Methods of improving service quality and increasing the reliability of locomotives registered in operational locomotive depot Agryz in the locomotive service depot Agryz-South

A T Kozlova

Abstract.
The method for managing the technological processes of repairing diesel locomotives registered at the Agryz operational locomotive depot in the Agryz-Yuzhny service locomotive depot using network planning has been developed to monitor and adjust the performance of technological operations, taking indicators of technological preparation of repair into consideration. Using improved non-standard equipment in technological processes of current repairs of diesel locomotives with motor-axial rolling bearings allows mechanization of technological operations during the assembly of a wheel-motor unit to improve the quality of the technological process and reduces the time spent in repair. Assembly operations have a special place in mechanical engineering. It is at this stage that various connections of individual parts and assemblies arise and indicators of the reliability of a technical object are formed.

1. Introduction
The method for managing the technological processes of repairing diesel locomotives registered at the Agryz operational locomotive depot in the Agryz-Yuzhny service locomotive depot using network planning has been developed to monitor and adjust the performance of technological operations, taking indicators of technological preparation of repair into consideration. The proposed algorithm makes it possible to estimate the necessary transitional equipment, spare parts and materials to ensure high-quality performance of technological processes for repairing diesel locomotives of the 2TE25KM, TEP70 series and consumption rates of materials at unscheduled repairs, considering the likelihood of failures in operation. The developed method monitors and manages the quality of technological repair processes and assesses the efficiency of using mainline diesel locomotives based on predicting additional power losses in limiting nodes and units based on the results of the repair [1,5]. Using improved non-standard equipment in technological processes of current repairs of diesel locomotives with motor-axial rolling bearings allows mechanization of technological operations during the assembly of a wheel-motor unit to improve the quality of the technological process and reduces the time spent in repair.
2. Maintenance and repair as a system to maintain the technical condition and efficiency of using main diesel locomotive

Nowadays, the operational reliability of traction rolling stock becomes significant, which is directly impacted by the increase in speeds, in weight standards and the requirements for train safety. The operational reliability of diesel locomotives is significantly influenced by timely and high-quality maintenance and repair, the quality of which, in turn, depends on the level of technological readiness of the locomotive repair production [2,4]. The problem of repair becomes especially urgent during the renewal of the locomotive fleet, when old machines are replaced by locomotives of new series with modern control systems, electrical equipment and new designs of the mechanical part and traction drives, such as TEP70BS and 2TE25KM. There are 29 diesel locomotives of the TEP70BS series and 23 diesel locomotives of the 2TE25KM series in the assigned fleet of the Agryz operational depot.

In general, the following main directions can be distinguished in the complex of issues of organizing high-quality repair of locomotives:
- availability of complete sets of design and technological documentation;
- technological equipment of workplaces and areas;
- staffing of workshops and departments with repair personnel of appropriate qualifications;
- material and technical supply;
- availability of the necessary production space.

All this determines the technological readiness of production. Technological preparation of the repair of railway rolling stock is a set of measures that ensure technological readiness to perform repairs on time with the specified technical and economic indicators at the required quality level. The requirements for the technological preparation of repairs are based on the Unified System for the Technological Preparation of Production and, in general, are aimed at solving the following problems:
- implementation of technological processes;
- design of technological equipment;
- tool preparation;
- providing the enterprise with means of transportation and storage;
- development of methods for technical control of technological operations and processes.

The design of technological processes takes a key position when preparing locomotive repair enterprises for the maintenance of new series locomotives, since the technical documentation prepared according to the GOST requirements contains comprehensive information about the necessary technological equipment, tools for performing operations, as well as the norms of time for their implementation. Thus, it is possible to assess the real need for resources (personnel, time, etc.), to determine the future layout of sites.

The continuity of the transportation process on railway transport makes it necessary to carry out maintenance and repair of rolling stock in the shortest possible time with minimal losses for the main technological process. The rolling stock of railways is subject to intensive exploitation, i.e. loads and wear, and therefore needs timely and high-quality maintenance and repairs to restore serviceability and performance.

The maintenance and repair system can be defined as a set of measures that allow the rolling stock to be kept in a given technical condition, providing a certain level of performance.

At present, the issue of choosing methods for organizing maintenance and repair of rolling stock, individual units, assemblies and parts have become relevant in addition to choosing a repair system [3].

In Russia, the operational locomotive depot is separated from the service locomotive depot. In the Agryz service locomotive depot, as in other regions of Russia in the field of mainline railway transport, a planned preventive system of maintenance and repair (M and R) of rolling stock has also been adopted, which is the main one in restoring the serviceability and operability of the locomotive fleet.

