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USE OF PLASTICS IN MECHANICAL ENGINEERING

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In the transition to a market economy saving of material resources becomes one of the most important tasks of every enterprise because material costs make up a large part of the costs of production on which the profit margin depends directly.

For processing methods, plastics have a significant advantage over many other materials. Due to the production of plastic products by the methods of pressing, molding, injection molding, extrusion and other methods, production wastes (chips) are removed, there is a possibility for extensive automation.

Finally, the biggest advantage of plastics over other materials is unlimited and the available resources (oil gas, oil, coal, waste of timber industry, agriculture and others).

The task of the research is to substantiate effectiveness of the use of plastics in mechanical engineering.

Plastics are organic materials, which are based on synthetic or natural macromolecular compounds (polymers). Plastics based on synthetic polymers are used exclusively widely [1].

By the nature of the binder, plastics are divided into thermoplastics, obtained on the basis of thermoplastic polymers, and thermosets, obtained on the basis of thermosetting resins. Thermoplastics are convenient for processing into products and give a negligible mould shrinkage (1–3 %). The material has great elasticity and low brittleness. Thermoplastics are usually manufactured without any filler. Thermosets become fragile after curing and the transition of the binder to the thermostable state, often give greater shrinkage (10–15 %) during their processing, so their composition is administered with reinforcing fillers.

Thermoplastics

In the basis of thermoplastics there are polymers of linear or branched structure, and sometimes plasticizers are administered. Thermoplastics have limited operating temperatures, when heated over 60–70 °C they begin to lose their physical and mechanical properties dramatically. More heat resistant structures can work up to 150–250 °C, and heat-resistant with rigid chains and the cyclic structure is stable up to 400–600 °C.

Under long static loading forcedly-elastic deformation appears and the strength decreases. The strength limit of thermoplastics is 10–100 MPa. The modulus of elasticity is 1800–3500 MPa. They are good at resisting fatigue, their durability is higher than that of metals. The endurance limit is 0.2–0.3 of the strength limit. When the loading frequency is above 20 Hz the material heats and its strength decreases. Properties of some thermoplastics are listed in Table 1[2].

Table 1 – Physical and mechanical properties of thermoplastics [2]

Material	Density, kg/m^3	The maximum temperature of long-term work , °C	Strength limit, MPa			Impact strength, kJ/m^2	The modulus of elasticity	Brinell Hardness
			tensile	compression	bending		MPa	
Teflon-3	2090—2160	125	30—45	—	60-80	20—160	—	100—130
Organic glass	1200	60	63—100	100-105	90-120	8—18	2900—4160	10—300
Polyvinylchloride	1400	65—80	40—120	80—160	40-120	70—80	2600—3000	10—160
Polyamides	1100—1140	60—110	38—60	—	35-70	80—125	1200—1500	74—150
Polycarbonate, DIFLON	1200	130—140	70	—	24—120	150	—	80—160
Polyarylate	1200	155—250	55—120	105—145	100—125	120	1650	—
Pentaplast	1400	150	80—110	—	—	12—16	—	—
Polyformaldehyde Stabilized	1140—1400	130	20—55	85—95	60-85	24—140	—	110—140
Polypropylene	900	150	25—40	11	—	33—80	1700	59—64
Polystyrene	1050—1080	90	37—48	90—100	65—105	10—22	3000—3300	140—200

Thermosets

In thermosets as binders thermosetting resins are used, in which sometimes plasticizers, curatives, accelerators or retarders, solvents are introduced. The main requirements for the binder is a high adhesive strength (adhesion), high heat resistance, chemical resistance and electrical insulation properties, ease of processing technology, small shrinkage and absence of toxicity (hazard). The resin glues both separate layers of filler and filaments and perceive the load simultaneously with them, however, after curing the binder should have a sufficient peel strength by splitting material. It is necessary that the temperature coefficients of linear expansion of the binder and filler are similar in magnitude. Properties of some thermosets are listed in Table 2 [2].

