Comprehensive Evaluation of Drum Dryer Flight Designs in The Matlab Environment

Adil Akhunbayev
Candidate of Technical Sciences, Associate Professor, Fergana State Technical University, Fergana, Republic of Uzbekistan

Aziz Isomidinov
PhD in Technical Sciences, Associate Professor, Fergana State Technical University, Fergana, Republic of Uzbekistan

Received: 28 Feb 2026 | Received Revised Version: 24 Mar 2026 | Accepted: 20 Apr 2026 | Published: 08 May 2026

Volume 08 Issue 05 2026 | Crossref DOI: 10.37547/tajet/Volume08Issue05-04

Abstract

This article considers the comprehensive evaluation of flight designs used in drum dryers and the justification of a new three-section flight design. For the analysis, straight radial, inclined, 90° right-angled, 120° angled, hook-shaped, two-segment, optimized two-segment, three-segment, inclined-flight, notched/opening and curved/notched flight designs were selected. These designs were chosen on the basis of real technical solutions reported in literature and patent sources and were evaluated according to their ability to lift the material, redistribute it, disperse it into the gas stream, direct it along the drum, intensify heat and mass transfer, and limit aerodynamic resistance. The comprehensive analysis was performed using a heatmap, radar diagram, 3D surface plot and moisture-profile graphs. The results show that simple straight radial and inclined flights can effectively perform some individual functions, but their ability to simultaneously lift, redistribute and disperse the material into the gas flow is limited. The three-segment design and the proposed three-section flight have high compatibility coefficients in zones 2–4 of the drum and are therefore evaluated as the most suitable structural solutions for intensifying the drying process.

Keywords: Drum dryer, flight, lifter, three-section flight, heatmap, radar diagram, moisture profile, aerodynamic resistance, drying efficiency.

Cite This Article: Adil Akhunbayev, & Aziz Isomidinov. (2026). Comprehensive Evaluation of Drum Dryer Flight Designs in The Matlab Environment. The American Journal of Engineering and Technology, 8(05), 41–46. https://doi.org/10.37547/tajet/Volume08Issue05-04

1. Introduction

Drum dryers are among the most widely used units for drying granular, fibrous, mineral and dispersed materials. In such equipment, the degree of contact between the hot gas stream and the material determines the drying efficiency. Although drum rotation alone provides a certain level of mixing, special lifting and distributing flights are installed on the inner wall of the drum to intensify heat and mass transfer.

The main function of flights is to lift the material from the lower bed of the drum, drop it from a higher position into the gas stream, form a material curtain and increase the contact surface between the material and the gas. However, if the flight shape is selected incorrectly, the material may fall as a dense layer, be distributed unevenly over the drum cross-section, increase the resistance to the gas flow, or accumulate on the flight surface when the material is wet. Therefore, the selection of a flight design should consider not only lifting capacity but also redistribution, dispersion, aerodynamic resistance and the ability to transport material along the drum.

In this study, flight designs described in real scientific and patent sources for drum dryers were analyzed. The considered designs include straight radial flight, inclined flight, 90° right-angled flight, 120° angled flight, hook-shaped flight, two-segment flight, optimized two-segment flight, three-segment flight, inclined-flight horizontal drum, notched/opening flight and curved/notched flight. These designs were selected for dissertation-oriented analysis according to their material lifting, redirection, retention, dispersion and axial transport capabilities.

2. Methodology

A comprehensive graphical analysis method was used to evaluate the flight designs. Each flight type was assessed according to selected functional criteria using normalized coefficients ranging from 0 to 1. Values close to 0 indicate lower performance for the corresponding criterion, while values close to 1 indicate a higher level of effectiveness.

The analysis was organized into four graphical blocks. The visual comprehensive analysis performed in the MATLAB environment made it possible to evaluate the flight designs simultaneously according to several criteria. This approach supports conclusions not on the basis of a single indicator but according to the overall technological, aerodynamic and structural efficiency of the designs.

Results

In the first block, a heatmap was used to evaluate the compatibility coefficient of different flight designs over zones 1–5 of the drum (Figure 1).