2.1 One of the advantages of service is an integrated approach to the organization of technological processes. Among the reasons for the transition to service maintenance, there is a lack of a reliable and effective supply of spare parts in the preventive maintenance system.

The Agryz-Yuzhny service locomotive depot has the opportunity to obtain spare parts directly from the locomotive manufacturer and trusted suppliers of parts and assemblies. This significantly reduces the level of prices, counterfeit goods and increases the efficiency of the maintenance and repair system.
Let us consider how the technical condition of the locomotive fleet is ensured in the service system. As of 01.01.2019, there are 23 units of diesel locomotives of the new 2TE25KM series manufactured in the conditions of the Bryansk Machine-Building Plant in 2019 in the registered (inventory) operational locomotive depot Agryz.

On average, five diesel locomotives are in the unexploited fleet per day (21.7% of the assigned depot fleet). This is caused by a large number of unscheduled repairs, overruns in scheduled repairs due to the lack of necessary spare parts for equipment and the unavailability of the Bryansk Machine Building Plant to provide a service locomotive depot Agryz-Yuzhny in the required amount for replacement during scheduled and unscheduled repairs [6-7].

At present, the interaction of service and operating enterprises in the Russian Railways system is evaluated on the basis of reliability and efficiency indicators, which are taken as the technical readiness coefficients, compliance with the standards for the duration of scheduled maintenance and repair, the reduced cost of scheduled maintenance and repair according to GOST R 56046-2014.

The technical readiness coefficient (TRC) is the ratio of the time that railway equipment is in working condition to the total duration of operation in a given time interval, including all types of maintenance and current repair:

$$TRC = \frac{T_{WC}}{T_{WC} + T_{OR} + T_{pl}},$$

(1)

where

$T_{WC}$ is the total residence time of locomotives in working condition in the considered period of operation;

$T_{OR}$ is the total time spent by locomotives in an inoperative state in connection with their repairs due to failures of established types in the considered period of operation;

$T_{pl}$ is the total time spent by locomotives in an inoperative state in connection with their scheduled preventive maintenance and current depot repairs in the considered period of operation.

The coefficient of compliance with the standards for the duration of planned maintenance and repair ($K_s$) is the ratio of the standard duration of scheduled maintenance or repair of locomotives of a given series relative to the actual duration of scheduled maintenance or repair of these locomotives

$$K_s = \frac{T_{N.m(p)}}{T_{A.m(p)}},$$

(2)

where

$T_{N.m(p)}$ is the normative duration of planned maintenance or maintenance of locomotives in this series;

$T_{A.m(p)}$ is the actual duration of scheduled maintenance or current repairs for the same type of locomotive.

The coefficient of the present value of planned maintenance and repair is the ratio of the actual cost of planned types of maintenance and repair for a certain calendar period of time to the cost of planned types of maintenance and repair for the same calendar period of time established by the regulatory documentation

$$S_{m(p)} = \frac{C_{a.m(p)}}{C_{s.m(p)}},$$

(3)

where

$C_{a.m(p)}$ is the actual cost of planned types of maintenance and repair for a certain calendar period;

$C_{s.m(p)}$ is the cost of scheduled maintenance and repair for the same calendar period established by the regulatory documentation.

1.3 Coefficient of output and technical condition of locomotives.

The locomotive productivity is assessed by quantitative and qualitative indicators.

The quantitative indicators of the locomotive fleet should include:

– mileage of locomotives in locomotive-kilometers;

– operating hours of locomotives in locomotive hours;

– the traffic volume in gross ton-kilometers.

Qualitative indicators expand the possibility of obtaining a more accurate assessment of the operation of locomotives and the locomotive complex as a whole. They can be roughly divided into three groups:

– by the time of using locomotives;

– by using locomotive power;

– by locomotive performance.
The power and productivity of locomotives are largely determined by their energy efficiency, which is taken as the absolute, specific or relative amount of consumption or losses of energy resources. The coefficient of performance (COP) is a value that characterizes the perfection of the processes of transformation, the transmission of energy, which is the ratio of useful energy to the supplied energy. This allows evaluating the energy efficiency of a locomotive. Thus, efficiency can be used as an indicator of locomotive utilization.

The quality indicators also include the total percentage of faulty locomotives, which reflects the technical condition and quality of repair and maintenance of locomotives. The indicator is expressed as a percentage measurement of the ratio of the front of locomotive repair to the fleet of locomotives at the disposal of the operational depot. It reflects the state of the repair base of the service depot and the degree of reliability of locomotives.

A decrease in the percentage of faulty locomotives is ensured by:
– improving the quality of performance and the technological processes of repair of locomotives;
– reduction of downtime for repairs;
– introduction of a diagnostic option for organizing service production and improving the professional culture of locomotive crews of the operational locomotive depot and employees of the service locomotive depot.

