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Mobile compact gravity-force concrete mixer

The article discusses the design of a compact gravity-force concrete mixer, which combines the advantages of gravity and forced mixers. An analysis of existing designs and the mixing processes within them was conducted. The proposed design is promising due to its high energy efficiency, reliability, and compactness. Its small size simplifies transportation, and its versatility allows it to be placed at any construction site, which increases its flexibility of use. The mixer ensures high-quality mixing of solutions and adapts to various conditions.

Keywords: mixer, gravitational, forced, mixture, small size, blade, axis, shaft, energy efficiency, productivity, mixture homogeneity

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Introduction.

Every day, the construction industry in Ukraine faces significant challenges in the modern world. The constant destruction of private households or low-rise buildings is causing increased demand for restoration and new construction in the country. This, in turn, leads to an increase in demand for the manufacture of concrete structures, which cannot always be met due to the lack of affordable and practical tools. Therefore, it would be advisable to consider the potential functionality of existing concrete mixing equipment and its parameters, as well as to propose a design idea that offers a modern solution for such cases. It should be noted that the compact size and energy efficiency of the future design are key factors, since possible damage to power grids leads to an unstable supply of electricity to people's homes, which requires the design to operate in such a mode that it achieves the maximum amount of concrete mix produced in the shortest possible time. Another critical parameter is compactness, which is a personalised solution for moving and storing concrete mixers. It is believed that larger models of concrete mixers can be used; however, due to their high metal content and size, they are not always advisable for use in low-rise and private households.

However, ensuring productivity while reducing dimensions should remain comparable to analogues, while maintaining the cost of manufacturing and using this design. It is also advisable to pay attention to the reliability of the design and reduce the number of potentially vulnerable components of the concrete mixer [1].

Review of the research sources and publications.

During the study of other publications on this topic, the works of prominent scientists who have dealt with solving problems related to operating modes and parameter selection for this type of equipment were analysed [1-11]. In their works, considerable attention was paid not only to the principle of operation of mixers, but also to achieving adequate mixing of ready-made mixtures, which significantly influences further research. It is worth distinguishing the comparative assessment of the efficiency of various mixers in terms of design, as studied in the work of Rogozin I.A. [11], since a universal indicator has been developed that allows evaluating the performance of mixers based on their design, which in turn provides a basis for a simplified analysis of the feasibility of design options for new construction equipment. His work also examines the efficiency coefficient of the mixer, which is determined by the machine's design features and parameters, resulting in the achievement of process efficiency through the parameter of mixing homogeneity. It is noted that this parameter can be achieved in several ways, namely by adjusting the coefficients of heterogeneity of the mixture concentration components, the degree of mixture separation, or the values of the limit shear stress of the solution, which still result in an exponential dependence of the building material preparation process. A quality mixing process for a construction mortar will involve macro-mixing and micro-mixing. Meeting the quality conditions for mixing will result in a symmetric mixture structure with a homogeneous distribution throughout the entire volume of the drum's working space.

The requirements of DSTU standards [12, 13] for construction equipment, as well as the quality and speed of preparing ready-mixed concretes, were taken into account. Specifically, about general points, we can highlight ergonomics, safety, transportability, resistance to dynamic loads, and resistance to vibrations. Based on the standards above, further research on the gravity-fed mixer should consider an optimal layout of working parts, a reduction in material consumption, and a unified overall design..

a)

b)

c)

Figure 1 - Forced-action concrete mixers,
a) RSP-800,
b) SGSh-500,
c) BP2-100.

In addition, the rheology of construction mixtures, namely the hydrodynamics of viscous substances, was analysed. This is one of many initial factors for quickly and reliably achieving mixture homogeneity [9, 10]. Construction mixtures, particularly concrete, are non-Newtonian viscous fluids. Their behaviour, like that of all sand-cement mixtures, depends not only on the water content, but also on the combinations of interactions between the binder and different fractions of the aggregate. Parameters of the rheological model, such as yield stress, plastic viscosity, and thixotropy, are crucial for designing mixers and selecting optimal operating modes. Hydrodynamics in mixing enable the determination of the distribution of velocities, flow vectors, and stresses in the liquid or semi-liquid phases of a cement-sand mixture [4].

