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ENSURING RELIABILITY AND RESOURCE CONSERVATION COULTERS DISCS OF GRAIN SEEDERS

A study was conducted aimed at studying the problems of the reliability of coulter discs and proposing ways, methods of restoring and optimizing the design of coulters of grain seed drills to maximize their reliability and durability.

Grain planters in agriculture play a key role in the process of growing crops. However, one of the most important components of these units are coulter discs, which are often exposed to aggressive conditions and heavy physical loads. Ensuring the reliability of coulter discs of grain seeders is a key aspect in agricultural production, since the efficiency of the technological process of sowing directly affects the yield and quality of agricultural crops.

A thorough analysis of the geometry and materials of the disks was carried out to identify weak points and potential sources of activation, as well as to determine the main factors that lead to their wear and destruction.

The values and distribution of the residual stresses in the material of the new disk and the restored one by welding three segments made of steel with surmite surfacing and vibration hardening were determined.

The values of the degree of strengthening of the material of the cutting edge of restored coulter discs were found. Optimal modes of vibration strengthening are established: frequencies and amplitudes of oscillations of the processing tool, time.

The research makes it possible to develop an optimized design of opener discs, which will ensure their high reliability and service life during various operating conditions.

The results of the research will be used to improve the technical characteristics and production technologies of coulter discs, which will help to increase productivity, reduce the costs of repairing seed drills and ensure efficient sowing.

__Keywords:__ seeder, sowing, coulter, seed, disk, sowing device, restoration, reliability, productivity, quality.

Introduction. The intensification of agriculture has posed one of the most important problems of increasing the durability of agricultural machinery, the level of technological maintenance, storage and repair, in which the main costs are spare parts. There are great reserves in increasing the resource of repaired machines, significantly reducing spare parts and saving public labor in the development and creation of new and cost-effective ways of restoring parts [1].

The current state of technical support of the agricultural sector of Ukraine is characterized by a decrease (16...20%) compared to previous years in the amount of equipment and its significant aging, with up to 40% having served their depreciation period [2].

Steel discs of coulters of grain planters are among the parts that need restoration of their dimensions and increase in efficiency.

At present, almost 85% of grain crops in Ukraine fall on the family of seed drills of the SZ type, equipped mainly with disc coulters. The short term of the technologically permissible operation of the discs is caused by the wear of the working surface to a diameter of 320 mm after sowing on an area of about 1300 hectares, which makes it necessary to manufacture them for spare parts in large quantities [3-4].

In this regard, the problem of increasing the durability of worn coulter discs is relevant today.

Analysis of recent research and publications. Modern seed drills use coulter discs for precise sowing and uniform seed dispersal. However, operational conditions, such as uneven ground, moisture and large volumes of work, often lead to breakdowns and reduced productivity due to disc wear [4-6].

As a result of abrasive wear of the cutting elements of tillage machines, their restoration is necessary. Existing methods of restoration are aimed at reducing the rate of wear by using wear-resistant materials and effective manufacturing and restoration technologies. Chemical and thermal treatment, plastic deformation [6-10] can be attributed to the materials for increasing the durability of the specified parts.

Methods of surfacing are used: the method of recovery with a wear-resistant tape, the method of strengthening by friction [6,7,10].

These methods are highly complex, require special expensive equipment, and therefore have not yet been widely used in repair production.

In mechanical engineering, the diamond smoothing method is used for surface strengthening of manufactured parts [6, 10]. In England, the USA, and Japan, the method of applying polymer materials to the surface of parts of agricultural machinery has become somewhat widespread [10-13].

There is a complex method of restoring the opener disk by welding sectors to it with a tungsten electrode in an argon environment with a controlled arc, as well as restoring the disk in diameter by the method of welding in a pass with subsequent strengthening with powders based on sormite, which is difficult, time-consuming and does not provide a full guarantee of the possibility of fatigue failure during operation of coulter disks [13].

The purpose of the work is the development and improvement of technical solutions to increase the reliability and increase the resource of coulter discs of grain seeders, to increase productivity and reduce costs for restoration using vibration strengthening of working bodies.

Materials and methods. The main goal of the modern technical and repair service is the timely provision of agricultural machinery and material resources, maintenance of the machine park in working order and its effective use.

