Determination of soya grain strength, reduction and loss in storage and processing

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Abstract. This scientific article analyzes, that with an increase in soybean production, an important role is given to reducing the loss of soybean grain per harvester and from crushing, when the plants are harvested, and post-harvest processing of grain in the production of reproductive seeds. The studied climatic conditions of the Amur region during the soybean harvesting period (October) are characterized by low precipitation and low relative air humidity, it helps dry the plants. Identified, that under these conditions, soybeans and grain are losing strength and, under the influence of the working bodies of motovil and reaper, beans are pulled off or uncovered and grain losses are noted, a threshing and separation devices (MSU) of a grain harvester crush grain when milled, resulting in crop losses. Formulated in the process of scientific research, that the tensile strength or destructive load of soybean kernels by grade at humidity 6,5% change from 13.03 before 29.02 kg. Knowing the destructive load for soybean grain, proposal for Action, prevent destructive modes of operation for the working organs of the threshing and transporting devices of the combine. Based on the reliably obtained regression equation, the response surface is represented, determining the force of the action of the working bodies of the combine in the function of the changing speed from 8.0 before 20 m/s, mass of grain from 0.15 before 0.35 g., which in the September variety increases to 10 N.

1 Introduction

Soya, high in protein and fat, It is the most important crop of the Far East... The area of its crops in Russia is increasing annually. This is due to the ever-increasing demand for soy products from the food and feed industry [1-3].

Amur region on soybean cultivation ranks first in the Far East, produces more than 64% of the gross volume of soybean grain and is one of the main regions of Russia, the cultivation of this crop (18,6% of all-Russian indicator) [4-6].

A lot of work is devoted to the issue of reducing damage to soybean grain during harvesting and post-harvest work. Every researcher, studying a separate working organ of a threshing-separating or transporting device, Find a technical solution, which allows in its pure form to significantly reduce damage to soybean grain [7-9].

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In all domestic and foreign harvesters productivity, loss and mechanical damage (crushing) of the grain primarily determine the perfection of the threshing and separation device (MSU). The improvement of the classical scheme of the threshing device goes in the direction of increasing its parameters in the width and diameter of the threshing drums, activation of sub-drum and failover beater, what will lead, Along with increased productivity, additional crushing losses due to threshing of soybean grain [9-11].

The stability of grain and plants to mechanical damage and losses is largely determined by its humidity. When cleaning and processing seeds of air-conditioned humidity 12...14%, there is a minimum of damage and loss. Mechanical damage and loss increase when treated as dry (W=8%), as well as wet (W18% of seeds and plants, However, the type of damage changes... On Dry Soy Plants, Beans and seeds from impact and pinching are destroyed, As a result, when working motovil and harvester observed cracking and scattering of grain on the ground. And when working threshing and transporting devices in marketable grain and seeds contains a large amount of finely milled grain, grain divided into halves along and across the seedpods, Seeds with part of the seed removed and the germ removed, as well as micro-damage with a shell crack, Seed and embryo. Wet seeds deform under load, and as a result, the total mass of the damaged seeds consists of flattened, cracked grains and grains with dents and rupture of the shell [12-14].

The classical theory of collision of solids Newton does not allow to determine the magnitude of the forces at impact, since this theory is limited only to the establishment of the initial and final velocities of the colliding bodies. Internal patterns of the impact process, The Contact Forces, Duration of impact, The amount of deformation during impact remains unexplored. As the main hypothesis, when taking into account local deformations during impact, it is accepted, that the relationship between contact pressure and local confusion is the same, As in static conditions... The impact force in elastic-plastic deformation of impacting bodies is determined from the position of the contact problem of the theory of elasticity [14].

Objective Studies - Determination of crushing and micro-damage during cleaning and post-harvest treatment, permissible load of force, preventing the destruction of soybean grain in order to obtain high-quality reproductive seeds.

2 Materials and methods

Mechanical damage to the soybean grain represents the local or general destruction of it as a single and complex biological system. By degree and types, these destructions are different and reduce field germination and yield (a crushed soybean grain does not produce seedlings), micro-damaged grain reduces germination to 70%).

Determination of the critical force of collision of grain with the working bodies of the combine was carried out under the condition of forceful static loading of soybean grain. The DOSM-3-0,05 dynamometer was used to determine the static deformation of the compression. Fragmentation and microdamage of soybean seeds were determined according to GOST 12036-85 "Seeds of the main crop".

