# ТЕХНИКА И ТЕХНОЛОГИИ АПК

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## ОПРЕДЕЛЕНИЕ ОПТИМАЛЬНЫХ КИНЕМАТИЧЕСКИХ ПАРАМЕТРОВ РЕШЕТНОГО СТАНА ПРИ СЕПАРАЦИИ ОБРАЗЦОВ СЕЛЕКЦИОННЫХ СЕМЯН

***ДОРОХОВ АЛЕКСЕЙ СЕМЕНОВИЧ,*** *докт. техн. наук, профессор РАН, член-корреспондент РАН*
E-mail: dorokhov@rgau-msha.ru

***МОСКОВСКИЙ МАКСИМ НИКОЛАЕВИЧ,*** *докт. техн. наук, профессор РАН*
E-mail: maxmoskovsky74@yandex.ru

***ХАМУЕВ ВИКТОР ГЕННАДЬЕВИЧ,*** *канд. техн. наук*
E-mail: victor250476@yandex.ru

***ГЕРАСИМЕНКО СТАНИСЛАВ АЛЕКСАНДРОВИЧ,*** *аспирант*
E-mail: stanislav.mkm@gmail.com

Федеральный научный агроинженерный центр ВИМ (ФГБНУ ФНАЦ ВИМ); 109428, 1-й Институтский проезд, 5, Москва, Российская Федерация

В послеуборочной обработке селекционного материала на сегодняшний день актуальным является отсутствие решетной машины соответствующей производительности, удовлетворяющей всем требованиям, предъявляемым к селекционным машинам. Для исследований использовался макетный стенд решетной машины, на котором определяли кинематические параметры решетного стана и углы наклона решет. Опыты проводились на пяти значениях амплитуды колебаний решетного стана (7, 10, 14, 18 и 22 мм) при изменении частоты его колебаний от 169 до 470 мин$^{-1}$. Кинематический показатель решета при этом изменялся в пределах 6,9…19,3 м/с$^2$. Также опыты проводились при двух углах наклона решетного стана 6 и 9 градусов. Определено, что с повышением кинематического показателя решет уменьшается забиваемость их отверстий. Оптимальные значения кинематического показателя решет с продолговатыми отверстиями в зависимости от амплитуды колебаний находятся в пределах 11,0…15,0 м/с$^2$. Коэффициент извлечения мелких примесей при этом составляет 84,6…89,6%. При большом угле наклона решет (9 градусов) забиваемость верхнего решета (с круглыми отверстиями) в 3…10 раз больше, а нижнего решета (с прямоугольными отверстиями) примерно в 2 раза больше забиваемости решет при их угле наклона, равном 6 градусов. Установлено, что оптимальным режимом работы решетной машины, как при обработке мелкосеменных, так и зерновых культур, являются амплитуда колебаний решетного стана 9 мм, частота его колебаний 350…450 мин$^{-1}$, угол наклона решет 7 градусов.

**Ключевые слова:** селекция, семена, очистка, сортировка, решетная машина.

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## DETERMINING OPTIMAL KINEMATIC PARAMETERS OF A SCREEN SHOE USED FOR SEPARATING BREEDING SEED SAMPLES

***ALEKSEI S. DOROKHOV,*** *DSc (Eng), Professor and Corresponding Member of the Russian Academy of Sciences*
E-mail: dorokhov@rgau-msha.ru

***MAKSIM N. MOSKOVSKIY,** DSc (Eng), Professor of the Russian Academy of Sciences*
E-mail: maxmoskovsky74@yandex.ru

***VIKTOR G. KHAMUYEV,** PhD (Eng)*
E-mail: victor250476@yandex.ru

***STANISLAV A. GERASIMENKO,** postgraduate student*
E-mail: stanislav.mkm@gmail.com

Federal Scientific Agroengineering Center VIM; 109428, 1st Institutskiy Proyezd, 5, Moscow, Russian Federation

