Increasing agricultural automation in conditions of international integration

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Abstract. The development and use of a set of highly automated agricultural machinery is necessary to ensure the effective involvement of agricultural land and the development of the land amelioration complex. The work analyzes the prospects for the development of the market of highly automated machinery and shows the barriers that obstruct the development of this market in Russia and in the world. The paper describes the steps to overcome these barriers. The authors substantiate the actuality of creating normative technical and legal bases, as well as the necessity of creating a center for testing agricultural and forestry tractors for compliance with the safety regulations. The paper explains international and Russian standards for safety requirements for products of the highly automated machinery. The paper presents the activities that need to be carried out in order to use highly automated agricultural machinery.

1. Introduction specifying the purpose of work

Analysis of the current and projected situation in Russian agriculture showed the following trends (Figure 1). In the period from 1990 to 2019, there was a process of steady decline in the working population in rural areas. Starting from 2013, the number of cultivated areas began to grow steadily, with a forecast of the further increase until 2030.

Taking into account this trend, the Ministry of Agriculture of the Russian Federation has developed a state program for effective involvement in the turnover of agricultural land and the development of the land amelioration complex. The draft government decision on its approval is posted on the portal of draft normative legal acts of Russia. The proposed term of the state program implementation is 2021–2030; its cost exceeds 1.41 trillion rubles [2].

The planned steps will allow increasing the export of agricultural products, improve the quality of life in rural areas and bring the standard of living the rural population closer to the urban level.

The government's draft decision provides for the involvement of at least 12,000,000 hectares of agricultural land in circulation by the end of 2030, with an annual input of 700,000 hectares in 2021–2022; 900,000 hectares in 2023–2024 and 2025 — 1,300 thousand hectares; in 2025–2030 — 1,500 thousand hectares.

Comparing the indicators of development of cultivated areas with the forecast of population growth in agricultural areas while bringing the quality of life of the rural population to the urban level, we conclude positive preconditions for intensive development of the market of the effective highly automated agricultural machinery and equipment.
2. Problem setting
Reveal the activities carried out by the Russian government to overcome some of the main barriers that negatively affect the development of production and use of highly automated autonomous machinery in the agricultural production in Russia, as well as the directions and planned activities for the development of the tractor products through the creation of legal and regulatory and technical regulations in Russia.

3. Results
The research was conducted using the analytical method [3-5] through monitoring of government documents, newsletters, and websites of international organizations.

The trend towards the development of highly automated tractor-implement units (HATIU) and their use is observed in many countries of the world (Table 1). The evaluation was made based on expert opinions of Fraunhofer Institute for Experimental Software Engineering IESE in cooperation with Kleffmann Group (KG) in 2019 [6]. According to this estimate, by 2045 in the vast majority of countries of the world, it will be expected 10–50 percent of the total number of fully autonomous machines.

Automatic machine systems are widely used in various industries. Until now, the automated machinery has been used in closed areas (e.g. ports and mines) and AGV automated forklift trucks and highly maneuverable robot systems are used in factories and warehouses in various countries.

At the moment, along with the high capacity for production of the highly automated tractor-implement units (HATIU), their successful production and use in the agricultural production in Russia is held up by the lack of:
- Regulations for interaction between the HATIU and GPS-GLONASS satellites and the cellular network;
- Standards for the safe operation of the HATIU;
- Regulations and unified technical norms of the digital field;
- Regulations of uniform parameters for field digitization;
- Regulations for certification of a unified line of digital equipment parameters;
- Unified technical regulations of the HATIU;
Unified parameters of communication with connected equipment from different manufacturers (ISOBUS);
- Unified regulations for interaction between the machine and the smart field infrastructure;
- Unified regulations of the smart field and its infrastructure;
- Unified regulations of telemetric parameters;
- Regulations on the protection of software and equipment against electromagnetic field interference;
- Regulations on the protection of software against intentional interferences;
- Regulations on the encryption of control channels;
- Regulations on the protection of software and hardware against external influences;
- Regulations for work procedures in the presence of moving and stationary obstacles;
- Regulations for agricultural and other works;
- Regulations for actions in case of emergencies;
- Regulations on the infrastructure of the digital field.

