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RATIONALE FOR POPULARIZATION OF PROCESSING OF POLYMER WASTE FROM TIRES IN INDUSTRY

ОБГРУНТУВАННЯ ПОПУЛЯРИЗАЦІЇ ПЕРЕРОБКИ ПОЛІМЕРНИХ ВІДХОДІВ ІЗ ШИН У ПРОМИСЛОВОСТІ

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Abstract. *The rubber and plastics industry is increasingly becoming an important industry. Polymers are used in almost all areas of material production and non-productive sphere. Demand for finished products made of polymeric materials from the most important consumer industries is growing steadily: construction, transport, agriculture, medicine, etc.*

Polymer and rubber products are becoming more and more sophisticated, but at the same time methods of waste management and disposal are being developed and complicated. Over time, they can no longer be used for their intended purpose, so they are discarded and sent to landfills, while polymers and rubber are valuable construction materials and their reuse will be positive not only for the environment but can also be a profitable branch of the agro-industrial complex. .

The generation of significant amounts of rubber and polymer waste leads to unorganized storage in landfills or uncontrolled dispersal in the natural environment, which increases the level of environmental hazards in the surrounding areas as a result of harmful substances from rubber and plastic into the environment.

This article investigates the methods of processing polymer and rubber waste by improving technologies for their processing into secondary raw materials. The relevance of polymer waste processing methods is determined. Types of recycling and stages of polymer waste processing are discussed. The life cycle of rubber is analyzed and the analysis of existing technologies of utilization and processing of rubber waste is carried out. Stages of rubber waste processing are substantiated. Pyrolysis technology for rubber waste processing is described. Taking into account the information obtained, conclusions were made and the characteristics of the studied composite, which includes sand, rubber and polymer, were determined.

Key words: *rubber-technical products, polymer waste, utilization, pyrolysis, composite.*

Formulation of the problem

In recent years, countries around the world have begun to pay considerable attention to the problem of using production and consumption waste, which is generated in ever-increasing quantities.

Mankind is living in an age of consumption - the production of a wide range of goods is only increasing.

Today, polymers are the most common raw material in many areas, as a result of which they have replaced more expensive raw materials - natural wood and metal. The cheapness of the material, the technical parameters of plastic doomed it to popularity.

The widespread use of plastic products has raised a number of questions about the disposal of plastics, which has lost its practical interest. The main problem is that the period of natural decomposition of plastic is from 100 to 400 years, and as a result, traditional burial in landfills does not solve the problem [1].

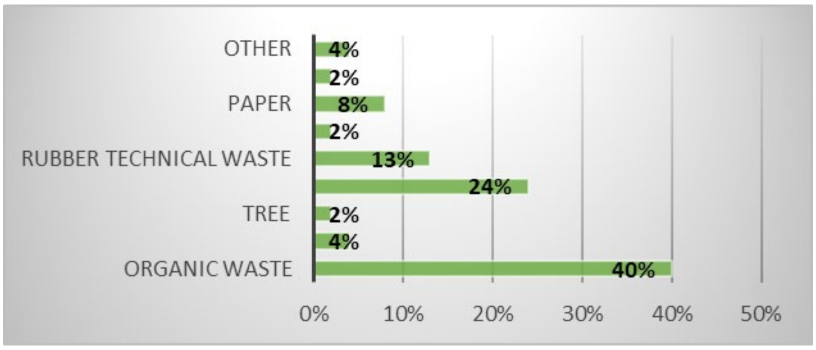

Fig.1. Percentage of waste in Ukraine.

Thermal destruction leads to the release into the atmosphere of harmful substances that are not excreted from the human body. The best option is recycling, ie recycling of plastic.

Plastic mass (plastic) - artificially created materials based on synthetic or natural polymers. They are formed at elevated temperatures, at a time when they have high plasticity. Raw materials for the production of polymers are oil, natural gas, coal, shale [2].

Plastics have a fairly low density (0.85-1.8 g / cm2), which contributes to their significant demand. This feature of plastic significantly reduces the weight of parts, in addition, they have high corrosion resistance and a wide range of other properties. Plastics make it possible to successfully use them for the manufacture of plain bearings, because they have good anti-friction characteristics. The high coefficient of friction of some plastics allows them to be used for brake devices. Some plastics have specific properties: high electrical and thermal insulation properties, high transparency, etc. [1].

An important advantage of plastics is the ability to process them into products in the most productive ways with a coefficient of material utilization of 0.9-0.95 - casting, extrusion, etc. [4].

The disadvantages of plastics include:

- low strength, hardness and mechanical rigidity;
- large value of the coefficient of linear thermal expansion (~ 15 × 10−5 K − 1);
- creep, especially in thermoplastics;
- low heat resistance (most plastics have an operating temperature not higher than 200 ° C, and only some can operate at 300… 400 ° C),
- low thermal conductivity (500-600 times less than metals),
- tendency to aging (loss of properties under the influence of heat, light, water and other factors) [2].

When the aging process occurs, polymer products lose their elasticity and strength while increasing their mechanical stiffness and fragility. The ability of a material to large back deformations is called elasticity. This term is physically similar to elasticity, but the former is used for amorphous and the latter for crystalline bodies [3].