The operation of agricultural machinery is accompanied by the processes of both physical activation of individual machine components and moral aging, the consequence of which is the deterioration of technical and economic indicators of its use. In order to maintain the machine and tractor park in working condition, effective management of the process of periodic maintenance.

The situation with technical support requires new approaches to the formation and implementation of technical policy in agriculture, the main directions of which are the preservation, restoration, repair and maintenance of existing machines in working condition and their effective use [6, 10-13].

When growing agricultural crops, which is one of the leading branches in the general structure of agriculture, the responsible operation that determines the yield is sowing [11]. Both the time of plant emergence and the activity of their growth depend on the quality of its implementation. Annually, about 30 mill. ha of agricultural land. The execution of these works is carried out by the corresponding park of various domestic and foreign planters, which is more than 110 thousand.

Among the large number of domestic agricultural machinery, machines equipped with disk working bodies, both spherical and flat, are quite common. Such machines include grain and grain-grass planters, which, depending on the purpose and conditions of use, are equipped with coulters (anchor, keel-shaped, slide-shaped, tubular, paw-shaped) and disc type (two-disc one- and two-row, two-disc single-row with flanges, single disk). The latter are more and more widely used during the sowing of agricultural crops [10, 11]. Despite the fact that there are more modern models of agricultural machinery, in the total mass, the majority of grain crops fall on the family of planters of the SZ type, equipped mainly with disc coulters.

The main prerequisites for the prospects of using vibration oscillations in technological processes are: intensification of existing technological processes; the possibility of developing new methods of processing materials; reduction of energy consumption. Vibration oscillations made it possible to create new processing methods and technological processes that contribute to the development of resource-saving technologies characterized by higher intensity.

The wear resistance of the surface of parts processed by the vibration method depends on the depth of the strengthened layer, but there are no specific recommendations for its determination in the literature [11-13].

Results. One of the promising methods that make it possible to restore the worn part of the disk to the nominal outer diameter is the method of winding a metal tape made of 65G steel in a cold state [11]. For this, you can use a specialized device with nozzles of different types and shapes.

The main difficulties during the implementation of the repair methods analyzed above are the need to ensure the uniform strength of the welded joint and the resistance of the repaired disc to abrasive wear and sign-changing fatigue failure. Such problems are primarily caused by physical and chemical processes that take place in the welding zone and are accompanied by a change in the structure and properties of 65G steel. As a result, a significant level of residual stress arises, which significantly affects the durability of the disc. Thus, residual tensile stresses reduce the wear resistance of the part when operating in abrasive and corrosive environments, while compressive stresses increase it. To reduce the stress level, as well as to increase the resistance of disks to fatigue failure, in the existing methods of disk repair [10-13] preheating and final heat treatment operations are used. These are the main disadvantages of these processes, since heating and heat treatment costs make up about 20% of the total cost of existing repair methods. Taking into account the conditions of operation and wear of discs, as well as the main shortcomings of the existing methods of their repair, in order to develop a new economically feasible technical process for restoring the working surface according to the outer diameter, it is necessary to solve three main problems: first, the geometric parameters of the welded joint during welding of the repair model the rings so that the connection surface is placed outside and does not interfere with the movement of the seeds (Fig. 1.6); secondly, in the working area of the disk, create conditions for the relaxation of tensile stresses and the occurrence of compressive stresses, which will ensure the necessary fatigue strength and resistance of the disk against wear and at the same time avoid heating and heat treatment operations; thirdly, to develop such a chemical composition of the core of the powder welding wire that ensures the formation of a joint surface with a structure resistant to wear in an abrasive environment without the use of energy-intensive strengthening processes (spraying, surfacing, etc.).

For welding 65G steel, in the case of repairing the coulter disk of a seed drill with restoration of their outer diameter, the most appropriate is the use of flux-cored wire, which can be used to reliably obtain the required chemical composition of the weld [13].