Today, post-harvest processing of breeding material requires using a screen seed cleaner that should be adequate in performance and comply with all the requirements for plant-breeding machines. For the research, use was made of a model bench of a screen seed cleaner with pre-determined kinematic parameters of the scree shoe and the inclination angles of screens. The experiments were conducted for five variants of the vibration amplitude of a screen shoe (7, 10, 14, 18 and 22 mm), with a change in the frequency of its vibration frequency from 169 to 470 min$^{-1}$. At the same time, the kinematic screen index varied within 6.9…19.3 m/sec$^2$. The same experiments were carried out at two inclination angles of the screen shoe – 6 and 9°. It has been shown that an increase in the kinematic indicator of screens leads to decreased clogging of screen holes. The optimal values of the kinematic indicator of screens with oblong holes, depending on the vibration amplitude, are within 11.0…15.0 m/sec$^2$. The extraction coefficient of minor impurities in this case varies within 84.6…89.6%. With a large inclination angle of the screens (9°), the penetration rate of the upper screen (with round holes) is 3…10 times higher, and the lower screen (with rectangular holes) is clogged approximately 2 times more intensively than at an inclination angle of 6°. The authors have determined that for a screen seed cleaner to operate at the modes ensuring optimal processing of both small seeds and grain crops, the vibration amplitude of a screen shoe should equal 9 mm, and its vibration frequency should range between 350 and 450 min$^{-1}$ at an inclination angle of screens amounting to 7°.

**Key words:** plant breeding, seeds, cleaning, sorting, seed cleaner.

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**Introduction.** To perform cleaning and sorting of seed samples grown on breeding plots, usy is made of complex machines from domestic and foreign producers [1-3]. Domestic machines feature the performance rate less than 150…200 kg/h. Processing lots of seeds weighing more than 15 kg with these machines is economically unfeasible. In this respect, there is a need to have a set of simple machines: an aspiration column, a screen cleaner and a grain sifter, which could be used depending on the content of impurities in the source material, either independently or as a production line. The most vivid drawback in post-harvest processing of breeding material today is the lack of a screen cleaner of an appropriate performance that could meet all the requirements for breeding machines [4-7].

**The research purpose** – to develop a screen cleaner for breeding enterprises and determine the kinematic parameters of its screen shoe, to study the influence of the inclination angle of the screen shoe on the performance.

**Material and methods.** The authors considered materials of theoretical and experimental studies on the cleaning of breeding seeds. For the experiments, use was made of a model bench of a screen cleaner shown in Fig. 1.

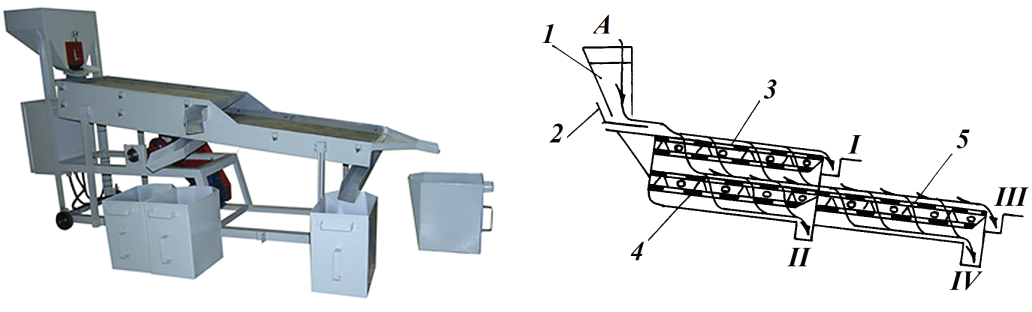


**Fig. 1. Model bench of a seed cleaner:**
1 – loading hopper; 2 – vibratory feeder; 3 – primary screen; 4 – cleaning screen; 5 – separating screen;
I – large impurities; II – fine impurities (dunst); III – cleaned material; IV – second grade

**Рис. 1. Макетный стенд решетной машины:**
1 – загрузочный бункер; 2 – вибропитатель; 3 – колосовое решето; 4 – подсевное решето; 5 – сортировальное решето;
I – крупные примеси; II – мелкие примеси (подсев); III – очищенный материал; IV – второй сорт

*Kinematic parameters of the screen shoe.* As the source material for the experiments, use was made of wheat with a seed variety purity of 97.9%, pretreated in a vertical air flow, after which all the light impurities were removed. The grain material contained 1.76% of fine and 0.34% of large impurities.

