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BASIC STRUCTURAL PLASTICS CLASSIFICATION

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Abstract
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.

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.

Keywords: Polyethylene; polypropylene; polyvinylchloride; fluoroplastics; plastifiers; polysterene; polymethylmethacrylate; pentaplast; polysulfones; polyethyleneterephthalate; polycarbonates; polyacrylates; polyamide; polyimides; phenol-formaldehyde resins; epoxy resins; urea-formaldehyde resins .

1. Introduction

Plastics, 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 con-tain 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 pro-duction of plastics was as high as 102 m tons/year, being increased by 52% in the period between 1980-1990. 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.

2. Methods

Reacoplasts are materials whose processing is accompanied by chemical reactions of formation of grid (three-dimentional) structure of macromolecules. In hardening, a plastic irreversibly loses the ability of transforming into thick-flowing state. Thermoplastic processing is not accompanied by cross-linking, and the material of a

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product maintains its ability to transform into thick-flowing state. Figure 1 shows the nomenclature of technical plastics which find application as construction materials, as well as lacquers, fibers, paints and glues.

Thermoplastic materials are represented by an extensive group of polymer materials. Polyolefines are unsaturated carbohydrates produced by polymerization of the corresponding olefines. Polyethylene, polyprolylene and their numerous copolymers are typical representatives of this plastic group.

Polyethylene (PE) is a product of polymerization of ethylene (CH_2= CH_2) with a linear macromolecule having a small number of branches. Depending on polymerization conditions (pressure, type of catalyst, temperature) a product with varying molecular weights is obtained. Chemical industry produces PE at different pressures. High pressure polyethylene (HPPE) has the molecular weight of 30-4000 thousand units atomic weight, while low and medium pressure polyethylenes (LPPE and MPPE) have the molecular weights of 50-800 thousand. Ultrahigh molecular weight low pressure and medium pressure PEs (UHMPPEs) with the molecular weights of several millions are also produced. PE obtained at high pressure is also named low density polyethylene (LDPE) and that produced at medium and low pressures is termed high density polyethylene (HDPE).

