

Y. Kuzub, R. Rudyk

National University «Yuri Kondratyuk Poltava Polytechnic», Ukraine

## INFLUENCE OF SPIRAL TAPE PARAMETERS MIXER FOR MORTAR HOMOGENEITY

*The article investigates the influence of mixer spiral belt design parameters on the mortar mixing uniformity. The features of the spiral working elements were analyzed and the effectiveness of their interaction with the material was assessed. The advantages of using a drive from a walk-behind tractor have been determined, which provides autonomy of operation and increased mixing efficiency. A comparison was made with traditional concrete mixers, and the relationships between the blade inclination angle, solution movement speed, and distribution uniformity were established. Recommendations for optimizing the mixer design to improve the quality of mortar and reduce energy costs are proposed.*

**Keywords:** mixer, mortar, mixing, mortar homogeneity, walk-behind tractor, drive, efficiency, mobility

### Introduction

Mixing mortar is one of the key technological processes in construction, since the performance characteristics of the material, in particular strength, adhesion, plasticity and resistance to external influences, depend on the uniform distribution of its components. Despite the development of modern technologies, ensuring high homogeneity of the solution remains an urgent problem, since the mixing process is complex and depends on many factors. In particular, the mixing efficiency is determined by the mixer type, kinematic parameters of the working elements, mixing chamber geometry, and mechanism actuation method.

Traditionally, gravity and forced concrete mixers are used to prepare mortar, each of which has its own advantages and limitations. Gravity mixers are simple in design but provide a lower level of mixing uniformity. Forced mixers, in which components are mixed due to the rotation of the working blades, are characterized by high mixing quality, but require significant energy costs and are more difficult to manufacture and operate.

One promising approach to improving mortar mixing technology is the use of a spiral ribbon mixer, whose design enables intensive component mixing by combining circular and axial material movement. A distinctive feature of this mixer is its spiral working elements, which provide gradual and uniform distribution of solution components throughout the mixing chamber. Studies of such structures are necessary, since their use can significantly improve the quality of mixing, especially when working with highly viscous and thick mortars.

Most modern concrete mixers use an electric drive, which imposes certain restrictions on their use in

construction sites where there is no possibility of connecting to the mains. The use of an alternative drive source, in particular a drive from a walk-behind tractor, can be an effective solution that will increase the mobility of mixing equipment and reduce dependence on centralized power supply. However, the effect of such a drive on mixing efficiency requires thorough research.

Therefore, it is crucial to study the influence of the spiral ribbon mixer's design parameters on mortar homogeneity, enabling the development of recommendations for optimizing the mixing process. In particular, it is necessary to assess the influence of the shape and arrangement of the working elements and determine the kinematic parameters of material movement.

### Analysis of Recent Research

In the scientific literature, various aspects of mortar mixing are widely studied, since the quality of this process directly affects the physical and mechanical characteristics of the final material. The main attention is paid to the efficiency of different types of concrete mixers, the kinematic characteristics of their working bodies, as well as methods for assessing the homogeneity of the mortar [1]. Since the uniform distribution of components in the mortar determines its durability and strength, improving the mixing process remains one of the priorities in the field of building materials production.

According to research, traditional mixers for mortars are divided into gravitational and forced, among which, in particular, belt mixers are distinguished. Gravity mixers are the most common due to their simplicity of design, however, they have significant limitations in ensuring uniform mixing, especially when working with thick and highly viscous solutions [2]. This

is due to the fact that during the free fall of components, dead zones can form in the drum, where the material does not move intensively enough. Forced mixers, on the other hand, provide significantly more efficient mixing due to the mechanical impact of the blades on the material, but such installations have higher energy costs and a more complex design [3].

A current area of scientific research is also developing new methods to assess the homogeneity of building mortars. Traditional methods include determining homogeneity using visual analysis, calculation of standard deviation, and coefficient of variation. In recent works, it has been proposed to apply mathematical modeling and statistical methods to quantify the mixing process [4-5]. In particular, the use of Markov processes is promising, which allow analyzing the probability of particles moving in the mixer depending on the initial state of the system.

In particular, the influence of the geometric parameters of the spiral belt concrete mixer on mixing uniformity has not been sufficiently studied, and there have not been enough experimental studies on the effectiveness of alternative drives. This determines the need for further research in this direction to improve the quality of mortars and expand the possibilities of using autonomous concrete mixing equipment.