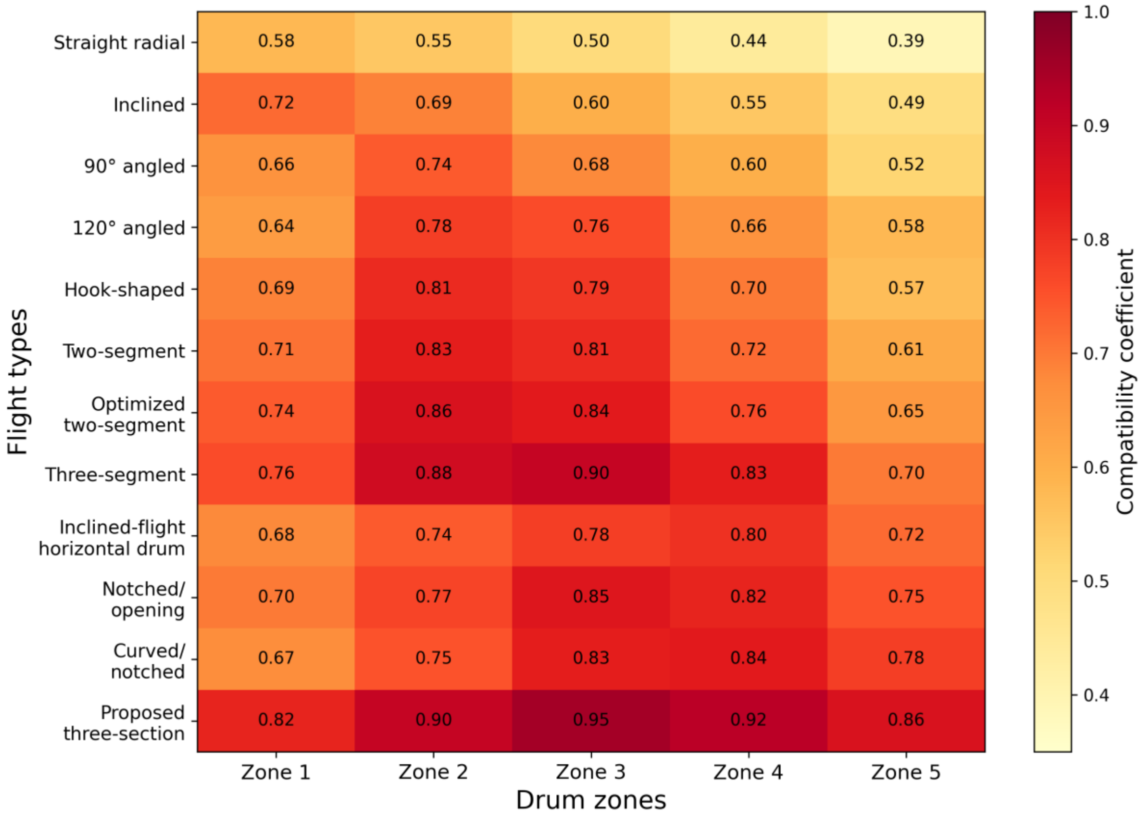

Figure 1. Compatibility coefficient of flight designs by drum zones.

The heatmap results show that the compatibility level of each flight type is not the same in different zones of the drum. For the straight radial flight, the compatibility coefficient is 0.58 in zone 1 and decreases to 0.39 by zone 5. This indicates that a straight radial plate is relatively reliable for initial lifting, but its ability to redistribute and disperse the material in the subsequent zones is low.

For the inclined flight, the compatibility coefficient is 0.72 in zone 1, 0.69 in zone 2, 0.60 in zone 3, 0.55 in zone 4 and 0.49 in zone 5. Thus, an inclined surface not only lifts the material but also redirects it laterally to a certain extent. For this reason, the inclined flight has higher effectiveness than the straight radial flight.

For the 90° right-angled and 120° angled flights, higher compatibility values are observed in zones 2–3. For example, the coefficient for the 90° right-angled flight is 0.74 in zone 2 and 0.68 in zone 3, while for the 120° angled flight it is 0.78 in zone 2 and 0.76 in zone 3. These designs extend the movement of material within the drum cross-section by holding it for a certain time and then discharging it.

The hook-shaped flight gives even higher results in zones 2–3: 0.81 in zone 2 and 0.79 in zone 3. This is associated with its ability to hold material up to a higher position. However, this type of design can also increase the probability of excessive material accumulation and aerodynamic resistance.

Two-segment, optimized two-segment and three-segment flights show a significant increase in efficiency in zones 2–4. In particular, the three-segment flight has a compatibility coefficient of 0.90 in zone 3 and 0.83 in zone 4. This indicates that such a design can organize material motion in several stages.

The proposed three-section flight has high coefficients in all zones. Its values are 0.82 in zone 1, 0.90 in zone 2, 0.95 in zone 3, 0.92 in zone 4 and 0.86 in zone 5. The highest result in zone 3 shows that this design redistributes the material most effectively in the middle part of the drum and brings it into active contact with the gas stream.