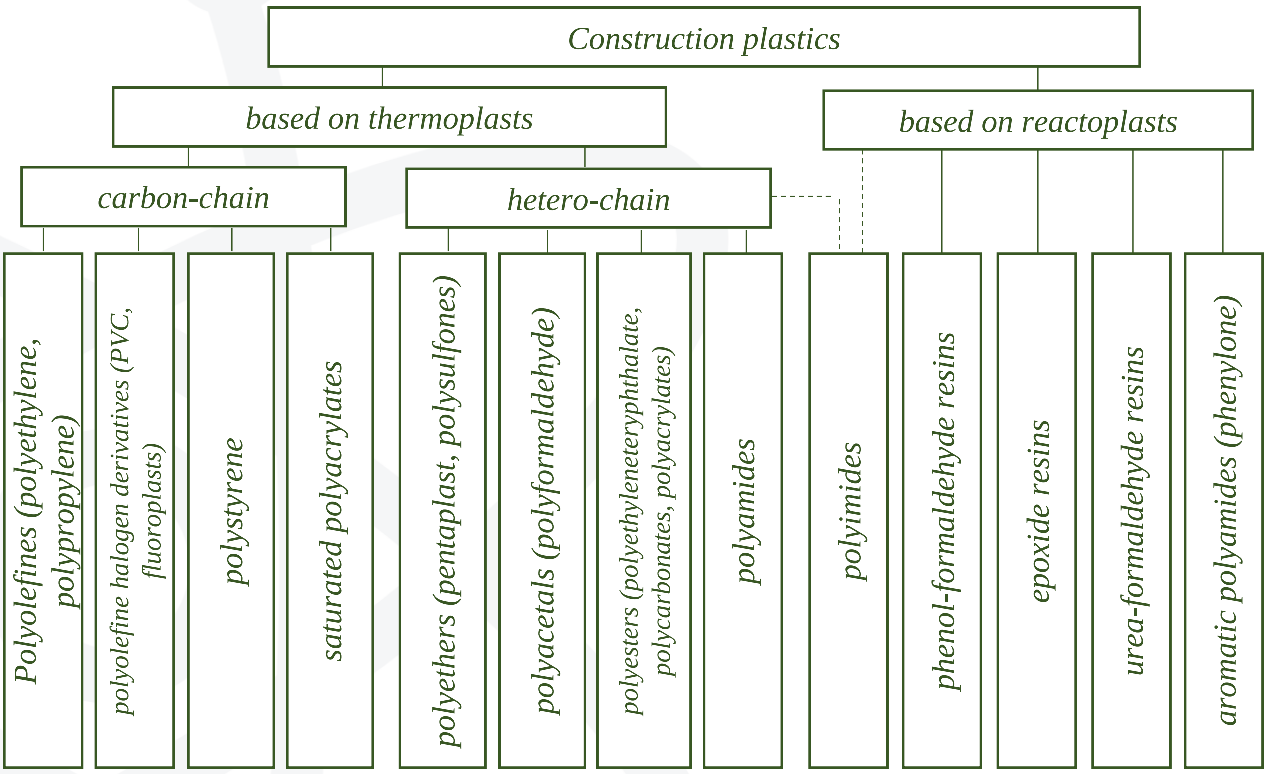

Figure 1. Nomenclature of the most common construction plastics

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The advantage of PE is a combination of high chemical stability, satisfactory mechanical properties with technologicity of treatment and low cost. PE and composites on its basis are used in machine building, radio engineering, chemical industry and agriculture. Industry produces films for various applications, tubes, hoses, cable insulation, fibers, etc. Polyethylene is among the most frequently used polymer materials.

Polypropylene (PP) is a thermoplastic linear polymer, the product of propylene polymerization $(CH_2=\underset{CH_3}{\underset{|}{C}}H)$. PP is a hard substance transparent when in thin layers and a foam white substance when in thin layers with a high degree (75%) of crystallinity and the melting point of around 170°C. PP is distinguished from PE in higher impact resistance, strength and endurance, has high dielectric properties and low thermal stability and gas permeability. PP is insoluble in organic solvents, stable to the action of boiling water and alkali but has low thermal and light stability. PP is used to produce machine components, different accessories, consumer goods, containers for storage and transportation of bulk cargoes and reservoirs for liquids. About 30% of PP is reprocessed into fibres, films, tubes and profile products.

Halogen-derived polyolefines make the basis for plastics, polyvinyl chlorides and fluoroplastics which are widely used in machine building.

Polyvinylchloride (PVC) is a high-molecular-weight product of vinyl chloride polymerization ($CH_2=CHCl$) with the molecular weight of 14-85 thousand units.

PVC classification is based on its polymerization: letters “C”, “E” and “M” in designation of its brands correspond to suspension, emulsion and mass polymerization technologies. The two types of plastics, vinyl plastic and plasticate, are produced on the base of PVC.

Vinyl plastic is rigid PVC which does not contain plastifiers. It is produced as sheets, tubes and welding rods. Vinyl plastic can be processed well by cutting, it is bent, molded, welded and glued. As a construction material, it can serve as substitute for nonferrous metals. Film vinyl plastic is used for brickworks of chemical devices (anticorrosion coating) for insulation of wires, packing of drugs and foods, for production of covering of books and folders, etc. Plasticized PVC is named plasticate. Addition of plastifiers does not only improve plasticity but also increases frost resistance of PVC (up to -50°) and the stability to exposure to alternating loads and vibrations. Plasticate is widely used for insulation of cables, production of tubes, artificial leather, linoleum and glues.

Fluoroplastics are polymers of fluoride derivatives of ethylene series; tetrafluoroethylene ($CF_2=CHF$), trifluoroethylene ($CF_2=CFCl$), finylfluoride

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($CH_2=CHF$), etc. The advantage of fluoroplastics is a high stability in aggressive media, including strong acids, except for hydrofluoric (fluoric) alkali, trifluoro-chlorine and elemental fluorine at high temperatures. Fluoroplasts are thermostable, the temperature of their intensive thermal oxidative destruction is 400°C.

Fluoroplastics of some brands have unique antifriction parameters: low friction coefficient, high durability under friction without lubrication.

The most common representative of fluoroplastics is polytetrafluoroethylene (PTFE)-fluoroplastic-4 (teflon, Fluon). Of all the machine building materials – polymers, metals, silicates, PTFE is the most stable to exposure to aggressive media, climatologic factors and microorganizms.

