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THERMOPLASTICS RECYCLING PROCESSING TECHNOLOGY FOR MECHANICAL ENGINEERING

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Plastics, the materials based on polymers, are capable of acquiring a specified form on heating under pressure and maintaining it after cooling. Depending on the designation and conditions of operation plastics can contain auxiliary materials: filling compounds, plasticizers, stabilizers, pigments, lubricants, etc.

Manufacture of plastics which was born in the middle of the 19th century has been developing at a high rate since the late 1930s. In the early 1990s, the world's production of plastics was as high as 102 m tons/year, being increased by 52% in the period between 1980–1990's. At present, the role of polymers in life activity of humans is so great that standards of living can be assessed by the levels of application of these materials. In 1995, the average consumption of plastics per capita in the world was 19.7 kg and in different countries, it varied from 200 g (Pakistan) to nearly 200 kg (Belgium). In the late 1990, the production of plastics in Belarus amounted to 58 kg/ man per year.

Depending on the temperature of forming of plastics the latter are subdivided into thermoplastics and reactoplastics, with the bases being composed of thermoplastic and thermoreactive polymers [1].

Up until the beginning of the 20th century, the methods for polymer processing into goods imitated the known methods for processing such materials as clay and soft metals (casting, pressing, forming), and it was not until the middle of the 20th century that novel technologic methods for molding of plastics appeared which are based on application of polymer specific properties: pneumatic-and vacuum molding, calendaring, etc. Now target methods and techniques for processing of plastics may number into the dozens.

High specific strength, corrosion resistance, thermal and electrical conduction as well as a combination of other advantages of metallic materials cannot completely meet requirements of experts in development of brand new technical equipment and technologies. Moreover, developers and technologists have to take into consideration depletion of raw stocks of traditional machine-building materials and increased power inputs and efforts related to their exploration, output, and transportation and processing [1].

Therefore the key problems of up-to-date material science cover development of structural materials using new types of raw materials, more integral application of traditional and secondary resources and optimization of material structures so as to impart them a complex of unusual and, often, contradictory properties. A topical orientation in solution of these problems is development of machine-building materials based on synthetic natural and artificial binding materials. Plastics, rubbers, wood plastics and ceramic materials are among the most common and promising materials.

In choosing the technology for plastics processing we can use the following classification based on the physical state of a polymer material in shaping the good or molding [2]:

- 1) polymers in a viscous-flow state are processed by extrusion, high-pressure casting, pressing;
- 2) film and laminary intermediates in high elastic state are processed by vacuum molding, warm forming, drawing;
- 3) hard polymers manifesting inducing high elasticity are treated by forming at room temperature, rolling;
- 4) polymer solutions and dispersion are applied in manufacture of films by flowing, forming of casings by dipping of a form, rotational forming of castings from plastisols (pastes based on PVC and plasticizer), application of polymer powder coverings;
- 5) sintering of pressed powder intermediates (pressings) from reactoplasts of thermal plastics with high viscosity in a viscous-flow state (fluoroplasts).

Thermal plastics goods can often be manufactured by several different methods. The choice of processing method for every specific product is governed by a diversity of factors, with the most important ones being the following:

- design;
- technological property of a polymer material;
- operation conditions of a product, and the resulting requirements for them (surface quality, dimensional accuracy, the presence of accessories, threadings, etc.);
- anticipated product replication;
- economic and ecologic factors (cost of equipment and accessories, their productivity and durability, labor inputs, qualification of workers, amount of material wastes, possibility of after-processing, etc.).

Thermoplastics are processed into goods with technologic equipment, the operational principle being based on the property of a thermoplastic material being reversibly converted into a viscous-flow state. The following methods for thermoplastic processing received industrial application: extrusion, high-pressure casting, compression forming, sintering and mechanical treatment [3].

Extrusion (squeezing-out) is a process of manufacturing of goods of required forms and dimensions or elongated profile semi-processed products by heating of polymer granules (granulate) and forcing the polymer mass that is in a viscous-flow state through the forming aperture of extruder head (Figure 1, a).

