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RESEARCH AND ANALYSIS OF THE PROPERTIES OF COMPOSITE MATERIALS. DEFINITION AND CLASSIFICATION OF COMPOSITE MATERIALS

Abstract. Unlike conventional materials, composites have become a suitable form for a range of current applications in industry, hospital and sports. This is combined with their remarkable physical, thermal, galvanic and mechanical properties, as well as, in addition, their low weight and investment cost in the given cases. This review article attempts to provide a general concept of composite materials, definition and classification of composite materials, most commonly polymer matrix composites and metal matrix composites. Polypropylene polyurethane and aluminum alloy were selected as matrices for this extract given their attractive properties and their use in various applications. All kinds of research are devoted to a variety of building materials, material processing and various properties. The determination of mechanical data appears to be a significant iterative process in the development and design of composite materials and their components. With regard to the mechanical properties of composite materials, this article highlights some of the uncertainties and limitations that affect the evaluation of mechanical properties, ranging from material constituents, industrial process, test characteristics and environmental conditions.

Keywords. Composite material, reinforcement, matrix, polypropylene, aluminum alloy, mechanical characteristics

Introduction.
In [1] they analyzed that all materials can be divided into four groups depending on their focus. The final division is indicated by the smaller boundary of two separate materials from three other classes of materials, combined into a single fruitful unit. Composite materials have been used since humanity has gained experience. In fact, a single substance in this area comes as a composite, because to consume a single case of an alloy in the process itself is a polycrystal (composite) from many separate crystals. However, there are many composite models in nature in which the position of the composite material enters as a beam in the process itself appears to be a stubborn material. In [2], animal bones were used - another example of an ordinary composite material. It is made from short, thin strands of collagen embedded in a mineral matrix called apatite.

In [3], by selecting the appropriate composition of the composite and surfacing material, it is possible to extract a composite that undoubtedly suits the needs of a particular application. The matrix stage appears to be soft and ductile and serves to retain the strengthening phase,
which is stronger and more rigid and improves the mechanical properties of the composite. Articles [4, 5] considered the interface limit or point of synthesis between two phases of a material, which gives loads applied by the external environment to a single reinforced material. Considering the matrices, the composites are referred to as polymer matrix composites (PMCs), metal matrix composites (MMCs) and ceramic matrix composites (CMCs).

In [6], thermosetting composites were considered to be strong with high rigidity and strength, and in addition good stability to wear and tear, but they have low ductility and terrible impact resistance, and they cannot be remade. While thermoplastic composites are harder, less brittle, and have extraordinary impact resistance, they lack creep resistance compared to thermoset composites. The main advantage of thermoplastics is that they can be freely reused [7]. The clay matrix is naturally held in place by other types of reinforcing ceramics. They have extraordinary corrosion resistance, superior compression properties, and stability at elevated temperatures with elevated melting points, but the main drawback of CMCs appears to be warping.

In [8, 9], the most commonly produced threads in composites were analyzed: carbon, hollow and aramid. Carbon fibers are designated by their elastic modulus (UHM, HM, IM and LM), stability (HT and SHT), starting materials and heat treatment temperature. The fiber can be tailored for various applications, such as E-glass, which has excellent galvanic resistance, C-glass, which has the best chemical resistance to acids, and T-glass for thermal insulation. S-glass has excellent stability and is widely used in composite materials.

In the article [10], sheets of thermoplastics were made, pultrusion of thermoplastics and tape filling are used for the manufacture of current thermoplastic materials, such as composites reinforced with permanent longish fibers. Thus, the creation of a composite liquid, thermosetting pultrusion, fiber winding and autoclave appear to be optimal processes for the manufacture of thermosetting composites. The scientific and technical strategies used for the manufacture of MMK are mainly divided into two classes. In the process of processing in a watery stay, the influence causes the reinforcement to seep through the liquid metal. Powder metallurgy is represented mainly by a well-known method in solid-state processes. The present method guarantees mainly excellent mechanical characteristics of metal composites reinforced with particles [5]. In [11], the process of friction stirring is also considered to be a strong solid-state process, which is characterized by the fact that it can rationalize features compared to conventional processing technology. In [12], the method of high-energy spherical crushing was usually used to extract nanocomposites.