The screen cleaner bench included: an upper screen with round holes of Ø4.5 mm in diameter and a lower screen with oblong holes of Ø2.0 mm. The screens were of the same size – 790×400 mm. The upper screen featured a slightly smaller size of the holes for the purpose of a more visual and a precise study of the effect of loading and kinematic parameters of the screen shoe on the quality of grain material separation.

The material was divided into three fractions at a capacity of 500 ± 5 kg/h: the siftings from the upper screen, the siftings from the lower screen and the pass through the lower screen. All fractions were weighed on AND GF600 scales and analyzed. Upon the analysis results, the authors determined the extraction coefficient for small impurities using a formula

$$K = \frac{Q_{из}}{Q_{о}} \cdot 100\%,$$

where $Q_{из}$ is the amount of impurities passing from the lower screen, %; $Q_{о}$ – the amount of fine impurities in the initial material, %.

The authors determined the losses of seeds in the total amount of material siftings from the upper screen, and the weight of 1000 seeds in the outcomes of the upper and lower screens.

The clogging of screens was determined after passing through them an amount of seeds weighing 10 kg. After the processed material passed through the machine, the latter continued to work idle for another minute. Then the screens were removed, turned over 180° upside down, to let off all the unseized grain seeds. Further on, the seized grains were separately removed from the holes of the upper and lower screens, collected, and weighed with scales.

The clogging of screens was determined with a formula:

$$K_{з} = \frac{m_1}{m} \cdot 100\%,$$

where $m_1$ is the mass of seeds seized in the holes, g; $m$ – the mass of seeds passing onto the screen, g.

One of the main parameters of grain separation mode are the number of vibrations per minute $n$ and the amplitude $A$, which are called kinematic parameters. The acceleration of the screen determined with the expression $\omega^2 A$ (ω is the angular velocity of the eccentric, rad/s) is referred to as a kinematic indicator of the screen. The experiments were carried out at five vibration amplitude variants of the screen shoe (7, 10, 14, 18 and 22 mm) when the vibration frequency changed from 169 min$^{-1}$ at $A$ = 22 mm to 470 min$^{-1}$ at $A$ = 7 mm. The kinematic indicator of the screen ranged between 6.9 and 19.3 m/s$^2$.

*The inclination angle of the screen shoe.* The experiments were carried out on the same initial material at two inclination angles of the screen shoe of 6 and 9$^0$. The influence of the screen shoe angle inclination on the machine performance and cleaning quality of wheat seeds was determined at a constant value of the kinematic indicator of the screen $\omega^2 A$ = 12.9 m/s$^2$. Only the area of the hopper's exhaust window changed in the range of 26.4…39.6 cm².

**Results and discussion.** The experimental results on the determination of the kinematic parameters of a screen shoe are presented in Tab. 1 and Fig. 2.

An increase in the kinematic indicator of the screens is accompanied by more intensive clogging of their holes. For example, at a change of this indicator from 6.9 to 19.3 m/s$^2$, clogging of a screen with oblong holes decreased from 0.34 to 0.02%, and that of a screen with round holes, – respectively from 0.019 to 0%. We should note that screens with round holes clogged about 10 times less frequently than those with oblong holes in all operation modes.

The sifting performance of the screen with round holes was the best at kinematic parameters of screens equaling 11.0…13.0 m/sec$^2$. Higher results were obtained at amplitudes of 7…10 mm and screen vibration frequencies of 410 and 340 min$^{-1}$, respectively.

Optimal values of the kinematic indicator of the screens with oblong holes, depending on the vibration amplitude, are within 11.0…15.0 m/sec$^2$. The extraction coefficient of small impurities in this case ranges between 84.6 and 89.6%. The lower the amplitude is, the greater value of the kinematic indicator of a screen should be observed. Thus, for an amplitude $A$ of 7 mm, the optimal value of the kinematic indicator of a screen $\omega^2 A$ equals 14.85 m/sec$^2$, and at $A$ of 22 mm, $\omega^2 A$ is equal to 11.0 m/sec$^2$. It should be noted that for screens with oblong holes, optimal values of the kinematic indicator (except for data obtained at $A$ = 22 mm) are more important than for screens with round holes. So, if at an amplitude $A$ of 7 mm, the optimal value $\omega^2 A$ for screens with oblong holes is 14.85 m/sec$^2$, and for screens with round holes $\omega^2 A$ = 12.9 m/sec$^2$, but at an amplitude $A$ of 14 mm, respectively, $\omega^2 A$ = 13.5 m/sec$^2$ for screens with round holes.