Fluoroplastic-4 is used for production of condensing and electrical insulating films, antifriction materials, packing elements. Its modifications: fluoroplastic-4D, fluoroplastic 4M (-4MB, -4MB-2, -4MD), fluoroplastic -4NA, etc. are technologic in processing, and make it possible to manufacture goods by piston extrusion and high-pressure casting. The drawbacks are low durability and cold flow. To eliminate them, modifiers and filling agents are added to the compositions. Fluoroplastic-3 (fluorolon-3, daiflon) is applied in manufacturing films, lacquers, fibers, tissues, protective coverings.

Carbon chain polymers of fatty and aromatic series are presented in the plastics nomenclature by the group of polystyrenes (PS), products of styrene polymerization $CH_2=CH$. Polymerization is brought about by block (in mass), emulsion and suspension methods. PS has high dielectric properties, water resistance and chemical resistance, is distinguished by radiation resistance and high refraction coefficient, it can be easily dyed in different colors. The drawbacks of PS include high fragility, low heat stability and impact resistance. Different types of modified PC and styrene copolymers for general purposes are produced: shockproof, foaming, acrylonitrile butadiene styrene (ABS) plastics. They have higher parameters of operating abilities than the initial PS.

General purpose polysterene is transparent and has sufficiently high mechanic properties. The main application of polysterene of this type are radio components, irresponsible constructional details, domestic goods. Principal large-size components are not manufactured of the above polysterene due to its fragility.

Shockproof PS is produced on the basis of styrene and rubber. It is applied for manufacturing cases and components of refrigerators, reservoirs and vessels, furniture, office equipment, machine components and equipment for food and textile industries, cases for TV- sets, vacuum cleaners and electric razors. Shockproof PS is widely used for packing of foodstuffs and medicines, manufacturing disposable tableware, toys, pens, etc.

ABS-plastics are a group of constructional materials on the basis of copolymer styrene with acrylonitrile that is similar in structure to shockproof PS. ABS-plastics have high water resistance and resistance to solvents, oils, acids and alkali. They have greater hardness and bending strength compared to PE and PVC. ABS-plastics are used for manufacturing of large-size car components (steering wheels, wings, instrument panels), cases for television and radio equipment, telephones, cases, containers, helmets, components for sanitary and technical equipment, etc.

Polymethylmethacrylate (PMMA) is a linear thermoplastic polymer, produced by polymerization of methacrylic acid methyl ester [CH_2= C(CH_3) – $COOCH_3$]. The molecular weight of PMMA can reach several millions units, the density is 1.19 g / cm^3 , the refraction index is 1. 492. PMMA (sometimes called organic glass) is a colorless transparent polymer having high penetrability for ultraviolet and visible fight (organic glass of 3-cm thickness transmits up to 92% of UV rays, while silicate one – only up to 3%), high atmospheric resistance and good physico-mechanic and electric insulation parameters. Organic glass can be easily welded and glued with the help of its solution in acetone and dichloroethane. Such glass can be sawed and cut using machine tools, as well as drilled and polished with ordinary instruments. PMMMA is used in electrotechnical and automobile industries. It is used to manufacture lamps, glasses for airplanes and cars, lenses and prisms in instrument engineering, glasses in watchmaking industry, protective panels on machine tools, etc.

Hetero chain thermoplastics which are mostly applied as constructional materials are polymers from class of esters and ethers as well as polyacetal resins and polyamides (see Fig. 20.9).

Pentaplast (PPl) is a thermoplastic linear polymer, a polymerization product of chloromethyloxetane $(CH_2Cl)_2$ (at temperatures of 120-135°C it is stable to the action of many solvents) surpasses PVC in chemical stability and is somewhat inferior to fluoroplastics. PPl is distinguished by small shrinkage, low linear extension coefficient, high resistance to abrasion and low melt viscosity. It is used for production of corrosionproof equipment: tubes, gate elements of valves, pump elements, pinion gears. Thin sheets of PPl are used for lining of large-sized equipment (glueing with subsequent welding of weld joints). Protective coverings of 0.55-mm thickness are obtained by FBS or flame spraying of powdered PPl while coverings of lower thickness – By diffusion of PPl suspensions in organic solvents with subsequent agglomeration at 200-220°C.