Table 1. Forecast of the highly automated machinery market development by 2045.

| World markets needs | Fully human driven (without technical assistance) | Assistance to a person (technical assistance, such as GPS) | Controlled autonomous | Fully autonomous machine |
|---------------------|--------------------------------------------------|--------------------------------------------------------|----------------------|-------------------------|
| North America and Australia (high technologies, large markets) | < 10 % | < 10 % | 50 - 80 % | 10 - 50 % |
| Western European markets (high technology) | < 10 % | < 10 % | > 80 % | 10 - 50 % |
| Small Asian markets (large markets) | 10 - 50 % | 10 - 50 % | 10 - 50 % | 10 - 50 % |
| Latin America (low technologies, large markets) | < 10 % | 50 - 80 % | 10 - 50 % | 10 - 50 % |
| African and Middle East markets | 50 - 80 % | 10 - 50 % | < 10 % | < 10 % |
| Eastern European markets | < 10 % | 10 - 50 % | < 10 % | 10 - 50 % |

Regulatory issues are being solved by ISO technical committees (TC):
- TC 127 – Earth-moving machinery;
- TC 110 – Industrial trucks;
- TC 82 – Mining;
- TC 23 – Tractors and machinery for agriculture and forestry;
- TC 22 – Road vehicles;
- TC 96 – Cranes;
- TC 299 – Robotics.

And by two technical committees (TC) of IEC:
- TC 44 – Safety of machinery. Electrotechnical aspects;
- TC 9 – Electrical equipment and systems for railways.

Analyzing information from ISO, IEC, and other standards, as well as technical reports from various sectors of industry, the areas of application of the highly automated machinery were studied: mobile mining equipment, mobile port equipment, earthmoving machinery, agricultural machinery, forestry
equipment, construction machinery, industrial cranes, industrial trucks and AGV trucks, and industrial robots, etc.

In practice, the terminology of highly automated technology is still very diverse. The terms “Unmanned”, “Highly automated”, etc. are used in scientific articles and standards. There is an inconsistency in definitions.

In the sector of mobile machinery, ISO 17757 defines the terms “autonomous work” and “autonomous machine” as follows [6]:

Autonomous operation is “a mode of operation in which the mobile machine performs all safety-critical functions of the machine, as well as excavation or mining functions related to its specific operations, without operator intervention. The operator may provide the destination or navigation input, but is not required to confirm the control during operation”.

An autonomous machine is “a mobile machine that is designed to operate offline during its normal operating cycle”.

The ISO 18497 standard specifies requirements for automation used in agricultural machinery and tractors [7]. ISO 3691-4 specifies the requirements for unmanned forklift trucks, robotic AGV trucks, and related systems [8].

Safety requirements have been studied, in terms of the characteristics of perception systems installed for off-road vehicles and autonomous vehicles (robots) that can be applied to off-road vehicles, such as those related to automatic driving, automatic navigation, braking, and collision avoidance.

The main problem in the development of autonomous mobile machinery was the requirements for sensor systems to detect people. Since the main risks associated with autonomous mobile work equipment are associated with a collision between a machine and a person due to the movement of the machine, tool, or payload, the movement of a person, so it is necessary to identify people. Current sensors have the problem that they do not detect a person upon failure. Failure in most cases is caused by various adverse external conditions. Also, the sensors have some measurement limits beyond which their operation is impossible. Unfortunately, these limits are often unclear and the sensitivity of the sensor decreases gradually as their operating conditions worsen. Changing outdoor conditions are a major source of the sensor failures. Currently, there are no standard definitions for external conditions. The sensor performance requirements may include work in the mist, dust, snow, etc., but without defining the levels of outdoor conditions.

Based on the analysis, two main problems were identified in standardizing safety requirements for the autonomous machinery:

1. There is a gap between the requirements established in the previous standards and the current level of technology and development. The existing standards imply full compliance of the manufactured products with the established technical standards. There are problems with the adjustment of the existing changing highly automated machines to the requirements of standards.
2. The existing safety standards are mainly intended for machine designers and manufacturers. The standards do not take into account the ethical principles of machine interaction with humans and the operating environment. At the design stage, the workflow and operating environment should determine the application of types and systems of autonomous equipment.

The development of the market for the highly automated agricultural machinery is largely obstructed by regulatory and legal barriers. The main problem is the uncertainty of liability in the event of an accident due to the lack of legal regulation of the use of unmanned vehicles, which is expressed by the absence of the following documents:

- The legal basis for the use of highly automated tractor-implement units;
- The legal status of entities engaged in the development and production of the highly automated machinery;
- The legal status of subjects testing the highly automated machinery;
- The legal status of subjects who are the owners of the highly automated machinery;
The legal framework that defines the operators’ activity, the legal prescription that regulates the person's behavior in the field of the HATIU management;
- The legal status of the digital field that regulates the level of danger by the similarity to a dangerous object;
- Technical regulations and database on the ownership, access, and use of accumulated data of the software;
- Technical regulations and database on ownership, access, and use of accumulated data of readable telemetry information to individuals and legal entities, state structures.