At larger values of the kinematic indicator of screens ($\omega^2 A$ > 15.5 m/sec$^2$), the grain mass is strongly loosened, the process of sifting sharply deteriorates, and the mass (up to 25.5%) overtails from the upper screen.

At small values of the kinematic indicator ($\omega^2 A$ < 8.0 m/sec$^2$), the grain mass on the screen is not loosened, but it is poorly transported, and the quality of sifting sharply deteriorates.

The extraction coefficient of small impurities drops to 44.5%, and the capacity of the screen shoe cannot be raised above 300…325 kg/h, though in all experiments, the authors have tried to set the performance within 500 ± 5% kg/h. At small values of the screen vibration amplitude ($A$ = 3 mm), the grain separation process is not working at all tested vibration frequencies of a screen (up to 450 min$^{-1}$).

On the basis of the conducted research it is possible to recommend the following kinematic modes for the separation of wheat seeds:

$A$ = 7 mm, $n$ = 410…440 min$^{-1}$ ($\omega^2 A$ = 12.9…14.85 m/sec$^2$);

$A$ = 10 mm, $n$ = 350…370 min$^{-1}$ ($\omega^2 A$ = 13.5…15.0 m/sec$^2$);

$A$ = 14 mm, $n$ = 250…280 min$^{-1}$ ($\omega^2 A$ = 9.9…12.0 m/sec$^2$);

$A$ = 18 mm, $n$ = 225…240 min$^{-1}$ ($\omega^2 A$ = 9.98…11.1 m/sec$^2$);

$A$ = 22 mm, $n$ = 214…220 min$^{-1}$ ($\omega^2 A$ = 11.0…11.3 m/sec$^2$),

that will be close to the optimal values for the performance of a screen shoe, equal to 500 ± 5 kg/h, for both screens with round holes and those with oblong ones.

*Table 1*

**The rate of screen clogging in course of cleaning wheat seeds depending on the kinematic indicator value of the screen shoe**

*Таблица 1*

**Показатель забиваемости решет на очистке семян пшеницы в зависимости от величины кинематического показателя решетного стана**

| № | Kinematic indicator of the screen shoe $\omega^2A$, min$^{-1}$ | Screen clogging, % | | № | Kinematic indicator of the screen shoe $\omega^2A$, min$^{-1}$ | Screen clogging, % | |
|---|---|---|---|---|---|---|---|
| | | upper Ø4.5 mm | lower Ø2.0 mm | | | upper Ø4.5 mm | lower Ø2.0 mm |
| $A = 7$ mm | | | | $A = 18$ mm | | | |
| 1 | 16.95 | 0.01 | 0.17 | 1 | 16.24 | 0 | 0.030 |
| 2 | 14.85 | 0.01 | 0.15 | 2 | 13.5 | 0.003 | 0.047 |
| 3 | 12.9 | 0.02 | 0.27 | 3 | 11.08 | 0.009 | 0.111 |
| 4 | 11.08 | 0.02 | 0.46 | 4 | 9.98 | 0.010 | 0.090 |
| 5 | 9.4 | 0.03 | 0.34 | 5 | 8.9 | 0.010 | 0.120 |
| $A = 10$ mm | | | | 6 | 6.9 | 0.02 | 0.170 |
| 1 | 19.3 | 0 | 0.02 | $A = 22$ mm | | | |
| 2 | 17.5 | 0.002 | 0.038 | 1 | 16.3 | 0 | 0.020 |
| 3 | 15.8 | 0,005 | 0.095 | 2 | 13.5 | 0.005 | 0.045 |
| 4 | 14.2 | 0.006 | 0.144 | 3 | 11.00 | 0.004 | 0.086 |
| 5 | 12.7 | 0.01 | 0.15 | 4 | 8.9 | 0.007 | 0.123 |
| 6 | 11.2 | 0.016 | 0.164 | 5 | 6.9 | 0.014 | 0.216 |
| 7 | 9.9 | 0.05 | 0.28 | | | | |
| 8 | 8.6 | 0.03 | 0.29 | | | | |
| $A = 14$ mm | | | | | | | |
| 1 | 15.9 | 0.002 | 0.018 | | | | |
| 2 | 13.6 | 0.006 | 0.054 | | | | |
| 3 | 11.1 | 0.008 | 0.112 | | | | |
| 4 | 9.9 | 0.010 | 0.100 | | | | |
| 5 | 8.83 | 0.018 | 0.141 | | | | |
| 6 | 6.9 | 0.019 | 0.151 | | | | |