To determine the amount of crushed grain from an average sample weighing 2 kg, selected in accordance with GOST 12037, Using the divider, Give them three 100g. From each of them, they are selected by type.., Weighed to ± 0.01 g and calculated as a percentage of the weight of the grain attachment. This part of the grain does not belong to the seeds and should be sorted when working. To determine the microdamage from each attachment, 200 grains in a row are selected without a choice (only on the average sample - 600 grains). Selected grains are viewed using a binocular microscope 8 - multiple magnification. The damaged seeds are weighed with an accuracy of ± 0.01 g. The results of

the analysis of each hundred seeds are recorded in the journal and the final result is obtained after analyzing six hundred grains.

The starting material for the study of strength was soybean grain of Far Eastern and Western varieties (Krasnodar region and Kursk region) as well as soybean grain of varieties of foreign selection from the PRC.., France, Canada, Japan and the United States, of different ecological and geographical origin, but grown in the experimental field of VNII soybeans in 2021. The mass of 1000 seeds of all varieties studied varies from 100 to 100..,8 to 322.4 g, Their length is from 6.21 to 9.31 mm, Width — from 5.74 to 8.49 mm, Thickness from 7.46 to 4.25 mm. With a certain assumption, the grain of soybeans of all varieties has the shape of a ball, The soy grain shape coefficient of these varieties varies from 0.931 to 0.755.

3 Results and Discussion

Analysis of the results of the agrotechnical assessment of soy seeds, received in 2021...2023gg with the actual harvesting of soybeans in the farms of the Amur region in the optimal agrotechnical terms with grain humidity of 13...16% by harvesters of domestic and imported production (Vector 410, Acros 530, KZS-1218-40 "Amur-Palesse", Claas "Tucano 430", "Case IH 6088", "John Deere W650") showing. The average height of the plant was 8.6…15.1 cm, losses from uncut beans, due to their low maintenance, cut down with fallen beans and ground grain was 1.56…2.48 c/ha, bunker grain contained: weed admixture 0.31…2.18%, fragmented and micro-damaged seeds — 2.61…5.98%, damaged pests, diseases and Illnesses − 6.14…14.46% (Table 1).

Table 1. Quality of soybean reproduction seeds of different varieties, by districts and districts of the Amur region.

Area, class soy	Fracture, %	Cracks in the area of the semiadult and the embryo, %	Sick, frostbite, damaged pests, %	Mass of 1000 seeds, g
Tambov district				
Kitrosa	1.3	1.6	0.5	156.8
Persona	6.34	2.71	0.73	117.86
Evgenia	1.8	3.65	0.35	186.5
Azure	4.30 5.41	4.35 4.14	0.15 0.8	171.06 161.85
Alena	5.73	4.34	0.53	167.0
Prudence	3.2 1.09	4.97 2.6	0.13 0.91	174.8 192.3
Nega	1.01 0.38	1.71 2.0	0.57 1.47	148.1 161.7
Umka	3.88	2.54	1.0	173.5
Konstantinovsky district				
Umka	3.55	1.31	1.34	176.6
Bonus	1.64	1.66	2.28	174.1
Nega	1.67	1.84	2.41	163.15
Prudence	5.74 4.32	1.87 5.89	0.72 3.10	174.7 168.7
Azure	2.59	1.24	1.92	180.3
Persona	3.44	0.73	0.74	114.4
Alena	3.76 2.16	5.14 2.63	1.09 5.14	167.7 162.76
Ivanovo district				
Terek	1.26	1.53	2.49	168.8
Umka	4.64	1.77	3.56	188.1
Alena	1.0	1.48	1.34	171.0
Nega	1.34	1.80	1.55	154.3
Dauria	3.21	2.52	1.01	165.8
Prudence	2.44	3.94	1.60	187.1

Study of the sowing qualities of soy reproductive seeds, in seed farms for sale to producers, showing, use in the cleaning of the harvester park, intended for the production of marketable grain and the deterioration of grain cleaning equipment, they do not produce good quality seeds.