An analysis of the main model designs currently available on the Ukrainian market has revealed that several distinct concrete mixers and their operating principles can be identified, which can serve as a basis for developing a new design, as they are the most common representatives in their category.

Most forced-action concrete mixers [15, 16, 17] are continuous in operation; their design includes a stationary drum and working blades that rotate relative to the drum axis. The working mixture is loaded into the stationary drum, and the blades, performing a rotational movement, ensure the mixture is thoroughly mixed. The finished mixture is discharged through an opening located at the bottom of the drum, which does not always meet operational requirements. In addition, complete unloading of such a mixer is complicated [3, 4, 5, 8].

A unique feature of the design is that the mixer drive can be located under the drum, above the drum, or, in the case of horizontal shafts, on the side. A drive shaft transmits the torque through a pipe to a traverse, to which the blades are attached. The pipe is rigidly and hermetically fixed to the lower plane of the drum, ensuring that there is no contact between the rotating drive shaft and the working medium, thereby providing greater reliability to the structure. However, this type of concrete mixer design is metal-intensive and, accordingly, heavy and expensive, which limits its mobility [2, 3].

Gravity mixers [17, 18] operate on the principle of the natural collapse of the mixture in the drum, under the influence of gravity. In such a mixer, the blades are rigidly fixed to the inner surface of the drum. As the drum rotates, the components of the mixture are prevented from sliding along the drum walls. The advantages of this mixer are its simple design, high reliability, and consequently, lower material consumption and cost, as well as its compactness and ease of transport.

In addition, complete unloading of the mixer is not problematic. Therefore, its design is the most common among mobile concrete mixers. However, this mixer design also has the disadvantages characteristic of gravity mixers, namely the difficulty of obtaining a uniform mixture composition [1, 4, 5, 8].

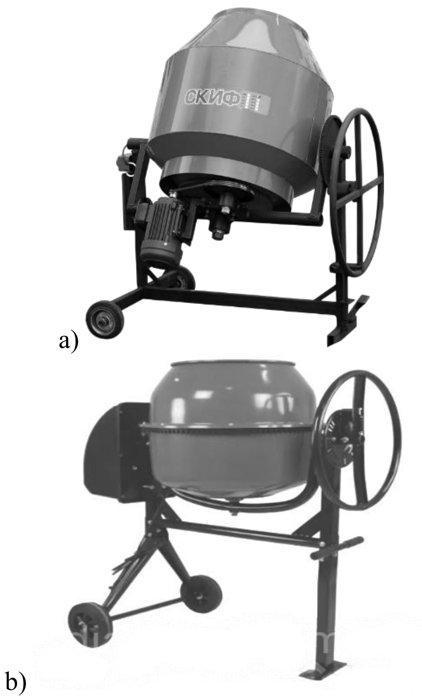

Figure 2 - Gravity-type concrete mixers.
a) Skif BSM-200,
b) Forte EW9180P.

Definition of unsolved aspects of the problem. This study aims to optimise the parameters of a small-sized concrete mixer that combines the advantages of different operating principles, including gravity and forced action mixers.

Among the main parameters studied, special attention was paid to energy efficiency and mixing quality. The general parameters included compact size, reliability of components, and metal intensity, which also took into account the manufacture of special concrete mixer components.

Problem statement.

One of the key problems with this type of equipment is maintaining a balance between mixing quality and energy efficiency. It is believed that further research on this topic, combining the design features of gravity and forced action mixers, will result in improved mixture quality with significantly lower energy consumption.

From the perspective of insufficient justification of the parameters of similar equipment, it stimulates further possible research on this topic.

Basic material and results.