The mathematical model of the method of determining the amount and nature of the distribution of residual stresses in a welded joint with a circular seam, taking into account the boundary conditions, is based on the use of equations of the mechanics of deformable bodies with intrinsic stresses, as well as information obtained using one of the experimental methods, in particular, the method of magnetoelastic tensometry. Assuming that the stress state in the circular weld of the recoverable disk is flat, we first accept the condition of axial symmetry, and the main directions in the case of forming a circular seam will be radial and circular. Accordingly, the stress tensor will have two non-zero components σ_{rr} and $\sigma_{\theta\theta}$, and strain tensor - two independent components ε_{rr} and $\varepsilon_{\theta\theta}$. Then, writing down the equilibrium condition [11-13]:

$$\sigma_{\theta\theta} = \frac{d}{dr}(r\sigma_{rr}), \qquad (1)$$

and taking into account geometric ratios:

$$\varepsilon_{rr} = \frac{dU}{dr}; \; \varepsilon_{\theta\theta} = \frac{U}{r};$$

$$\varepsilon_{rr} = \frac{d}{dr}(r\varepsilon_{\theta\theta}) \qquad (2)$$

r - coordinate in the radial direction; U = U(r) - radial movement, according to the method of conditional plastic deformations [13]:

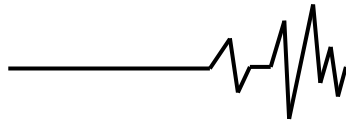$$\varepsilon_{rr} = \frac{1}{E}(\sigma_{rr} - \mu\sigma_{\theta\theta}) + \varepsilon_{rr}^0,$$

$$\varepsilon_{\theta\theta} = \frac{1}{E}(\sigma_{\theta\theta} - \mu\sigma_{rr}) + \varepsilon_{\theta\theta}^0 \qquad (3)$$

ε_{rr}^0, $\varepsilon_{\theta\theta}^0$ - conditional plastic deformations; μ - Poisson's ratio; ε - Young's modulus.

The definition of residual stresses is adapted for the case of a disc repaired by welding with a central technological hole of radius R_0 and a limited radius R.

The general appearance, assembly geometry and dimensions of the restored disk of the seed drill are shown in (Fig. 1). Given that the repaired disc has a process hole, the overall stress state may vary somewhat. Therefore, it is necessary to take into account this factor during the calculation, and then the solution of the problem for a circular plate with a radius of R (radius of the repaired disk R=350 mm) with a technological hole with a radius of R_0 (R_0=16 mm) assuming the following conditions: r = 0, U = 0, can be represented as:

$$U(r) = \frac{1+\mu}{2r}\int_0^r \left[\varepsilon_{rr}^0(\xi) + \varepsilon_{\theta\theta}^0(\xi)\right]\xi d\xi + \frac{r(1-\mu)}{2}\int_r^R \frac{\varepsilon_{\theta\theta}^0(\xi) - \varepsilon_{rr}^0(\xi)}{\xi}d\xi + C_1 r + \frac{C_2}{r}, \qquad (4)$$

C_1 i C_2 - constant integration.

The constants of integration are determined from the following boundary conditions: at the outer edge of the disk at r = R, the radial stresses σ_{rr} = 0; radial stresses on the inner contour at r = R_0 the radial stresses σ_{rr} = 0.

Accordingly, by substituting the boundary conditions into the expressions for determining the residual stresses, we obtain the following system of equations:

$$\int_{r_1}^{r_2} \frac{\varepsilon_{\theta\theta}^0(\xi) - \varepsilon_{rr}^0(\xi)}{\xi} d\xi - C - \frac{B}{R_0^2} = 0, \; r = R_0 ,$$

$$-\frac{1}{R^2}\int_{r_1}^{r_2} (\varepsilon_{\theta\theta}^0(\xi) + \varepsilon_{rr}^0(\xi))\xi d\xi - C - \frac{B}{R^2} = 0,$$

$$r = R . \tag{5}$$

$$\hat{\sigma}_1 = \int_{r_1}^{r_2} \frac{\varepsilon_{\theta\theta}^0(\xi) - \varepsilon_{rr}^0(\xi)}{\xi} d\xi \; \text{and}$$

$$\hat{\sigma}_2 = -\frac{1}{R^2}\int_{r_1}^{r_2} (\varepsilon_{\theta\theta}^0(\xi) + \varepsilon_{rr}^0(\xi))\xi d\xi ,$$

we will obtain a system of equations for determining integration constants:

$$\left. \begin{array}{ll} \hat{\sigma}_1 + C - \dfrac{B}{R_0^2} = 0, & r = R_0 \\[3mm] \hat{\sigma}_2 + C - \dfrac{B}{R^2} = 0, & r = R \end{array} \right\} . \tag{6}$$

