Radial pins are placed in the radial holes of the worm with the possibility of reciprocating movement and interaction with the mandrel. In this design of a worm with radial pins in the mixing section, the movable pins are flowed around the resulting melt due to increased shear deformations. This ensures intensive mixing and dispersion of the components of the processed material, which helps to improve the quality of finished polymer products.

We propose to choose a technical solution based on a prototype [6] with a worm with radial pins in the mixing section to improve the design of the extruder. A drawing of the design of the modernized worm was made, which is shown in Fig. 2. Fig. 2 in view A-A shows the longitudinal section of the mixing section of the worm with radial pins on an enlarged scale. Fig. 2 in view Б-Б shows the longitudinal section of the worm key. Fig. 2 in the B-B view shows the cross-section of the mixing section of the worm with radial pins. In Fig. 2, in the Г-Г view, the longitudinal cross-section of the worm with turns is shown on an enlarged scale.

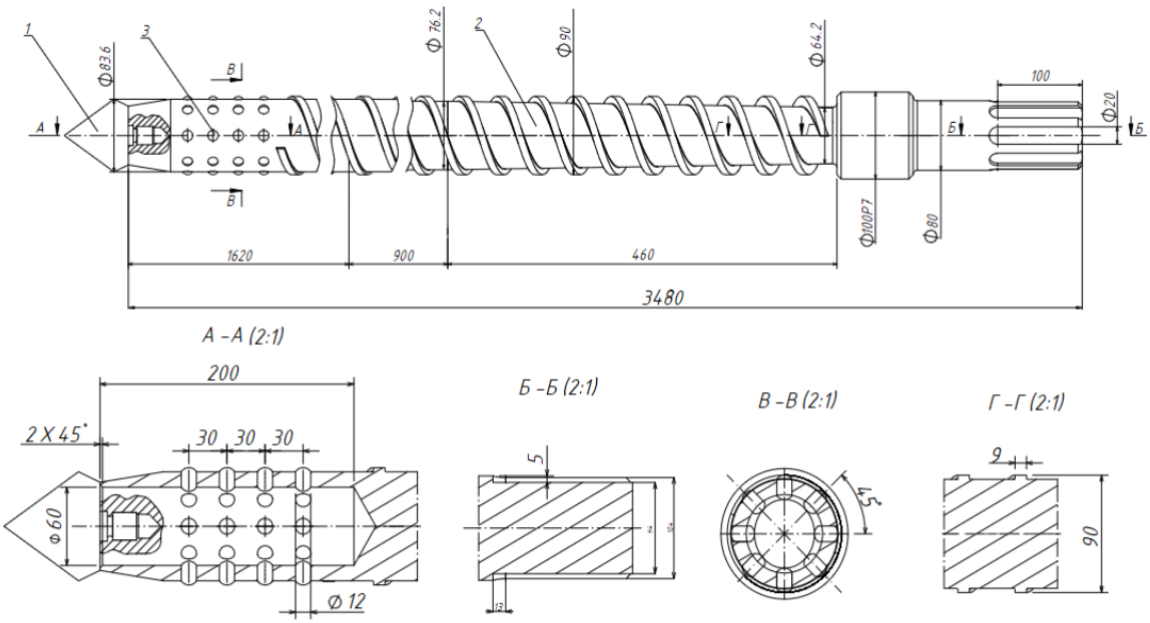

Fig. 2. Upgraded worm design:
1 - head; 2 - radial pins; 3- worm

Consider the principle of operation of an upgraded worm with radial pins in the mixing section. The single-worm extruder has a hollow body with an extrusion head equipped with a fixed mandrel 1. In the cavity of the body with the possibility of rotation, a worm 3 with a mixing section at the end section is placed. The mixing section of the worm 3 has radial pins 2 and is made hollow with the possibility of placing the mandrel of the extrusion head 1 in it. And the mandrel in cross section at the location of the radial pins 2 is made of a non-circular shape, for example, in the form of an epicycloid. And pins 2 are located in the radial holes of worm 3 and have the ability to reciprocate and interact with the mandrel [6].

The proposed design of an upgraded worm extruder with a mixing section with radial pins, which provides more intense shear deformations. This will achieve an increase in melt uniformity and will contribute to the improvement of mechanical properties (tensile strength and impact toughness) of finished polymer products. Also, a more complete dispersion of fillers and dyes is achieved, which makes it possible to obtain materials with a wide range of colors and Properties. The upgrade also helps to reduce energy consumption by mixing more efficiently and reducing the time the material stays in the extruder. These flows, combined with the rotational motion of the worm, provide intensive stretching and compression of the material, resulting in efficient dispersion of the mixture components. mixing efficiency with minimal energy consumption [6].

The technical result for the proposed design for the modernization of the extruder worm is that thanks to the mixing section of the worm with radial pins, more intensive melt mixing is ensured. This contributes to obtaining finished polymer products of higher quality.

The use of the proposed design of the extruder worm makes it possible to achieve the goal, namely, to improve the quality of the resulting polymer products.

Conclusions.

Thus, the technical result of the proposed design for the modernization of the extruder worm is that during the rotation of the worm, due to the contact of the pins with the curly surface of the fixed mandrel, their reciprocating movement in the working gap of the extruder between the worm and the body is ensured, and therefore the intensive effect of the pins on the material to be processed. This increases the mixing and dispersing effect, and also contributes to the production of better obtained polymer products in the extruder.

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