In the seeds of selection of VNII soybeans, DalNIISH, Canadian varieties, cultivated in seed farms, different content of crushed and micro-damaged seeds. Highest Fragmentation (6.34; 5.73; 5.41; 3.2%) and micro-damage (2.71; 4.34; 4.14; 4.97%) identified in seeds in farms of the Tambov district on varieties of soy Persona, Alena, Azure, Prudence (Table 2).

Table 2. Quality of soybean reproduction seeds of different varieties, by districts and districts of the Amur region.

Area, class soy	Fracture, %	Cracks in the area of the semiadult and the embryo, %	Sick, frostbite, damaged pests, %	Mass of 1000 seeds, g
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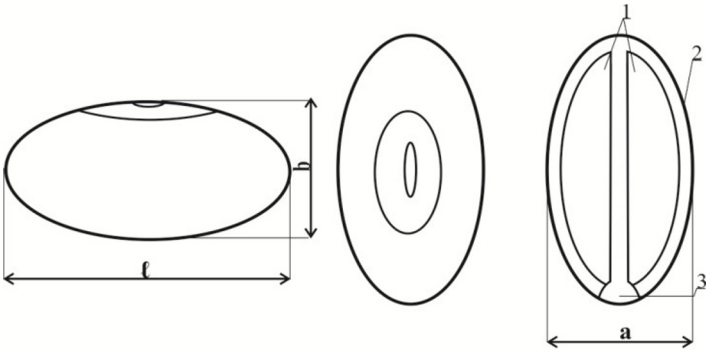
Nega	1.34	1.80	1.55	154.3
Dauria	3.21	2.52	1.01	165.8
Prudence	2.44	3.94	1.60	187.1

The seeds of farms of the Konstantinovsky district on varieties of Prudence, Alena and Umka the value of fractionation is somewhat lower and is 5.74; 3.76; 3.55%), but significantly higher than the value of microdamages (5.89; 5.14; 1.34%). The amount of fragmentation and microdamage is much lower in the seeds of farms of the Ivanovo district. Here is the crushing of soy seeds in Umka varieties, Dauria and Prudence (4.64; 3.21; 2.44%) and micro-injury (1.77; 2.52; 3.94%). Lowest mass, Seeds of the Persona variety (114.4…117.9 g), whose division in the Tambov district is 6.34% and micro-damage 2.71%. The highest mass is Prudence and Azure (180.3…174.8 g). The total amount of mechanical damage to Prudence soybeans is from 6.38 to 8.17%, Classes from 3.83 to 8.65%. The data for the three districts and districts of the region show, that the highest

value of mechanically damaged soybean seeds is noted in the variety of Canadian selection Prudence; from the varieties of selection of the VNII of soybeans - Persona, Alena, Azure. It should be noted that, mechanical damage to soybean seeds is much higher than biological damage, damaged by pests and diseases.

Soybean (Figure 1) covered with a dense peel (seed shell 2), protect its inner part (germ 3 and semen 1) from destruction. The seeds are about 89.5%, rind (seed sheath) 6.7% and embryo respectively 2.8% of the total grain. The germ of the seed is enclosed within the grain, Rounded form. Soybean membrane has low strength, which causes increased damage. A distinctive feature of mechanical damage to soybean grain is the detachment of the protective shell from the seed. And the part that is broken dies, and the post-harvest phase of grain life is disturbed. If there is a crack in the shell, closing the seeds, it causes trauma to the fetus.



1 – semiadults; 2 – seed shell; 3 – embryo;
l – length; b – width; a – thickness of soy

Fig. 1. Soybean grain.

The structure of different layers of the soy shell with cells that are longitudinal, which are transverse, Lots of capillaries, predominance in the chemical composition of the carbohydrate shell, exposed to wood, It leads to Tom., that the resistance to fracture and breaking forces in the shell is small, especially in low humidity. Due to the different structure of the cells of the individual layers of the shell in their mutual arrangement, the bursting force of the soybean shell changes when the load application direction changes, that is, the soy shell has anisotropy of strength properties.

The design and technological parameters of the machines do not fully take into account the peculiarities of grain processing, representing a living being with all the components of the vital activity process.

Soybean grain, when milled and transported, experiences free and non-free impact with the working surface and compression when pinched and will not be destroyed, if the strength characteristics of it will be higher than the force effects, between them as a result of force.