The hardness of plastics according to the Brinell method is 30… 200 MPa [2].

Many polymers have an amorphous (glassy) state, such polymers are called resins.

Plastics may contain a certain amount of crystalline phase, which increases the strength, stiffness and heat resistance of the polymer. In the production of plastics using mainly synthetic resins [3].

In addition to polymer raw materials, plastic products can be filled with fillers, plasticizers and special additives that give plastic certain properties.

Fillers (reinforcing components) can be organic or inorganic substances in the form of powders (graphite, wood or quartz flour), fibers (paper, cotton, asbestos, glass) or canvases or sheets (fabric, paper, wood veneer). Fillers increase the strength, wear resistance, heat resistance and other properties of plastics. Their share in plastic can reach 40… 80% [2].

Plasticizers are introduced to increase the plasticity and elasticity of plastics (glycerin, castor or paraffin oil, etc.) [2].

Additives can be:

- stabilizers - substances that slow down aging (soot, sulfur compounds, phenols);
- lubricants - substances that eliminate the adhesion of the material to the mold, increase its fluidity, reduce friction between the particles of the composition (wax, stearin, oleic acid);
- dyes - substances that give plastic products a decorative look (ocher, etc.);
- catalysts - substances that accelerate the hardening of plastics (urotropin, metal oxides);
- flame retardants - substances that reduce the flammability of polymers (eg antimony compounds);
- antistatic - substances that prevent the occurrence and accumulation of static electric charge in products made of polymeric materials;
- pore formers - substances that decompose during heating, releasing resin-foaming gases, resulting in the formation of pores and foams with a porous structure.

Plastic waste also includes worn tires, which are one of the most heavy-duty polymer wastes. Automotive industry It has developed a lot in recent years, and as a result there has been an increase in total waste [4].

Used rubber should be classified as industrial waste. Millions of tons of waste are generated during the wear of rubber products. Most of them are used car tires (tires of trucks, cars, agricultural vehicles, tractors, motorcycles and special vehicles), as a rule, are subject to disposal. Their suppliers are industrial and private farms, as well as administrative institutions [5].

Tires of fleets of industrial enterprises and administrative institutions in the framework of general technical and repair work are subject to regular replacement every 1-2 years. Tires of private cars have a service life of 60-80 thousand km, which corresponds to an average of 3 years of operation. This also includes conveyor belts, household rubber products, shoes. 700-750 kg of new rubber can be made from 1 ton of worn tires [5].

Rubber crumb from car tires is used in the production of roofing materials, available in the form of mastic, rolls and plates. It can also be used in the production of bio-resistant thermal insulation material for floor insulation, car interiors, tractors.

Rubber crumb is a valuable raw material for the manufacture of various building materials and is widely used for the preparation of rubber-asphalt mixtures in road construction. Worn tires can be used to produce adsorbent and ion exchange materials. Ion-exchange materials made of crushed rubber are suitable for wastewater treatment from ions of some metals with 99.5 percent efficiency, and adsorbents - for collecting spilled oil from the water surface and purification of waste oils [5].

Crushed rubber can be used as a backing layer when growing plants by hydroponics or in a mixture with soil to increase soil fertility. Whole worn tires can be used to strengthen river banks and canals from erosion, create depreciation barriers on dangerous roads, strengthen dumps in mines, as well as for decorative purposes [6].

The purpose and objectives of the study

The aim is to solve the problem of recycling polymer and rubber waste by improving the technology for recycling.

To achieve this goal you need to solve the following tasks:

1. Determine the relevance of methods of processing polymer waste;
2. Analyze existing technologies for the processing of rubber waste.
3. Justify the parameters of the mechanism for recycling of polymer and rubber waste. waste.

Analysis of recent research

Today the problem of polymer waste disposal is quite relevant, high oil prices (raw materials for polymer production), the global energy crisis, the state of the environment encourage the development of effective recycling systems of spent polymers, which in conditions of oil shortage become a valuable raw material and energy resource [4] .

Methods of plastic waste recycling

Wastes from the production, processing and operation of some polymers can be recovered to the original synthesis products and returned to industry. This method is the most promising direction of polyurethane (PU) waste disposal, as their incineration is unprofitable, and pyrolysis is accompanied by the release of toxic gases [8].

Table 1. - Methods of processing polymers and obsolete products.

Method name	Brief description
Hydrolysis	This method of recycling plastic waste is the decomposition of polymers by acids with a simultaneous effect on recyclable raw materials at high temperatures. The most common way of recycling plastic abroad. There are different methods of hydrolysis - the most efficient, expensive, using catalysts.
Glycolysis	Processing involves the use of glycols - special alcohols. These alcohols contain hydroxyl groups. To carry out the required reaction, two conditions must be met: maintain a high temperature and choose the right catalyst.

Methanolysis	This method of waste disposal consists in deep polymerization and splitting of plastics using ethanol. Without the presence of special reactors that maintain a temperature of 15 degrees and a pressure of 1.5 MPa, to recycle plastic in this way will not work.
Gyrolysis	Simply put - thermal destruction. That is, the decomposition of raw materials by heat treatment without oxygen. The output is the initial monomer. The technology of this method of polymer processing allows not to sort raw materials before recycling.