Figure 1 – Relative share of materials used by humans in the process of evolution
The purpose of this review is to combine information from the literature on polymer and metal matrix composites. Polypropylene and duralumin alloy material were preferred as composites for this article. Most of the surveyed research is devoted to these two materials, with certain exceptions when additional results are needed.

**Materials and methods.**

Polymer and metal matrix composites: body made of composites based on polypropylene and aluminum alloys. Polypropylene is a thermoplastic polymer that is available in three different compositions: isotactic polypropylene (iPP), syndiotactic polypropylene (sPP) and atactic polypropylene (aPP). There are also all kinds of polypropylene: homopolymeric polypropylene (HPP), in which polypropylene is made from the propylene monomer in a semi-crystalline rigid form. Independent copolymer (RCP) and impact copolymer, the polypropylene chains of which store ethylene as comonomers in quantities (1-8% for RCP and 45-65% for ICP) [7]. Numerous technical plastics have been modified by polypropylene, thanks to which they have excellent mechanical properties, are easy to process and recycle, lightweight and cost-effective. Paper [13] examined polypropylene, which makes up more than 40% of the total size of plastics used in automobiles and is reinforced with a variety of fiber varieties. Due to this factor and the reason for its discovery, polypropylene has been attractive to numerous scientists and current companies who have sought to rationalize its characteristics and make it suitable for additional technical applications. In [14], the malleability of polypropylene melts filled with mica flakes and their mechanical properties were studied. As a result, the quality of the molded composite reveals elastic modulus values that are higher than those of unfilled polypropylene. [15] studied the possible exacerbating effects of six different types of filler elements in composites made from thermoplastic isotactic polypropylene. As reinforcing components, they used cut glass fibers, ceramic threads (aluminum oxide Al2O3 and silicon carbide SiC), two unequal empty spheres (type E with a small diameter of 10 to 40 microns and type P with a large diameter of 75 to 110 microns) and, carbon spheres. Their results showed that the addition of a filler with a higher elastic modulus to a polypropylene matrix with a lower elastic modulus enhances the hardness of the composite, also in cases where the fillers are empty spheres. The attachment of carbon spheres into a polypropylene matrix results in a decrease in tensile stability and ductility. [16] investigated the electrical, thermal and mechanical properties of polypropylene matrix composites filled with independently dispersed closely spaced aluminum fibers (three varieties with three different aspect ratios). The results are increased electrical and thermal conductivity of composites without sacrificing the superiority of low density. The article [17] set out individual characteristics of composites with a polypropylene matrix, improved by four types of magnesium hydroxide elements Mg(OH)2. By introducing more than 57% by weight of Mg(OH)2 elements, the material is made non-flammable, and its hardness is further improved when the dimensions of the Mg(OH)2 crystallites are increased in the range of approximately 2 microns. Conversely, strong edges have decreased significantly.

**Results and discussion.**

Matrix composites made of aluminum alloys. Aluminum alloys have been the most popular and enticing choice for the automotive and aerospace industries because they offer unmatched characteristics such as light weight, high strength, fire resistance, excellent corrosion resistance, ease of batch fabrication and low cost. However, they have terrible performance data at high temperatures and wear resistance. Aluminum alloys of the 2000, 5000, 6000 and 7000 series are widely used [18]. For this mission, aluminum iron matrix composites (AMMCS) are naturally developed through the addition of a ceramic strengthening phase to the alloy matrix. The induced characteristics are achieved through durable ceramic particles, tendrils or fibers uniformly distributed in an aluminum alloy matrix. In [19], aluminum alloys were studied and
became the predominately commonly used supporting matrix for the manufacture of metal-matrix composites. The use of ceramic tendrils allows us to use the superior mechanical properties of ceramics, since they provide a maximum increase in stability and rigidity, as well as resistance to creep. However, the secret of extracting a homogeneous dispersion in the matrix, processing costs and high costs for viscose make them less suitable at present [20]. Aluminum matrix composites reinforced with ceramic particles have emerged as a promising material, particularly due to their excellent tribological properties and corrosion resistance.

