The effect of the seed shape on the reflection process of the concave slatted grating

Gennady Kuzin¹, Elena Fisunova¹, Oksana Pyatnitskaya¹, Tatyana Lavrenova¹, Olga Baryshnikova¹

¹Don State Technical University, sq. Gagarina, 1, Rostov-on-Don, 344010, Russia

E-mail: bys_ka87@mail.ru

Abstract. The model for the reflection of spherical bodies of different diameters (millet, steel balls, peas) from adjacent concave slats was proposed. An area of guaranteed reflection is found as the sum of the segments equal to the plank thickness, the diameter of the spherical body and the special size determined by the trajectory dividing separation from reflection. It is established that the proposed model can be used at the design developing. In addition, a comparison of the results of bench modeling the separation through a deck of seeds with spherical (millet) and ellipsoidal (grain) shapes is presented. Deck slats had adjustable angles of deviation from the radial direction within 0°-50°. It is shown that, despite the larger size, seeds of grain crops are relatively less reflected by concave at working inclination angles of the slats 0°-30° than spherical bodies.

1. Introduction

The main development trend of modern combine construction is the creation of regional harvesting equipment. In this regard, there is a need to create a number of models of harvesting units, the design of which would take local conditions into account. Machine design is based on background experience. Existing calculation methods [1], individual parameters of some working bodies are imperfect. Therefore, when designing [2], parameters that are far from the final result are initially built in, which leads to overvaluation. This fully applies to the threshing unit [3] and to the functioning of its most important part, which is the outlet zone of the threshing space. It implements the main type of threshing [4], which is the rub threshing. Rub threshing is carried out by the interaction of rasps and planks through the plant mass [5].

When threshing crops, seeds of various shapes and sizes are formed. In particular, one can distinguish a fairly common class of spherical shape seeds. It was previously established [1] that the found millet seed model provides a good approximation to the experimental results with radially oriented concave planks. The adequacy check of the model for the interaction of different-sized spherical objects [6] with the slatted concave lattice was performed, depending on the deviation angle of the slats from the radial direction.

The millet, steel balls and peas of 2 mm, 4.5 mm and 6.7 mm diameters, respectively, were used as the objects. Moreover, the seeds of millet and pea had a shape close to spherical [8].

Pea seeds had the greatest deviation from the spherical shape. The experiments were carried out on a bench where the separated objects rolled down along the rotation surface with a brachistochrone-shaped generatrix and scattered on a lattice with vertical slats simulating the slatted grating of the
After one repetition, the fractions of the reflected and separated seeds were measured and their ratio was calculated. The experimental results are presented in Figure 1.

Here, the numbering on the abscissa axis corresponds to the incline of the slats from 0 to 50 degrees with 10° increments. According to the figure, the reflectivity increases with increasing deflection angle. The adequacy of the model of impact interaction of the components was verified.

**Figure 1.** Reflection of a sphere-shaped objects with a slatted grating (experimental data).

The process of improving the model is shown in Figure 2. This figure shows the transition from the original model (left: guaranteed reflection zone "b") to the intermediate (center: guaranteed reflection zone "b+D"), and then to the final one (right: guaranteed reflection zone "b+D+2c").

**Figure 2.** Comparison of the reflectivity of steel balls for different impact models (with L=34mm, b=6mm, D=4.5mm, c=0.65mm).
Figure 2 shows that, as the refinement is made, the differences in the reflectivity decrease from 21.92% to 8.69% and then to 0.96%, which indicates a good approximation level of theoretical and experimental data. The decisive role in establishing the adequacy of the model here was played by the “c” parameter, which determines the critical value of the trajectory that is boundary between the reflection and separation of objects [9].

Figure 3 shows the schemes for determining the areas of guaranteed reflection for spherical bodies of different diameters [10] for not quite elastic collisions (collision coefficient K=0.6). For all three cases, it was found that as the critical reflection trajectory [11] passes through the upper left vertex of the right adjacent plank profile with a certain accuracy, the lengths of the areas, as expected, increase (9.22mm, 13.78mm, 17.1mm).

Determining of critical reflection trajectories by the successive graphical approximation method for radially oriented planks [12], schematically described by V. Shevkun, needs to be specified.

Checking the adequacy of models for spherical bodies of different diameters [13] with radially oriented bars is shown in Figure 3. The test consisted in comparing experimental (millet, steel balls, peas) and theoretical (model) data.

