ORIGINAL ARTICLE
DOI: https://doi.org/10.30932/1992-3252-2023-21-6-8

World of Transport and Transportation, 2023,
Vol. 21, Iss. 6 (109), pp. 232–237

Digitalisation of the Database of Passenger Coach's Elements Using the Example of Wheelset Repair

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ABSTRACT

Meeting the needs for transporting passengers while ensuring the appropriate level of comfort and safety are always paramount when repairing rolling stock.

The creation of automated systems to support repair and maintenance works allows systemising the repair process itself and clear and timely planning of material and production resources. Digitalisation of the production process makes it possible to achieve a coherent functionality and to link production and economic indicators together to ensure a balanced load on the repair bay, and subsequently on the entire enterprise, while development of a single digital system allows one to unlock the potential for improving the technological base.

Development of software and hardware system of «digital» repair of a wheelset is studied with object-oriented and heuristic methods The study's subject refers to technological operations and production processes of reception and repair of a passenger coach's wheelset. The object of the study is the process of organisation of the repair of rolling stock components at the operational stage of the life cycle. The study describes main characteristics of organisation of repair of a passenger coach's wheelset from its reception for maintenance and defect detection to release into operation after current, medium or, respectively, major repairs. Particular attention is paid to the processes of interaction between managers and performers at each stage of repair. The novelty of the research is regarded through the application of a system approach to the use of digital technology in the production process to obtain analytical data and generate economic and production indicators. The main conclusions tend to substantiate creation of a hardware and software system of a «digital twin» of a passenger coach's wheelset repair bay.

Keywords: *railways, wheelset, wheelset element, turnover, gearbox, digitalisation, roller bearing.*

For citation: *Evseev, D. G., Shinkaruk, A. S., Kulikov, Yu. M. Digitalisation of the Database of Passenger Coach's Elements Using the Example of Wheelset Repair. World of Transport and Transportation, 2023, Vol. 21, Iss. 6 (109), pp. 232–237. DOI: https://doi.org/10.30932/1992-3252-2023-21-6-8.*

The full text of the article in English is published in the second part of the issue.
Полный текст статьи на английском языке публикуется во второй части данного выпуска.

INTRODUCTION

Currently, digitalisation of production processes is the most promising in terms of optimising technological and economic performance indicators [1]. At the same time, this direction is insufficiently studied from a scientific point of view [2; 3]. In the railway passenger sector, serious attention is paid to implementation of the production process as well as to its analysis during intermediate operations [4; 5]. However, issues of improving quality and reducing production costs require constant improvement, and correct implementation of the technological process is always a priority task [6; 7]. To solve it, innovative approaches are applied that ensure more transparent implementation of standard procedures and control of the parameters laid down in the regulatory and technical documentation [8; 9].

The largest number of unscheduled repairs of passenger coaches (52 %) is associated with the presence of defects on the tread of wheelsets (flat spot, spalling, sharp flange, out-of-roundness, etc.) and, to form the necessary working stock of wheelsets, as well as to reduce coach downtime, it is necessary to ensure timely and prompt current repairs. To do this, at maintenance points it is necessary to store and keep the required quantity and range of spare parts and materials, the number and list of which must be adjusted depending on the workload of the production site, traffic intensity and rolling stock series operated.

Currently, there are 21 modifications of passenger wheelsets used for passenger coaches in Russia, which differ from each other in:

– configurations of axle box units (for rolling under a bogie with cradle/cradleless suspension; a separate configuration of axle box units for coaches used in international traffic);

– the distance between the brake discs (depending on the brake system type);

– type of bearing installed in the axle box unit (roller, cassette one);

– type of gearbox (for coaches with a power system of 32 kW and 28 kW, as well as for coaches with 32 kW power system and a disc braking system).

As a result, the measures taken at workshops for timely release of coaches after repair, despite the preventive effect obtained, do not fully eliminate the existing problem to ensure availability of the required working quantity of wheelsets and to balance the «cost – quality» ratio [6; 7], as well as to minimise coaches' downtime.