One of the components is the matrix (base), which binds the composite and gives it hardness and strength; the second is a storage device (reinforcing element). The role of the matrix is to protect the reinforcing material, bind it, transfer external stresses to it, and give it the desired shape. And the function of the drive is to ensure high mechanical properties. They excel in their maximum strength, reliability, rigidity, durability and light weight. Thanks to such data, composites are currently very widely used in our lives, namely in aviation, transport, marine, aerospace, industry, and civil engineering, and have seriously displaced the main homogeneous materials we are accustomed to.

In order to systematize a composite material (CM) according to various characteristics, competently implement the procedure for selecting it for the manufacture of various parts, and streamline the terminology in the field of materials science of composites, a well-founded classification of these materials is necessary. There is no single generally accepted classification of composite materials. This is explained by the fact that CMs represent the widest class of materials, combining metals, polymers and ceramics. The most frequently used classification of composite materials is based on their division according to materials science.

In [21], it was pointed out that the thermal conductivity of an aluminum matrix reinforced with SiC particles with a content of 40% depends very much on the average size of SiC elements in the range from 0.7 to 28 microns. They found a decrease in thermal conductivity with decreasing SiC particle size, because as the particle size decreases and the overall interface area increases, the corresponding contribution of SiC to the overall electrical conductivity of the composite decreases. [22] outlined the mechanical action and microstructure of 2080 aluminum matrix composites reinforced with 20% SiC particles processed by a novel low-cost sintering method. The structure of the bonded composites showed a relatively uniform dispersion of SiC elements. In addition, the connected composites showed higher elasticity and tensile stability limits - 103 GPa and 434 MPa, respectively. In addition, the fatigue properties of the bonded composites were assigned. [23] made A356-SiC and 6061-SiC composites using a high-pressure vacuum casting process. In [24] they indicated that an increase in the percentage of presence to
25% of the addition of B4C elements into the Al 1100 metal matrix led to a decrease in interfacial stability due to the weakening of the volume of composite grains during sintering at a temperature of 837 K below the melting point of Al in the vacuum mixture.

The most important feature of CM classification is the matrix material. CMs with a metal matrix are called metal composite materials (MCMs), those with a polymer matrix are called polymer composite materials (PCMs), and those with a ceramic matrix are called ceramic composite materials (CCMs) (Fig. 3). Composite materials containing two or more matrix materials with different compositions are called polymatrix [18]. The name of the PCM usually consists of two parts. In the first part the filler material is called, in the second the word “plastic” or “fiber” is given. For example, (Fig. 4), glass fiber reinforced polymer composites are called glass fiber reinforced plastics (GRP); metal fibers—metal plastics (metal fibers), organic fibers—organoplastics (organofibers), boron fibers—boron plastics (boron fibers), carbon fibers—carbon plastics (carbon fibers), asbestos fibers—asboplastics (asbestos fibers) [18].

\[ \rho_c = \rho_f V_f + \rho_m V_m \]

where \( \rho_c \) is the composite density, \( \rho_f \) is the fiber density, \( \rho_m \) is the matrix density, \( V_f \) is the fiber volume, \( V_m \) is the matrix volume.

The volume fractions \( V_m, V_f, V_p \) of the matrix, fibers and particles, respectively, are most often used for calculations. The following English subscripts are used: c-composite, m-from the word matrix, f-fibers,
The fiber volume fraction \( V_f \) is expressed as the ratio of the volume occupied by the fibers to the volume of the entire composite.