In each case, the extent of the guaranteed zone for a reflection of spherical body from radially oriented planks within a single cell was found using the ratio L=b+D+2c. It can be seen from Figure 3 that the moduli of the differences between the theoretical and experimental data are 1.02% (millet), 0.96% (balls) and 1.22% (peas), which indicates the adequacy of the simulation results in the case of radially oriented planks.

| Diameter | Reflectivity (%) | Theory  | Experiment |
|----------|------------------|---------|------------|
| 4.61 mm  | 27.12%           | 28.14%  |            |
| 6.89 mm  | 40.53%           | 39.57%  |            |
| 8.55 mm  | 50.29%           | 49.07%  |            |

Figure 3. For the determination of critical trajectories by the method of sequential graphical approximation with radially oriented bars: a) millet; b) steel balls; c) peas.

The reflectivity values for millet, balls, and peas were found using the same successive graphical approximation method [14], depending on the deviation angle of the planks. These values are shown in Figure 4 in comparison with the experimental data.

It can be preliminary noted that the figure gives an idea of the adequacy of the models. For more visual comparability of experimental and theoretical data, Table 1 shows the differences of the values indicated in this figure.
Table 1. For the comparison of experimental and theoretical data, (%).

| Model | 0  | 10 | 20 | 30 | 40 | 50 |
|-------|----|----|----|----|----|----|
| Peas  | 1.22 | 1.23 | 1.7 | 2.63 | 3.45 | -1.77 |
| Balls | 0.95 | 0.51 | 1.03 | 0.86 | 2.54 | 0.6 |
| Millet| 0.37 | -0.33 | 0 | 1.74 | 2.54 | 6.06 |

From the table it follows that the greatest difference in the reflectivity does not exceed 7.27% (peas) in the range of 0°-40° pitch angles. With a further increase in the deviation angle of the planks (over 40°), the difference becomes heterogeneous and noticeable, which indicates a feature in the behavior of attacking objects.

This phenomenon is obviously associated with secondary reflections of objects from adjacent planks occurring in the indicated zone and, as a result, with the insufficient number of measurements in it [15].

Figure 4. On the adequacy analysis of models of spherical bodies.
In addition to experiments with spherical bodies (millet), an array of data (reflectivity) for ellipsoidal bodies (wheat, barley, oats) was obtained. Here, all values were obtained in experiments at the bench according to the method of the research [1], in which separated [16] objects rolled down along the rotation surface with a brachistochrone-shaped generatrix and scattered on a grating with vertical bars. After one repetition, the fractions of reflected and isolated seeds were measured and their ratio was calculated. The reflection indicators of seeds from vertical planks (analogue of a vertically oriented concave grating) are presented in Table 1. A preview of the results of the experiments from Table 2 revealed some feature. It can be seen that there is a significant difference in the reflectivity of millet and other crops only at large slope angles of the slates (40-50 degrees).

### Table 2. Reflection indicators of seeds by a slatted grating, %.

| Slateslope angle | 0° | 10° | 20° | 30° | 40° | 50° |
|------------------|----|-----|-----|-----|-----|-----|
| Wheat            | 27.77 | 27.27 | 25.40 | 24.10 | 23.59 | 31.38 |
| Barley           | 28.22 | 27.28 | 27.20 | 25.08 | 24.68 | 34.28 |
| Oats             | 27.50 | 26.74 | 26.32 | 24.31 | 25.28 | 34.54 |
| Millet           | 28.14 | 27.60 | 25.40 | 22.36 | 21.05 | 25.32 |

At the same time, in the angle changing range from 0 to 30 degrees the indicated values almost coincide. To explain this, a graphical interpretation of the experimental data should be considered.

For ease of display and analysis in each case, three parameters of the seed (length "a", width "b" and thickness "c") are replaced by equivalent radii (R) calculated by Shevkun V. using the formula $R = \frac{1}{3} \sqrt{abc}$. The use of this ratio for all three crops is shown in Table 3.

It can be noted that all values in the array of dimensional characteristics of grain seeds are approximately 2-5 times greater than the dimensions of millet. In this regard, based on the results of experiments with spherical bodies of various sizes [3], a significant increase in the reflection index would be expected for seeds of cereal crops compared to millet.

Figure 5 shows the curves of changes in the reflectivity [17] of the studied objects depending on the slope angle of the slats. The upper curve was plotted using the points from experiments with millet, and the lower one was plotted using the average values of the wheat parameters, barley and oats as bodies [18], which significantly differ from spherical ones (see the abovementioned formula). It can be noted that a trend with an increasing discrepancy between the experimental data with the same nature of the curves is observed.