To increase the efficiency of managing wheel-roller repair bays, a software algorithm has been created that allows automating the processes of accounting for the turnover of wheelsets in a passenger coaches repair shop, the management process, real-time monitoring of implementation of the production program, the availability and range of spare parts and materials, as well as analysing the economic and production indicators [7; 8; 10].

This system makes it possible to achieve the implementation of the assigned tasks in the following main areas[1] [11]:

– optimisation of repair planning in the wheel-roller repair bay;

– monitoring the repair of wheelsets throughout the entire production process;

– planning of supply of spare parts and materials;

– identification of «bottlenecks» when performing technological operations;

– digitalisation of the accounting and reporting system;

– determination of the cost of repairing wheelsets at the production site;

– integration of a digital model into existing control systems for the technological process of repairing the of components of passenger coaches.

TASK SETTING

The task solved within the framework of the presented study is the analysis of the functionality of the digital software algorithm for the wheelset repair process through providing control and accounting for the main indicators – reception of a wheelset for repair, input and operational control of the repair of the elements of the wheelset. The operational processes include:

– reception of a wheelset;

– wheelset troubleshooting, identification of maintenance/repair works to be done;

– diagnostics;

– repair;

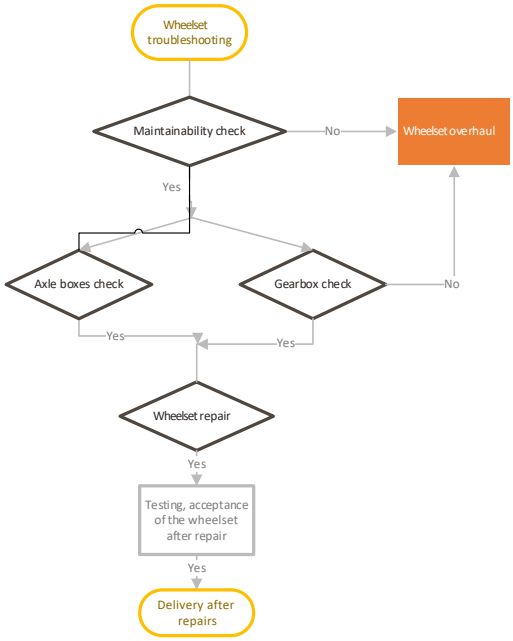
– assembly;

– mounting;

– running tests (diagnosis);

– acceptance and delivery of fault-free wheelset for operation.

[1] On approval of forms of internal primary accounting of JSC Russian Railways for wagon facilities. Order No. 1545/r dated June 21, 2023. Moscow, JSC RZD, 2023.



Pic. 1. Structure of repair of a wheelset using the example of a wheelset wit gearbox [performed by the authors].

The strict sequence and hierarchical structure of data entry makes it possible to eliminate simplification in the execution of the technological process, and it is easier to control the process itself from the workplaces of managers at various production levels, which ultimately increases the entire productivity and quality of coaches' repairs. The structural diagram using the example of repair of a wheelset with gearbox is shown in Pic. 1.

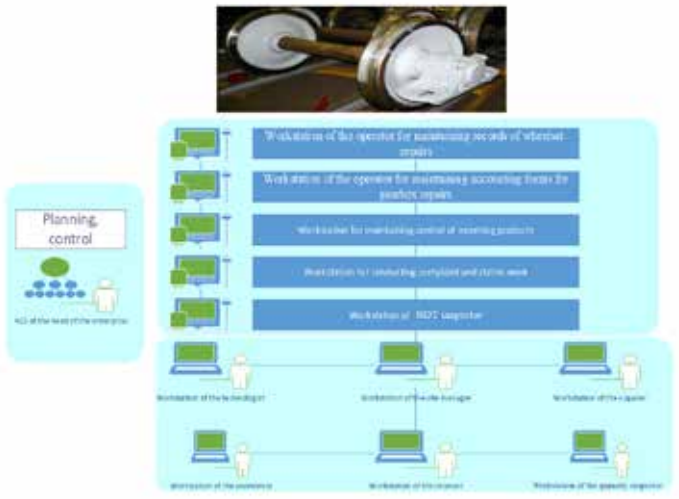
The operation of this hardware and software system is based on the life cycle of the wheelset elements, as well as the corresponding technology maps (Pic. 2). Within the framework of the above operations, the implementation of workstations (hereinafter referred to as WS) of performers and managers at the production level of the enterprise is provided (Pic. 3):

