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The introduction of a mixed system of maintenance and repair of metal-cutting equipment

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Abstract. The article provides a comparative analysis of the Russian and foreign systems for the maintenance and repair of metal-cutting equipment. The limitations of the application of systems of universal maintenance of equipment , scheduled preventive maintenance and repair by state are analyzed . The influence of the age of the equipment and the percentage of the repair plan on the amount of emergency shutdowns is shown . The main stages of the introduction of mixed service and repair systems are highlighted. Criteria for classifying equipment groups are proposed for the selection of repair and maintenance systems. Examples of typical diagnostic signs of malfunctions of metal-cutting equipment and statistical time of emergency shutdown after their detection are given. The recommendations on planning the need for spare parts and organization of repair work are given .

1. Introduction

The change in the structure of the metal-cutting equipment park, the increase in the price and, accordingly, the cost of an idle hour, make the traditional system of preventive maintenance (PPR) ineffective , the standards of which were developed back in the 60s of the last century [1]. S systems maintenance work in other industrialized countries are based on different principles. In Europe, USA, Canada, this system has the name "service system". In Japan, South Korea and other Asian countries, the “conservation system”.

Machine-building US factories PPR system is used for high-performance equipment of I with a big boot, and the scope of the outage in the enterprise is subject to continuous analysis, with a view to identifying and addressing the changes taking place in the loading of individual machines and their importance for the production as a whole. The system of standard durations for equipment maintenance periods is individual for each piece of equipment, based on statistical data. The duration of these periods depends on the admissibility of performing part of the repair work in an unscheduled manner (the degree of importance of the equipment for the enterprise and its load are taken into account). It can be concluded that the system of preventive maintenance in the United States is quite flexible in nature (the system does not provide for certain amounts of scheduled maintenance and servicing), relies on the analysis of statistical data for past periods and is based on economic calculations. This system is different in different enterprises and has a non-permanent nature, it is a service system “by state” [2] .

In Japan, in the early 70s, a system of universal care for TPM equipment was developed (Total Productive Maintenance) within the framework of the Toyota production system . The TPM system has its own philosophy as a central figure, which is a person , therefore, it is often considered as a tool for lean manufacturing or a “world-class production” tool (WCM) [3]. A qualitative improvement in the state of the equipment is achieved by using TPM due to a coordinated change in two factors. The first is the professional development of a person: employees of an enterprise should be able to independently perform daily maintenance and maintain the performance of high-tech equipment. The second is the modernization and design of equipment with the full life cycle, requiring minimal maintenance and repair [4], [5].

There are organizational differences in carrying out repairs at Russian and foreign enterprises. At the Russian enterprises, the repair services are divided into separate divisions and are highly specialized (group mechanics, energy, etc.). At foreign enterprises, the technical manager of the equipment company is responsible for the work. The absence of mechanical repair shops at enterprises, determines one of the fundamental features of the repair production - almost no repair with complete disassembly of equipment is used. Repairs are performed by replacing parts that have become unusable on factory-made parts. In terms of the purchase of spare parts for electronic trading schemes, the duration of the purchase of original factory assemblies can be up to 3 months, and the equipment unit’s idle time is more than 2 thousand rubles.

2. Formulation of the problem

The main goal of equipment maintenance and repair is to ensure uninterrupted work and reduce the time spent in repairs. Consider whether it is possible to eliminate unscheduled repairs when using the traditional CPD system.

To check the effectiveness of planned repairs, a correlation-regression analysis was performed depending on the number of unscheduled repairs (y) on equipment age (x_1) and the percentage of fulfilling the repair plan (x_2) for two years (2014-2016) in quarterly breakdown by mechanic production of an enterprise where machines of different types are installed.

As a result of data analysis, the following mathematical model was obtained

$$y = 3{,}29 \cdot x_1 - 0.26 \cdot x_2 , \tag{1}$$

The model according to the criteria of statistical significance is reliable. The value of the coefficient of determination R- squared is 0.811, which suggests that there is a close relationship of indicators, and the influence of the age factor is greater than the percentage of the implementation of the CPD plan. It can be assumed that there is an age limit at which the fulfillment of repair plans for 100% excludes the possibility of emergency shutdowns (y = 0). According to our calculations, this is possible with an average age of equipment not more than 8 years.

According to the Rosgosstat, the average age of equipment for manufacturing industries is 12 years [1] , and in individual enterprises and equipment groups even more. With an average age of equipment of the analyzed production of 12 years, the number of unscheduled repairs , even if the schedule of maintenance and repair is observed, will be 13.5 cases per quarter.

Thus, the PRD system, even under the condition of 100% fulfillment of planned tasks, does not guarantee the absence of unscheduled repairs. Consequently, the loss of time associated with the emergency stop of the equipment remains. In addition, the cost of full scheduled maintenance of equipment is higher than with systems that use elements of repair as.