Thus, to ensure the reliable operation of locomotives and the efficiency of their use, it is necessary to maintain their performance and regulatory technical and energy indicators in operation. This is mainly determined by the quality of maintenance and current repair.

3. Locomotive failures in operation. Indicators of reliability and productivity of mainline locomotive

To determine the main standard indicators (mileage rates, lists of work performed by type of repair, etc.) when performing service maintenance and current repair of traction rolling stock, it is necessary to establish and study the parameters that determine the patterns of wear, distribution of failures and the resource of parts and units of the locomotive.

The presence of these parameters would draw up a plan for maintenance and current repairs. Intervals between inspections and other maintenance and repair work are established for each part or assembly, depending on their reliability [8]. Besides, the amount of necessary spare parts and time standards for their repair and replacement are determined.

Thus, the most important task of any service locomotive depot is to monitor the locomotive fleet and technological support of repairs. The processing of big data for monitoring the reliability of locomotives is impossible without using mathematical and statistical methods that allow obtaining an actual objective assessment of the technical condition of the fleet based on the results of operational tests. Unsatisfactory provision of service locomotive depots with material resources, including linear equipment, and low qualification of repair personnel are some of the reasons for the increase in locomotive overtime for scheduled and long-term unscheduled repairs [10].

The duration of downtime of locomotives for maintenance or current repair directly depends on the volume and organization of work, on the reliability and maintainability of the repair facility.

For 12 months of 2019, according to the responsibility of SLD Agryz-Yuzhny, there admitted:
- Event - 6 cases (2018 - 4 cases), target - 5 cases (+16.6%).
1) 06.01.2019 TEP70 № 566 - Malfunction of the differential pressure gauge (malfunction in the plug connector - short circuit in the electrodes).
2) 03.11.2019 TEP70BS № 233 - Lack of diesel oil in the diesel crankcase due to its leakage through the technological hole of the diesel camshaft drive (69th group) thanks to unscrewing the technological plug.
3) 26.04.2019 TEP70BS № 278 - There is no automatic start of the diesel engine when controlled from both control cabins on semi-sets "A, B". When checking the control unit BU30T3-06M of the electronic speed controller ERCHM30T, the absence of signal transmission to the actuator was detected.
4) 10.06.2019 TEP70 No. 563 - Fracture of the fan wheel blade of the additional circuit as a result of the weakening of the blade landing on the hub in the fan wheel disk, followed by an imbalance of the
wheel, its wedging and the creation of increased oil pressure in the hydraulic system, which led to the squeezing out of the gasket in the bypass valve, and also a fracture of the blade along the old crack.

5) 22.09.2019 TEP70BS No. 072 - Self-excitation failure due to a malfunction of the power switch block BSK 27.T.245.08.00.001.1 No. 8067732 UOI of the MSU-TE system with the subsequent loss of the electrical circuit to the KVG 2 contactor.

6) 16.09.2019 TEP70BS No. 233 – A violation of the procedure for installing the copper-plated gas joint ring, as well as the moment of pulling the cylinder cover, which led to the breakdown of gases and the destruction of the rubber seals of the rings installed between the cylinder sleeve and the cylinder cover, followed by the flow of coolant through the control holes 8th cylinder.

Failures 1.2 categories - 53 cases (55 cases (3.6%) - 2018), the target - 44 cases (25%).

334 cases of unscheduled repairs of diesel locomotives registered in TCHE Agryz (+34% of the target indicator (249 cases) and -5.6% of those allowed by HP in the same period of 2018 - 354 cases of unscheduled repairs).

- by series of locomotives, unscheduled repairs registered in TCHE Agryz were distributed as follows:
  2TE25KM - 9 cases (0 cases- 2018); TE10 v/i - 118 cases (186 cases - 2018); M62 v/i - 47 cases (37 cases - 2018); TEP70 in / and - 73 cases (82 cases - 2018); PME3 v/i - 87 cases (49 cases - 2018).

By the type of equipment, HP were distributed as follows: - diesel - 97 cases (128 cases -2018); auxiliary equipment - 35 cases (43 cases -2018); malfunction of other equipment: Failure of the automated control system - 44 cases (70 cases -2018), untimely withdrawal from TO-2 due to the fault of SLD - 9 cases (15 cases -2018); - electrical equipment - 69 cases (46 cases -2018); - TED –38 cases (14 cases -2018); - braking equipment - 21 cases (15 cases -2018); - fire alarm - 1 case (0 cases -2018); - the crew unit (CP, TRP, KZP) - 13 cases (8 cases -2018); - safety devices - 7 cases (15 cases -2018).