– WS of the head of the enterprise;
– WS of the repair bay manager;
– WS of the receiver;
– WS of the technologist;
– WS of the operator for records of wheelset repairs and test results;
– WS of the operator for accounting forms for repairs of gearbox of the middle part of the axle and test results;
– WS of the operator (rolling stock repairman) for results of incoming inspection of incoming products;
– WS of the operator for complaint and claims work;
– WS of the NDT inspector;
– WS of the economist;
– WS of the logistics manager;
– WS of the employee of the labour and wages department.

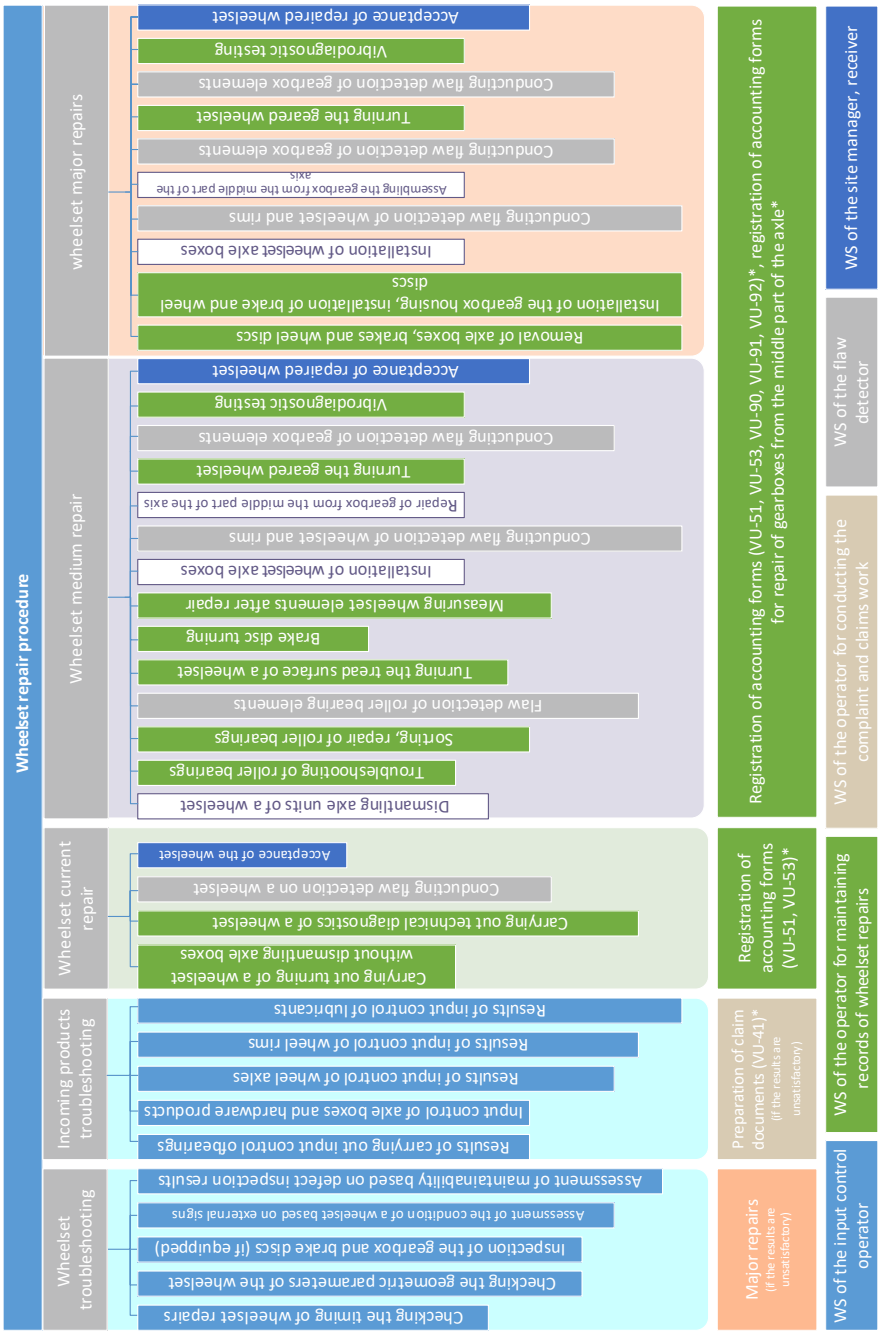
Users' workstations are equipped based on personal and/or wearable (including keyboardless) terminals.

