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Metrological support characteristics for life cycle of agricultural machines

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Metrological support characteristics for life cycle of agricultural machines

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Abstract. Statements stated in this paper prove the essential role of the influence of metrological support on the quality parameters of complex equipment at each stage of the product life cycle. When designing aggregates and technological units, it is necessary to ensure the given accuracy of the sensors, while manufacturing technology, significant savings can be achieved due to the use of a more expensive and accurate measuring instrument. When operating machines, constant monitoring of power consumption, fuel, productivity, speed and other technological parameters with a given accuracy is required.

1. Introduction

Metrological support at each stage of the product life cycle, in particular, high-technology equipment for the agricultural sector, is a necessary element of economic activity; it is subject to the same trends as the quality economy. Measurements and control are constantly involved in the areas of production and services, and the results of measurements and control have a significant impact on losses and costs [1].

A feature of modern technological processes is an increase in the share of labor costs for performing measurements and continuous monitoring at all stages of the design, production, testing and operation of equipment and technologies [2], with an average component of about 10%, and for complex technologies this value actually increases to 50 %

There are up to 800 thousand manufacturing enterprises, organizations, and laboratories in the agro-industry of Russia. They have a constant need to improve measuring, testing and control instruments, in modern laboratory equipment that allows one to obtain reliable information, to effectively manage agricultural production, and conduct research. The list of measuring control and automation instruments includes about 1000 items, and the total number of measuring instruments is more than 30 Mio units [3]. According to Rosstandart, more than 1.5B units of measuring instruments for various purposes are used in the national economy of Russia.

When operating it is necessary to periodically check the measuring instruments used in the areas of state regulation, the rest are subject to calibration. The use of measuring, control and automation instruments is always accompanied by the development of measurement techniques and assessment of accuracy.

As the requirements for product quality and ensuring its safety increase, new means of measurement, control and automation are used at agricultural enterprises. In Russian industries, the use of foreign measuring equipment has increased due to the purchase of machinery and technical equipment, which on the one hand increases the dependence on the import of spare parts, components, standard and consumables, and on the other, increases production costs.

2. Research ideologies

Note that improving the quality of machinery, equipment and complex special-purpose equipment for agriculture is always associated with an objective tendency of strict limits applied to the characteristics of materials, assembly units and components, for example, rotary seals of oil-lubricated assemblies, the reliability of which is associated not only with failure risks equipment and subsequent repair costs, which leads to forced outage and crop losses, but also with the risk of potential pollution [4]. The gaps in the cylinder - piston group of internal combustion engines increase according to the parametric failure model [5], and it is possible to estimate not only the failure itself, but also the beginning of a decrease in power and an increase in polluting emissions. Similar models are also used for pressure coupling [6]. The increased accuracy of maintaining the modes of technological processes performed by this technique leads to the need to conduct control directly while soil cultivation or harvesting. This increases the quality requirements for metrological support of the entire product life cycle - equipment for agriculture (figure 1).

