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The development and justification of the opening plow parameters of grain-sowing-grassy seeder and increase its service life of the working surface

ABSTRACT

on dissertation work PhD - doctoral student Kosatbekova D.Sh. for the Doctor of Philosophy (PhD) degree on the speciality 6D072400 - Technological machines and equipment

Relevance of the research work

The problem of pasture degradation and provision of quality fodder for farm animals is relevant for all regions of Kazakhstan. According to the cultural and technical condition, more than 30-35% of pastures are overgrown - 23.5 million ha, stained - 1.4 million ha, forested - 3.6 million ha, stoned - 4.7 million ha, covered - 7.7 million ha, knocked down - 26.6 million ha. Degraded pasture areas are as follows: in the foothill plain - 3.8 million ha, in the desert zone - 13.2 million ha, in the forest-steppe and steppe zones - 5.6 million ha. There are 8.3 million ha of overgrazed pastures [1, 2, 3]. Low productivity of fodder lands, especially in unfavourable years due to unfavourable moisture conditions, does not allow to provide the existing livestock of farm animals with adequate fodder. The situation is aggravated by the lack of special equipment for restoration and improvement of pastures. The domestic industry currently does not produce seeders for sowing small-seeded crops. For sowing small-seeded crops, grain seed drills not adapted for grasses are used, which cannot provide seeding with the necessary rate, resulting in significant overconsumption of seeds. In addition, when sowing under cover crops and in turf, seed drill coulters are subjected to intensive wear due to the density of the soil-grass cover and have a short service life.

Availability of the necessary set of agricultural machinery is the main condition for competitive development of the agro-industrial complex of the RK. Today, there are 149.8 thousand tractors, 38 thousand combines, 4.9 thousand sowing complexes and 76.3 thousand seeders, as well as about 219 thousand units of various tillage tools. Thus, according to the Ministry of Agriculture of the Republic of Kazakhstan, the average wear and tear of the machine and tractor fleet is about 80%. The share of extremely worn out main types of agricultural machinery (older than 15 years) is: tractors - 79%, combines - 54%, seeders - 86%, reapers - 63%. At the required technological level of renewal of 10 ÷ 12.5% per year, today renewal is only within 1 ÷ 3%. The use of outdated equipment leads to an increase in fuel costs by 20% and production reduction by 14% [1-2].

Currently, the research on the development and formation of the System of machines for pasture livestock breeding, on which the Ministry of Agriculture of the Republic of Kazakhstan has made a number of decisions on the revival of the industry at a new level, is in demand. The significance of the research lies in the need to make strategic science-based decisions on a number of key problems, such as the introduction of innovative technologies and machinery for the restoration of degraded pastures, increasing the productivity of hayfields, the use of information

technology to control and manage the processes of pasture animal husbandry, i.e. agriculture needs the development of modern, science-based system of technologies and machines that meet the world level.

Consequently, the development of technology for restoration and improvement of meadows and pastures and technical means for restoration of knocked down pastures, development and transformation of fallow lands withdrawn from agricultural turnover and improvement of productivity of old age crops of perennial grasses is the most important problem facing the agro-industrial complex of the RK.

The work was carried out within the framework of the project №AP05134800 «Development of automated grain-fertilizer-grass seeder for differentiated direct sowing of crops under cover crops and turf with simultaneous application of mineral fertilisers» under the grant of the Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan.

Purpose of the research

Improvement of sowing quality and resources of seeder work by justification of the constructive scheme and rational parameters of coulter for direct sowing of agricultural crops under cover crops and in turf.

Research Objectives:

- to study the technological process and determine the factors affecting the quality of direct seeding under cover crops and in turf, work resource and justify the constructive-technological scheme of coulter;
- theoretically and experimentally justify rational constructive and technological parameters of the coulter;
- to substantiate the optimum parameters of the surfacing mode of the coulter bit surface and to investigate the service life of the hardened bit of the grain and grass seed drill;
- to test in production conditions the performance of the coulter for direct sowing of crops under cover crops and in turf and to give technical and economic evaluation of the efficiency of its application.

The object of research - technological processes of direct sowing of agricultural crops in turf and hardening of the working surface of the coulter bit of the grain and grass seed drill.

The subject of the research is the regularities of influence of design and technological parameters of the coulter on the quality of sowing and properties of coatings on the resources of coulter operation.

Research methodology

1. Theoretical studies were carried out by applying the main provisions of classical and earth mechanics, tribology, engineering and materials technology and metal technology.

2. Mathematical and computer simulations were carried out on the basis of

laboratories of the Department of «Technological Machines and Equipment» of S. Seifullin KATRU. Planning of experiments were carried out by the programme of central composite rotatable planning of the second order by the method of Box-Wilson and polynomials of the second degree describing the region of optimum were obtained. Factor values and desirability functions were determined in an industrial experiment (DOE) in Statistica 10 and Statistical Analysis Software (SAS) (SAS Institute, Cary, NC 27513, USA). Dependency plots and the best-fit values of the factors were obtained using the Box-Behnken method.

3. The established parameters and wear of the working organ of the grain and grass seeder were justified by computer modelling in SOLIDWORKS and ANSYS programs by the finite element method (FEM), and in LS-DYNA program by the SPH method.

4. Strengthening of samples, macro and microstructural studies were carried out on the basis of laboratories of the department of ‘Technological Machines and Equipment’ of S. Seifullin KATRU. Used methods of wear resistance increase: surfacing with carbide electrodes T590 and CS-1 by arc welding VDM-2x313 U3; high-frequency current heating of chisels under hardening in electric furnace of chamber laboratory model SNOL 12/12-V. The state of worn surface layers of coulter chisels for the presence of defects in them was studied by ultrasonic defectoscope model A1212 MASTER. Biomed MMR-1 microscope was used for microstructural analysis and MET U1 hardness tester was used to determine the hardness of the investigated surfaces.