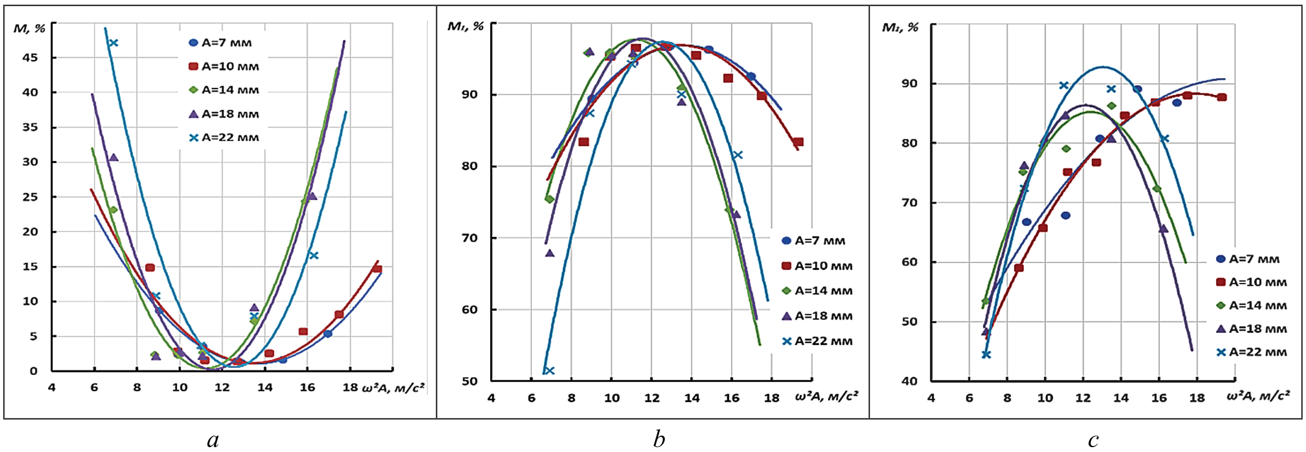


**Fig. 2. The amount passing from the upper screen (a), the amount passing from the lower screen (b) and the extraction coefficient of small impurities (c) depending on the value of the kinematic indicator of screens**

**Рис. 2. Сход с верхнего решета (a), сход с нижнего решета (b) и коэффициент извлечения мелких примесей (c) в зависимости от величины кинематического показателя решет**

When installing screens with oblong holes only in the screen shoe, the following operating modes can be recommended:

$A = 7$ mm, $n = 440$ min$^{-1}$ $(\omega^2 A = 14.85$ m/sec$^2)$;

$A = 10$ mm, $n = 360$ min$^{-1}$ $(\omega^2 A = 14.2$ m/sec$^2)$;

$A = 14$ mm, $n = 300$ min$^{-1}$ $(\omega^2 A = 13.5$ m/sec$^2)$;

$A = 18$ mm, $n = 240$ min$^{-1}$ $(\omega^2 A = 11.1$ m/sec$^2)$;

$A = 22$ mm, $n = 214$ min$^{-1}$ $(\omega^2 A = 11.0$ m/sec$^2)$.