### Research Goal

The purpose of this study is to determine the impact of a spiral belt concrete mixer design parameters on the homogeneous mortar forming process, in particular, an assessment of using drive from a walk-behind tractor efficiency, analysis of working bodies kinematic characteristics and their influence on the component distribution uniformity.

The task of the study is to analyze the operation features of a mixer with an alternative drive, determine its advantages over an electric drive, and identify key indicators that characterize mixing quality for use in the research.

### Methodology and Results

Traditional electric concrete mixers are widely used in the construction industry due to their simple construction, reliability, and relatively low cost. They operate by mechanically mixing mortar components in a drum powered by an electric motor through a gear or belt drive. The main working body of the concrete mixer is a rotating drum, inside which there are blades that contribute to the solution components mixing.

The operation of an electric concrete mixer is based on the drum rotating around its axis, causing the materials to mix as they are lifted and fall under the influence of gravity. In this case, there is a mechanical grinding of cement clumps and a uniform distribution of components throughout the mortar entire volume. This method of

mixing allows to obtain the necessary homogeneity of the solution, although in some cases it leads to an increase in mixing time.

The main characteristics of traditional gravity concrete mixers (Fig. 1) are the power of the electric motor, the speed of the drum, the capacity of the working body and the performance. For most mobile models used on construction sites, drive power typically ranges from 0.55 to 1.5 kW, resulting in optimal drum speed (15 to 30 rpm). The capacity of the drum can vary from 100 to 500 liters, depending on the type and purpose of the equipment. The design of such mixers provides for the presence of a gearbox or V-belt transmission to reduce the load on the electric motor and ensure stability of operation [6].



Fig. 1. Gravity concrete mixer

Despite their popularity, concrete mixers with a traditional electric drive have a number of limitations and disadvantages that can affect the efficiency of work. First, they require a constant connection to the power grid, which significantly limits their mobility and makes it difficult to use in construction site environments where access to electricity may be limited. Secondly, in such mixers, energy losses are observed due to mechanical transmissions, which reduces their overall efficiency. A significant disadvantage is also the wear of the drive mechanism, in particular the gearbox or belt drive, which can lead to unstable drum operation over time.

Another significant disadvantage of traditional concrete mixers is the uneven mixing at large loading volumes. Due to the specifics of the design, there is a risk of mortar sticking to the inner walls of the drum, which can complicate its cleaning and reduce the quality of subsequent batches.

Based on the analysis conducted and the identified influence of the drive and working elements on mixing

quality, an experimental spiral ribbon mixer driven by a walk-behind tractor was developed. To evaluate its effectiveness, appropriate tests were carried out aimed at determining the uniformity of mixing, performance and energy characteristics of the equipment.

The test results showed that the use of a spiral belt mixer allow to achieve a more uniform distribution of components in the solution, which helps to improve its quality. In addition, the use of a drive from a walk-behind tractor ensured the stable operation of the equipment even when working with thick solutions, which was a difficult task for traditional mixers.

The spiral belt mixer used in this study (Fig. 2) is a modern version of mixing equipment that combines the principles of gravitational and forced mixing. Its design includes spiral working elements that provide simultaneous circular and axial movement of the material, which contributes to the uniform distribution of the mortar components. The main feature of this mixer is the use of a drive from a walk-behind tractor, which ensures autonomy of operation and allow to use the equipment in construction sites without access to the mains [7].

The main structural elements of the mixer are the mixing chamber, spiral belt working bodies, support frame, drive mechanism and rotation speed control system. The mixing chamber is made in the form of a cylindrical tank, inside of which there are spiral blades.

The geometry of the spiral blades determines the trajectory of the material and significantly affects the quality of mixing. The blades are mounted on the central shaft, which is driven by a chain drive from the walk-behind tractor.

The mixer drive system is one of the key design elements. The use of a drive from a walk-behind tractor allows to provide sufficient torque necessary for intensive mixing of the solution. Thanks to the walk-behind tractor's gearbox, the operator can adjust the mixing shaft speed, allowing optimization of the operating mode based on the type of solution. In addition, this solution increases the mobility of the mixer, as the equipment can be easily transported and quickly commissioned on the construction site.

One of the advantages of a spiral belt mixer is the ability to work with various types of mortars, in particular with highly viscous and thick compositions. Thanks to the design of the working bodies, an even distribution of components is achieved, which helps to reduce mixing time and improve the homogeneity of the solution, ensuring its high quality. An additional advantage is the reduction of energy costs, since the drive from the walk-behind tractor allow to do without power supply, which is especially important in field construction or the absence of a stationary power supply [8].