5. Field tests of serially manufactured and hardened samples of coulter chisels were conducted in spring sowing campaigns 2019-2020 in soil and climatic conditions of Akmola region of Kazakhstan on ordinary chernozem (moisture 25 - 45 %, soil contamination with stones with an average diameter of 0.050 m was 0.6 - 1.5 pcs/m²) at sowing of sowing vetch (spring), creeping clover and alfalfa on a machine-tractor unit consisting of a wheeled tractor of traction class 2 + seed drill.

6. Laboratory studies were carried out in the soil channel to determine the traction resistance of the working organ of the grain-fertilizer-grass seeder. To determine soil moisture the T-350 Aquaterr device was used and for soil density the Wile density meter (ASAES313.3) was used.

Research novelty:

- technological and constructive parameters of coulter for direct sowing of agricultural crops under cover crops and in turf have been substantiated;
- regularities of interaction of the experimental sample of the ploughing working tool with soil were revealed;
- dependence of coulter traction resistance on parameters of cultivated soil layer and its physical and mechanical characteristics, progressive speed of the working organ and angles of its installation, solution and friction has been obtained;
- optimum parameters of the surfacing mode of the coulter chisel surface were substantiated.

The main points to be defended:

- design-technological scheme of the experimental sample of the coulter of a grain and grass seeder;
- theoretical dependence of coulter traction resistance on its design and technological parameters and soil characteristics;
- equation of dependence of hardness of the clad layer on structural, technological and operational factors, equations of dependence of clad layer thickness and machining allowance on cladding modes;
- models of unitary stress distribution on the coulter bit and in the soil, wear of the working part.

Practical significance consists in designing the design of the grain and grass seed drill and preparation of its mock-up and experimental samples, determination of the optimal design parameters of the coulter, optimal values of cladding modes to increase the life of the chisel, development of the methodology of research of abrasive wear of the chisel in special computer programmes. The drawings of the planter were transferred to the machine-building company ‘AGRITECH-KATU’ LLP for implementation and further commercialisation. In LLP ‘Tselinselmash Astana’ implemented recommendations on the selection of the surface of the working surface to increase wear resistance, the method of hardening and increasing the working stock of grain-fertilizer-grass seeders.

The validity and reliability of scientific provisions, conclusions and results are confirmed by the correctness of the problem statement, adequacy of theoretical and experimental studies. Patents of the Republic of Kazakhstan (RK, №34241 and №34242) and the Eurasian Patent Office for the design of a grain and grass planter (№38584) have been obtained.

Performance of work

Research work on the thesis was carried out within the framework of the grant theme №AP05134800 ‘Development of automated grain and grass seeder for differentiated direct sowing of agricultural crops under cover crops and in turf with simultaneous application of mineral fertilisers’. The results of the dissertation work are implemented in JSC ‘Akmola-Phoenix’ Tselinogradsky district of Akmola region (2020) and LLP ‘Tselinselmash-Astana’ (Astana, 2024).

The author's personal contribution consists in setting of tasks and development of research methodology; development of designs and preparation of mock-up and experimental samples of grain-fertilizer-grass seeders, determination of optimal parameters of the coulter chisel and the method of its hardening, planning and carrying out of experimental studies of the coulter chisel of grain-fertilizer-grass seeders with optimal parameters on the distribution of unitary stresses and on the wear of the working part.

Approbation of the work

The main provisions of the doctoral thesis were reported and discussed at:

- Scientific and practical conference of young scientists ‘Contribution of young scientists in innovative technologies for agro-industrial complex’ (Shortandy, 2019);
- international congress ‘VII International scientific congress. Agricultural machinery 2019’ (Burgas, Bulgaria, 2019);
- international scientific-practical conference ‘Technical support of innovative technologies in agriculture’ (Minsk, 2020);
- Republican and international scientific-theoretical conferences ‘Seifullinskije readings’ (2018, 2021);
- meeting of the Department of TMO NAO ‘Kazakh Agrotechnical Research University named after S. Seifullin’ (2023);
- Council of the Faculty of ‘Technical Service in agro-industrial complex’ of the Belarusian State Agrarian Technical University (Minsk, Republic of Belarus, 2020).

Publications

According to the results of the doctoral dissertation, 17 works have been published in Russian, Kazakh and English languages, including: 2 articles in the international scientific edition, according to the Clarivate database or included in the Scopus database, 5 articles in the editions recommended by the Committee for Quality Assurance in Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan, 1 article in the RSCI database. The reports of the presented work were considered at 6 international and republican conferences. 2 RK patents for invention, 1 Eurasian patent were obtained.

Scope and structure of the work

The doctoral thesis consists of an introduction, 5 chapters and a conclusion, set out in 175 pages of typewritten text, which are explained by 92 figures, 30 tables, a reference list of 134 titles, 6 appendices.

Evaluation of the completeness of the solutions to the set tasks.

According to the results of the thesis work it can be considered that the goals and objectives have been achieved:

1. The technological process of sowing has been investigated and the factors influencing the quality of direct sowing under cover crops and in turf, the resource of work and the constructive-technological scheme of the coulter have been determined.

2. Rational constructive and technological parameters of the coulter are theoretically and experimentally substantiated. The design of the grain and grass seeder is approved by patents of the Republic of Kazakhstan (№34241 and №34242) and Eurasian Patent Organization (№38584).

3. Optimal parameters of the surfacing mode of the coulter bit surface are substantiated and the service life of the hardened grain and grass seed drill bit is investigated;

4. The performance of the coulter for direct sowing of agricultural crops under cover crops and in turf has been tested in production conditions and the technical and economic evaluation of its application efficiency has been given.