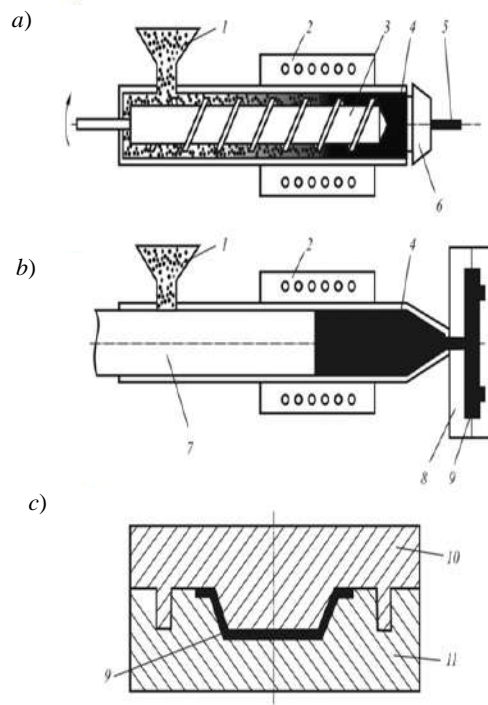


Figure 1 – Methods for plastics processing:

- a* – extrusion (squeezing out); *b* – high-pressure casting (injection); *c* – compression forming;
 1 – granulate; 2 – heater; 3 – screw conveyer; 4 – melt; 5 – extruded profile; 6 – head; 7 – piston (plunger); 8 – casting form;
 9 – cast product (pressing); 10 – plug; 11 – matrix

The main part of a special extruder for squeezing out of melt is a screw (screw conveyor). Thermoplastic as granules or powder *1* comes from a feed hopper into a heated cylinder 4 where it is moved by a rotating screw 3. The material is tightened and under the action of heat coming from a heating element 2 is converted into a thick-flow state. Thereafter it is continuously forced through a calibration instrument (head) 6 as profile 5.

Flat (sheets), profile (profile (angles, channels) and voluminous (tubes) goods are formed depending on the form of the aperture in the head. By ballooning of the squeezed tube hose stock with the help of air, films of various thickness and length are obtained. To increase strength and decrease thickness of the films, the hose is subjected to one- or two-axis orientation. Special design of heads with extrusion nozzles supplied by a great number of low diameter apertures makes it possible to extrude filaments and fibers. The *melt-spinning technology* allows for extrusion of fiber with subsequent gravitation drawing and strengthening. The *melt-blowing method* (spraying of polymer melt by a gas flow) is used for production of fibrous unwoven fabrics with various porosity and density.

Extrusion is one of the most productive methods for processing of thermal plastics. Aggregates with the productivity as high as 10 t/h are created with a great degree of technologic process automatization. Extrusion is used to produce polymer tubes with a 1.5-m diameter and films of 25-m width. A new promising equipment, reactors-extruders, is developed. The processes of melting and polymerization are combined in such instruments. The first specimens of such equipment of 50 kg/h productivity were used for manufacture of polymethylmethacrylate articles.

High-pressure casting is executed with the help of special machines with a plunger and screw injection device (Figure 1, *b*). Processing of thermoplastics by high-pressure casting is based on heating of the material to a viscous-flow state, its replacement under pressure to a mold and subsequent cooling of the cast providing for stability of its shape. A thermoplastic polymer *1* as granules enters a feed hopper to a cylindrical cavity of an injection machine where the predetermined temperature is maintained. A piston or a plunger 7 which is periodically set into motion squeezes the polymer mass into a divided cooled mold 8 where the end product 9 is being molded. Modern casting machines can mold production weighing in the range from a fraction of a gram to 100 kg.

The high-pressure casting is used to produce a high production mix of items for constructional, antifirction and general purposes. The equity of the method is a high accuracy and quality of the goods, Application of multicavity molds, preliminary heating of raw materials and the high degree of process automatization (completely automated lines have been developed which are operated by a computer) allow for attainment of high efficiency of equipment application.

Thermoplastics as sheets or films are processed by *compression molding*. The essence of the method is in forming of a polymer intermediate as a sheet or a film with the help of compressed air (pneumoformation) or vacuum (vacuum-formation). Compression molding is used for manufacture of large-sized items of a complex configuration: parts of automobiles, casts for television- and radio equipment, hulls of boats, etc [3].