Table 2 – Physical and mechanical properties of thermosets [2]

Materials	Density, kg/m^3	The maximum temperature of long-term work, °C	Strength limit, MPa			Impact strength, kJ/m^2	The modulus of elasticity	Brinell Hardness
			tensile	compression	bending		MPa	
Powder	1400	100-110	30	50-150	60	4-6	6 300-8 000	300-400
Fibrous:								
FRP	1350-1450	110	30-60	80-150	50-80	9-10,4	8 500	250-270
asbovoloknit	1950	200	—	110	70	20	18 000	300
GFP	1700-1900	280	80-500	130	120-250	25-150	—	—
Layered:								
getinaks	1300-1400	150	80-100	160-290	80-100	12-25	10 000	—
textolite	1400	125	65-100	120-150	120-160	30	5 000-10 000	—
asbotekstolit	1600	190	55	—	—	20-25	20 000	186-300
particleboards	1350	140-200	180-300	100-180	140-280	80-90	18 000-30 000	—
glass fiber	1600-1900	200-300	250-600	210-260	150-420	50-200	18 850-30 000	—
SVAM	1800-2000	200	350-1000	350-450	500-700	180-500	35 000	—

In mechanical engineering thermosetting pressing masses produced on the basis of phenolic resins or their modifications (phenolics) are widely used.

Depending on the composition and destination, phenolics are divided into the following types:

О — general purpose;
Сп — special without ammonia;
Э — electric insulating;
Вх — moisture and chemical resistance;
У — shockproof;
Ж — heat-resistant [3].

The main applications of plastics in mechanical engineering are:

— **Gear and worm wheel:** polyamides, polypropylene, pentaplasts, polycarbonates, polyformaldehydes, phenolics, FRP, textolite, particleboards;

— **Pulleys, flywheels, handles, buttons:** polyamides, aminoplasts, phenolics, FRP, textolite, particleboards;

— **Rollers, runners:** polyamides, polyvinylchloride, polypropylene, polycarbonates, particleboards;

— **Slide bearings:** polyamides, polyethylene, polypropylene, polyacrylates, epoksiplasts, pentaplasts, polycarbonates, polyformaldehydes, phenolics, FRP, textolite, particleboards;

— **Guides of machine tools:** polyamides, epoksiplasts, textolite;

— **Parts of rolling bearings:** polyamides, polycarbonates, polyformaldehydes;

— **Brake pads, linings:** phenolics, FRP, particleboards;

— **Pipes, armature parts, filters of oil and water systems:** polyethylene, polyvinylchloride, polypropylene, polycarbonates, GRP;

— **Working bodies of fans, pumps and hydraulic machines:** polyamides, polyethylene, polyvinylchloride, polypropylene, pentaplasts, polycarbonates, GRP.

— **Seals:** polyamides, polyethylene, teflons, polyvinylchloride, polypropylene;

— **Housings, cases, covers, reservoirs:** polyethylene, aminoplasts, polyvinylchloride, polypropylene, polystyrene, polyacrylates, polycarbonates, phenolics, GRP;

— **Details of devices and machines of precision mechanics:** polyamides, polyethylene, polyvinylchloride, Polypropylene, pentaplasts, polycarbonates, polyformaldehydes, phenolics, FRP;

— **Bolts, nuts, washers:** polyamides, polyethylene, aminoplasts, polyvinylchloride, polypropylene, pentaplasts, polycarbonates, polyformaldehydes, phenolics, FRP;

— **Springs, cam mechanisms, valves:** polyamides, polyvinylchloride, polypropylene, polycarbonates, polyformaldehydes, текстролит, GRP;

— **Large structural elements, tanks, trays, etc. :** polyethylene, polyvinylchloride, polystyrene, GRP;

— **Electrical insulating parts, panels, dashboards, instrument cases:** polyamides, polyethylene, teflons, aminoplasts, polyvinylchloride, polypropylene, polystyrene, polyacrylates, epoksiplasts, pentaplasts, polycarbonates, polyformaldehydes, phenolics, FRP, textolite, particleboards, GRP;

— **Light-transmitting optical parts (lenses, sight glasses, etc.):** polyethylene, aminoplasts, Polypropylene, polystyrene, polyacrylates, polycarbonates;

— **Copiers, check patterns:** polyethylene, polyvinylchloride, polypropylene, epoksiplasts;

— **Cold sheet stamps:** epoksiplasts, pentaplasts, phenolics, GRP;

— **Foundry models:** polystyrene, polyacrylates, epoksiplasts, phenolics, GRP[4].