In these modes, the separation efficiency of small impurities is equal to 84.6…89.6% and clogging of screens does not exceed 0.15%. When installing screens with round holes only in a screen shoe, the following operating modes can be recommended:

$A = 7$ mm, $n = 410$ min$^{-1}$ $(\omega^2 A = 12.9$ m/sec$^2)$;

$A = 10$ mm, $n = 340$ min$^{-1}$ $(\omega^2 A = 12.7$ m/sec$^2)$;

$A = 14$ mm, $n = 254$ м min$^{-1}$ $(\omega^2 A = 9.9$ m/sec$^2)$;

$A = 18$ mm, $n = 212$ min$^{-1}$ $(\omega^2 A = 8.9$ m/sec$^2)$;

$A = 22$ mm, $n = 214$ min$^{-1}$ $(\omega^2 A = 11.0$ m/sec$^2)$.

These modes will ensure maximum sifting and clogging of the screens will not exceed 0.02%.

The experimental results to determine the inclination angle of a screen shoe are shown in Tab. 2 and Fig. 3.

At an increase in the hopper outlet window area, the machine performance grows as well at all inclination angles of the screens. And with higher inclination angles, the performance was greater by about 40 kg/h at all operating modes.

*Table 2*

**The rate of screen clogging during the cleaning of wheat seeds, depending on the inclination angle of the screens ($\omega^2 A = 12.9$ m/sec$^2$)**

*Таблица 2*

**Показатель забиваемости решет при очистке семян пшеницы в зависимости от угла наклона решет ($\omega^2 A = 12,9$ м/с$^2$)**

| № | The area of the hopper outlet window, cm$^2$ | The inclination angle of the screens, ° | Screen clogging, % | |
|---|---|---|---|---|
| | | | upper Ø4.5 mm | lower Ø2.0 mm |
| 1 | 26.4 | 6 | 0.004 | 0.16 |
| | | 9 | 0.026 | 0.38 |
| 2 | 29.7 | 6 | 0.003 | 0.18 |
| | | 9 | 0.018 | 0.32 |
| 3 | 33.0 | 6 | 0.002 | 0.18 |
| | | 9 | 0.021 | 0.33 |
| 4 | 36.3 | 6 | 0.002 | 0.15 |
| | | 9 | 0.019 | 0.35 |
| 5 | 39.6 | 6 | 0.006 | 0.17 |
| | | 9 | 0.018 | 0.36 |

The coefficient of extraction of small impurities decreases as the performance grows by a dependence that is close to linear. So, at an inclination angle of the screen shoe $\lambda = 0°$, the coefficient decreased from 89.12 to 75.2% at the performance rate, respectively equal to 360.1 and 691.9 kg/h. At an inclination angle $\lambda = 9°$, the coefficient decreased from 81.91 to 73.51% with an increase in performance from 400.5 to 721.3 kg/h. It should be noted that at the performance rate above 600 kg/h, the values of the extraction coefficients of small impurities converge and range within 72.4…76.86%, i.e. the inclination angle of screens does not have almost any effect on this indicator. The clogging of the screens is almost the same for all performance values. At a large inclination angle of the screens ($\lambda = 9°$), the penetration rate of the upper screen (with round holes) is 3…10 times higher, and that of the lower screen (with rectangular holes) is about 2 times higher as compared with screen clogging at an inclination angle of 6°. The siftings from the upper screen at the performance rate of up to 450 kg/h was less (up to 1%) at an inclination angle of the screen shoe $\lambda = 9°$, and the screen shoe performance rate of 593.2…674.5 kg/h, it increased up to 7.6…17.59% and became 2…3 times higher than the amount of siftings for the inclination angle of the screens of 6°. At 691.9…721.3 kg/h, the screen value remained the same.

The carried out research has allowed to determine the operating modes of a screen shoe, which are close to optimal for the separation of grain seeds. However, the developed screen seed cleaner should process the seed material of small-seed crops (grass, etc.), which is usually heavily clogged with various impurities. According to V. Lampeter, for their effective removal, the kinematic indicators of the screen should not be less than 14.4 m/sec$^2$ and the inclination angle of the screen shoe should equal 7°.