Replacing density with other quantities in equation (1), for example, \( K \) – thermal conductivity, thermal expansion, it is possible to predict what the selected properties of the composite will be. Young’s modulus \( E \), one of the most important mechanical properties required by designers (the stiffness of a structure depends on \( E \) and the thickness of the element), can also be predicted based on the rule of mixtures for a single layer of a composite reinforced with unidirectional continuous fibers under tensile loading in the direction of the fiber length:

\[
E_c = E_m V_m + E_f V_f . \tag{2}
\]

In the transverse direction (2), the elastic modulus is calculated using relation (3):

\[
E_c = \frac{E_m E_f V_m}{E_f V_m + E_m V_f} . \tag{3}
\]

Calculations indicate a high anisotropy of properties for unidirectional composites, where the elastic modulus in the direction perpendicular to the length of the fibers is similar to the elastic modulus of the pure matrix, i.e. many times less than the elastic modulus of the fibers, hence the need to create layered structures (laminates) in which the fibers are distributed at different angles, which gives the apparent (quasi) isotropy of the material in the plane of the plate.

The properties and amount of the reinforcing phase affect the density, thermal expansion, and elastic modulus. In turn, the elasticity part and reliability improved with increasing reinforcement from 0% to 25%, from 22 GPa to 183 GPa and from 50 to 550 Hv, respectively, indicating a high interdependence of the elastic modulus on the mass fraction of boron carbide elements. In [25], researchers increased the hardness, compressive and wear-resistant properties of high purity aluminum by adding various numbers (5, 10 and 15 wt%) of B4C nanoparticles with an average size from 10 to 60 nm. With increasing occurrence of B4C nanoparticles, the sample having 15% showed the highest reliability in compression - 485 MPa compared to pure Al (130 MPa), a similar improvement in hardness, which increased from 33 HV for pure Al to 164 HV for the composite, where the wear resistance is significantly increased. [26] studied the production of aluminum carbide and boron composites by stir casting. They found that changing processing parameters (e.g., temperature, particle surface treatment, mixing speed, and mixing time) and volume fraction of reinforcement affected the microstructure and mechanical performance of the composites. Strengthening the bulk of B4C from 0 to 20%, increasing the processing temperature from 800°C to 1000°C, and increasing the stirring time to 12 min improved the mechanical properties and wettability potential of aluminum and B4C elements. In addition, aluminum alloy composites reinforced with titanium carbide (TiC) are increasingly being explored [27, 28].

**Conclusions.**

Composite materials are advanced structural materials. Due to the strict preference for matrix reinforcement, easy access to these components, their lightness and exceptional physical, thermal, electrical and mechanical properties, composite materials are becoming a candidate for classical materials and are used in various applications. This review article presents a global analysis of composite materials, particularly polymer matrix composites and aluminum alloy metal matrix composites. A number of studies were discussed to illustrate various types of reinforcement materials, material processing and various properties such as physical, mechanical, electrical, thermal and tribological. Various types of reinforcement were thoroughly examined, as well as their enhancing resistance to matrices made of polypropylene and
aluminum alloys. Carbon, glass and aramid have been the most commonly used artificial reinforcing materials, because they give polypropylene polymers a great deal of elasticity, durability and fatigue resistance. It has been shown that mechanical performance is highly dependent on many aspects and parameters, ranging from material composition, manufacturing processes, test characteristics and environmental circumstances. Most studies have found that increasing the reinforcement content improves the mechanical properties as well as the fatigue reliability of both polypropylene and aluminum alloy composites. The study showed that polypropylene composites reinforced with long fibers have better mechanical properties compared to polypropylene composites reinforced with similar fibers. On the other hand, nanoparticles have been found to greatly strengthen aluminum alloys compared to microparticles, resulting in the highest number of cycles to failure. Many reinforcing materials are incompatible with the matrix, resulting in poor interfacial adhesion. Humidity and temperature appear to be two key environmental factors affecting the fatigue behavior of composites.