Polysulfones (polyarylene sulfones polyestersulfones) are products of condensation of aromatic sulfonyl chlorides with hydrocarbons, hard noncrystalline white thermoplastics. According to their mechanical properties they are close to polycarbonates, however, they are less prone to creeping. The main advantage of polysulfones is high thermal stability: they are stable on heating in air up to 400°C. Physical and electric properties of polysulfones are changed insignificantly within a wide range of temperatures (from 100 to 175°C) as well as during long-term heating at 140°C. Polysulfones are applied for manufacture of construction elements (cars, machine tools, home appliances, etc.), electrotechnical goods (for instance cases of electrochemical batteries), pipelines for food industry, metallized matrixes for typographical cliche as well as binding agents in production of glass-fibre plastics.
The group of materials with oxygen-containing polymer chains includes polyformaldehyde (PF) and formaldehyde copolymers with dioxolane (SFD) and trioxane with diaxolane (STD). These polymers are linear polyacetal resins obtained by formaldehyde polymerization and the mixture of formaldehyde with dioxolane and trioxane. The average molecular weight of polyacetals is 30-120 thousands. The materials of this group are characterized by a combination of high parameters of impact resistance, coefficient of elasticity during extension and bending . In their mechanic characteristics the polyacetal resins surpass the majority of thermoplastics, are distinguished by high durability, low friction coefficient and low creeping.

3. Results and Discussion

The raw materials base for synthesis of polyfofmaldehydes is comparable to that of PE. Therefore PF belongs to promising polymer materials. The main areas of PF application are machine elements, including elements of friction units: bushes, tooth gears, gear wheels, springs, instrument cases, elements of switches, taps, oil and gasoline lines.
Polyethyleneterephthalate (PETP) is a hard white polymer representing polyester of terephthalic acid and ethyleneglycol. PETP does not dissolve in the majority of organic solvents, has a high melting point (255-265°C), is resistant to the action of weak alkali, stable to lubricants, oils, alcohols, ketones and esters. PETP is mainly used in production of polyester fibers (lavsan). It is also used for production of films (base for tapes for tape transcripts and motion picture and photographic films, thermostable isolation of transformer winding) and molding goods (radio components, tableware, chemical and other equipment).
Polycarbonates (PK) are esters of carbonic acid produced by polycondensation of diphenylpropane and phosgene. They are hard, colorless or yellowish transparent

substances dissolving in chlorinated hydrocarbons, cresol and other solvents. Their melting points vary from 150 to 270°C. PKs have high mechanical strength over a wide range of temperatures (from -135° to + 140°C), thermostability, good isolation properties, atmospheric and moisture resistance. They are resistant to the action of diluted oils, solutions of mineral salts, hydrocarbons, gasoline, oils, etc., but are nonpersistent in alkaline solutions and chlorine-containing hydrocarbons. PKs are used for production of components for construction and electric isolation purposes in machine- and instrument engineering (gear wheels, bearings, telephone sets, fans, kinescope screens, etc.), in medicine (blood filters, cases for drilling machines and dentures). Powdery PKs are used for application of coverings on metallic components.

Polyacrylates are esters of diatomic phenols with the general formula $[-OCRCOOR'O-]_n$, where R is the residue of dicarbonic acid R' is the residue of diatomic phenol. These are thermostable polymers (with the maximum of operating temperature of up to 250°C, having high dielectric properties and mechanical strength as well as chemical resistance to the action of acids and diluted alkali and high radiation resistance. Poliacrylates find application as constructional materials, antifriction self-lubrication plastics (in filling with graphite, molybdenum disulfide and other hard lubricants) as films (electrical insulating materials in radio-and and electric engineering and filtering materials (Petryanov filters).

Polyamides (PA) are hetero chain polymers containing amide groups –CO-NH- in the main chain of the macromolecule. PAs are produced by polycondensation of diamine and dicarbonic acids or by polymerization of amino acid lactam. Depending on their chemical structure PA can be linear, branched or cross-linked.

Polyamides are one of the most distributed constructional polymer materials. Presently industry produces polyamides of many grades: P6 (caprone), P66 (anide), P610, P12, etc. The main advantage of PAs as constructional materials is a combination of high strength, durability, thermal and chemical resistance with manufacturability of transformation into goods. Being in an unmodified form, PAs are subjected to oxidation in air, particularly at elevated temperatures, which results in a dramatic decrease of their strength. PA is used to produce bearings, bushes, blades of marine propellers, electric insulators and medical instruments. PA is widely applied for production of films, fibers, protective coverings, impregnating materials, glues. PA is also used to manufacture tire cords, driving belts, ropes and different consumer goods.