These recycling methods, with a well-established process, minimize harmful emissions and waste, but these physico-chemical options have expensive and complex processing technology, which requires the presence of highly qualified specialists [11].

Mechanical method

In Ukraine, mechanical recycling is used - a method based on the physical grinding of processed raw materials.

It should be noted that in this process the plastic does not lose its properties.

The peculiarity of the method is that there is no need to buy expensive equipment and hire specialists for it.

For modern lines involved in machining, the following is suitable for recycling:

The output is several species products [9].

Fig. 2. Flex of polymer waste

The most promising for further implementation are granules and flex. In addition to the high demand for this secondary raw material, the technology of production of granules and flex is the least complex. For flex it is ordinary crushing, for granules - extrusion.

Flex are polymer flakes, which are consequently used for the manufacture of fiber, plastic containers and other products.

Granules are widely used on an industrial scale, so secondary raw materials of this type are in high demand.

The cost of pellets is also out of competition [9].

Stages of polymer waste processing

At processing of plastic on secondary raw material first of all it is subjected to sorting further the following stages of recycling are realized:

1. Grinding of recycled material.

2. Agglomeration - sintering of polymers into small particles.

3. Granulation of mass - production of granules of different fractions in special equipment [8].

Fig. 3. Ready granulate

Purified ground polymer (flex) or agglomerate can be sold as a final product.

Due to the thermal effect of plastic as a secondary raw material can be recycled no more than 4-5 times, because when exposed to high temperatures, the properties of polymers deteriorate.

The raw material obtained by recycling is used in the production of fibers for carpets, synthetic clothing and threads (about 30% of all recycled materials).

About 70% of recycled plastic is used in the production of polyester fibers, which are later used to insulate sportswear, sleeping bags, as a filler for soft toys.

After the last cycle, as a rule, plastic is used in road construction [11].

Tire life cycle

The life cycle of tires can be divided into six stages:

Manufacturers and retailers establish rules for the return, retreading and replacement of tires to reduce tire waste and take responsibility for accepting tires for disposal or recycling [5].

High-quality maintenance and timely replacement of tires during use by consumers affects the wear of tires and safety of their operation.

Proper manufacturing and quality delivery reduce the amount of waste in production.

The development of strategies for the disposal of tires, their incineration, or the processing of waste into new products, creates viable enterprises, and implements public policy.

Product developments and innovations such as component improvements and tire breakdowns will extend their service life, reduce replacement rates, improve consumer safety, and reduce the number of tires in waste.

Direct distribution through retailers, reduces inventory time and ensures that customers will be properly informed about the service life and safety of products [5].

Technologies for processing and utilization of rubber waste

Recently in Ukraine the use of rubber products is becoming more intensive - the amount of waste is increasing accordingly.

Waste rubber products can be divided into industrial waste and consumer waste. Wastes from the production of rubber products are accumulated at enterprises that produce rubber technical products, car tires, rubber footwear [7].

Wastes from the production of rubber technical products are divided into:
• waste rubber compounds;
• unvulcanized rubber waste;
• vulcanized rubber waste.

The main, most common type of consumer waste is depreciated tires. In the world, the production of car tires consumes half of the synthetic rubber produced (more than 15 million tons per year), and eventually all the tires produced after some time fall into the trash. The service life of car tires is less than the service life of most rubber products [7].

Fig. 4. Worn tires

Tire recycling, or rubber recycling, is the process of recycling used tires that can no longer be used on vehicles due to wear or damage. Tires are a problematic source of waste due to the large volume of production, durability of tires and their components, which is an environmental problem. They can take up a lot of space in landfills because they are very durable and non-biodegradable.

In 1990, it was estimated that more than 1 billion used tires were stored in the United States. In 2015, only 67 million tires were in storage. From 1994 to 2010, the number of recycled tires in the European Union increased, from 25% of annual emissions to almost 95%, with about half of the tires used going to energy, mainly in cement production. New technologies such as pyrolysis and de-vulcanization have made tires recyclable despite their durability and quantity. The end products of tire recycling include alternative fuels, new rubber products, playground coatings, new tires and rubber, and asphalt modifiers [10].

Why is it necessary to recycle rubber products?

Used car tires are hazardous wastes of the fourth class. It contains 15 toxic compounds, most of which are carcinogens that cause cancer. Their concentration in rubber exceeds the concentration of toxins in exhaust gases. The release of toxins occurs even during storage of rubber products.

The process of decomposing rubber dumped in landfills takes more than 100 years. Rain washes toxins into the soil and groundwater. Thus harmful substances get into a human body, causing oncological pathologies. Disposal of rubber products by incineration leads to the transfer of hazardous compounds into the air. Tire production accounts for a significant share of oil, the supply of which is limited and not renewable. Therefore, the proper disposal and recycling of rubber products is important for maintaining an acceptable environmental condition, natural resources and human health [10].

How is the processing of rubber products?

Tires with textile cord are processed mechanically. It is implemented in the following sequence:

1. cutting the side ring;
2. coarse grinding;
3. average grinding of the obtained parts;
4. grinding into particles of 1-0.5 mm;
5. scattering of crumbs with cord separation.