Non-production losses (without downtime in anticipation of HP and on HP) for the repair of diesel locomotives amounted to 499.76 thousand rubles registered in TChE Agryz for 12 months of 2019:
- TE10 v/i - 432.9 thousand rubles; - M62 v/i - 15.94 thousand rubles; - TEP70 v/i - 18.466 thousand rubles; - ChMEZ - 32.455 thousand rubles.

Distributed by equipment:
- diesel - 221.8 thousand rubles; - auxiliary equipment - 126.76 thousand rubles; - braking equipment - 35.72 thousand rubles; - electrical equipment - 52.88 thousand rubles; - TED - 54.654; - crew equipment (KP, MOP, KZP, TRP) - 10,135 thousand rubles.

The number of unscheduled repairs of locomotives registered in TCHE Agryz by responsibility for 12 months of 2018/2019:
- SLD-59 - 110 cases (127 cases -2018); - SLD-55 - 30 cases (30 cases -2018); - SLD-57 - 24 cases (29 cases -2018); - SLD-58 - 35 cases (45 cases -2018); - SLD-61 - 30 cases (9 cases -2018); - other SLDs - 29 cases (32 cases -2018); - Factories - 7 cases (1 case -2018); - Russian Railways - 69 cases (81 cases -2018).

The number of unscheduled repairs of locomotives registered in TCHE Agryz by category of malfunction for 12 months of 2018/2019:
- Production - 167 cases (205 cases -2018); - Degradation - 96 cases (64 cases -2018); - Operational - 71 cases (85 cases -2018).

The number of unscheduled repairs of locomotives registered in TCHE Agryz with distribution by blocks:
- Technology (group of the chief technologist) - 8 cases (22 cases -2018); - Personnel - 66 cases (84 cases -2018); - Spare parts and materials - 7 cases (3 cases -2018); - Production (elimination of remarks in TU-152) - 72 cases (58 cases -2018); - OTC - 14 cases (38 cases -2018).

Downtime of diesel locomotives registered in TCHE Agryz for 12 months of 2018/2019 due to admitted HP (in hours):
- Awaiting for HP – 33986 h. (24462 h. – 2018);
- HP – 14241,34 h. (15926 h. – 2018).

Average idle time of diesel locomotives registered in TCHE Agryz for 12 months of 2018/2019 due to admitted HP (in hours):
- Awaiting for HP – 100,15 h. (89,12 h. – 2018);
- HP – 42,15 h. (48,11 h. – 2018).
Downtime of diesel locomotives registered in TCHE Agryz for 12 months of 2018/2019, due to admitted unscheduled repairs, with distribution by series in thousand rubles:

- **TE10**: Costs for downtime pending – 1016 thousand rubles; Costs for HP – 1313.8 thousand rubles;
- **М62**: Downtime costs – 15.5 thousand rubles; Costs for HP – 8.21 thousand rubles;
- **TEP 70**: Downtime costs – 798.6 thousand rubles; Costs for HP – 1339.6 thousand rubles;
- **ChMEZ**: Downtime costs – 510.6 thousand rubles; Costs for HP – 366.6 thousand rubles.

Unscheduled repairs are mainly associated with the occurrence of system failures (traction motors, mechanical equipment, and electrical equipment). The main reason for the failures was poor quality maintenance or current repairs.

Traction motors, traction gears, wheelsets and electric devices can be identified as the main components and assemblies that limit using power and the operability of mainline diesel locomotives.

### 4. Technology management and quality of locomotive repairs

4.1 One of the tasks of the Agryz-Yuzhny service locomotive depot is to manage the technological processes of maintenance and routine repair of diesel locomotives. Their results are reducing the time for maintenance and repair of locomotives, also the number of over-cycle works, timely replenishment of inventories, ensuring the quality of technological processes [9]. Thanks to this, labor productivity is significantly increased; the cost of servicing diesel locomotives and their repairs is reduced. An important management function is planning and analysis of the availability of spare parts and materials for technological processes. Automation of technological process control increases the availability of locomotives and depot equipment.

One of the options for implementing production management of locomotive repair is network planning. Network planning is a method that is based on using the mathematical tools of graph theory and a systematic approach to display and algorithmization of complexes of interrelated works, actions or activities to achieve a clearly defined goal. Network planning determines, firstly, which works or operations are "critical" in their impact on the total calendar duration of the repair and, secondly, how to build the best plan for all work on this repair in order to meet the specified deadlines at a minimal cost.

The task of network planning is to graphically, visually and systematically display and optimize the sequence and interdependence of works, actions or activities that ensure the timely and systematic achievement of ultimate goals. For displaying and algorithmizing certain actions or situations, economic and mathematical models are used, which are usually called network models, the simplest ones of which are network graphs.