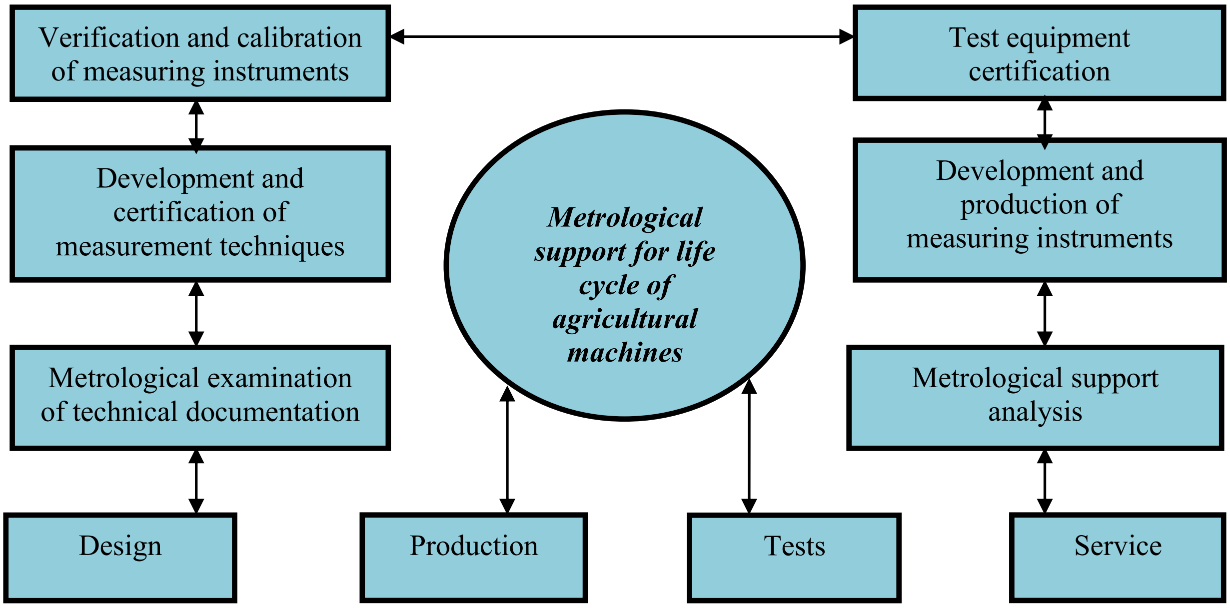

Figure 1. Metrological support of complex equipment at all stages of the product life cycle.

3 Research results and their analysis

At the design stage of complex agricultural equipment, it is necessary not only to ensure the principles of measurement traceability, the designed parts testability, but also to incorporate measuring transducers and sensors in the designed assembly units that meet the accuracy standards, to install them properly, guaranteeing not only long-term operation, but also the smallest measurement error in technological process parameters.

When choosing sensors, it is useful to use an approximate inequality between the possible limits T (scattering, tolerance) of the controlled parameter and the measurement error Δ:

$$\Delta \leq (0{,}1\ldots0{,}3)T \qquad (1)$$

The methodology for selecting the fittings of agricultural machinery is noteworthy. So, for cylindrical joints with a key, interference fit was calculated, instead of old fittings with a gap, which allowed increasing the wear resistance of joints from 3 to 12 times [7]. But the accuracy of these landing has increased significantly. Instead of dimensional tolerances according to IT8 ... IT9, tolerances IT6 ... IT7 have been used, which means that the permissible measurement error decreased by 3 times, i.e. previously used measuring instruments to control such shafts and holes is absolutely impossible. Therefore, any technological measurements in the process of designing or finalizing the components and assemblies design must necessarily be accompanied by n metrological support analysis of the process.

At the production stage, at each stage of the technological process, there is control over the dimensions, weight, geometry and other parameters of parts and assembly units. Most of the controlled geometric parameters are standardized in the Unified Tolerance and Landing System [8]. Moreover, modern equipment usually performs control automatically using various measuring instruments and sensors. It is at the production stage, as a result of the designation of tolerances and landings of high accuracy, measuring instruments with a small error are required.

With mass production, special control machines and measuring modules are designed trying to minimize losses from measurement error due to the installation of high-precision optical measuring and control instruments.

With serial manufacturing, universal measuring instruments are used. Meanwhile, type 1 and type 2 errors of control occur, which can be reduced by using a more accurate measuring instrument.

The savings from reducing improperly rejected parts with more accurate measurements can be calculated using the formula [9].

$$Э_{\text{п}} = N \cdot C_{\text{д}} \cdot (n_{(1)} - n_{(2)}) \cdot 0{,}01, \tag{2}$$

where N – production programme; $C_{\text{д}}$ – product cost (part); $n_{(1)}$ and $n_{(2)}$ – the number of improperly rejected products when using the first and second measuring instruments.

The savings from reducing the number of improperly received parts with more accurate measurements can be determined by the formula [9]

$$Э_{\text{m}} = N \cdot З_{\text{у}} \cdot (m_{(1)} - m_{(2)}) \cdot 0{,}01, \tag{3}$$

where $З_{\text{у}}$ – the cost of eliminating the defective part in the unit; $m_{(1)}$ and $m_{(2)}$ – the number of improperly received products when using the first and second measuring instruments.