Measures to ensure favorable conditions for the development of the market of the highly automated machinery for the agricultural production should include:
- Creation of legal and regulatory and technical basis for testing and use of the highly automated tractor-implement units;
- Creation of specialized equipped testing centers and training of personnel for the HATIU testing, including laboratories for software security testing and laboratories for control channel security testing, testing platforms for testing control systems in adverse environmental conditions.

For the development of the market of unmanned agricultural machinery and its admission into circulation in agriculture, the Center of Agricultural Engineering of FSUE “NAMI” [9–11] participates in the joint development of regulations based on current standards and technical regulations (Table 2) on the admission to the operation of tractors, road-building and other self-propelled machines with a high degree of control automation for the testing period, on the requirements for proving grounds for testing of the highly automated machinery, on safety requirements and methods of conformity assessment of tractors, self-propelled road-building and other self-propelled machines with a high degree of control automation.

**Table 2.** Existing regulatory and legal framework for safety in the operation of agricultural and other equipment in Russia.

| Environmental monitoring conducted directly by the mechanic | Autonomous environment monitoring system |
|------------------------------------------------------------|------------------------------------------|
| GOST 12.2.140-2004                                         | International standard ISO/FDIS 18497.2 |
| System of labor safety standards. "Small-sized tractors. General safety requirements". | Agricultural machinery and tractors. Safety of highly automated agricultural machines. Design principles. Adopted in October 2018. |
| GOST 12.2.019-2005                                         |                                          |
| System of labor safety standards. "Tractors and self-propelled machines. General security requirements". |                                          |
| GOST ISO 12.1.00-2013                                       |                                          |
| Interstate standard. Safety of machines. "Basic principles of design. Risk assessment and risk reduction". |                                          |
| Technical Regulation of the Customs Union 031/2012          |                                          |
| "On safety of agricultural and forestry tractors and their trailers". |                                          |
| Technical Regulation of the Customs Union 018/2011          |                                          |
| "On wheeled vehicles safety"                               |                                          |
| Technical Regulation of the Customs Union 010/2011          |                                          |
| "On safety of machinery and equipment".                    |                                          |
| Resolution of the Government of the Russian Federation No. 740 of August 1, 2016 |                                          |
| "On Determining Functional Characteristics and Efficiency of Agricultural Machinery and Equipment". |                                          |
4. Conclusion

With a proper approach to the problems discussed in the work, joint search and implementation of solutions not only by producers of component base and machinery for agricultural purposes but also by government agencies, scientific institutions, educational organizations, it is possible to obtain a high-quality and competitive product that will make a breakthrough in the development of the domestic agricultural engineering and make a leap in the development of rural areas.

References

[1] A project of State Program for the effective involvement of agricultural land and the development of the land amelioration complex of the Russian Federation. Retrieved from: https://www.agroinvestor.ru/analytics/news/33051-minselkhoz-razrabotal-gosprogrammu-vovlecheniya-v-oborot-selkhozzemel/ (accessed 15.07.2020).

[2] Orlov A I 2012 Organizational-economic modeling. In the 3rd volume. Statistical methods of data analysis: a textbook (Moscow: Bauman Moscow State Technical University) p 623

[3] Kulaichev A P 2013 Methods and means of complex data analysis: a training manual (Moscow: Forum, SIC INFRA-M) p 512

[4] Kravchenko I N, Kolomeichenko A V, Logachev V N et al 2015 Basics of scientific research: a textbook (St. Petersburg: Lan Publishing House) p 304

[5] Retrieved from: https://www.iese.fraunhofer.de/de/presse/current_releases/PM_2019_1108_autonome-landwirtschaft.html (accessed 15.07.2020).

[6] ISO 18497:2018. Agricultural machinery and tractors – Safety of highly automated agricultural machines – Principles for design

[7] ISO 3691-4:2020. Industrial trucks – Safety requirements and verification – Part 4: Driverless industrial trucks and their systems

[8] ISO 17757:2019. Earth-moving machinery and mining – Autonomous and semi-autonomous machine system safety

[9] Solovev R Yu, Cheranev S V, Karyakin S B, Kolomiichenko A V, Gribov I V 2019 About the center of agricultural engineering Technical service of machines 4 12-18

[10] Solovyov R Y, Cheranev S V, Karyakin S B, Kolomeichenko A V, Gribov I V 2019 Importance of Development of High-tech Tractors of 0.6-2 Traction Classes with High Degree of Automation Technics and equipment for rural areas 11(269) 14-17

[11] Solovyev R, Cheranev S, Karyakin S, Kolomeichenko A, Gribov I, Evgrafov V, Mezentsev N 2020 The need for creation of high-tech tractors of 0.6-2 traction classes with high degree of automation IOP Conference Series: Materials Science and Engineering 012026