Analysis of the network schedule highlights those works, on which the total duration of the entire complex of works depends. The number of such jobs is small compared to the total number of jobs on the network. On average, the number of critical jobs, as a rule, does not exceed 10-15% of the total number of jobs in network models.

When using usual methods of planning a complex of works, it is not uncommon to reduce the duration of all or most of the works while reducing the total period of its implementation. This approach, as a rule, did not give the corresponding effect, since it required additional costs and slightly reduced the duration of the entire complex of works. Optimization of the network schedule reduces the duration of the critical path by carrying out a number of measures: varying the time indicators of events and works, using the aggregate-nodal repair method, redistributing resources between critical and non-critical works.

The feasibility of any event, the acceptability of the planned timing of its implementation, the effectiveness of the proposed organizational measures should be determined based on how they influence the corresponding indicators of the entire network model of locomotive repair.

After reducing the duration of work along the critical path, the network model is recalculated again to determine the sufficiency of the measures taken and to find out if new critical paths have appeared. If the new version of the network schedule did not ensure compliance with the established service intervals, then the whole procedure is repeated until a satisfactory result is obtained. In other words, bringing the network model in line with the established repair period for locomotives is carried out by consistently improving the original version of the plan with the required number of recalculations. At the same time,
to decrease the number of recalculations of the network model to its indicators, measures should be taken to reduce the work not only on the critical, but also on the subcritical paths \[11\].

One of the urgent tasks for any repair enterprise is to ensure technological readiness, which is influenced by scheduling, which efficiently uses the technological resources of the enterprise, ensures the continuity of the technological process and high quality of service.

Using network planning in the Agryz-Yuzhny service locomotive depot significantly simplifies the process of technological preparation of service production; make it transparent and easily reconfigured. Besides, network planning facilitates the depot's transition to a quality management system due to strictly prescribed time standards for performing technological operations, material consumption rates, processing modes and control methods.

This approach is proposed to be implemented on the basis of a model for quality management of technological processes of locomotives' repair using network planning within the automated control system (ACS) "Network Schedule", used to control and adjust the performance of technological operations.

When the diesel locomotive is placed for service, the supervisor of the production site begins to work with registering the payroll. After that, the master executes a request from the ACS "Network Schedule" about the locomotives set aside for service by the dispatcher. After processing the request, the ACS "Network Schedule" appoints locksmiths to work and issues problem areas for resources.

For each job \((i,j)\) the index of the closeness of the job to the critical path \(D\) is estimated. A schedule is drawn up for the next job that has the largest value \(D\), and whose initial event has already entered the schedule. After the start and end of the next work \((i,j)\), \(C(i,j)\) is subtracted from the required value of the TPR \(C\) indicator. If \(C^* \geq 0\), then the schedule \((i,j)\) of the work is saved, \(C\) is taken equal to \(C^*\), the start time of work according to the schedule \(t_s\) is taken equal to \(T\), the end time of the work according to the schedule is \(t_e = T + t(i,j)\).

If \(C^* < 0\), then the work schedule \((i,j)\) is canceled. A job with the next \(D\) is selected, the initial event of which has already been included in the schedule and occurred by time \(T\), for these jobs, steps 2 and 3 are repeated. The operation ends when all jobs whose previous event has already been included in the schedule are considered. The value of \(T\) is replaced by the nearest higher value from the set of values \(t_e(i,j)\). The work that ends by the time point \(T\) is determined, and the values of the TPR indicator for these works are taken into account in \(C\).

The shop foreman adjusts the start of work according to the proposed ACS "Network Schedule" scheme, after which he starts the procedure for assigning orders and ordering materials and spare parts. The shop foreman enters the "Repair monitoring" subsystem and selects the desired locomotive from the list in the process of carrying out repairs. The system performs a request for data on completed orders, a request for data on parts and assemblies requiring repair in automated technical diagnostics systems, a request for data on repaired parts received at the warehouse. The received data is marked in the subsystem "Work with orders" and "Repair monitoring". In the case of lagging behind the work schedule, the start and end times of the work depended on them are automatically recalculated. When a diesel locomotive is handed over from repair, the shop foreman enters the "Start for repair" subsystem and selects the locomotive. The system performs a request for data on acceptance or remarks by the receiver and the issue of a diesel locomotive, respectively. After that, it goes to the subsystem "Work with orders".

When there are no comments, the shop foreman closes the orders, and the system sends data on the technological operations performed. This approach allows for operational control and management of technological processes servicing locomotives.

