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PROBLEMS AND ACHIEVEMENTS OF MODERN MATERIALS SCIENCE

Abstract Materials are a multitude of objects of labour which humans transform during the flow of work turning them into products of labour (commodities and means of production). Both source substances for manufacturing of products and auxiliaries for carrying out productive process are materials. Depending on the amount of labour expended and functions of materials in productive process the following kinds of materials are recognised. Raw material is an object of labour which was previously affected by labour and is subject to further processing, e.g. iron ore at a metallurgical works or cotton at a textile factory etc. Raw material is of animal, plant, mineral, or other origin. Initial raw material is an object on which labour was expended; secondary raw material is waste of production, physically or morally obsolete commodities subject to processing.

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Machinery engineers have always been seeking to make efficiency and quality of new articles exceed those of known ones. Currently this trend is the most pronounced as state-of-the-art achievements of science are utilised in the best machinery specimens.

The endeavour of machinery engineers to increase operating pressure, speed, and temperature and decrease specific weight of articles related to a unit of created or transmitted power determined a close dependence of machine efficiency and achievements of materials science.

Further the most topical issues of current materials science and successful steps towards their solution are summarised.

Material strength improvement is the most important issue for materials science at all times. Development of many areas of current technology is related to application of high-strength materials. By the beginning of the XXI century strength of basic engineering materials known had increased 8–10 times; stresses under which high-strength steels destruct exceed 103 MPa. Whisker-like filamentous monocrystals of perfect structure which do not destruct under stress of 104 MPa are manufactured. Science faces the problem of making high-strength materials as reliable and inexpensive as ordinary metals are.

Manufacturing and use of super-hard materials, including many hard alloys, carbides, borides, industrial diamonds etc., characterise industrial capacity and technological durability of the country largely. These materials are so hard and brittle that they cannot be processed using conventional methods. Technological challenges were managed to be overcome only in the second half of the XX century through the phenomenon of superplasticity when it became possible to give required form to workpieces by strain under pressure of 103–105 MPa [2].

The trend in mechanical engineering towards a decrease of effective mass of an article, i.e. the mass per power or machine capacity unit, determines the need of development of materials in which high strength combines with low density. Examples of such materials are magnesium, lithium, and beryllium alloys, strain resistance of articles made of which exceeds the one of steel and titanium constructions. They are applied in aviation, in rocket and spacecraft building. A large group of gas-filled materials is used in modern technology as light fillers of load-bearing units, dampers, and heat and sound insulators.

Shift of aviation to jet engines made the issue of creation of materials reserving initial strength at high temperatures a topical one. High-temperature strength margin of iron-, nickel-, aluminium-, and other metal-based alloys are limited and actually worked out. This gave rise to the problem that operating temperature of many parts of engines reached 1200°C and neared the melting point of the said alloys. Thus, commercial steels upper operating temperature limit does not exceed 770°C, the one of nickel and cobalt alloys – 1100°C etc. Until recently low values of steel high-temperature strength prevented engine building from further development as operating characteristics are related directly to gas temperature in the turbine. Currently this problem is solved through processing of metals into grains by means of rapid solidification and further moulding of grains into articles. Rapid solidification in the course of rapid cooling of liquid melt leads to formation of small-sized crystals only (nano- and microcrystals) or even amorphous materials. At high temperatures strength of metal crystal and amorphous alloys is 1.5 times higher than those of alloys obtained through a conventional technology.

Perspectives of use of ceramic parts in internal combustion engines are being studied. The aim of such use of ceramics is the possibility to increase working temperature in the combustion chamber with simultaneous decrease of unit weight, which leads to an engine efficiency factor increase.

Stability of properties of materials in extreme operating conditions becomes more and more topical in relation to technology progress and exaggeration of working conditions for machines.

Cryogenic technology which provides obtainment and use of temperatures below –150°C solves many manufacturing problems related to gas liquefaction and distribution of gas mixtures, first of all air. It owes its achievements to a group of engineering materials which neither lose their mechanical characteristics nor become brittle with decreasing temperature. Thanks to cryogenic technology cryoelectronics appeared which deals with use of phenomena occurring in solid bodies at cryogenic temperatures (in presence of electric, magnetic, and electromagnetic fields) to build electronic devices. Upcoming is building of superconductive transformers, power transmission lines, and super-strong magnets required to hold plasma during a thermonuclear reaction etc.

Purity of materials is in most cases a prerequisite to stability of their properties. Therefore material purity requirements have soared. Until recently pure materials met the definitions “commercially pure” (basic component level is 99.9% or “chemically pure” (99.99%). Now atomic energetics needs super-pure uranium and thorium (e.g. boron impurity in uranium may not exceed 10–5%). Material purity requirements in semiconductor technology are even higher: impurity standard in most materials is not more than 10–11%. Quantum electronics (working parts of lasers) and space technology (solar batteries, fuel etc.) became super-pure material consumers. Many super-pure materials revealed unexpected properties. Thus easily corroding iron and zinc successfully resist corrosion when purified; chromium, titanium, tungsten, molybdenum, and other refractory metals considered hard and brittle become compliant after high purification and may be rolled into foil. The issue of material property stability is solved in technology in several directions among which the following are the most important ones.

Conclusion. Composite materials are one of the greatest achievements of materials science. Strengthening of technical and economical requirements for materials and limited raw material resources of the Earth determined increased consumption of natural materials at a new technological level – combined with their strengthening elements of more sound materials. Use of such materials named composites promotes a machinery working ability increase, a production costs decrease, and establishment of flexible manufacturing. Not all composite material consumption increase prerequisites are favourable. Manufacturing of some of them is connected with health risk for human at working places and gives rise to additional environment-protection problems.

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