Restrictions on the implementation of a universal equipment service (TRM) system, in our opinion, are related with the motivation of workers and are common for the introduction of all tools of lean manufacturing. An additional factor hindering the introduction of TRMis the piece-bonus form of remuneration that is common in machine-building enterprises. The time rate should include the cost of servicing the workplace as a percentage of operating time, but their value in the total piece time, which determines the rate, is insignificant, and when introducing CNC machines this component is often taken into account as a time component of passive observation. Problems of implementation of TSR are considered in [6] .

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The state of the repair system requires the development of a large array of statistical data for reasons of failures, the introduction of advanced equipment diagnostics methods, and the improvement of spare parts supply systems.

The solution is to combine the principles of various systems, allowing you to optimize repair costs and downtime in both planned and emergency repairs.

3. Concept

The first stage of the introduction of a mixed repair system is the classification of equipment into three main groups depending on its age, load, degree of progressiveness and loss per hour of inactivity. The classification of equipment groups is presented in Table 1.

The first group consists entirely of modern progressive equipment. On this equipment, planned work is carried out in accordance with the technical passport and operating instructions. The passports contain time intervals for monitoring and replacing hydraulic and lubricating oils, coolant, filters, etc. The system of preventive maintenance , based on equipment certificates , is applicable here .

Table 1. P repair and maintenance equipment

Equipment group	Assignment criteria				Introduced repair and maintenance approach
	age	Load factor	Additional criteria	Cost of machine hours of work, rub.	
Group number 1	less than 5 years	More than 0.8	progressive imported equipment	More than 2000	Scheduled repairs and maintenance carried out in accordance with the technical passport and operating instructions
Group number 2	From 5 to 10 years	More than 0.8	High maintainability	700-2000	Repair of equipment according to its actual condition
Group number 3	Over 10 years	-	-	-	Emergency stop repair

The second group of equipment is represented by various types of equipment, but they are united by high workload. The big advantage of the equipment of this group is its high maintainability. Almost all nodes can be disassembled and repaired. This equipment has all the necessary documentation for its repair. This equipment has been well studied by maintenance personnel and machine operators, which allows early detection of characteristic deviations from the normal operation of the machine and does not bring it to an emergency stop. For this system, a repair system by actual condition is suitable.

Equipment group number 3 is the largest, represented by small machines, which have spare capacity in the shop . Most of this equipment has developed its potential and has significant wear. But due to the fact that the equipment does not have a high repair complexity, the machines are maintained in good condition. An emergency stop repair system should be used for this equipment.

The second stage of work is the creation of a statistical base for diagnosing faults. A two-year analysis of faults in the equipment of the second group allowed us to create a list of signs of major faults and determine the time from the first detection of a symptom to stopping the machine. A fragment of the list is given in table 2.

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Table 2.Signs of equipment malfunction group №2

.	Time to emergency stop, days	Name of the spare part	Term of purchase (manufacture) of spare parts , days
Model machines: 1D325, NR-44 (turning-turret)			
Increased body temperature of the coolant motor	thirty	Bearing 60205	14
	thirty	Filter element (mesh)	1 (production)
Increased noise of the main drive of the machine	3	A-900 belt	thirty
Unstable feeder operation	7	Microswitch MP-1101 isp. one	60
Increased noise in the gearbox	thirty	7506 bearing wear	14
	45	Gear wear	50 (production)
Increased temperature of the electromagnetic clutch box speeds	2	Copper tube 5x0,5	1 (production)
Vibration when the main spindle is running	one	A-1500 belt	thirty
The noise in the electrical panel when turning on the main drive	2	Magnetic starter PME-221-380	60
The noise in the electrical panel when turning on the feed drive	2	Magnetic starter KMI-22510-25A	60
The smell of insulation out of the box speeds	one	Electromagnetic clutch ETM-122-1N	60
Periodic shutdown of the machine when switching speeds	five	Brush holder EShchM-2A-60 / M18	60
Short-term working light shutdown	one	Lamp LPO 36h60	60
	3	Wire PV-3x0.75	60
Model machines: 1B240-6, 1A240-6 (automatic lathes)			
Beating, spindle vibration	five	Bearing 3182118	60
Noise during operation of main drive	15	Bearing 6314	60
	2	A-1180 belt	60
The noise in the electrical panel when turning on the main drive	2	Magnetic starter KMI-34012-40A-110	60
Increased body temperature of the oil pump motor	five	Bearing 6203	60
Periodic shutdown of the machine in the adjustment mode	15	MP-2101 microswitch isp.3	60
When shutting down the working feed, the camshaft makes an overrun by 10-15 degrees	one	Electromagnetic clutch ETM-102	60
When moving from accelerated to working stroke, there is an overrun of the camshaft	one	Relay RT-5	60
Periodic shutdown of the machine on the working course	five	Brush holder EShchM-2A-60 / M18	60
Periodic shutdown of the machine on the accelerated course	five	Brush holder EShchM-2A-60 / M18	60
Model machines: KD-2326 (hydraulic presses)			
Increased temperature of the electric motor of the hydraulic station	3	4WE6D6X directional valve	60
The noise in the hydraulic station when switching to idle	7	Directional control valve 2WE2D	60
The noise in the hydraulic station when switching the working and accelerated progress	7	Directional control valve 2WE2D	60
The noise in the electrical cabinet when the working stroke is turned on	2	Relay REK78 / 3-24	60
The increase in time during the transition to idle	one	Timer VL-6-3	60
Model machines: multimat 130m, 3E183 (centerless grinding machines)			
Increased temperature of the motor separator coolant	2	Worm Gear Gearbox	50 (production)
The noise of the electric motor hydrostation	15	Bearing 6012	60
Reduced coolant consumption	20	Filter element	1 (production)
Not stable work leading circle	five	Hydrodistributor K2141-06	60