Using the proposed control technique, technological processes were optimized and network schedules for the repair of locomotives in the service locomotive depot were compiled. Thus, for example, when performing repair in the amount of TR-2, the locomotive should be placed in the position of dismantling the roof equipment. Then the roofs over the diesel generator set are removed. Next, the diesel fuel equipment is dismantled and sent to the fuel equipment repair department for repair work. Then the exhaust manifolds are removed and transferred for repair to the department for the repair of diesel units. Then they dismantle the water pumps and transport them to the diesel unit repair department. After that, the turbocharger is removed and moved for repairs to the site for the repair of diesel units. After dismantling the turbocharger, proceed to the removal of the camshaft drive (group
In this case, the cylinder kits are disassembled and sent for repair to the diesel unit repair section. Inspection and repair of pistons, connecting rods, cylinder covers and bushings are carried out, malfunctions are eliminated, after which the cylinder sets are assembled. The fuel equipment, oil and water systems of the diesel engine, the gas distribution mechanism, the block and the crankcase of the diesel engine are examined for oil and diesel fuel leaks. The hydraulic pushers of the diesel engine gas distribution mechanism in the diesel-unit compartment are repaired. In addition, the crankshaft and the diesel engine muffler, the gearbox and the coupling of the shafting drive of the exciter and the starter-generator are inspected; the coarse oil filters and the centrifugal filter, the water cooling system of the diesel engine are washed. The condition of pipelines, durites and flange connections of the oil and water systems of the diesel engine is checked. Also, in the diesel-aggregate department, repairs of the shaft line to the hydraulic pump gearbox, oil separator tank, controlled damper, water meter, cold and hot water pumps, camshaft drive, the cooling fans for traction motors are performed. The refrigerator sections and the air cleaner housing are inspected and cleaned. Maintenance of electrical equipment includes inspection and verification of the fastening of all electrical machines and devices, as well as lead wires, terminal strips and connections. The condition of collectors, slip rings, brushes and brush holders, insulators, bandages is checked, and parts are cleaned. In addition, a rectifier unit, fan wheel blades and refrigerator shafts are examined. The condition of the power and interlock contacts of electrical devices is checked. The alignment of the main generator, starter-generator, and exciter is checked, and the shaft lines are revised. The detected faults are eliminated. Also, relays, panels, voltage regulators are repaired [13].

4.2 Determination of the amount of materials and spare parts required to perform repair technological processes.

As mentioned earlier, maintenance and current repairs registered in operating locomotive depot Agryz are carried out on an outsourcing basis by the service locomotive depot Agryz-Yuzhny, LLC Lokotech-Service. At the same time, new approaches to the maintenance and repair system are introduced, associated with the growth of overhaul mileage. In order to ensure timely and high-quality repairs, it is necessary to create a revolving fund under these conditions, that is, the presence of a transitional stock of units and assemblies in a working technical condition in the depot. In this regard, the question arose about the quantitative and qualitative composition of this transitional stock. In addition, many locomotives of new series have been put into operation. For JSC "Russian Railways" and the service locomotive depot Agryz-Yuzhny, LLC "LocoTech-Service", there was an acute problem of accounting and ordering spare parts and materials to ensure the technological preparation of service maintenance of diesel locomotives.

Inventory rationing for material and technical resources. The stock rates are determined based on the maximum value of the current stock, the minimum stock rate and the transition stock rate.

However, the purpose of these norms is very difficult, especially for locomotives of new series, as well as when switching to new norms of overhaul mileage. Since for their use, it is necessary to know the planned average daily demand for materials, the interval between deliveries, the actual intervals, the planned volumes of deliveries, the size of the statistical sample for assessing the average deviation of the actual volume of deliveries from the planned one, the time of loading and unloading operations, the estimated time of cargo in transit, and other logistic parameters. It is possible to accurately estimate the required transition margin using the probabilistic approach. For this, the transitional margin is necessary to be determined, which consists of the technological stock F tech, defined on the basis of the requirements of the technological process and the repair program, and the minimum stock Fst for replacing units during unscheduled repairs, as well as units that cannot be restored or which require restoration special conditions and time longer than the standard:
The required number of spare units $F_{tech} = (t_a + \Delta t_a - t_b) / t_p + \Delta t_p) + x_a)$, where $n_a$ is the number of similar units in the locomotive; $x_a$ is the number complementing the value $F_{tech}$ to the nearest integer; $t_a + \Delta t_a$ is the actual downtime of the unit for repair, taking into account the deviation $\Delta t_a$ from the standardized one; $t_p + \Delta t_p$ is the actual downtime of the locomotive, taking into account the deviation $\Delta t_p$ from the standardized one; $t_b$ is the time of period, during which the unit is absent in the locomotive according to the schedule of the repair process. If $M_p$ locomotives are repaired at the same time, then

$$F_{tech} = M_p n(t_a + \Delta t_a - t_b) / t_p + \Delta t_p) + x_a).$$

For the settlement period

$$M_p = M^2_p (t_p + \Delta t_p) / T^2_p,$$

where $M^2_p$ is the annual locomotive repair program; $T^2_p$ is the time fund for the settlement period.