Fig. 2. Spiral belt mixer driven by walk-behind tractor

During operation, it is important to take into account the design parameters that affect the quality of mixing. In particular, the inclination angle of the spiral blades, their width, and the shaft's rotation speed determine the mixing intensity and the uniformity of material distribution in the mixing chamber. Optimizing these parameters allow to increase the efficiency of the mixer and ensure the stability of the technological process [9].

To determine the efficiency of a traditional electric mixer and an advanced mixer using a walk-behind tractor as a source of rotation, a comparative analysis of their key characteristics was carried out. The table below provides a comparison of the main characteristics of both types of equipment, which allow to determine their advantages and disadvantages when used on construction sites.

Table 1

Comparative analysis between mixers		
Characteristics	Traditional concrete mixer (electric drive)	Mixer driven by walk-behind tractor
Drive type	Electric motor with reducer	Walk-behind tractor engine through transmission
Drive power, kW	0,5–1,5	4–8 (depending on the walk-behind tractor)
Power Supply	Fixed power grid	Fuel engine (petrol/diesel)
Mixing mechanism	Rotation of the drum through the reducer	Rotation of the drum through the wheel drive shaft
Energy efficiency	Limited, depends on mains voltage	High autonomy, independence from the power grid
Mobility	Low, power binding	High, can work in any conditions
Uniformity of mixing	Depends on the load, solution adhesion is possible	Improved with more drive torque
Wear and tear of parts	High in gearbox and motor due to constant load	Less wear due to a more powerful motor and easier torque transmission
Noise and vibrations	Moderate	Higher due to the operation of internal combustion engines

Comparative analysis shows that a traditional electric concrete mixer has certain limitations related to the need to connect to the mains and lower motor power. At the same time, a mixer driven by a walk-behind tractor has significantly higher mobility, which allows it to be used in the field without the need for power supply. The higher torque of the walk-behind tractor motor provides better mixing quality and reduces the risk of mortar sticking to the inner walls of the drum.

In traditional electric mortar mixers, power is limited by the characteristics of the electric motor, which usually has a range of 0.55–1.5 kW, which makes it impossible to mix thick or highly viscous mortars, especially in conditions of unstable power supply.

The walk-behind tractor-driven mixer uses an internal combustion engine with significantly higher power (from 4 to 8 kW), which provides a greater margin of torque and allow to maintain efficient mixing even at maximum load. This feature makes it possible to be more versatile and suitable for work in conditions where there is no or limited access to the power grid.

The torque on the shaft of the working body is one of the key parameters that determine the efficiency of the concrete mixer. It characterizes the force with which the rotational motion is transmitted to the mixer drum, providing the necessary conditions for mixing the mortar.

High torque is especially important when working with thick and highly viscous mortars that create significant resistance during mixing. Insufficient torque can cause the drum to mix unevenly or even stop under high loads. That is why the analysis of this parameter is important for assessing the efficiency of various concrete mixer drives.

A spiral belt mixer differs from traditional mixing devices by the presence of special spiral blades, which are fixed on the central shaft and act as the main working body. The main feature of this design is the combined mixing of the solution, which occurs simultaneously in two directions: along the axis of the drum and in the radial direction. This ensures high mixing uniformity and reduces the risk of undermixing areas [10-11].

The working elements of the spiral ribbon mixer are designed as spiral blades (Fig. 3), ensuring the translational transportation of material along the drum axis. The geometry of these blades dictates the solution's speed, turbulence, and homogeneity level. The key parameters influencing mixing efficiency include the spiral's diameter and pitch, the blade inclination angle relative to the rotation axis, and the spacing between adjacent spiral turns.

One of the main advantages of spiral blades is the ability to create a uniform circulating flow of material, ensuring simultaneous mixing in all directions. Thanks to

this, the mortar passes through the entire working space of the mixing chamber, avoiding the formation of stagnant zones. Additionally, the spiral shape helps to reduce the mechanical resistance to particle movement, which reduces energy costs for the mixing process [12].



Fig. 3. Working body of spiral ribbon mixer

The evaluation of mixing efficiency in a spiral ribbon mixer relies on analyzing the kinematic characteristics of mortar particle movement influenced by the geometric parameters of the working elements. The main factors affecting the mixing process are the diameter of the mixing drum, the spiral pitch, the angle of inclination of the blades, the radial velocity of the particles and the overall flow rate of the material.