Features of the plastic materials are: low density (1–2 t/m^3); low thermal conductivity, high thermal expansion, 10–30 times more than steel; good dielectric properties; high chemical resistance; friction and antifriction properties. Strength power of plastics is comparable to the strength of steel and above. Plastics have good technological properties [2].

One of examples of using plastics in mechanical engineering are bearings made of caprolon. They are widely used in many industries due to their high physical and mechanical properties:

1) Durability, even under constant mechanical load;
2) Low friction when paired with any metal;
3) Ability to work without lubrication in friction units;
4) Reliable and quiet operation of devices and mechanisms;
5) Corrosion-resistance;
6) Adaptability to manufacture.

In addition, caprolon is 6 times lighter than steel and the is 10–12 times cheaper than bronze. The bearings made of caprolon in the presence of the lubricant can operate at circumferential speeds of up to 15 m/s and a pressure of 50 kgf/cm^2. The coefficient of friction on steel and bronze with lubrication (water, oil) is 0,04 – 0,08. Wear per 1000 hours of operation shall be 0.10 mm [5].

Disadvantages of plastics are: low heat resistance, low elastic modulus and impact strength compared to metals and alloys and the fact that some plastics have propensity to aging [2].

The use of plastics reduces costs significantly, as it lowers the complexity of design work and need for equipment. The effectiveness of the use of plastics in manufacturing is expressed in cost and mass reduction, lowering the costs of material (materials consumption), reducing the complexity of manufacturing of plastic parts compared with metal (a reduction of wages per unit of product); shortening of the production cycle and timing for the design and development of new constructions**.**

The effectiveness of the use of plastics in exploitation is reflected in the reduction of the structural mass, reducing operating costs (lubrication, repair, etc.), increase of operational reliability of machines, the expansion of the technical capabilities of construction and improving its technical and economic parameters (capacity, efficiency, service time, etc.).

So, replacing metal parts with plastic ones is very effective. This reduces the weight of construction by 4-5 times; complexity of manufacturing parts is reduced by 4–5 times; the number of operations and their labor intensity is reduced by 5-6 times, thus reducing cycle times and freeing up working capital. Capital cost (the cost of buildings, equipment, inventory) is also reduced by 4–6 times. Production costs are reduced by 2–3 times.

Plastic materials are not only by 4–9 times cheaper than nonferrous metals, but in some cases (molded) are 2–6 times smaller than ferrous metals.

In the constructions of aircraft, engines and other devices plastic and other non-metallic materials are increasingly used, on average, they make up 7–25% of the mass of subsonic transport aircraft and up to 20-50% of the mass of a rocket (without fuel).

In the agricultural machinery replacement of sintered parts in ethylene copolymers parts will extend the life of the bearing bushings of cultivators by 2.4–3 times. In cement production using liner copolymers instead of steel sheets increases the service time of bins and chutes by several times.

The economic effect is achieved in the mining and processing enterprises, factories of ferrous and nonferrous metallurgy (1 ton of sheet of low pressure polyethylene or ethylene copolymers can save 16–20 tons of stainless steel) and others [2].

REFERENCES

1. Пластмассы [Электронный ресурс] // Википедия. – 2017. – Режим доступа: https://ru.wikipedia.org/wiki/Пластмассы. – Дата доступа: 09.01.2017.
2. Лахтин, Ю. М. Материаловедение / Ю.М. Лахтин, В.П. Леонтьева. – Л. : Машиностроение, 1990. – 528 с.
3. Классификация пластмасс, применяемых в машиностроении // knigitut.net [Электронный ресурс]. – 2017. – Режим доступа: http://knigitut.net/2/89.htm. – Дата доступа: 09.01.2017.
4. Применение полимеров в машиностроении // MPlast.by [Электронный ресурс]. – 2017. – Режим доступа: http://mplast.by/encyklopedia/primenenie-polimerov-v-mashinostroenii. – Дата доступа: 09.01.2017.
5. Капролон, производство капролона, продажа капролона, полиамид-6 блочный : Капролон [Электронный ресурс] // ГлавМехСЕРВИС. – 2017. – Режим доступа: http://kaprolon.biz/?id=2. – Дата доступа: 18.01.2017.