All stages of work take place at specialized enterprises with the help of high-tech equipment.

Processing of tires with a metal cord occurs on other principle:

1. cutting of an onboard ring;
2. cutting into 3-4 parts;
3. coarse, then medium crushing;
4. electromagnetic extraction of the metal cord;
5. final crushing into particles of 1-0.8 mm;
6. removal of textile cord;
7. separation of crumbs.

The resulting crumb is then used in the production of regenerate, in some cases replaces rubber. It is also used to make new products: tires, shoes, building materials, floor coverings for agricultural and warehouse premises, car mats, under-rail gaskets, mudguards, wheels of household carts and more [10].

Various technologies are used in the world for the processing and disposal of rubber waste and worn car tires. These technologies involve the use of worn tires and rubber waste to produce energy by burning, shredding tires and rubber waste to obtain rubber crumbs, powder and regenerate.

Burial of tires in landfills is not desirable, as 75% of their volume is a cavity that quickly fills the valuable space of the landfill. Tires can collect methane gas, and as a result become floating, or rise to the surface like bubbles. Due to the similar effect of bubbles, tires can damage the insulating material between waste horizons, which are installed to keep sewage from landfills from contaminating local surface and groundwater.

Shredded tires began to be used in landfills as a replacement for other building materials, as a material that is easily filled with gas in ventilation systems, drains, collection systems and operating tabs. Crushed tire material can also be used for covers, coverings, or daily landfill cover. Used car tires as a material for shelter and filling are also cost-effective, because the tires can be crushed on site, rather than importing other materials [10].

Tire dumps pose a great danger to the environment and a risk to health. Tire fires can start very easily, and burning can take months, creating significant air and soil pollution. Recycling reduces the number of tires in storage. Stacks of tires, which provide shelter for pests and serve as a breeding ground for mosquitoes that can spread disease, also pose an additional health risk.

Illegal landfills of used tires pollute ravines, forests, deserts and wastelands; which has led in many states to the creation of rules and laws that require proper management of delivery and acceptance of used tires [11].

Fig. 5. Rubber waste landfill

Unfortunately, the storage and recycling of tires is sometimes associated with illegal activities and lack of environmental awareness.

Undamaged worn tires are often used in the construction of artificial reefs, for example, off the coast of Australia, the company "GoodYear" has created an artificial reef with 15 thousand tires, off the coast of Florida - with 215 thousand tires. Artificial reefs made of tires are also available in New Zealand, Greece, Japan, Jamaica and other countries. Sea water is not polluted.

Sometimes worn tires are used as protective elements, for example when strengthening slopes from erosion processes. In this case, the slopes are covered with tires, cover them with soil and sow grass.

The use of worn tires for energy from an environmental point of view is ambiguous, because it is associated with the release into the atmosphere of large amounts of zinc and sulfur. However, in order to dispose of tires and obtain additional energy in the world, tire burning is widely used.

The main reason for the use of methods of burning tires for energy in many developed countries - the lack of effective technologies for integrated processing of tires to obtain high quality products.

Bridgestone / Firestone technology has been used as a fuel in the cement industry and has been used successfully in Japan since the early 1980s. This technology is implemented as follows: whole or cut into pieces tires are fed into an upgraded rotary kiln, metal cord, located in the tires, partially replaces the iron ore needed in the production of cement [7].

Old tires can be used as an alternative fuel in the production of Portland cement, a key component of concrete. Tires are usually fed to cement kilns by pumping them into the top of the kiln heater, or by dropping them into a slot in the middle of a long wet kiln. In any case, high gas temperatures of 1000 - 1200 ° C cause almost instantaneous, complete and smokeless combustion of tires. In addition, the tires can be crushed to a size of 5-10 mm, and in this form they are fed into the combustion chamber of the precalciner. Iron and zinc from tires are chemically included in cement.

However, in Switzerland, the company "Jura cement works". Stopped burning tires in cement kilns due to environmental pollution by combustion products. In the United States, only 12 of the 200 existing kilns burn worn-out tires, despite the fact that the cost of retrofitting coal kilns to replace worn-out tires is relatively small. fuel for a long time [7].

Usually tires are not recycled, but burned, but today the search continues and to find them useful. One of the options: crushed tires, as a rubber crumb, is added to the hot melt of asphalt, as a modifier - in the processing of asphalt pavement, and as a filler for concrete with Portland cement. Tires can also be converted into other tires. Tires can be cut and used in beds as mulch to retain water and prevent weeds. Some of the "green" buildings, both private and public, were made from old tires.

Pyrolysis can be used to convert tires to combustible gas, oils, solid semi-coke residue, and low-grade soot that cannot be used in tire production. A pyrolysis method has been developed that allows the production of activated carbon and high-quality carbon black [7].

Products made of tires

Tires can be reused for many purposes, although in most cases they are burned to produce heat. As of 2003, according to a report by the Environmental Protection Agency, 80.4% of used tires in the United States are either recycled or used for useful purposes, which is about 233 million tires per year. Assuming that the weight of one is approximately 10.2 kg, according to a 2003 report, the total weight of tires used was 2.62 million tons.

One of the options for recycling tires involves the production of alternative products for sale. New products derived from used tires create greater economic activity than incineration or other low-level production, while reducing waste flow without creating excessive pollution and emissions from recycling.