Then

$$F_{tech} = n(t_a + \Delta t_a - t_b) / T^2_p + x_a)M^2_p.$$

Transition stock

$$F_a = a n_a M_t b / T^2_p.$$

where $a$ is the coefficient of the changeability of units (parts) that are necessary for unscheduled repairs and are not subject to the restoration process or require a long time to repair.

When determining the consumption rates of materials, the main initial information would be:
- drawings of parts (assembly units);
- specifications;
- technological documentation;
- standards of material consumption;
- standards for waste and losses.

One of the problems in determining the safety stock during the repair of new series locomotives is the data lack on the number of unscheduled repairs that occur during operation. However, the estimated level of unscheduled repairs can be estimated based on the adopted technical readiness factor (TRF). The initial data will be the operating fleet of locomotives, the estimated total residence time of locomotives in the operational state of $T_{os}$, for scheduled maintenance and repair (M and R) $T_{pl}$, as well as for unscheduled repairs of $T_{ot}$ for the considered period of operation:

$$n = (t_{os} N / TRF - t_{os} N - t_{pl} N) / t_{ot}$$

where $n$ is the number of unscheduled repairs.

5. **Forecasted power losses in assemblies and units by results of repairs and efficiency of using mainline locals**

High-quality repair of diesel locomotives is the most important factor in the reliability and safety of the transportation process in railway transport. In connection with the restructuring of Russian Railways, the repair of traction rolling stock owned by the holding is carried out by repair plants and service locomotive depots. The main task of these enterprises is to ensure the required indicators of the technical readiness of the company's locomotive fleet at an economically justified level of financial costs. Technical, economic indicators, one of which is the energy efficiency (power use) of the repaired locomotive, characterize the quality of repair technological processes. When repair is performed in units and assemblies, additional power losses may appear due to the deviation of their technical parameters and characteristics from the factory values established in the design documentation, which reduces the efficiency of the locomotive. Additional power losses depend on the admissions set in the repair process.
documentation for the technical parameters and characteristics of units and components. Generally, the larger the admissions, the more significant the additional power loss can be.

5.1 Technical parameters and characteristics of parts, components and assemblies after a repair, affecting power losses in diesel locomotives.

The procedure for performing maintenance and repair of parts and assembly units of locomotives is regulated by the Repair Rules, technological instructions, technological processes (maps), etc. Measurement data and values of technical parameters and characteristics of the main parts, assemblies and assemblies after a repair, replacement or modernization are recorded in the technical passport (assembly unit form) of the locomotive. To assess possible additional power losses in units and assemblies, we use only those technical parameters that are regulated by the current regulatory documents. Losses associated with operating modes are not taken into consideration. The energy efficiency of a locomotive is influenced by technical parameters measured during repairs, such as:

- radial clearance in axle box and motor-armature bearings;
- side clearance in the gear train;
- the difference in the diameters of the wheelset tires;
- frequency of rotation of the traction motor;
- contact gaps;
- failure of power contacts;
- pressing of power contacts (initial and final), etc.

To determine the increments of power losses in units and assemblies due to poor-quality repair, it is necessary to find an analytical or experimental relationship between the predicted additional power losses and the technical parameters measured during the repair.

5.2 Quality locomotive repair technological processes and energy efficiency. The time spent by locomotive repair is largely determined by the availability of technological equipment that ensures the mechanization of repair operations and repair quality. This is especially important when performing routine repairs in the amount of TR-3. The repair quality of technological processes also significantly influences the efficiency of locomotive use in operation, largely determining the degree of power utilization of the repaired locomotive. The research results show that one of the main reasons for the decrease in the efficiency of a diesel locomotive is the increase in power losses in units and assemblies. This is caused by the deviations of their technical indicators and characteristics from the nominal values obtained in the case of poor quality of the repair performed. At the same time, radial clearances in motor-axle bearings, general lateral clearances in gear drives, speed characteristics of wheel-motor units and diameters of wheel set tires have a significant effect on reducing losses and using the power of a locomotive. Thus, in order to reduce power losses and gain the energy efficiency of locomotives, it is necessary to ensure the quality of technological operations during the formation (assembly) of wheel-motor units and a selection of KMB for one locomotive with the same speed characteristics and diameters of wheel set tires. The fulfillment of these requirements is ensured by equipping locomotive repair enterprises with appropriate technological and diagnostic equipment.