The components of the field of plastic deformations can be represented for a class of steels that are not prone to hardening in the form of a special function. It is determined experimentally for each type of welding [13]. Expressions for calculating residual welding stresses, depending on the areas of the repaired disc, are represented by the following ratios:
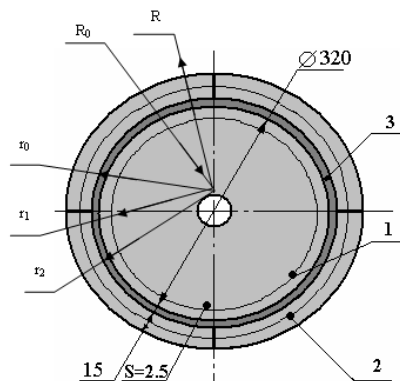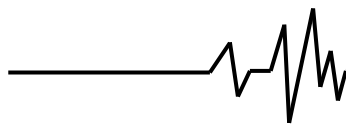
area $R_0 \le r \le r_1$:

$$\sigma_{rr}(r) = -\frac{E\varepsilon_0^*}{2}\left[(1-k)\int_{r_1}^{r_2} \frac{\varphi(\xi)}{\xi} d\xi + \hat{C} - \frac{\hat{B}}{r^2} \right],$$

$$\sigma_{\theta\theta}(r) = -\frac{E\varepsilon_0^*}{2}\left[(1-k)\int_{r_1}^{r_2} \frac{\varphi(\xi)}{\xi} d\xi + \hat{C} + \frac{\hat{B}}{r^2} \right], \tag{7}$$

area $r_1 \le r \le r_2$

$$\sigma_{rr}(r) = -\frac{E\varepsilon_0^*}{2}\left[(1-k)\int_{r}^{r_2} \frac{\varphi(\xi)}{\xi} d\xi - \frac{1+k}{r^2}\int_{r_1}^{r} \varphi(\xi)\xi d\xi + \hat{C} - \frac{\hat{B}}{r^2} \right],$$

$$\sigma_{\theta\theta}(r) = -\frac{E\varepsilon_0^*}{2}\left[(1-k)\int_{r}^{r_2} \frac{\varphi(\xi)}{\xi} d\xi + \frac{1+k}{r^2}\int_{r_1}^{r} \varphi(\xi)\xi d\xi - 2\varphi(r) + \hat{C} + \frac{\hat{B}}{r^2} \right], \tag{8}$$

area $r_2 \le r \le R$

$$\sigma_{rr}(r) = -\frac{E\varepsilon_0^*}{2}\left[-\frac{1+k}{r^2}\int_{r_1}^{r} \varphi(\xi)\xi d\xi + \hat{C} - \frac{\hat{B}}{r^2} \right]$$

$$\sigma_{\theta\theta}(r) = -\frac{E\varepsilon_0^*}{2}\left[\frac{1+k}{r^2}\int_{r_1}^{r} \varphi(\xi)\xi d\xi + \hat{C} + \frac{\hat{B}}{r^2} \right] \tag{9}$$

Fig. 1. Geometric dimensions of the disk 1 - basic part, 2 - sector of the repair ring, 3 - circular weld r_0 - axis of the weld, r_1, r_2 - limits of the zone of plastic deformations, R, R_0 - outer and inner radii of the disk, respectively.

Restoring the outer diameter of the disks involves welding to the base part four sectors, made from non-repairable disks, with a circular seam, followed by the execution of straight lines to connect the sectors to each other (Fig. 2).
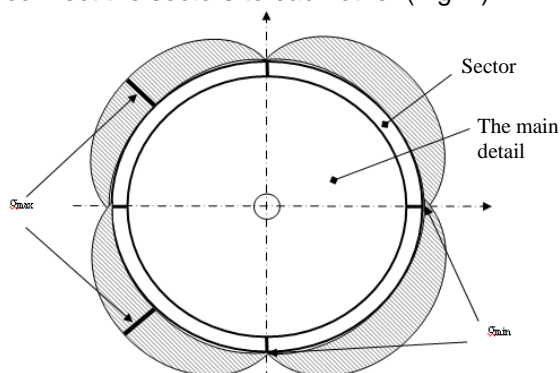
Fig. 2. Distribution of the residual stress state in the repaired disk.