The mixing process itself is much more complicated than it may seem at first glance. To obtain a homogeneous mixture, it is necessary to distribute its components evenly throughout the entire volume of the mixing drum and to achieve dispersion of liquid droplets and air bubbles, while maintaining a uniform shear stress in the mixture during circulation. To accurately study the mixing process, a parameter is needed that can summarise and evaluate the quality of the prepared mixture. The most accurate and fair criterion for construction mixtures is the heterogeneity criterion, also known as the coefficient of variation; as this parameter increases, the heterogeneity of the mixture increases [1-7].

$$K_{var} = \frac{100}{\overline{c}} \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} \left(c_i - \overline{c}\right)^2} \qquad (1)$$

where $\overline{c}$ – arithmetic mean value of the concentration of the key component in all n samples of the mixture, %;

c –concentration of the key component in the i-th sample of the mixture, %.

Among the main parameters, mixing performance will also be taken into consideration.

$$П_{експл} = V_{заг} \cdot Z_{ц},\ m^3 / hour. \qquad (2)$$

$$П_{експл} = V_{заг} \cdot Z_{ц} \cdot \rho_0,\ m^3 / hour. \qquad (2)$$

$V_{заг.}$ – total volume of the mixture in the mixer body, m^3;

ρ_0 – average density of concrete mix, kg/m^3;

$Z_{ц} = 3600/t_{ц}$ number of machine cycles per hour;

$t_{ц}$- duration of one cycle, which consists of the sum of the duration of loading components t_1, and their movement [7, 8].

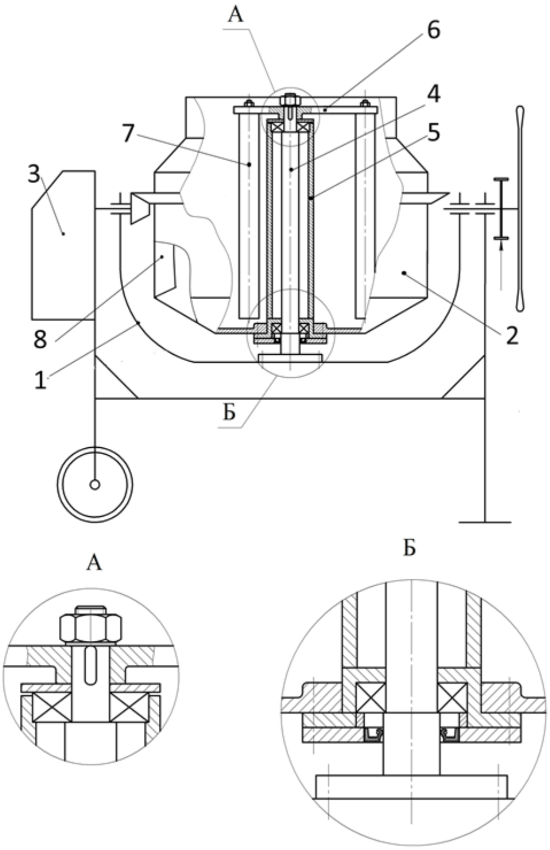

Figure 3 - Compact mixer

An analysis of the main model designs currently available on the market has revealed several separate concrete mixers that can serve as the basis for a theoretical design. During construction or renovation work, both forced-action and gravity concrete mixers can be used. After reviewing existing mixers and considering the necessary calculations, the following model is proposed [19].

The design kinematic diagram of the mixer for a rotating drum entirely coincides with that of a conventional gravity mixer. The mechanical energy of rotation from the electric motor drive 1 is transmitted through a bevel gear to the rim of drum 2, causing it to rotate. The drum, as before, rotates freely around the central axis. The central axis 4 is rigidly fixed to the movable frame 1, and the movable frame 1 can tilt, tilting the drum 2 to the required position. The central axis 4 runs along the axis of the drum 2, coaxially in the central pipe 5. In the central pipe 5, bearings are located at the upper and lower ends, on which the central axis 4 is fixed. The central pipe 5 is hermetically sealed to the lower part of the drum 2, which allows the drum 2 to rotate freely on the bearings of the central axis 4. At the same time, the mixture cannot directly contact the central axis 4, which ensures the proper reliability of the drive. A traverse 6 is installed on the upper end of the central axis 4 using a spline connection, so it cannot rotate with the drum 2. The blades 7 are attached to the traverse 6, allowing for the necessary radial positioning relative to the axis of the hollow pipe 5.