Engines of the Yaroslavl Motor Plant have gained in wide popularity due to the fact that tractors, combines and special machines for agriculture manufactured there have simplicity of design, ensure reliability and maintainability. One of the most important parts of the engine is the crankshaft, in which there are four connecting-rod bearings and five main bearings, which are subjected to continuous control after finishing. Consider a simple example of the control accuracy influence on the economic results of an enterprise. The table 1 shows the calculation of the savings from replacing the ICh 10 head with a reading accuracy of 0.01 mm in the Si 100 indicator bracket with a digital head - the Ic 10 indicator with a reading accuracy of 0.001 mm when monitoring the connecting-rod bearings of the YaMZ engine crankshaft with a production program of 1000 shafts per year.

Table 1. The results of calculating the savings from replacing the measuring instrument with a more accurate.

Indicators	Symbol	Values for measuring heads	
Indicator bracket	Si 100	ICh 10-0,01	Ic 10-0,001
Controlled size	-	$88_{-0{,}015}$	$88_{-0{,}015}$
Size scattering zone	ω	21 μm	
Measuring accuracy	Δlim	±5 μm	±1 μm
Price of bracket with head assembly	Ц	5600 Rub	12300 Rub
Measurement accuracy coefficient	$A_{\text{мет}}$	16,7 %	3,3 %
Number of improperly received shafts	m	0,77 %	0,19 %

Number of improperly rejected shafts	n	5,61 %	0,68 %
Crankshaft cost	C	65000 Rub	
The cost of eliminating the consequences of installing a defective shaft in the engine	$З_у$	24000 Rub	
Shaft production program	N	1000 pc.	
Savings from reducing improperly rejected shafts	$Э_n$	3 200 350 Rub.	
Savings from reducing the number of improperly received shafts	$Э_m$	139 200 Rub	

The table proves that with the right approach to the metrological support of production, there is a significant savings from the reduction of improperly rejected parts in the amount of 3 million rubles with a production program of 1000 shafts per year only when replacing the measuring head with an error of ± 5 μm with a head with an error of ± 1 μm.

When testing machines and tractors, a number of universal and special measuring instruments and systems are used. There is control over power consumption, fuel, productivity, speed, etc. As an example, tests of YaMZ engines can be given as a result of which the rated power is determined. Power is a parameter of indirect measurement and the error of power measurements is affected by both the error of the tachometer - a means of measuring the rotational rate, and the error of torque measurement, which is also indirectly determined by the energy expended during braking of the electric motor of an internal combustion engine.

During the operation of equipment, constant monitoring of the efficiency of machines is carried out; many parameters are monitored during maintenance [10]. In case of inconsistencies, the repair is needed, where, as at the production stage, it is necessary to control the quality of spare parts, parts, and materials [11, 12]. Moreover, during engine overhaul, the same control operations are used as in mechanical engineering, and acceptance tests of engines are also carried out [13]. A feature of machine repair is the need for fault detection of worn parts, i.e. continuous monitoring is carried out twice - before and after repair, where it is also necessary to use the principles of metrological support. In Russia, such a field of activity as maintenance and repair of machinery refers to services; services are not subject to mandatory certification, therefore, state control and supervision in the field of metrological support is not carried out there. The repair fund is quite worn out and there are no technological bases that were used in the manufacture of parts. The control, especially during the fault detection, is carried out not at the edges of the size scattering zone, but in the middle, which leads to an increase in the number of improperly received and improperly rejected parts. If, due to measurement error, the equipment goes into repair ahead of schedule, economic losses will form from an unperformed production process and early repair costs. What is more, if due to control errors, the equipment fails during intensive field work, there will be significant losses from untimely harvesting and non-compliance with deadlines for storing the agricultural products.

4. Conclusions

Thus, the essential role of metrological support for complex equipment at all stages of the product life cycle is proved, which provides the specified quality of technological processes in agriculture. It is shown that at the stage of machine production it is possible to achieve significant savings through the use of more expensive and accurate measuring instruments, and the achieved savings are much higher than the cost of measuring instruments. When operating machines, constant monitoring of power consumption, fuel, productivity, speed and other technological parameters with a given accuracy is essential, which requires continuous implementation of metrological support functions. When repairing complex equipment for the agro-industrial complex, metrological support is doubly important due to the deterioration of the repair fund and the characteristics of the defect and control processes.

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