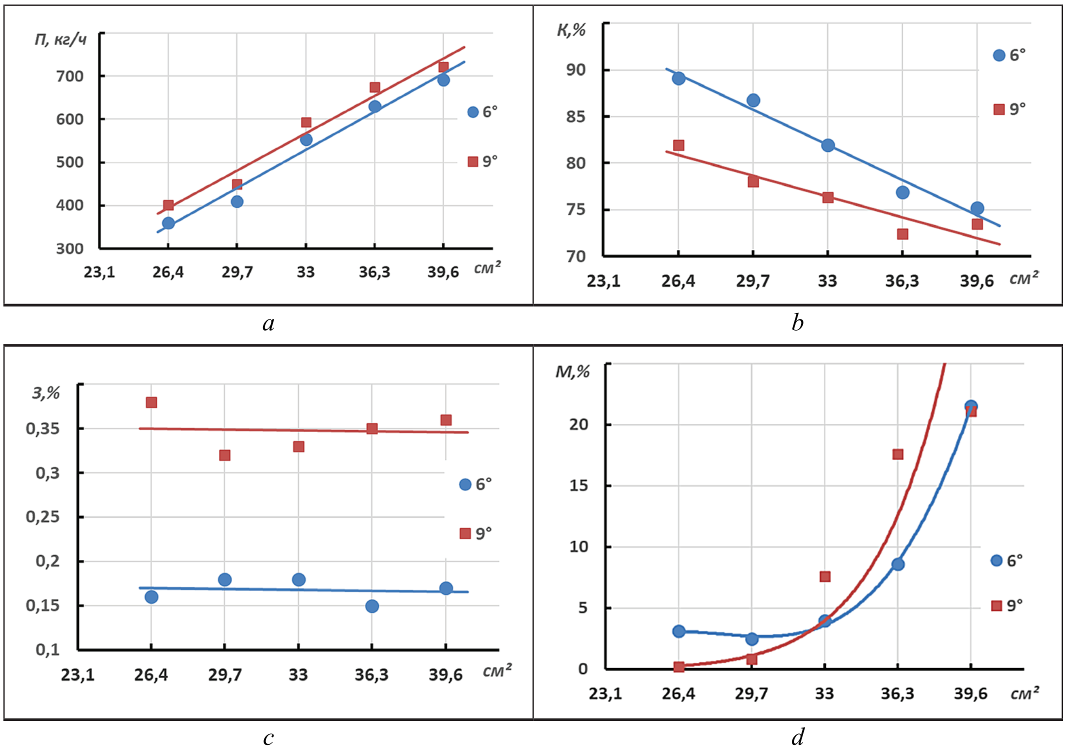


**Fig. 3. The performance of the screen shoe in cleaning of wheat seeds, depending on its inclination angle:**
a – change in the shoe performance; b – change in the extraction coefficient of small impurities;
c – change in lower screen clogging; d – change in the amount of siftings from the upper screen

**Рис. 3. Показатели работы решетного сепаратора на очистке семян пшеницы в зависимости от угла наклона решетного стана:**
а – изменение производительности сепаратора; b – изменение коэффициента извлечения мелких примесей;
с – изменение забиваемости нижнего решета; d – изменение схода с верхнего решета

## Conclusion

In order for a screen seed cleaner to operate in modes that are close to optimal when processing small-seed and grain crops, the vibration amplitude of the screen shoe should be equal to 9 mm, and its vibration frequency should be adjustable in the range of 350…450 min$^{-1}$ at an inclination angle of the screens of 7°. In this case, a screen seed cleaner can operate with an adjustable value of the kinematic indicator of screens in the range of 12.2…20.0 m/sec$^2$, which will allow processing seed material of practically all crops with different content of impurities.

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**Критерии авторства**

Дорохов А.С., Московский М.Н., Хамуев В.Г., Герасименко С.А. выполнили экспериментальную работу, на основании полученных результатов провели обобщение и написали рукопись. Дорохов А.С., Московский М.Н., Хамуев В.Г., Герасименко С.А. имеют на статью авторские права и несут ответственность за плагиат.

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**Contribution**

Dorokhov A.S., Moskovskiy M.N., Khamuyev V.G., Gerasimenko S.A. carried out the experimental work, on the basis of the results summarized the material and wrote the manuscript. Dorokhov A.S., Moskovskiy M.N., Khamuyev V.G., Gerasimenko S.A. have equal author’s rights and bear equal responsibility for plagiarism.

**Conflict of interests**

The authors declare no conflict of interests regarding the publication of this paper.

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