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КОМПОЗИТТІК МАТЕРИАЛДАРДЫҢ ҚАСИЕТТЕРІН ЗЕРТТЕУ ЖӘНЕ ТАЛДАУ.
КОМПОЗИТТІК МАТЕРИАЛДАРДЫҢ АНЫҚТАМАСЫ ЖӘНЕ ЖІКТЕЛУІ

Андатпа. Онеркәсіптегі, ауруханада және спортта қазіргі колданыстардың ауқымы үшін жәй материалдардан айырмашылығы, композитті қолайлы түрге айналды. Бұл олардың физикалық, жылу, гальваникалық және механикалық қасиеттерімен, сондықтан жеткілікті жағдайларда инвестициялық қаражаттың шамамы мен құның үйлеседі. Бұл шолу макалады композиттік материалдар турақты, композиттік материалдарды анықтау және жіктеу туралы, көбінесе полимерлі матрицалық композиттер мен металл матрицалық композиттер турақты түсінік беру екі үшін қолданыстың ауқымына, полипропилен поліуретаны және алюминий қорытпасы олардың тартымды қасиеттерін және әртүрлі қолдану аймақтарын айырмашылығына, полимерлі матрицада, металл матрицалық композиттер туралы жағдайларына, материалына, мекенжайына және орналасу сақтау және жоғарынанөкту айырмашылығын анықтауға әсер етеді. Механикалық, және электрліқ қасиеттерін анықтау композиттік материалдар мен олардың компоненттерін өндіріс процессін, орналасу сақтау және жоғарынанөкту дәрежеге арналган. Композициялық материалдардың композиттік материалдарын құрылуын, жоғарынанөкту әртүрлі қасиеттерге арналған материалдардың жоғарынанөкту немесе электрлі қасиеттерге арналған материалдардың, композиттік материалдардың құрылуы және электрлі қасиеттерге арналған материалдардың құрылуына, жоғарынанөкту әртүрлі қасиеттерге арналған.

Түйінді сөздер.
Композициялық материал, арматура, матрица, полипропилен, алюминий қорытпасы, композиттік сипаттама.
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ИССЛЕДОВАНИЕ И АНАЛИЗ СВОЙСТВ КОМПОЗИТНЫХ МАТЕРИАЛОВ. ОПРЕДЕЛЕНИЕ И КЛАССИФИКАЦИЯ КОМПОЗИТНЫХ МАТЕРИАЛОВ

Аннотация. В отличие от обычных материалов, композиты стали подходящим видом для целого ряда нынешних применений в промышленности, больнице и спорте. Это сочетается с их примечательными физическими, тепловыми, гальваническими и механическими свойствами, а также вдобавок незначительным весом и стоимостью инвестиционных средств в поставленных случаях. В этой обзорной статье предпринята попытка подать всеобщее понятие о композитных материалах, определение и классификация композитных материалов, чаще всего о полимерно-матричных композитах и металломатричных композитах. Полипропиленовый полиуретан и алюминиевый сплав были избраны в качестве матриц для данного экстракта учитывая их привлекательных качеств и их использования в различных участках применения. Все возможные изыскания посвящены разнообразным строительным материалам, обработанию материалов и различным свойствам. Определение механических данных представляется значительным циклическим процессом при разработке и конструировании композитных материалов и их компонентов. Что касается механических качеств композиционных материалов, то в данной статье придается о некоторых неустойчивых и ограничениях, которые воздействуют на оценку механических свойств, начиная составляющие материала, промышленный процесс, характеристики испытаний и условия окружающей среды.

Ключевые слова. Композиционный материал, армирование, матрица, полипропилен, алюминиевый сплав, механическая характеристика.

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