One of key parameters affecting mortar mixing quality is the material's movement speed in the mixer. It determines the uniformity of component distribution and the intensity of the mixing process. In particular, assessing the material's translational speed along the mixing drum axis is crucial, as this movement ensures component transport and uniform particle distribution throughout the mixer. This rate is calculated using the formula:

$$V_{\alpha} = \omega R \tan \theta, \quad (1)$$

where  $\omega$  – angular speed of shaft rotation, *rad/s*;  
 $R$  – drum radius, *m*;  
 $\theta$  – spiral blade angle, *deg*.

This equation shows that increasing the helix angle accelerates the axial motion of the particles, while decreasing this angle makes mixing slower, which can affect the uniformity of component distribution [13].

In addition to translational motion along the axis, the material in the mixer also moves in a radial direction. This parameter is crucial for solution homogeneity, as it determines the extent of particle mixing across the drum's entire cross-section. Taking into account the radial velocity allows to assess how effectively the spiral blades

contribute to mixing the components and prevent the formation of zones with insufficient circulation. The radial velocity of material movement is determined by the equation:

$$V_r = \frac{\omega R}{n} \sin(\theta), \quad (2)$$

where  $V_r$  – radial velocity of material movement, *m/s*;

$n$  – amount of spiral turns per unit drum length.

Also, the mixing efficiency is characterized by the coefficient of particle distribution uniformity in the solution, which can be estimated through the coefficient of variation  $K_{\text{var}}$ , which is defined as the ratio of the standard deviation of components concentration to their average value [14]:

$$K_{\text{var}} = \frac{\sigma}{C_{\text{серед}}}, \quad (3)$$

where  $\sigma$  – root mean square deviation of particle concentration, %;

$C_{\text{серед}}$  – average particle concentration, %.

To assess turbulence and uniformity of mixing, the Pecle  $Pe$  number is also used, which determines the ratio of the convective transfer of the material to the diffusion transfer:

$$Pe = \frac{V_{\alpha} L}{D}, \quad (4)$$

where  $L$  – mixer length, *m*;

$D$  – diffusion coefficient of particles in the mixing medium, *m<sup>2</sup>/s*.

If  $Pe \geq 1$ , convective transfer dominates, and if  $Pe \leq 1$ , then mixing process is predominantly diffusion. In the practice of mixing mortar, it is important to strike a balance between these two processes.

The ratio of the drum diameter to the spiral pitch also affects the mixing quality. Its optimal value is determined empirically and can be expressed as a ratio:

$$\lambda = \frac{D}{S}, \quad (5)$$

where  $\lambda$  – relative helix pitch;

$D$  – mixer diameter, *m*;

$S$  – step of the spiral, *m*.

Too large step can reduce the mixing intensity because the mortar will move too quickly without sufficient distribution of the components [15]. On the contrary, a step that is too small can increase the resistance to the movement of the mortar and energy expenditure.

Another important indicator of the efficiency of the mixer is the torque on the shaft, which determines the

load on the drive mechanism and the required power to ensure high-quality mixing. The assessment of this parameter is especially relevant in the case of using a drive from a walk-behind tractor, since it has different kinematic characteristics compared to electric drives. Torque determination allows you to optimize energy consumption and avoid excessive loads on the mixer structure. The torque on the shaft is calculated using the formula:

$$M = \frac{P}{\omega}, \quad (6)$$

where  $M$  – torque on the shaft,  $N\cdot m$ ;  
 $P$  – drive power,  $W$ .

Due to the higher power of the walk-behind tractor engine compared to a traditional electric drive, the torque of the mixing drum can be adjusted, which is especially important when working with stiff and highly viscous mixtures. The increased torque allows to maintain an optimal mixing mode even at maximum mixer load, which reduces the adhesion risk and contributes to an even component's distribution.

The spiral belt working body creates an efficient internal flow of the solution, ensuring simultaneous radial and axial movement of the solution particles. This significantly improves the homogenization of the material, since the mortar passes through all working areas of the mixer without the formation of cement or aggregate local accumulations. In traditional concrete mixers, insufficient mixing often occurs in the central part of the drum. In contrast, a spiral mixer minimizes this effect through the directed movement of particles along the mixer's axis.

The increased mobility of equipment driven by a walk-behind tractor allows for adjusting the speed of the central shaft's rotation with spiral blades, enabling adaptation of the mixing mode to specific conditions. For example, for liquid mortars, it is advisable to use lower speeds, while for thick and highly viscous formulations, the optimal solution is to increase the mixing speed to achieve uniformity. An additional advantage is independence from a stable power supply, which is especially important for working in the field or on construction sites without access to a three-phase power grid.