Sintering is used for processing of thermal plastics with high melting points and great viscosities of the melts (fluoroplasts, high-filled polyolefines). The traditional technology of sintering includes operations of component mixing, pressing of the mixtures in a mold, sintering of the pressing and cooling of the product. The products are sintered at a temperature of 5...10 °C in excess of the melting point of the basic thermoplastic. A protective gas medium (nitrogen, carbon dioxide) is used for prevention of product oxidation.

Reactoplasts are processed into goods by pressing, compression molding, centrifugal molding and winding. The most common method for processing of reactoplasts is pressing: direct (compression), casting (transferring), rotor and continuous profile pressing (extrusion pressing).

General operations for pressing of all types are loading of the press composition into a form, its transition to a viscous-flow state, shaping the blank under pressure, fixation of the product form by formation of a cross-linked structure of the material under pressure and temperature and cooling of the product. In direct, casting and rotor pressings, the products are implemented and the form is fixed in a closed volume, a tool's molding cavity (Figure 1, *c*). Large-sized products are molded by extrusion pressing during continuous process of plunger pressing combined with heating of the powder composition. The process is completed by squeezing of the product through a nozzle.

The technologic process of manufacturing from a special type of polymer raw materials named press materials includes the following main operations: preparation of materials and their dosing, pressing of

tablets, preliminary heating of tableted material, its loading into a molding tool, closing the molding tool, premolding, exposure to pressure, disclosure of the molding tool and withdrawing of the product, cleaning of the molding tool and preparation to the subsequent cycle of molding [4].

The initial thermoreactive press-powder which has passed through input control is tableted to decrease the volume of the press mass and increase the accuracy of its dosage. To reduce the duration of material exposure to pressure, preliminary heating of the tablets is carried out at the temperature of reactoplast cross-linking. During heating the binding product is partially cross-linked and the adsorbed low-molecular-weight products are removed. The heating is implemented with IR-heaters or RF current. After closure of the heated matrix and plug of the loaded molding tool, the press material undergoes cross-linking of the polymer binding agent. These are generally polycondensation processes accompanied by release of water and gases. The latter stipulate the porosity of the product, worsening its properties. To remove low-molecular-weight substances from the molding tool, 2 or 3 *premoldings* are carried out: lifting of the plug for a short time followed by a rapid closure of the molding tool. The premolding duration amounts to 1–5 s.

The most prolonged operation of the molding technological cycle is high temperature exposure of the molding tool to pressure which is required for complete hardening of thermoreactive press material. To remove residual strains occurring during molding, the parts are thermally processed.

Transfer molding includes similar technological operations. The constructive feature of the molding tools applied for this method implementation, it the presence of a special loading chamber (precombustion chamber) from which polymer material in a viscous-flow state is squeezed into tool's molding cavity.

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К ВОПРОСУ ИСПОЛЬЗОВАНИЯ БЕЗУГЛЕРОДНОГО ТОПЛИВА ДЛЯ ПОВЫШЕНИЯ ЭКОЛОГИЧЕСКОЙ БЕЗОПАСНОСТИ ДИЗЕЛЕЙ ТЕПЛОВЗОВ

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Согласно Стратегии долгосрочного развития Российской Федерации до 2050 года для железнодорожного транспорта предполагается снижение уровня выбросов парниковых газов с 3,9 т на тонно-километр до 3,2 т на тонно-километр. Проблема снижения выброса в атмосферу парниковых газов тесно связана с проблемой улучшения показателей топливной экономичности двигателей, которую можно достичь конвертацией дизельного двигателя в биодизель путем применения безуглеродного топлива, такого как аммиак [1, 2].

При переводе дизелей тепловозов на работу с использованием альтернативного топлива возникает необходимость создания или модернизации системы подачи двух топлив и оптимизации её работы, а также обеспечение надёжного, своевременного и устойчивого воспламенения топлива и надёжной работы топливных насосов и форсунок [3].

Наиболее значимыми токсичными компонентами отработавших газов дизелей тепловозов являются оксиды азота NO_x , которые представляют особую опасность для атмосферы, имеют II класс опасности, высокий в сравнении с монооксидами углерода, дымностью и углеводородами (ГОСТ 33754-2016).

Комплекс мероприятий по снижению вредных выбросов в отработавших газах и повышению экологической безопасности включает в себя три основные группы такие, как: конструктивные, эксплуатационные и химико-технологические [4].