Thus, the technological conditions for disc restoration are such that the residual stresses caused by welding will be cyclically symmetrical with the period $T = 2\pi/3$.

To accurately determine the components of the stress tensor σ_{rr} and $\sigma_{\Theta\Theta}$ we build a solution to the problem and use the data in sections where the stresses are maximum (Fig. 2). Thus, in the cross-sections of the welded joint, the residual stresses calculated on the basis of the solution slightly exceed the actual stresses, which, when calculating the durability of the disc, increases its margin of strength.

Therefore, the developed mathematical apparatus and the available data make it possible to take into account the real state of operation of the part (change in the stress field due to man-made or natural influences) and to obtain the value of stresses at any point of the welded joint with a circular seam of a thin-sheet disk part made of high-carbon or alloy constant and limited by the radius.

Conclusions. The level of permissible stresses and the microstructure of the working area, which ensure the necessary resistance of the repaired disc to abrasive wear, have been determined.

A mathematical model has been developed that adapts the calculation method of determining the residual stresses for a circular joint when welding a disk part made of 65G steel, taking into account the boundary conditions and structural transformations in the zone of thermo-deformation influence.

Taking into account the features of the non-destructive method of determining the characteristics of the stress state and the means of measurement, a functional is proposed, the minimization of which makes it possible to determine the parameters of the field of plastic deformations and calculate the residual stresses at an arbitrary point of the circular welded joint of the repaired coulter disc of a grain seeder.

Ensuring the reliability of coulter discs is an important task for maintaining the efficiency of grain planters to increase the duration of their service and the efficiency of crop cultivation.

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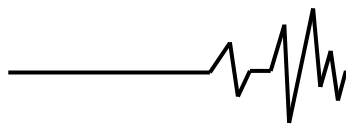
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ЗАБЕЗПЕЧЕННЯ НАДІЙНОСТІ ДИСКІВ СОШНИКІВ ЗЕРНОВИХ СІВАЛОК

Проведено дослідження яке спрямовано на вивчення проблем надійності дисків сошників і запропонування шляхів, способів відновлення та оптимізацію конструкції сошників зернових сівалок для максимізації їх надійності та довговічності.

Зернові сівалки в сільському господарстві відіграють ключову роль у процесі вирощування врожаю. Однак, однією з найважливіших складових цих агрегатів є диски сошників, які часто піддаються впливу агресивних умов та великих фізичних навантажень. Забезпечення надійності дисків сошників зернових сівалок є ключовим аспектом в аграрному виробництві, оскільки ефективність технологічного прцесу сіби напряму впливає на врожайність та якість сільськогосподарських культур.

Проведений ретельний аналіз геометрії та матеріалів дисків для виявлення слабких місць та потенційних джерел спрацювань а також визначення основних факторів, які призводять до їх зношення і руйнування.

Визначені значення і розподіл залишкових напружень в матеріалі нового диска і відновленого приварюванням трьох сегментів зі сталі з наплавленням сормайтом і вібраційним зміцненням.

Знайдені значення ступеня зміцнення матеріалу ріжучої кромки відновлених дисків сошників.

Встановлені оптимальні режими вібраційного зміцнення: частоти і амплітуди коливань обробного інструменту, час.

Визначені оптимальні параметри дисків сошників: зовнішній діаметр, товщина ріжучої кромки, кут леза, що забезпечує їх найменший знос і якість сівби зернових.

Наведені результати зміни товщини диска і зносу його по діаметру підчас стендових досліджень нових дисків та відновлених приварюванням сегментів зі сталі 45 з автоматичним наплавленням сормайтом і вібраційним зміцненням.

Аналіз дослідження дозволить застосовувати використання сучасних програм для моделювання та симуляції для визначення динаміки та напружень, які виникають під час експлуатації дисків сошників при сівбі.

Дослідження дає можливість до розроблення оптимізованої конструкції дисків сошників, які забезпечать їхню високу надійність та тривалість служби під час різних умов експлуатації.

Результати дослідження будуть використані для вдосконалення технічних характеристик та технологій виробництва дисків сошників, що допоможе збільшити продуктивність, зменшити витрати на ремонт сівалок та забезпечити ефективну сівбу.

Ключові слова: сівалка, сівба, сошник, насіння, диск, висівний апарат, відновлення, надійність, продуктивність, якість

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