Metallurgical plants can use tires as a source of carbon, replacing coal or coke in steel production.

The process of stamping and cutting tires is used to make some goods. For example, for the manufacture of sandals or an additional layer of the base of the pavement, connecting together the cut side walls to form a flexible mesh [10].

Finely ground rubber crumb can be used for paving projects and similar purposes. Types of products for paving: rubber, modified asphalt, concrete modified rubber, and as a replacement in general. Examples of rubber molded products are carpet or lining, bumpers, decks, bumpers, blocks at railway crossings, livestock coatings, rubber bricks for sidewalks, moving lying cops.

Rubber can be fused with plastic for products such as pallets and railway sleepers. Sports and recreational areas can also be paved with shock-absorbing rubber-molding materials. Rubber from tires, crushed to medium size can be used directly as a rubber coating. Rubber crumb can also be used as a filler, alone or in a mixture with coarse sand, in coatings such as synthetic lawn.

Shredded tires are widely used in civil engineering. They can be used as a filler for retaining walls, backfill for collector wells of landfill gas, backfill of landslides during repairs, as well as a material for damping vibrations of railway tracks [11].

Tires are also often recycled to cover basketball courts and new footwear.

The main results of the study

Pyrolysis of tires

The pyrolysis method of recycling used tires is a technology in which whole or shredded tires are heated in a reactor in an oxygen-free atmosphere. In the reactor, the rubber softens, then the rubber polymers break down into smaller molecules. Eventually, these small molecules evaporate and leave the reactor. The resulting vapors can be used immediately to generate electricity, or condensed into a fatty liquid, which is then usually used as fuel. Some of the resulting molecules are too small to condense. They collect as gas, which can also be burned as fuel. Minerals that were part of the tires, about 40% by weight, are removed as solid ash. If the process is done properly, pyrolysis of tires is a clean process with little emission and waste, however, there may be concerns about air pollution by incomplete combustion products, which were recorded in cases of burning tires [12].

The properties of gases, liquids and solids depend on the type of raw material and production conditions of the process. For example, all tires contain fiber and steel. Shredded tires contain more steel, and most of the fibers are removed. Processes can be periodic or continuous. The energy required to decompose rubber includes the use of directly obtained fuel gas stove, electrical induction similar to ovens that are heated by electricity or a microwave oven. Catalysts are sometimes used to accelerate decomposition. The choice of raw materials and process can affect the cost of finished products.

The historical problem of pyrolysis of tires is a solid mineral residue, which accounts for about 40% of the original mass. Steel impurities can be pre-removed with magnets for recycling. The solid material that remains, the so-called "charm", has no important use other than the probable low-carbon fuel. "Charm" is used instead of technical soot, which is used to strengthen and increase the wear resistance of tires. The solid residue also consists of minerals used in the rubber industry. This high volume of tire pyrolysis components is a major obstacle, although this topic continues to be a source of innovation [12].

Processing by pyrolysis - a modern way of bottling tires and other rubber products. It is successfully used abroad, but is not very popular in Ukraine yet.

Pyrolysis - the most cost-effective way of processing rubber from used tires and other rubber products, while not polluting the combustion gases environment.

Fig. 6. Pyrolysis of rubber products

Pyrolysis technology proceeds as follows:

The tires are pre-divided into front and side by means of a boring machine.

Cut tires are loaded into a special container (retort), which is sealed and placed in the oven.

The furnace is heated to 450 C° and the pyrolysis process begins, during which gas is released. When the decomposition of raw materials is completed, the retort is removed and replaced with a new one.

After cooling for several hours, the container is unloaded, separating the carbon residue from the metal cord.

The procedure differs from conventional combustion by the lack of oxygen required for combustion [12].

Under such conditions, chemical reactions take place, as a result of which gaseous oil fractions are released from the tires, and carbon powder and cord remain in the furnace.

Production is waste-free, because all pyrolysis products are used in industry, bringing good profits.

Output products:

• liquid fuel;
• carbonaceous residue;
• pyrolysis gas;
• metal cord tires.

Each product obtained can be sold in various sectors of the agro-industrial complex.

Fluid output

The liquid obtained at the outlet during the pyrolysis of rubber - synthetic oil, similar in composition to natural.

With additional processing, it can replace many fuels and lubricants - gasoline, diesel fuel, oil and more.

In the United States, more than 100 million used tires are converted to diesel every year fuel, and one tire is equivalent to 30 liters of oil [12].

As a last resort, untreated pyrolysis oil from tires can be used as fuel for stoves and boilers.

Solid carbon-containing residue is used in various fields: in the manufacture of certain rubber products (eg, conveyor belts or new tires); in paint and cement production - as a dye; used as a sorbent instead of activated carbon; can serve as a solid fuel or a component for liquid fuel.

Pyrolysis gas is a volatile component resembling natural gas.

The main part of it during the operation of pyrolysis equipment is converted into a liquid fraction, and the non-condensable residue is used to support the combustion of the furnace.

Metal cord is the core of the tire, the only component that does not change during pyrolysis.

The reinforcing material of car tires is a high-quality steel, which with additional processing is successfully used as a knitting wire or is remelted.