In the second block, a radar diagram was used to compare the main flight types according to lifting, dispersion, material curtain formation, axial direction, quality preservation, heat and mass transfer, and low-resistance criteria (Figure 2).

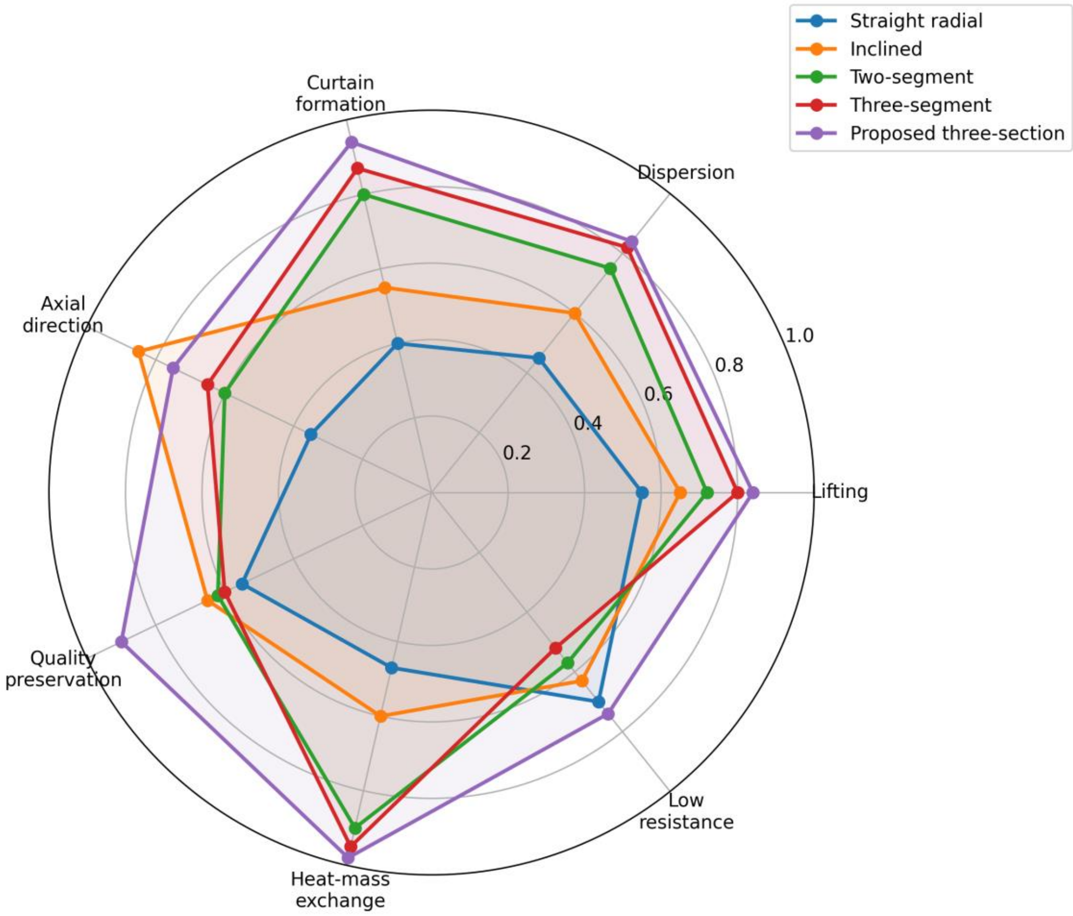

Figure 2. Radar diagram of flight designs according to functional criteria.

The radar diagram provides a clearer representation of the functional advantages of the flights. The straight radial flight is effective to a certain extent in lifting the material, but it shows lower results in dispersion, curtain formation and axial direction. This confirms that it is mainly a single-function design.

The inclined flight has an advantage in axial direction and material redistribution. Its geometric shape allows the material not only to be lifted upward but also to be shifted across the drum cross-section. However, the ability of the inclined flight to break the material into finer streams and disperse it is limited.

The two-segment and three-segment designs show good results for lifting, redirection and curtain formation. The three-segment flight is highly rated in terms of heat and mass transfer because the material passes over several working surfaces and becomes more open to the gas stream.

The proposed three-section flight forms the widest overall contour on the radar diagram. It has high values for lifting, dispersion, curtain formation, quality preservation and heat and mass transfer. At the same time, it also provides a relatively acceptable result for the low-resistance criterion. This indicates that the design can not only intensify drying but also keep aerodynamic losses within reasonable limits.