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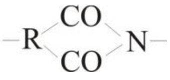
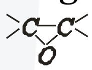
Polyimides (PI) are aromatic heterocyclic polymers having a cyclic imide group  in the macromolecular chain. Depending on the production method and the polymer chain structure PIs can be thermoplastic and thermoreactive.
The important advantages of PIs are high thermal stability (up to 350ºC) resistance to thermooxidative destruction and radiation, strength and durability. PIs are not dissolved in organic solvents, are resistant to oils, weak acids and bases and are not hydrolyzed under exposure to alkali and overheated vapor. PIs are characterized by low friction coefficient (0.05-0.17 according to steel) and thermal conductivity which is rather high for organic polymers (150-180 Wt/ (m·K). Goods made of PI can be successfully exploited at temperatures from -200 to +350ºC. PI is used for production of electric insulating films, enamel for coils wires, flood compounds, fibers and glues. PI is applied to manufacture structural parts (in airplanes and spacecrafs) as well sa highly heat resistant composition self-lubricating materials.
Thermoreactive plastics are distinguished from thermoplastics by increased thermal stability, almost complete absence of creeping under the load both at usual temperatures, stable physical and mechanical parameters over the exploitation temperature range. Generally thermoreactive (hardenable) plastics contain, along with a binding component (resin), fillings: powdered, fibrous or laminated. The majority of thermoreactive plastics are produced on the basis of phenol-formaldehyde, epoxy and urea-formaldehyde resins.
Phenol-formaldehyde resins (PFS) – are oligomeric products of condensation of phenols with formaldehyde. Depending on the polycondensation conditions resol (thermoreactive) or novolak (thermoplastic) PFS are formed. During treatment they harden to form three-dimensional polymers. Hardened PFS have high atmospheric – and thermostabilities, possess good electric insulating properties and resistance to the majority of acids. During prolonged period PFS are stable on heating to 200ºC and during limited period they are capable of resisting to higher temperatures (several hours at 250-500ºC, several minutes at 500-1000ºC). PFS find the widest application in production of several types of plastics (phenolic plastics, foamed phenoplasts), plywood and wood/plastic composites, as well as for binding of glass fiber and asbestos in production of heat-and sound-insulating materials. FFS are used as the base for lacquers, enamels, glues and sealants.
Epoxy resins (ER) are oligomers or monomers containing as many as two epoxy groups in the molecule  which are capable of converting into polymers of spatial structure during polycondensation or polymerization with the help of hardeners (aliphatic and aromatic polyamines, anhydrides of dicarboxylic acids, synthetic

resins). Hardened ERs have good moisture protection properties, high adhesion to metals, glass and ceramics, good dielectric properties and high chemical stability. As for strength parameters, products of ER hardening surpass all the polymer materials, based on other synthetic resins that are used in industry. For instance, the longitudinal strength (for compositions based on ER without filler) can reach 140 MPa, whereas the compression strength can be as great as 400 MPa, the impact resistance can be 250 kJ/m² while relative elongation at break – 750%. ESs are widely used as a base for varnish-and -paint materials, glues, sealants, flood and impregnating compounds and binding agents for high-strength reinforced plastics , for production of abrasive and friction materials, for modification of other oligomers and polymers so that to enhance their strength, heat resistance and adhesion to different materials.

Urea-formaldehyde resins (UFR) are oligomeric products of urea polycondensation with formaldehyde, which are converted into cross-linked polymers on hardening.

Products of UFR hardening are colorless, light resistant, easy to paint polymers. To enhance water resistance and to impart the ability to dissolve in organic solvents, increasing adhesion or improving compatibility with other polymers of components, UFR are generally modified by butyl and furyl alcohols, polyvinylacetate emulsion and glycerol. UFR are used as binding agents in production of amino plastics, glues and for manufacture of electric isolation, as well as decorative, anticorrosion vanish-and -paint materials.

4. Conclusion

Among thermoreactive polymer hetero chain materials, most promising are aromatic polyamides with the molecule containing aromatic fragments of varying structures that are connected by amide links. The advantages of aromatic polyamides are stability of properties at operating temperatures of -60 to + 250°C.

Some types of these materials have heat resistance at temperatures of above 350°C.

Of industrial significance is the aromatic polyamide phenylone. Due to their high mechanical properties, durability, thermal stability, heat stability and chemical stability phenylones are used for manufacture of friction parts, including those operating at elevated temperatures (up to 220°C), pressures of operating environment (up to 35 MPa) and loads (up to 25 MPa).

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