The use of a drive from a walk-behind tractor in combination with a spiral belt working body ensures the uniformity of the mortar, increases mixing efficiency and reduces energy costs, which gives a high potential for use in various construction conditions.

## Conclusions

The analysis of spiral ribbon mixer design parameters demonstrated that using this type of working

element enhances mortar mixing by combining axial and radial particle movement. Due to this, an even distribution of components is achieved, which has a positive effect on the homogeneity of the final product. In addition, optimizing the blade geometry allows for reduced energy costs, allowing for efficient mixing without the need for a significant increase in drive power.

The use of a walk-behind tractor drive is a promising alternative to traditional mains faucets. This solution increases the mobility of the equipment and allows it to be used in conditions where there is no access to power supply. The analysis of the mixer's kinematic characteristics revealed that using a more powerful drive ensures stable mixing and enhances efficiency, particularly when working with thick and highly viscous mortars.

The results obtained can be used to further optimize the design of mixers and develop methodological recommendations for their use. The defined dependencies between design parameters, drive torque and mixing quality make it possible to improve the process of preparing concrete mixtures and increase the efficiency of construction equipment.

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**Author:** Yuriy KUZUB,

Postgraduate student,

Department of Industrial Engineering and Mechatronics National University «Yuri Kondratyuk Poltava Polytechnic»

КУЗУБ Юрій Олегович,

Здобувач вищої освіти третього рівня, кафедри галузевого машинобудування та мехатроніки, Національний університет «Полтавська політехніка імені Юрія Кондратюка»

E-mail – [kuzub\\_yuriy@ukr.net](mailto:kuzub_yuriy@ukr.net)

ID ORCID: <https://orcid.org/0009-0006-8463-3914>

**Author:** Rostyslav RUDYK,

Postgraduate student,

Department of Industrial Engineering and Mechatronics National University «Yuri Kondratyuk Poltava Polytechnic»

РУДИК Ростислав Юрійович,

Здобувач вищої освіти третього рівня, кафедри галузевого машинобудування та мехатроніки, Національний університет «Полтавська політехніка імені Юрія Кондратюка»

E-mail: [rostyslavrudyk@nupp.edu.ua](mailto:rostyslavrudyk@nupp.edu.ua)

ID ORCID: <https://orcid.org/0000-0001-8386-977X>

## ВПЛИВ ПАРАМЕТРІВ СПІРАЛЬНОГО СТРИЧКОВОГО ЗМІШУВАЧА НА ОДНОРІДНІСТЬ БУДІВЕЛЬНОГО РОЗЧИНУ

Ю.О. Кузуб, Р.Ю. Рудик

Національний університет «Полтавська політехніка імені Юрія Кондратюка», Україна

У статті проведено аналіз конструктивних параметрів спірального стрічкового змішувача та їхнього впливу на якість перемішування будівельного розчину. Розглянуто основні геометричні характеристики робочих органів, зокрема діаметр і крок спіралі, кут нахилу лопатей та швидкість обертання барабана. Встановлено, що оптимізація цих параметрів сприяє рівномірному розподілу компонентів, зменшенню налипання розчину на стінках барабана та зниженню енергетичних витрат. Окрему увагу приділено аналізу ефективності використання приводу від мотоблока як альтернативи бетонозмішувачам, що працюють від електромережі. Визначено, що застосування двигуна внутрішнього згоряння підвищує автономність роботи змішувача, забезпечує стабільний крутний момент та покращує продуктивність обладнання. Проведено порівняльний аналіз характеристик двох типів приводів, який підтвердив переваги приводу від мотоблока у контексті мобільності, енергонезалежності та можливості роботи в умовах будівельних майданчиків без доступу до електромережі. Запропоновано методи оцінки однорідності будівельного розчину, що базуються на коефіцієнті варіації концентрації компонентів. Наведено математичні моделі, які описують вплив конструктивних параметрів змішувача на рівномірність розподілу частинок у розчині. Проаналізовано залежність швидкості переміщення матеріалу вздовж осі барабана від кутової швидкості обертання, радіуса барабана та кута нахилу лопатей. Результати дослідження підтверджують, що поєднання спірального стрічкового робочого органу з приводом від мотоблока дозволяє підвищити ефективність процесу змішування, знизити енергетичні витрати та покращити якість кінцевого продукту. Запропоновані підходи можуть бути використані для подальшої оптимізації конструкції змішувального обладнання та розробки рекомендацій щодо його практичного застосування.

**Ключові слова:** змішувач, будівельний розчин, змішування, однорідність розчину, мотоблок, привід, ефективність, мобільність