Fig. 7. Synthetic oil from recycled tires

The composition of the simplest pyrolysis unit is as follows: Crucible, which is loaded with raw materials - tires; combustion chamber where heating takes place; a heat exchanger in which pyrolysis gas condenses into a liquid fuel [12].

Processing of rubber tires with high-performance ultrasound

Waste rubber is a toxic, non-biodegradable material, making it an environmental and economic problem. Ultrasonic desulcanization is a fast and efficient method of waste rubber waste disposal, which allows reuse of waste [12].

Ultrasonic recycling of rubber tires is a relatively simple process that has been successfully tested. Linear process scaling of ultrasonic tire processing makes it possible to treat large volumes of industrial scale at economical costs. The problem of rubber waste Rubber waste Rubber causes significant environmental problems due to their toxicity and non-decomposition. Their vulcanized crosslinking of carbon structure and toxicity imposes an environmental burden.

Conventional methods of rubber disposal are uneconomical, not environmentally friendly, and new rubber material made from recycled rubber shows low quality, as the main polymer chains of rubber waste are changed and weakened. Since tires are part of the most problematic sources of waste, environmental and economic methods or recycling are needed [12].

Pyrolysis and desulcanization are the most successful processing processes for tires. Progress in tire recycling is essential to halt the environmental burden of rubber tires and helps reduce tire dumping. Ultrasound treatment can enhance and improve both modern tire recycling, pyrolysis, and desulcanization processes.

Ultrasonic desulcanization of rubber

With the help of ultrasonic desulcanterization, sulfur-sulfur and sulfur-chemical bonds in the tires there is a splitting, which leads to a soft rubber melt. This ultra-generated rubber melt can be recycled and shaped into new rubber products, such as new tires [13].

The main advantage of ultrasonic devulcanization is much less heat is required. First, parts of the waste are heated to about 400 º F or 200 º C, then fed with a screw feeder through a stream of cells, where the rubber waste is juiced with high performance ultrasound under high pressure.

During ultrasonic deculturation, the rubber is transformed from the previous solid state into a very viscous substance. Intense ultrasound disrupts the threedimensional network of vulcanized elastomers rapidly. Ultrasonic treatment of chemical bond decisions takes only a few seconds. Juicy rubber melts can be reinforced with drugs and fillers and be molded into new rubber products.

Pyrolysis wastes can be upgraded by zoning them in hydrochloric and hydrofluoric acids in order to obtain pyrolysis carbon black. Ultrasonic treatment can successfully upgrade pyrolysis waste from tire waste to the high added value of black commercial carbon. Ultrasonic post-pyrolysis treatment thus improves the overall efficiency of the pyrolysis plant significantly [13].

High-precision rubber extraction system using near-infrared technology.

Extracted rubber of high purity is transferred for use in a new role of recycled raw materials.

Extracted and recycled high-purity resources are given new life as "resource-oriented products".

Fig. 8. Extracted rubber

Recycled rubber is used in interior parts of air conditioners, refrigerators and induction hobs. Vacuum insulation, which uses fiberglass obtained from the processing of cathode ray tubes of televisions, is used in new refrigerators.

The problem of recycling worn-out car tires and obsolete rubber products is of great environmental and economic importance for all developed countries. The irreversibility of natural crude oil dictates the need to use secondary resources with maximum efficiency, ie in place of garbage mountains we could get a new industry for our region - commercial waste processing [12].

One of the most promising methods of disposal is pyrolysis - thermal decomposition of organic compounds without access of air.

Given that the tires of cars and trucks change on average every 2-3 years, the scale of subsidence in landfills is more than significant. Thus, according to the State Motor Transport Research and Design Institute (Kyiv), in Ukraine the annual increase in worn tires is 200 thousand tons. At the same time, only a small share of this material is processed at specialized enterprises in Ukraine - up to 14 thousand tons, ie about 7%.

In the process of pyrolysis of car tires, waste rubber products and / or polyethylene, valuable products are released: Pyrolysis fuel, carbon residue (carbon black), metal cord and pyrolysis gas.

Liquid Pyrolysis Fuel is an analogue of dark petroleum furnace fuel. This is a high-calorie fuel. The amount of heat released when burning 1 kg of liquid pyrolysis fuel is 5% more than when burning 1 kg of fuel oil. One kilogram of furnace fuel replaces 1.18 cubic meters in terms of heat energy. natural gas. This fuel has the highest quality analog of fuel oil M-100, while surpassing it in its technical characteristics and properties (table 2) [10].

Table 2. - Characteristics of pyrolysis liquid:

Property	Indicator
Density at 20ºC	920 kg / m3
Ash content	0,11%
Mass fraction of water no more	1,0%
Mass fraction of sulfur is not more	1,5%
Mass fraction of mechanical impurities	0,2%
Flash point in a closed crucible	41ºC
The pour point is not higher	35ºC
The heat of combustion is lower	42 MJ / kg (9,996 kcal / kg)
The heat of combustion is higher	50.5 MJ / kg (12,019 kcal / kg)

This type of fuel is intended for use in power thermal installations (kilns of drying complexes, heat generators, steam generators and other vodka-combustion devices), as well as in road construction works. It is used as a liquid fuel for boilers, as a substitute for furnace fuel.