One of the quality indicators of diesel locomotives is the quality of the connections. Deviations in the shape and relative position of parts from the standard values that occur at the assembly stage, as a rule, reduce the performance of the assembly unit. Thus, assembly operations have a special place in mechanical engineering. It is at this stage that various connections of individual parts and assemblies arise and indicators of the reliability of a technical object are formed.

For example, enhanced technological equipment improves the quality of technological operations for assembling a traction gear, installing a wheelset with motor-axial rolling bearings in the frame of a traction motor and forming a wheel-motor unit as a whole, and provides an increase in the level of mechanization of technological operations and reduces motor block.

It can be concluded that when performing repairs in assembly units, additional power losses may appear due to the deviation of their technical parameters and characteristics from the factory values established in the design documentation. This reduces the efficiency of the locomotive. Additional power losses depend on the admissions for technical parameters and characteristics of units and assemblies established in the repair documentation. Generally, the larger the admissions, the more significant the additional power loss can be.
References

[1] Davydov, A. D., Erokhina, O. O., Ryaboshuk, S. V., & Kovalev, P. V. (2020). Analysis of the causes of cracks in the production of ingots and forgings from austenitic stainless steel 08X18H10T (aisi 321) doi:10.4028/www.scientific.net/KEM.854.16

[2] Drobintsev, P., Voinov, N., Kotlyarova, L., Selin, I., & Aleksandrova, O. (2020). Optimization of technological processes at production sites based on digital modeling doi:10.1007/978-981-15-2341-0_75

[3] Kalinin, M. O., & Pavlenko, E. Y. (2015). Increasing the fault tolerance and availability of software defined networks using network equipment control based on multiobjective optimization by service quality parameters. Automatic Control and Computer Sciences, 49(8), 673-678. doi:10.3103/S014641161508026X

[4] Klochkov, Y. S., & Tver yakov, A. M. (2020). Approaches to the improvement of quality management methods. International Journal of Systems Assurance Engineering and Management, 11, 163-172. doi:10.1007/s13198-019-00939-x

[5] Abyzov, O. V., Galyshev, Y. V., Dobretsov, R. Y., Krasilnikov, A. A., Sidorov, A. A., & Uvakina, D. V. (2020). Stationary test complex for vehicle and tractor gearboxes. International Review of Mechanical Engineering, 14(2), 127-132. doi:10.15866/ireme.v14i2.18267

[6] Borisoglebskaya, L. N., Sergeev, S. M., Provotorova, E. N., & Zaslavskiy, A. A. (2020). Digital algorithms for supply chain automation of mechanical engineering production. Paper presented at the IOP Conference Series: Materials Science and Engineering, 862(4) doi:10.1088/1757-899X/862/4/042025

[7] Dobretsov, R. Y., Porshnev, G. P., Semenov, A. G., Bulakh, D. V., & Bondar, K. A. (2020). The estimation of main parameters of the power plant and electromechanical powertrain for the wheeled vehicle. International Review of Mechanical Engineering, 14(2), 139-145. doi:10.15866/ireme.v14i2.18262

[8] Kalyutik, A., Kiselev, V., & Rouzich, E. (2018). Impact of the underground metal construction cover layer on the cathode protection efficiency. Paper presented at the IOP Conference Series: Materials Science and Engineering, 463(2) doi:10.1088/1757-899X/463/2/022057

[9] Makarov, E. S., Cheglov, A. E., Gvozdev, A. E., Zhuravlev, G. M., Sergeev, N. N., Yusupov, V. S., . . . Breki, A. D. (2018). Power required in the plastic deformation of metallic powder materials. Steel in Translation, 48(9), 597-602. doi:10.3103/S0967091218090061

[10] Mamutov, V. S., & Mamutov, A. V. (2018). Numerical simulation of electrohydraulic processes. Paper presented at the MATEC Web of Conferences, 245 doi:10.1051/mateconf/201824509015

[11] Popovych, A. A. (2020). Additive technologies as breakthrough solutions for creating advanced functional materials. Metal Science and Heat Treatment, 62(1-2), 18-24. doi:10.1007/s11041-020-00507-2

[12] Provotorov, V. V., Danilevich, D. V., Fedotov, A. A., Sergeev, S. M., & Kravets, O. J. (2020). Digital management by supply networks in engineering. Paper presented at the IOP Conference Series: Materials Science and Engineering, 862(3) doi:10.1088/1757-899X/862/3/032024

[13] Tsvetkova, G., & Skotnikova, M. (2018). Engineering and research of wearability coating on the basis of high-strength steel. Paper presented at the Proceedings of 9th International Scientific Conference, BALTTRIB 2017 - Dedicated to 100th Anniversary of Restitution of Lithuania, 166-171. doi:10.15544/balttrib.2017.30