Optimization of Production Lines and Cross-sections of Fiberglass Rebar

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Abstract. The article substantiates the need of the construction industry in new lightweight and durable materials that ensure reduction in the cost of work and increase in the operational characteristics of the constructed facilities. These materials include fiberglass reinforcement which is an auxiliary bar made of heavy-duty glass fibers impregnated with a polymer adhesive composition and additionally entwined to create a ribbed surface and tight fit with fiberglass threads. This fitting has undeniable advantages in comparison with steel fittings. The polymer composite is resistant to corroding medium, does not corrode, does not conduct electricity, has high elastic properties, low thermal conductivity, increased tensile strength, etc. It is shown that the issues related to the improvement of technology and the form of a fiberglass rebar section are relevant for the construction industry. So, in particular, the presented developments will significantly reduce the consumption of adhesive composition for impregnating roving threads, reduce production costs by eliminating the loss of adhesive composition in impregnating vessels and pull-guide rollers, increasing the environmental friendliness of production and increasing the line productivity. In addition, it is possible to improve the strength characteristics by optimizing the cross-section and longitudinal cross-sections of the resulting fiberglass reinforcement. The presented changes in the design and technology of fiberglass reinforcement production can be realized as a separate independent module. It is easy to integrate into existing lines during repair work or routine maintenance of equipment.

1. Introduction
The modern construction industry need new lightweight and durable materials, which ensure a reduction in the cost of construction and an increase in the operational characteristics of the constructed facilities. In this regard, the market began to actively use composite materials. Among them there is a fiberglass reinforcement, which is an auxiliary bar made of heavy-duty glass fibers impregnated with a polymeric adhesive composition and wound in addition to create a ribbed surface and tight fit with fiberglass threads [1]. The adhesive composition provides for the joint interaction of the glass fibers, and also protects the reinforcement from mechanical damage and exposure to aggressive environmental factors.
The estimated service life of fiberglass reinforcement is about one hundred years. This material is much lighter (6 ... 7 times) compared to steel reinforcement, it has increased tensile strength (compared to steel reinforcement, this figure is 3 ... 5 times higher). At the same time, the polymer composite is resistant to corrosive medium, does not corrode, does not conduct electricity, has high elastic properties, low thermal conductivity and is not affected by electromagnetic fields [2-6]. Fiberglass reinforcement is technologically efficient in transportation and installation, which saves resources at all stages of work with it.

Fiberglass reinforcement is widely used in road, industrial and civil construction [7-12]. However, due to the low coefficient of elasticity [13], fiberglass reinforcement is used only as a thermal insulation fastener, for laminated masonry, as a reinforced mesh, as a supporting and facing layer for the construction of multilayer walls, for the construction of various lightly loaded engineering elements.

The availability of components, fabricability of production and the relative compactness of the manufacture of fiberglass reinforcement ensured its mass production.

2. Timeliness
As stated above, fiberglass reinforcement has a lot of undeniable advantages (tensile strength, weight characteristics, technological, etc.) in comparison with metal fittings [14-18]. Therefore, issues related to the improvement of technology and equipment for its manufacture are relevant for the construction industry [19-24]. So, changes in the part of the technological process can increase the productivity of production, reduce the costs of constituent components and energy for the production of fiberglass reinforcement. In addition, the possible modernization of the line will reduce part of the technological equipment, reduce its dimensions or make the process of manufacturing fiberglass reinforcement more environmentally friendly. Changes in the shape of the section of the reinforcement can increase the coefficient of elasticity and the strength characteristics of the reinforcing element.

3. Theoretical part
Currently, the technology of manufacturing fiberglass reinforcement is carried out as follows [25]. Filaments of the glass fibers pulling from the coils of the creel 1 are initially heated and dried in the device 2 to ensure subsequent qualitative impregnation with the synthetic adhesive (Figure 1).

Subsequently, the filaments are immersed in a container 3 with an adhesive composition and the excess of the binder component is removed. Details of pulling and guiding devices at this stage of technology are exposed to interaction with liquid glue, they need periodic cleaning.