Pyrolysis equipment

The installation is a set of equipment that provides thermal destruction (decomposition into low molecular weight components without access to oxygen) of carbohydrate waste. The main process equipment is mounted on frames and has the dimensions of a 20-foot sea container. The installation is quite resistant to atmospheric temperatures, so it can be placed not in an insulated building. Control of technological equipment is carried out from the operator's control panel [12].

Fig. 9. Installation for rubber pyrolysis

The installation of thermal destruction of car tires includes technological units of pyrolysis and condensation, as well as an automated control system for equipment with start-up valves.

The pyrolysis unit includes: pyrolysis furnace, pyrolysis chamber (reactor), furnace, combined burner with compressor, smoke extractor, chimney.

The condensing unit includes: a filter of pyrolysis gases with a fan, a condenser unit with a circulating water pump, an air cooler and an expansion tank, a gas-liquid separator, a water seal, a storage tank, a liquid fuel pump.

The principle of operation of the installation

Raw materials through the lid are loaded on the pallet into the chamber (chamber volume - 25 m3), where the pyrolysis process takes place when heated without access to oxygen. Heating to a maximum operating temperature of 450-520C in the chamber is carried out by a burner installed in the furnace. The pressure in the chamber is regulated by the rate of temperature rise. The discharge of flue gases into the atmosphere is carried out through the chimneys.

The results of the study of samples for compression and wear

The use of recycled rubber and plastic products is possible in the manufacture of composites. Composite materials are a special class of structural materials in which the filler is present in our case, sand and rubber are connected to the polymer by mixing at high temperature. The filler can be from 40 to 80% [8,9].

Polymeric composite materials suitable for the production of parts by the method of injection molding, extrusion, or compression, composites include three components: organic or mineral filler; synthetic or organic thermoplastics or mixtures thereof; a set of chemical additives that improve the properties of the mixture of the final product.

Today, composite materials are mainly used for siding, fencing systems, transport pallets, window fittings and other products are only experimental in nature, such as railway sleepers and polymer beams [8].

Testing of experimental materials for compression allowed to determine the highest values in samples with 50% rubber and polymer sand content.

Table 3. - The results of the study of samples for compression.

№	Compressive strength, MPa				
	50/50	60/40	70/30	80/20	100
1	22,00	19,75	15,6	12,65	10,45
2	21,98	21,00	16,73	13,95	9,12
3	22,47	19,10	18,15	14,80	10,00
Average	22,15	19,95	16,8	13,8	9,85
max	22,47	21,00	18,15	14,80	10,45
min	21,98	19,10	15,6	12,65	9,12

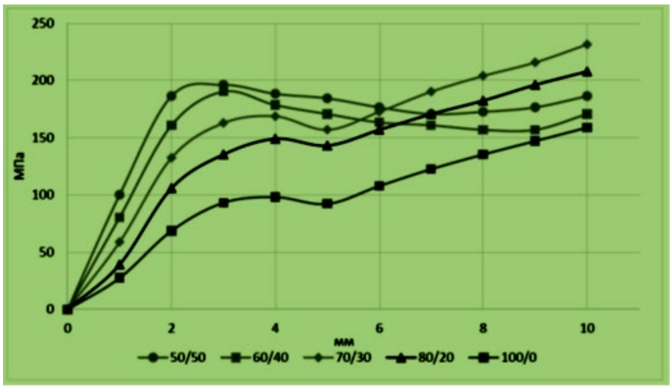

Fig.10. Graph of deformation of samples.

Table 4 shows the results of compression tests. It shows the value of the yield strength of the material and the deformation of the sample at a given force.

Table 4. - Test results of compression samples.

Deformation L, mm	Samples, effort, MPa				
	50/50	60/40	70/30	80/20	100
1	100	85	63	42	29
2	190	163	134	104	71
3	192	185	159	129	96
4	181	172	163	144	94
5	186	169	161	135	90

From the graph it is seen that there is a decrease in the yield strength of the sample material by reducing the filler (sand) from 50/50 to 100/0 in the mixture in the range of 196.13 ... 98.06 MPa.

The dependence of the yield strength of the composite material on the content in the sample of polymer and sand are shown in Figure 11

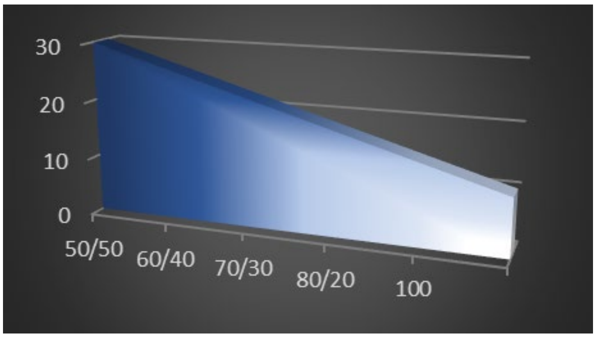

Fig. 11. The dependence of the yield strength of the material on the polymer content in the mixture.

From the graph it is obvious that the yield strength of the material decreases with a decrease in the content of filler (sand and rubber) from 50/50 to 100/0 in the mixture in the range from 196.13 ... 98.06 MPa.