The impact force during elastic-plastic deformation of impacting bodies can be determined from the position of the contact problem of the theory of elasticity [15-16].

$$P_1 = \frac{2.32 g^{0,9} m^{0,6} v^{1,2} \left(R_1 R_2\right)^{0,2}}{\left(2R_2 + R_1\right)^{0,2}} \left[\frac{E_1 E_2}{E_1\left(1-\mu_2^2\right) + E_2\left(1-\mu_1^2\right)}\right]^{0,4} \quad (1)$$

$$P_2 = 0.84m^{0,6}\nu^{1,2}R_1^{0,2}\left[\frac{E_1E_2}{E_1(1-\mu_2^2)+E_2(1-\mu_1^2)}\right]^{0,4} \quad (2)$$

Where: E_1 and E_2 — modules of elasticity of soybean grain and working organ, MPa; R_1 and R_2 - radii of curvature of the grain and the working organ, m; μ1 and μ2 – poisson coefficients $\mu = \varepsilon_{poper}/\varepsilon_{prolon}$; g – acceleration of free fall, m/s$_2$; m_1 и m_2 – mass of grain and working body, kg; ν – speed of the working body.

Soybean grain in shape can be taken for a ball with a radius R (form rate by grade is from 0.931 до 0.755), and the actual surfaces of threshing and transporting devices are overwhelmingly considered as planes, cylindrical surfaces and sharp edges.

The mechanical state of soybean grain is characterized by its static and dynamic strength, which, mainly, depends on the type, humidity, mass of 1000 seeds, forms, and buildings of grain and other.

Under load Soybean grain due to the peculiarities of its structure and chemical composition is interpreted by elastic-plastic deformations of the grain. As a result of the compression of it when pinched, as well as when it collides with the working organs in the contacting grain, elastic and plastic deformations occur. On the basis of the empirical law, elastic deformations in the grain during dynamic loading develop independently of plastic deformations, Therefore, the main effort, acting on grain, develops in contact due to elastic deformation of the grain. As the main hypothesis, when taking into account local deformations in the collision of working organs with grain, such a, that the relationship between contact pressure and local shock is the same, as in static conditions. The starting point of the theory of elasticity is the assumption, that the elastic state of the grain near the surface of the impact and throughout the impact is very close to that state of equilibrium, which would arise in the grain and the working body if they were slowly brought together.

In the well-known theory of contact deformations of Hertz bodies, neglecting the fluctuations, in a grain of dust, and assuming, the energy of these vibrations is extremely small, and then all the kinetic energy of the relative motion of the grain is converted into the potential energy of elastic deformations. And the total force of the blow, causing these grain deformations, is defined as the sum of the elastic and plastic component of the force of impact.

The plastic component of the impact force in its magnitude is much less elastic and accounts for up to 7% of the total impact force [15-16]. Taking into account only the elastic component of the impact force, take it for the full force of the dynamic load of the grain. Tensions, preservation of the shape and size of grain, they must be below those, in which there is a permanent deformation.

To obtain the limits of the resistance of soybean grain to the destruction of the shell and grain as a whole under changing load, diagrams of the compression of soybean grain of two varieties and three humidity parameters were built. Tests were carried out at air-conditioned humidity 12.3%, as well as dry humidity 6.5% and over-hydrated soybean grain with a humidity of 18%. You can see it in the diagrams, what is a dry grain (Line AD) coincides with the limit of static strength of soybean grain. Until the crack (point B appears, C and D), which should be considered as corresponding to the elastic limit and the beginning of the destruction of the grain shell at different humidity. With grain moisture, 18 and 12.3% shell crack appears with less static load - on the diagram (points B and C, respectively).

The resistance of soybean grain to mechanical damage has varietal features and is due to the mass of the grain, linear dimension and spherical shape, determined by the form factor.