In the third block, the integral efficiency of the proposed three-section flight was evaluated as a function of the number of flights and drum rotation speed using a 3D surface plot (Figure 3).

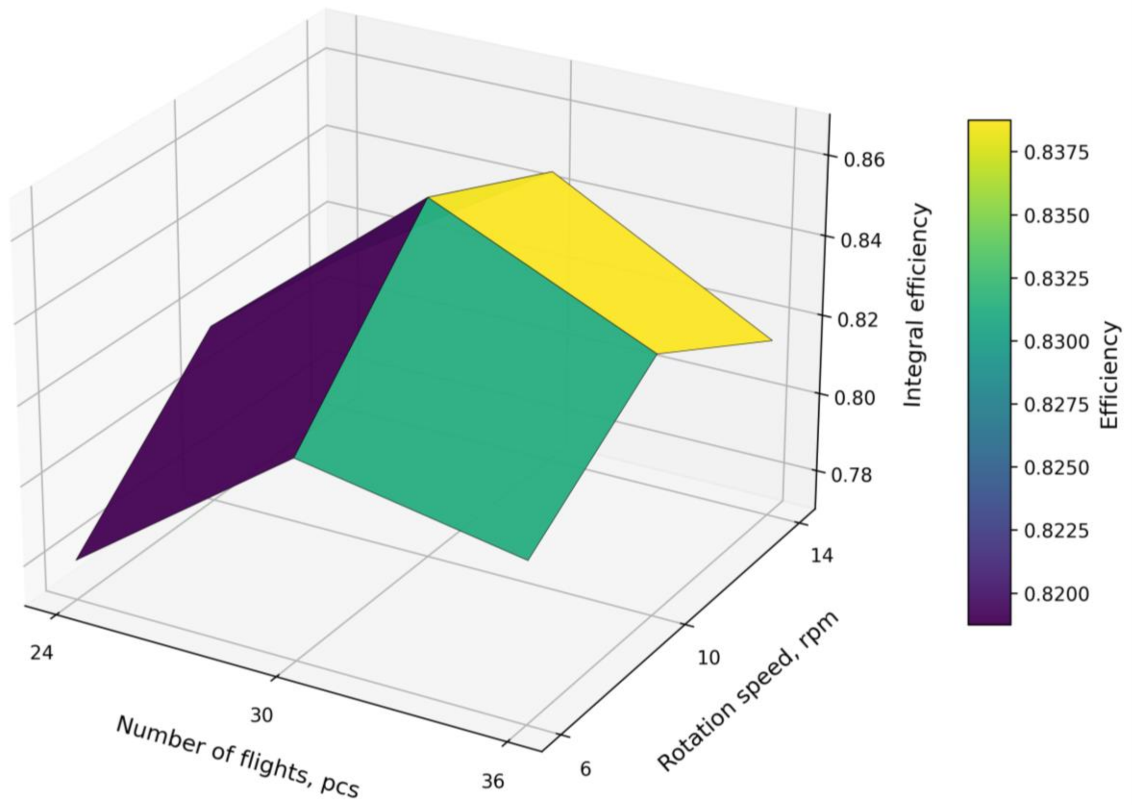

Figure 3. Dependence of integral efficiency on the number of flights and rotation speed for the proposed three-section flight.

The 3D surface graph illustrates the effect of the number of flights and the drum rotation speed on the integral efficiency of the proposed three-section flight. The graph shows that efficiency increases with the number of flights up to a certain limit. The rotation speed has a similar effect: at a low rotation speed the material is not lifted sufficiently, whereas at an excessively high speed the material may be transported along the drum wall without remaining in active contact with the gas flow for a sufficient time.

The most suitable zone in the graph is formed approximately around 30 flights and a rotation speed of about 10 rpm. At this point, the integral efficiency approaches 0.86. When the number of flights reaches 36, efficiency may remain relatively high in some regimes, but aerodynamic resistance and structural load may increase. Therefore, the range of 30–36 flights can be considered practically suitable.

In the fourth block, the moisture profile along the drum was analyzed and the ability of different flight designs to reduce material moisture by zones was compared (Figure 4).