The mixer operates as follows. Drum 6 contains a preloaded mixture that is to be mixed.

Depending on the technological needs (mixture recipe), the number and location of the replaceable blades 5 are set (mixing can also occur without the blades 5 in gravity mode). By changing the position of the movable frame 1, the required tilt angle of the drum 2 is set. The position must be such that the mixture inside the tank covers the blades of the drum, allowing the mixture to rotate with the drum. The blades 8 prevent the mixture from sliding along the inner walls of the drum 2. The mixture moves with the drum 2, while the blades 7 of the traverse 6 remain stationary and begin to forcibly mix the mixture. Simultaneously, in addition to the forced mixing provided by the blades 7 of the traverse 6, the gravity mixing process continues with the help of the blades 8 of the drum 2. This makes it possible to ensure high mixing efficiency in a shorter period.

Conclusion. after considering the advantages of the proposed design for a mobile compact gravity-force concrete mixer, we found that despite its low material consumption, the design is highly reliable. The drum 2 rotates on a rigidly mounted axis 4 and rests on two bearings, which are spaced as far apart as possible. This ensures extremely stable operating conditions for the bevel gear, especially under a full load. Additionally, the design is compact and easy to transport. If needed (for example, when manually moving the mixer from one floor to another), drum 2, along with traverse 6, can be easily detached from movable frame 1, which significantly simplifies transportation, as reinstalling drum 2 is not difficult.

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Мобільний гравітаційний бетонозмішувач примусової дії

У статті розглянуто конструкцію малогабаритного гравітаційний бетонозмішувач примусової дії, який міг би бути ефективним у приготуванні бетонних сумішей за рахунок поєднання принципів роботи бетонозмішувачів гравітаційної і примусової дії. Припускається, що зазначена конструкція малогабаритного гравітаційно-примусового бетонозмішувача виявиться перспективною та інноваційною у сфері приготування будівельних сумішей. Її унікальність полягає в тому, що вона успішно поєднує переваги як гравітаційних, так і примусових бетонозмішувачів, а також ефективно вирішує проблеми, що виникають при їхньому застосуванні на будівельних майданчиках. Також у статті проаналізовано аналоги існуючих бетонозмішувачів гравітаційної дії і примусової дії. Досліджено процеси виникаючі при обох видах змішування сумішей в існуючих аналогах, які виконують дані операції перемішування на будівельних майданчиках. Передбачається, що дана конструкція забезпечує високу ефективність змішування, має покращену енергоефективність серед аналогів, надійність своїм розташуванням вузлів. Один із головних плюсів запропонованої конструкції полягає в малогабаритності конструкції, що сприяє полегшенню транспортування її по будівельному майданчику. Це не тільки збільшує ефективність робіт, але й робить процес будівництва економічно вигіднішим. Розроблена конструкція є достатньо компактною та універсальною. Додатковою перевагою є універсальність конструкції, яка дозволяє розміщувати обладнання в будь-якому місці будівельних робіт. Це робить змішувач гнучким і адаптованим до різних умов та завдань на будівельному майданчику. Вона забезпечує ефективне змішування будівельних розчинів у встановленому об'ємі, забезпечуючи при цьому енергоефективність змішування. Однак вона також має переваги завдяки об'єднанні виникаючих процесах в обох видах змішувачів, а також можливості розміщення обладнання в будь-якому місці будівельних робіт. Загалом, дана конструкція гравітаційно-примусового бетонозмішувача видається перспективною і обіцяючою, вирішуючи численні технічні та економічні аспекти, пов'язані з будівництвом

Ключові слова: змішувач, гравітаційний, примусовий, суміш, малогабаритність, лопатка, вісь , вал, енергоефективність, продуктивність, однорідність суміші.

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