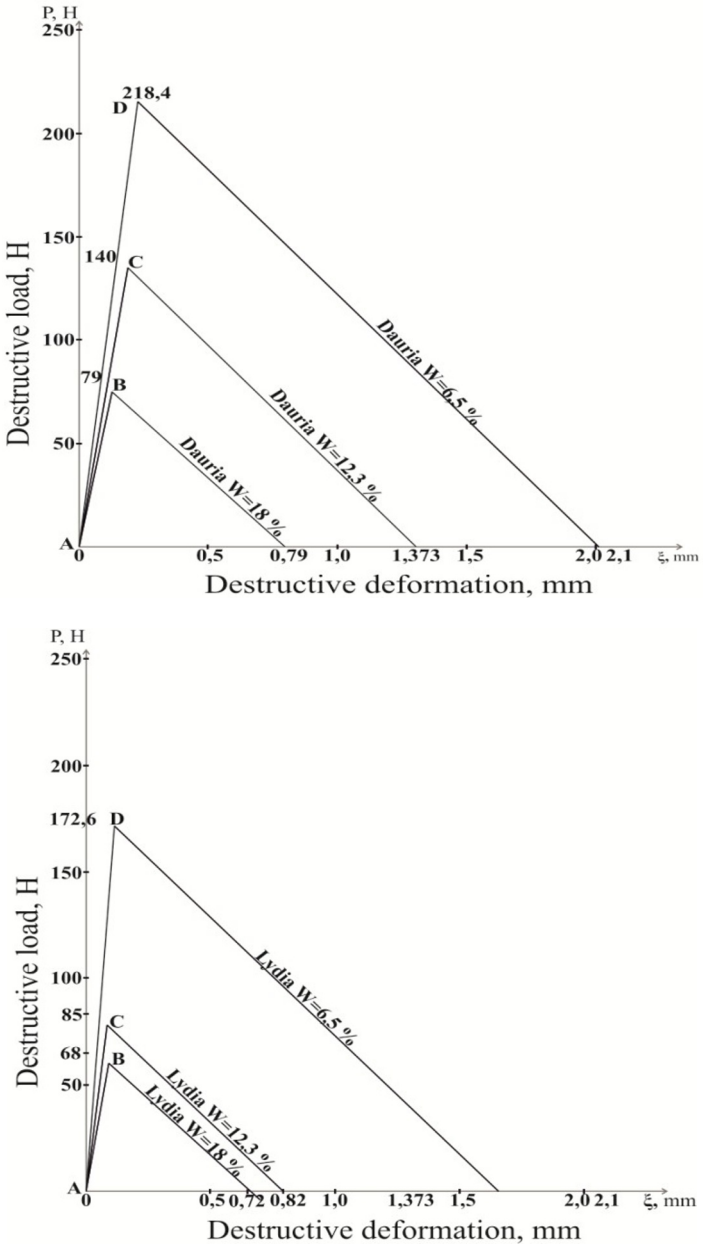


Fig. 2. Grain compression diagrams of medium and early soybean varieties.

Loading, after which the, the proportionality between load increment and relative compression (deformation) is violated, soybean grains, the corresponding proportionality limit. And the proportionality factor E, normal tension and relative compression, is the elastic modulus of the soybean grain during compression. Physically, it characterizes the resistance of soy to elastic deformation. As a result of experiments, based on Hooke's law, determined the value of the modulus of the elasticity of soybean grain (Table. 3). You can see from the table, modulus of elasticity and limit of strength of soybean, characterizing the ability of grain to resist elastic deformation, classes at humidity 6.5% change from 470.1 before 114.2 MPa, which decreases with increasing humidity in 1.5 to 2 times.

The moisture content of grain significantly affects its mechanical damage. With free collision of grains with a metal surface, a grain of high humidity is least susceptible to destruction. At an impact speed of up to 20 m/s, Lydia soybean grain with a humidity of 6.5% completely 100% damaged, and with humidity 12.3% damaged 78% of grain, while with 18% humidity, only 36% of the grain is damaged. Average critical impact speed, in which there is a destruction of the grain (crushing) when colliding with the metal surface in the varieties Dauria and Alain at humidity 6.5% is 25.5 and 22.5 m/s.

Table 3. Destructive load and elastic modulus of soybeans of various varieties.