### Table 3. To a comparison of the overall dimensions of millet and grain seeds.

| Crop | Repetition No. | Length “a” | Thickness “b” | Width “c” | R |
|------|----------------|------------|---------------|-----------|---|
| Wheat| 1              | 6.8        | 2.5           | 2.7       | 3.58|
|      | 2              | 6.5        | 3.1           | 3.2       | 4.01|
|      | 3              | 6.2        | 2.6           | 2.9       | 4.02|
|      | 4              | 5.3        | 2.5           | 2.6       | 3.26|
|      | 5              | 6.8        | 2.6           | 2.9       | 3.72|
|      | Rav.           |            |               |           | 3.72|
| Barley| 1             | 7.8        | 2.2           | 3.0       | 3.72|
|      | 2              | 8.4        | 2.4           | 3.3       | 4.05|
|      | 3              | 7.2        | 2.4           | 3.2       | 3.81|
|      | 4              | 7.5        | 2.8           | 3.6       | 4.23|
|      | 5              | 8.7        | 3.2           | 3.9       | 4.77|
However, a significant difference is observed only in the region of large deviation angles. Here, obviously, the unconsidered factor intervenes.

Figure 5. Change in the reflectivity of millet and grain depending on the angle of the slats.

Thus, using the combined action of all factors analyzed in the article, the following can be concluded. A model with a guaranteed area of reflection from the planar lattice within the "b+D+2c" limits gives an acceptable coincidence level of theory and practice (on the example of spherical bodies). With an increase in the diameter of the object, the degree of reflection increases and, accordingly, the degree of separation (shaded areas) decreases. Subsequent studies should be aimed at refining the model of non-spherical bodies, in particular, cereals.

According to the conducted study, it can be concluded that the seeds of cereals (wheat, barley, oats), which have an ellipsoidal shape, have a relatively better separation than millet (spherical body) at absolutely large sizes in any direction. The reason for this behavior of elongated seeds may be the predominance of off-center collisions with planks. This peculiarity should be taken into account when designing separating surfaces.

References
[1] Kuzin G, Barkov A, Prikolotin I, Antanosyan A 2018 ITNO-2018 (Rostov n/D: Don. gos. texn. un-t, Agrarny’j nauchny’j centr «Donskoj)
[2] Sewell A 1990 Journal of Agricultural Engineering Research 46 pp 207-217
[3] Akhalkatsi M, Otte A, Togonidze N, Bragvadze T, Mazanishvili L 2017 Annals of Agrarian Science 15 1 pp 11-16
[4] Khan A 2016 Annals of Agrarian Science 14 2 pp 25-34
[5] Guo C, Tang Y, Lu J, Zhu Y, Tian Y 2019 Agricultural and Forest Meteorology 272–273 pp 69-80
[6] Anderson W, Seager R, Baethgen W, Cane M 2018 Agricultural and Forest Meteorology 262 pp 298-309
[7] Rosenzweig C, Jones J, Hatfield J, Ruane A, Winter J 2013 *Agricultural and Forest Meteorology* **170** pp 166-182
[8] Lizana C, Hess S, Calderini D 2009 *Agricultural and Forest Meteorology* **149** 11 pp 1964-1974
[9] Magney T, Eitel J, Huggins D, Vierling L 2016 *Agricultural and Forest Meteorology* **217** pp 46-60
[10] Chenu K, Roy Porter J, Martre P, Basso B, Asseng S 2017 *Trends in Plant Science* **22** pp 472-490
[11] Ewel J, Schreeg L, Sinclair T 2019 *Trends in Plant Science* **24** 2 pp 121-129
[12] Abinasa M, Ayana A, Bultosa G 2011 *Afr. J. Agric. Res.* **6** 17 3972e3979 http://www.academicjournals.org/AJAR
[13] Maqbool R, Sajjad M, Khaliq I, Reham A, Khan A, Khan S 2010 *Am-Euras. J. Agric. Environ. Sci.* **8** 2 pp 216-224
[14] Raghuwanshi R 2012 *Opportunities and challenges to sustainable agriculture in India* NEBIO **3** 2 78-86
[15] Akhalkatsi M 2015 *Genetic Diversity and Erosion in Plants* (Switzerland: Springer International Publishing,) pp 159-187 ISBN 978-3-319-25637-5
[16] Akhalkatsi M, Ekhvaia J, Asanidze Z 2012 *Perspectives on Nature Conservation patterns Pressures and Prospects in Tech.* Rijeka pp 51-92 http://dx.doi.org/10.5772/30286
[17] Girgvliani T 2010 *The History of Aboriginal Forms of Wheat Varieties of the Upper Svaneti* (Tbilisi: Artanuji)