The wear value of the composite material depending on the duration of the test, the percentage of sand, rubber and polymer in the composite mixture is shown in table 5.

Table 5. - The dependence of the degree of wear of the sample on the test time and the composition of the composite.

The ratio of components	№ in order	Research time, min	Depreciation, g	Height of the sample, mm
50/50	1	360	0,01	20,10
	2	720	0,03	20,07
	3	1080	0,06	20,01
70/30	1	360	0,03	20,65
	2	720	0,06	20,5
	3	1080	0,11	20,40
100	1	360	0,07	20,48
	2	720	0,14	20,32
	3	1080	0,20	20,20

The analysis shows that the greatest wear are samples of pure polymer 0.07 g for 360 min, and the least wear samples of composite material with a ratio of 50/50 components wear of the sample is 0.01 g 360 min.

The test results are displayed in the form of a graph of the degree of wear on the wear path, for the ratio of polymer to sand 50/50, 70/30 and 100/0.

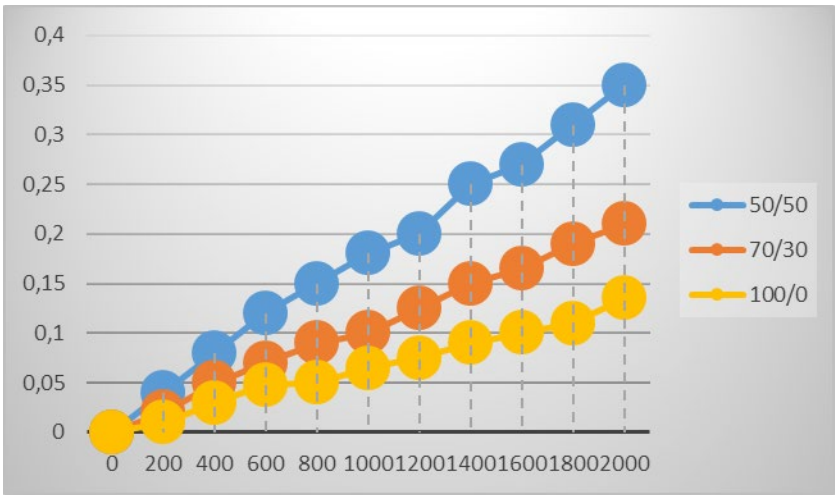

Fig. 12. Graph of the dependence of wear of the composite material on the path of friction.

Conclusions

The use of polymer and rubber waste in further production is one of the main components of any production process. To do this, the waste is processed into secondary granular material or directly into products.

The use of secondary material from polymers and rubber as a raw material allows to obtain a significant environmental and economic effect in the manufacture of products.

Processing of polymers and rubber is a complex, high-tech process. During this process, crushers for polymers and rubber are used, as well as specialized equipment, such as agglomerators, polymer granulators, as well as extrusion machines and pyrolysis plants.

Wastes from the production, processing and operation of some polymers can be recovered to the original synthesis products and returned to industry.

Methods and technological modes of processing significantly affect the properties of products.

The technology of production of composite materials is connected with the study of the influence of the filler on the properties of the synthetic polymer. Sand and rubber as a filler can partially or significantly change the physical and mechanical properties of composite materials.

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Анотація. *Галузь виробництва виробів з гуми та пластмаси все більше набуває ознак важливої галузі індустрії. Полімери застосовуються практично в усіх напрямках матеріального виробництва й невиробничої сфери. Стабільно зростає попит на готові вироби з полімерних матеріалів з боку найважливіших галузей-споживачів: будівництва, транспорту, сільського господарства, медицини та ін.*

Вироби з полімерів та гуму стають все більш досконалими, але одночасно з цим розвиваються та ускладнюються методи поводження з відходами та їх утилізація. З часом вони вже не можуть використовуватись за прямим призначенням, тож вони вибраковуються і відправляються на сміттєзвалища, в той час як полімери та гума є цінними конструкційними матеріалами і їх повторне використання буде позитивним не лише для навколишнього середовища, а й може стати прибутковою галуззю аграрнопромислового комплексу.

Утворення значних об'ємів гумотехнічних та полімерних відходів призводить до *неорганізованого їх складування на звалищах чи неконтрольованого розсіювання у природному середовищі, що підвищує рівень екологічної небезпеки на прилеглих територіях в результаті потрапляння шкідливих речовин із гуми та пластику у довкілля.*

В даній статті досліджуються методи переробки полімерних та гумових відходів шляхом вдосконалення технологій для їх переробки у вторинну серовину. Визначенно актуальність методів переробки полімерних відходів. Розглануто види рециклінгу та етапи переробки полімерних відходів. Проаналізовано життєвий цикл гуми та проведений аналіз існуючих технологій утилізації та переробки гумових відходів. Обгрунтовано етапи переробки гумових відходів. Охарактерезована технологія піролузу для переробки гумових відходів. З врахуванням отриманої інформації, зроблені висновки та визначенно характеристики досліджуванного композиту в склад якого входять пісок, гума та полімер.

Ключові слова: *гумо-технічні вироби, полімерні відходи, утилізація, піроліз, композит.*

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