No. p/p	Name of class	Coefficient forms	Destructive load, kg	Module resilience, MPa
1	Acrane	0.832	27.64	465.1
2	№3-2014 J-35	0.900	26.75	394.2
3	Vegetable	0.793	28.63	469.6
4	Honshu	0.888	29.02	471.1
5	Mikavasima	0.931	26.94	398.3
6	Sorcerer	0.875	21.45	268.9
7	AD-3 Mageva	0.898	22.62	298.8
8	Kanata	0.856	23.51	349.4
9	Kyoto	0.824	23.81	373.7
10	Alena	0.943	22.43	318.9
11	Dauria	0.851	21.54	292.5
12	Pepelina	0.908	23.53	314.6
13	Kofu	0.844	19.87	263.8
14	September	0.919	18.57	200.2
15	Static	0.896	19.07	246.2
16	RJT Speeda	0.801	24.52	454.8
17	The Leader - 10	0.755	17.58	285.1
18	Lydia	0.847	17.26	213.7
19	Chico	0.853	14.88	187.8
20	SK Rusa	0.873	14.44	150.1
21	McCall	0.828	13.03	114.2

Theoretical dependencies (1), (2) and soy grain elasticity modules, different varieties allow you to determine the impact force when the grain interacts with the working organs of the combine harvester and transporting devices, treating them as flat and cylindrical surfaces.

As a result of the calculations, the regression equation was compiled and the response surfaces of the combined effect of the impact force from the speed of the impact of the working surface of the threshing devices of the modernized "Yenisei-1200" combine harvester and the mass of the threshed grain were built.

$$P = 6.54 + 1.9X_1 + 2.89X_2 - 1.37X_2^2 \quad (3)$$

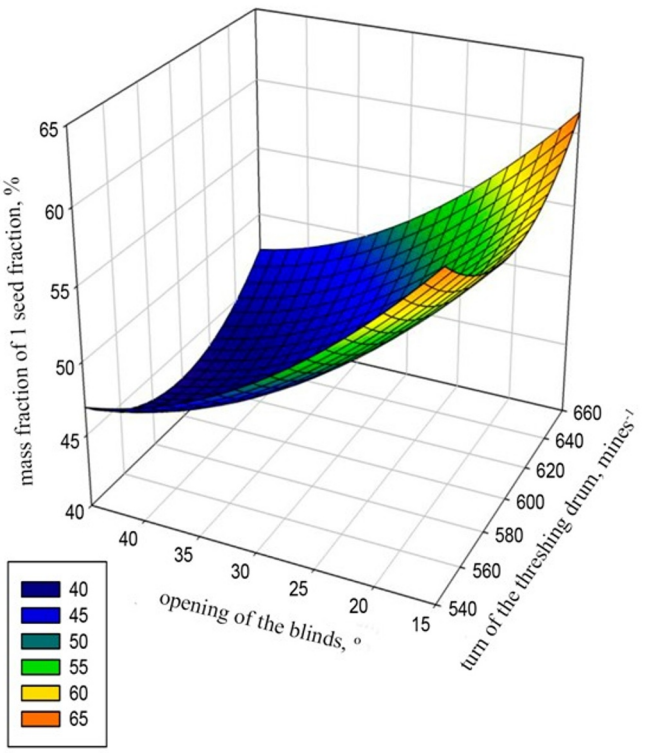


Fig. 3. 3D- Impact force response surface, when grinding grain with the first and second threshing drums of the combine "Yenisei-1200".

Analysis of the graph (Figure 3) shows, that in the first threshing drum, the force of the whips when threshing is from 0.5 to 6 H, it provides high-quality grinding of soybean grain and is not particularly dangerous for grain destruction. With a second threshing-drum, The speed of impact increases to 20 m/s, At the same time, the strength of the interaction of the working organs with the grain increases to 10 N and it is destructive and dangerous to the grain, in case of non-free collision.

4 Conclusion

When receiving marketable grain and soybean seeds, there are losses and crushing of grain at all stages of mechanized processing:

- Grain loss per harvest is from 1.56 before 2.48 c/ha.
- Crushing and microdamage of bunker grain is from 2.61 before 5.98%.
- The content of crushing and microdamage of grain in reproductive seeds is from 5.91 before 11.31%.

Destructive load characteristics obtained from 13.03 to 29.02 kg and modulus of elasticity of soybean grain of different varieties from 114.2 to 471.1 MPa depends on soy variety, Grain Humidity, Form and mass ratio of 1000 seeds. The established value of the permissible force load of soybean grain allows you to regulate the current voltage when threshing and transporting preventing its destruction.

Simulation of the grain impact process with the working surface of the combine harvester devices from the position of the contact problem of the theory of elasticity allows determining the magnitude of the impact force during the operation of the threshing and transporting devices of the combine, Designing and building devices, Preventing and reducing grain crushing and loss.

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