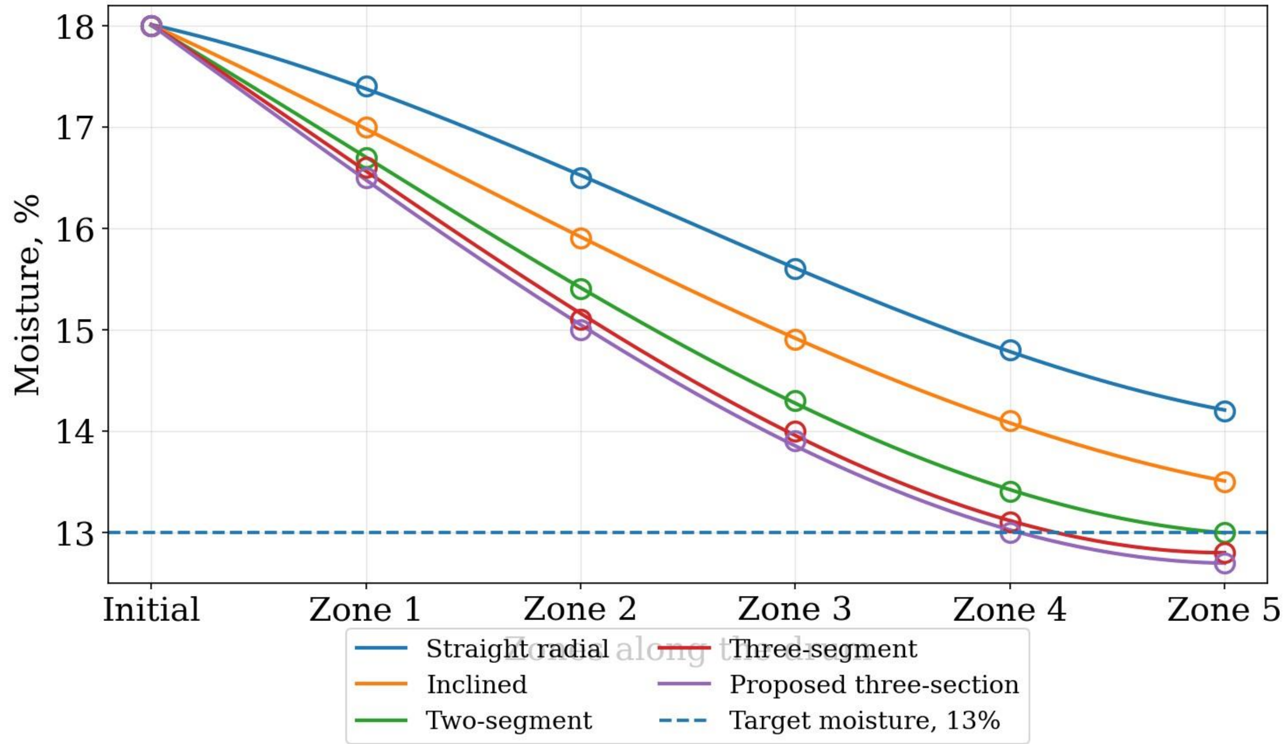

Figure 4. Moisture variation profile of the material along the drum for different flight designs.

The moisture-profile graph shows the decrease in material moisture along the drum by zones. The initial moisture was assumed to be 18% for all flight designs. With the straight radial flight, the moisture at the end of zone 5 remains at approximately 14.2%. This indicates that the design mainly lifts the material but does not disperse it sufficiently into the gas stream.

For the inclined flight, the final moisture is approximately 13.5%, which is better than the straight radial flight. For the two-segment flight, the moisture decreases to 13.0% by the end of zone 5. For the three-segment flight, this value is 12.8%. In the proposed three-section flight, the moisture decreases to 12.7% at the end of zone 5. This graph confirms that the proposed design intensifies drying by lifting, redistributing and dispersing the material in stages.

3. Discussion

The obtained results show that a one-sided approach is not sufficient when selecting a flight design. If only the material lifting capacity is considered, straight radial or 90° right-angled flights may appear suitable. However, the main objective in the drying process is not only to lift the material but also to present it to the hot gas stream with the maximum possible contact surface. For this reason, material redistribution and dispersion are of particular importance.

Inclined flights are effective in directing the material laterally and provide the idea of an inclined working surface for the new design. Two-segment flights are important because they combine lifting and redirection. Three-segment flights demonstrate the possibility of organizing material movement in a more stepwise manner. Notched/opening and curved/notched designs are also important from the viewpoint of earlier material dispersion and improved contact with the gas flow.

On this basis, the proposed three-section flight is considered as a solution that combines the most effective working features of existing designs. Its first section serves as a high lifting plate. This section is based on the lifting principle of straight radial and 90° right-angled flights. The second section is an inclined redistribution plate, incorporating the redirection concept of inclined and two-segment flights. The third section is an outer short plate that disperses the material into the gas flow in the form of smaller streams.