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The fault base allows you to plan in advance repair work and order spare parts. Similar work is being done on machines of the 1st group.

The third stage of work is the optimization of the planning system and the purchase of spare parts. To do this, the ABC (at the annual cost of consumption) and XYZ- analysis (at the regularity of consumption) used spare parts. For category AH, direct annual stock planning is applicable with regular deliveries based on the established fault base. . For categories Z (A, B, C) - it is possible to purchase as needed, using a supply scheme with a single supplier.

The fourth stage of work is to ensure timely recording of faults as an element of the TPM system for all groups of equipment. The reason for stopping or malfunctioning the machine is not always obvious (there is no reliable data about the failed node, only assumptions about the group of nodes appear). Often, after restarting the machine, the error automatically resets and the equipment starts up again in normal mode. In such cases, a mandatory mark is required in the equipment repair logbooks to identify the dynamics and frequency of failures.Mostly such situations occur on high-tech equipment with high workload and hard-to-reach nodes, which become an obstacle to more detailed diagnostics. As an example of an implicit reason for the basis of the equipment, we give the shutdown of a Moller circuit breaker. pilz-012- S 4, on an EMCOTURN E45 CNC lathe. According to the wiring diagram, this automatic switch serves as protection for a number of machine components (hydraulic drive, cooling drive, spindle drive, etc.). After a number of assumptions and minor repairs, the problem remained unsolved. After two days of work with shutdowns, based on observations of a similar machine installed in the workshop, it was revealed that the hydraulic drive has a more frequent switching mode. It was also found that there is no inert gas pressure in the hydrocompensator. After refueling the problem has been fixed.

The organization of effective repair and maintenance of equipment requires changes in the organization of repair services. To increase the level of work, a brigade service is required, in which each team will be responsible for the proper operation of the equipment assigned to them. In case of separate maintenance, the so-called “circulation” occurs, the main essence of which is to fully delegate the causes of breakdowns from one production group to another, during which a large amount of time is lost, as well as the quality of diagnostics, which is the necessary criterion for planning the order of spare parts for early failure of equipment.

As an example, we give a stop of the KMX 413 CNC machine. During the operation of the equipment, an error appeared: the lack of cooling of the spindle. After the initial inspection by repairmen, a preliminary conclusion was made that the reason lies in the electrical part. When inspecting the machine by an electrician, it turned out that we need to call electronics engineers. After a joint diagnosis of electronics engineers, it was concluded that the coolant control valve is faulty. This element is not collapsible, and repair will be made only with its replacement. At this point, repair technicians replaced the coolant. After the release of air from the system, the equipment worked normally. The above example fully reflects the existing interconnection of repair services .

4. Conclusions

An effective equipment repair system must combine elements of various systems. For each subdivision, grouping should be carried out according to their specific and individual characteristics (workload, availability of reserve capacity, operating conditions, etc.) and a system of equipment maintenance corresponding to the criteria should be selected.

A prerequisite for the formation of a preventive maintenance system and the system as it is is the accumulation of a statistical base of causes for equipment shutdowns, indications of their preliminary diagnosis, which requires timely and correct maintenance of equipment maintenance documentation. The accumulated statistical base will also improve the procurement plan for spare parts, which is relevant in the conditions of electronic trading. Reducing downtime can only be achieved by proactively acquiring components, and for this you need:

- Early diagnostics of malfunctions, improvement of the quality of service and work (assignment to a separate equipment repair team), increasing the responsibility of operators;

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- Modernization of equipment, replacement of imported spare parts with analogues, the possibility of manufacturing spare parts on their own;
- Improving the order tracking system, electronic submission of applications, regular tracking of the current order status;
- High-quality documentation in the repair of equipment.

An important condition is a change in the motivation and organization of work of both key workers and maintenance personnel. For repair services it is advisable to use the brigade form of work organization. Attach a repair crew to each piece of equipment. To increase the responsibility of equipment operators for the timely identification of serious and minor deviations from the normal operation of the machine.

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