This affects the performance of all production equipment. The impregnated filaments are then fed to the device 4 to form the reinforcing ribbed surface of the reinforcement and the bundle of fiberglass into a single core. In this form, the formed armature extends through the tunnel (tube) furnace 5 for the polymerization. At the outlet of the furnace in the device 6, the hardened bar is intensively cooled by air or water. After the cooler, a pulling mechanism 7 is installed that ensures the advancement of the glass fiber strands and the finished reinforcement at all stages of the production line. Then, a cutting device 8 is provided that defines the length of the articles to be produced. At the last stage, the reinforcement is stocked either by winding it into the bay 9, or by placing the reinforcement bars on the rack.
The described technology has a series of disadvantages:

1. In an open container with prepared synthetic adhesive:
   - Over time it occurs polymerization (hardening);
   - Intensive processes occur evaporation of light adhesive components, which can negatively affect the health of workers and the general pollution of the production room air;
2. The adhesive cannot be fully developed from the bottom of the container due to design features. Therefore, considerable time is spent on cleaning it at the end of the work shift, which significantly reduces the efficiency of the process;
3. Impregnation of filaments by the dipping method is wasteful, since an excessive amount of adhesive composition rises. This requires a spinning device. In addition, the guide and pulling rollers are contaminated with adhesive, which reduces the efficiency of their work, the quality of the resulting reinforcement or requires their constant cleaning.
4. The cross-section and the shape of the obtained reinforcement are not optimal for ensuring the maximum possible elastic properties of the product.

4. **Formulation of the problem**

For the wide distribution of fiberglass reinforcement, the following tasks must be solved:

- Reduce the overall dimensions of the line for the production of fiberglass reinforcement. This will allow to place production in more compact production areas.
- Minimize harmful emissions (evaporation) of the adhesive composition into the air of the production area and the environment.
- Reduce the time and minimize the costs of additional materials for cleaning the elements of the container design, as well as guiding and squeezing rollers from the adhesive composition.
- Ensure dimensional dosing of the adhesive composition, according to the requirements for the formation and reliable adhesion of the roving strands to the bundles forming the core of the composite reinforcement.
- Optimize the shape and cross-section of the profile of fiberglass reinforcement to improve its strength characteristics (modulus of elasticity).

In work it is supposed to exclude from the technological chain an open container with adhesive. Show the principal possibility to use a new approach to the formation of a bonded rod of fiberglass filament by targeted dimensional metering of the adhesive composition directly into the knot of the string. Reduce the consumption of adhesive, increase the efficiency of the line for the production of fiberglass rebar and improve its performance.

5. **Practical use**

The implementation of measuring the metering of the adhesive in the middle of the reinforcing bar is shown on the developed scheme. The filaments of the glass fibers are fed from the creel 1 (Figure 2) through the heating and drying device 2 directly to the device 3 to form the reinforcing ribbed surface of the bar. In the lay of filaments, a nozzle 4 is placed in a single bar, which provides the necessary and sufficient dosing of the adhesive.

![Figure 2. The modernized unit for the formation of fiberglass reinforcement](image-url)
Relatively thick consistency of the adhesive ensures its tightening by filaments of fiberglass and uniform distribution along the core of the reinforcement to be formed. The nozzle 4 is adjusted not only by the volume flow, but also by axial movement. At the same time, the technology of feeding glutinous composition and dry filaments of fiberglass into the zone of the twist makes it possible to produce complex weaving. This will make it possible to form hollow rods (Figure 3) including increased strength characteristics. The technology of weaving will ensure the obtaining of uneasy forms of both transverse and longitudinal sections (Figure 4).

6. Conclusions
Realization of the presented changes in the design of the line for the fiberglass reinforcement production will allow:

- Significantly reduce the consumption of adhesive composition for impregnating the roving strands and secure their adhesion in shaping the profile of fiberglass reinforcement;
- Reduce production costs by eliminating the loss of adhesive composition in impregnating vessels, on pull-guiding rollers, wiping materials and solvents;
- Increase the environmental friendliness of production by minimizing the active surface area of the liquid adhesive composition with air at the time the profile of the fiberglass reinforcement is formed;
- Increase the productivity of the line by reducing the time for cleaning parts and equipment components from the adhesive composition;
- Increase the strength characteristics by optimizing the cross-section and longitudinal cross-sections of the resulting fiberglass reinforcement.

The presented changes in the design and technology of production of fiberglass reinforcement can be realized as a separate independent module. The upgraded module can easily be integrated into existing lines during repair work or routine maintenance of the equipment. The developed module is easily automated, by installing servo systems. In general, the new technology, using the proposed changes in the point-by-dimensional dimensional dosing of the adhesive composition directly into the roving strand of the roving and the formation of a modified form of the reinforcement cross-sections, will ensure high competitiveness of the profile and production.

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