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## PROSPECTS FOR THE USE OF CARBON FIBERS IN THE CREATION OF FINISHED PRODUCTS BY THE 3D PRINTING METHOD

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Recently, carbon fiber has become popular in many sectors of the economy, as it has valuable properties: high rigidity and tensile strength; low weight; high resistance to chemical reagents and high temperatures; low thermal expansion (Fig.1). These characteristics make carbon fibers in demand in many industries.

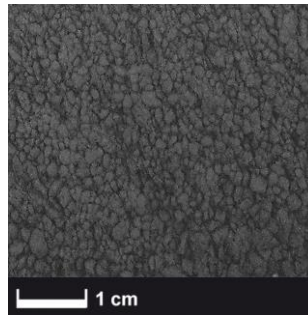


Figure 1 - Carbon fibers [1]

Carbon fibers themselves are rarely used. They are usually combined with other materials, thus forming composite materials reinforced by them. Polymer material acts as a matrix in these materials. The main advantage of such a composite is that the result is a stronger, but lighter plastic with an increased level of rigidity. Carbon-filled composites are gradually taking over the market and are already widely used in the aerospace, automotive, and instrument-making industries; military and civil engineering and even in sports due to the highest strength-to-weight ratios. Carbon fiber reinforced composites can be used to create many products, such as: bicycle frames; wings of airplanes and unmanned aerial vehicles; propeller blades, automotive and home appliance components, etc.

There are two types of reinforcement of the original material with fibers - short fiber and continuous. In the first case, chopped fibers less than a millimeter in length are combined with a base material such as nylon, ABS or PLA. In the case of continuous fibers, they must be integrated into the thermoplastic during extrusion. This is a rather complex and time-consuming process, but thanks to continuous reinforcement, it is possible to create parts with strength at the level of metals.

Considering the many advantages of carbon fiber, it is already used not only in traditional production systems, but also in additive manufacturing. In

recent years, 3D printing companies offering carbon fiber reinforced materials have appeared.

According to IDTechEx, the world market for 3D printing with composites will reach \$1.7 billion by 2030 [2]. This figure clearly shows the prospects for conducting scientific research on the creation of new composite materials reinforced with carbon fiber.

There are basically two ways to use carbon fiber in 3D printing: the first is carbon fiber reinforced filaments, and the second is continuous carbon fiber reinforcement.

In the thread with carbon fibers, short fibers are used, consisting of segments less than one millimeter in length, which are mixed with thermoplastic, acting as the base material (matrix). The polymer matrix can be PLA, PETG, ABS, polycarbonate, nylon, or other plastics. High-performance polymers (HPPs), such as: PEEK or PEKK, which have durability, can also be used as a base; high mechanical and chemical characteristics; improved strength-to-weight ratio.

Carbon fibers, being extremely strong, increase the strength and stiffness of the filament, and also reduce its overall weight. When making a thread, the question arises of the correct selection of the "polymer matrix - reinforced material" percentage ratio. If a certain fiber threshold is exceeded, the part printed on a 3D printer may lose its properties. The quality of printing on a 3D printer will depend on the design features of the extruder itself and correctly selected technological parameters. HPPs materials require extruders that can heat up to 400 °C and systems that have heated chambers and precast plates.

A thread with carbon fibers is significantly stronger than a thread that is reinforced with them. However, to get an even stronger part, another method called continuous carbon fiber reinforcement can be used. Since the fiber is not cut into smaller pieces, it retains much more strength. In this way, it is possible to increase the strength of the product while simultaneously reducing material consumption.

In order to print with continuous carbon fiber, you need to develop the appropriate technology and a 3D printer. The printer must be equipped with two heads, one of which is designed for extruding polymer material, and the second - for simultaneous feeding of carbon fiber.

The development of carbon fiber-reinforced consumables according to the specific requests of customers, the improvement of 3D printers for printing with them, the development of technology and equipment for continuous carbon fiber printing will allow expanding the scope of use of composite materials in various industries and significantly increase production efficiency.

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