The comprehensive graphs show that the proposed three-section flight has the highest compatibility coefficient in zone 3. This means that the most active contact between the material and gas stream is formed in the middle part of the drum. At the same time, the high values retained in zones 4 and 5 indicate uniform material movement along the drum and the continuous development of the drying process.

From a practical point of view, a flight number of around 30 and a medium rotation speed can be considered suitable when selecting the three-section flight. Under these conditions, the material is sufficiently lifted, redistributed over the drum cross-section and dispersed into the gas flow. Excessively increasing the number of flights may increase aerodynamic resistance, reduce the useful internal volume of the drum and raise energy consumption.

4. Conclusion

As a result of the comprehensive evaluation of drum dryer flight designs, the following conclusions were obtained.

First, the straight radial flight design is simple and reliable for lifting the material, but its ability to redistribute and disperse the material is low. Therefore, it is not sufficient for deep intensification of the drying process.

Second, inclined, 90° right-angled, 120° angled and hook-shaped flights are effective in extending material movement and dropping it from a certain height. However, the hook-shaped design may increase the probability of material accumulation and aerodynamic resistance.

Third, two-segment and three-segment flights are among the most promising designs from the viewpoint of organizing stepwise material motion. Their lifting and redistribution concepts can be used in the development of a new flight design.

Fourth, notched/opening and curved/notched flight types justify the idea of dispersing the material into the gas flow earlier and in the form of smaller streams. This is important for the structural justification of the outer short plate of the new design.

Fifth, the heatmap, radar diagram, 3D surface and moisture-profile analyses demonstrated the comprehensive superiority of the proposed three-section flight over the other designs. It has compatibility coefficients of 0.95 in zone 3, 0.92 in zone 4 and 0.86 in zone 5, and it performs lifting, redistribution and dispersion functions simultaneously.

On this basis, the three-section flight design consisting of a high lifting plate, a middle inclined plate and an outer short plate is recommended as a suitable structural solution for increasing the technological efficiency of drying wet granular materials in drum dryers.

References

1. Mirsharipov R.H., Akhunbaev A.A. Research of Hydrodynamic Parameters of Drum Dryer // International Journal of Advanced Research in Science, Engineering and Technology. – 2020. – Vol.7, № 11. – P.15683-15689.
2. Tojiev R.J., Mirsharipov R.H., Axunbaev A.A., Abdusalomova N.A. Optimized dryer design based on system process analysis // Universum: technical sciences. – Moscow. 2020. – № 11(80). – P.59-65.
3. Tojiev R.J., Axunbaev A.A., Mirsharipov R.X., Mullajonova M.M., Yigitaliev M.M. Analiz protsessa sushki mineralnых udobreniy v barabannom apparate // Universum: texnicheskie nauki. – Moskva. 2021. – № 8(89). – S.31-36.
4. Axunbaev A.A., Xusanboev M.A. Vliyanie vraщeniya sushilnogo barabana na raspredelenie materiala // Universum: texnicheskie nauki. – Moskva. 2022. – № 4(97). DOI: 10.32743/UniTech.2022.97.4.13333.
5. Axunbaev A.A. Optimizatsiya formы nasadki barabannых sushilok // Universum: texnicheskie nauki. – Moskva. 2023. – № 6(111). DOI: 10.32743/UniTech.2023.111.6.15705.
6. Axunbaev A. Industrial Tests of Drying of Mineral Fertilizers in a Rotary Drum Dryer // International Journal of Materials and Chemistry. – 2023. – Vol.13, № 2. – P.28-33. DOI: 10.5923/j.ijmc.20231302.03.
7. Axunbaev A.A., Xusanboev M.A. Baraban nasadkasining optimal shaklini tajribaviy aniqlash // Nauchno-texnicheskiy jurnal FerPI. – Fergana. 2023. – Spes. vыр. № 3. – S.23-27.
8. Axunbaev A., Rajabova N., Siddikov M. Matematicheskaya model sushki dispersnых materialov s uchyotom temperaturы materiala // Zbirnik naukovix pras SCIENTIA. – 2021.
9. Akhunbaev A.A., Rajabova N.R., Madaminova G.I. Drying of sprayed dispersed materials // International Conference Dedicated to the Role and Importance of Innovative Education in the 21st Century. – 2022. – Vol.1, № 7. – P.184-191.

.