Thus, based on the structure of digital workstations, they can be divided into three main blocks:

– planning and control (managerial level);
– control of the stage-by-stage implementation of technological operations and their acceptance, delivery of the required number of spare parts and elements, accounting of financial and economic indicators (line manager);



Pic. 2. Hierarchical structure of digital workstations of the wheelset repair bay[performed by the authors].

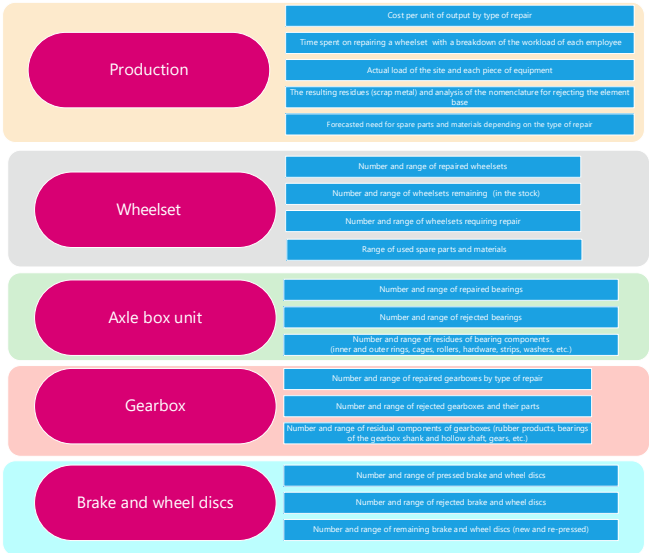


** – filling out accounting forms is carried out in the digital format of the software package.*
Pic. 3. Stage-by-stage digital model of wheelset repair process [performed by the authors].

– entering the results of repairs, inspections, non-destructive testing and diagnostics (job/performer level).

The use of portable and stationary terminals allows conducting and monitoring all production operations in real time, which, in turn, increases the responsibility of personnel for quality of production procedures and eliminates disruption of the step-by-step execution of the operations within technological process. Information is entered in real time based on user's identification, which allows for a personalised analysis of operations performed by each employee during a work shift and excludes data entry by unidentified users.

Upon completion of the production cycle, the job performer marks a note on completion of the stage. Thus, the software and hardware system allows moving to the subsequent operation of repairing the wheelset. If control parameters or results of assessing the state of the wheelset



Pic. 4. Structure of digital indicators of operation of the wheel-roller repair workshop [performed by the authors].

elements are not entered, the stage completion button will be inactive, and it will be impossible to proceed to the next stage of technological operations. If data are entered into the automated control system that are not within the permissible controlled range, this element will be identified as faulty and sent either for re-repair or scrap.

RESULTS AND DISCUSSION

The peculiarity of repair of wheelsets of passenger coaches is that their range is much larger than of those used in the carriage complex. To form the necessary technological stock of wheel sets and ensure timely and high-quality repairs, a digital model of the operational process of reception and repair has been implemented, the algorithm of which is shown in Pic. 3. The start time for technological operations is reception of the wheelset for repair and its defect detection; based on the results of the defect detection, the receiver makes a decision on the volume of further repairs (current, medium or major).

After the wheelset is received for repair and after turning, the results are entered into a digital analogue of the registration form VU-53 «Wheelset Repair and Turnover Log»[1]. Next, the wheelset is transferred to the flaw detection position, and if inconsistencies or defects are detected on the elements of the wheelset, a corresponding note is made regarding the need for repeated repairs or the wheelset must be rejected. If the decision is positive, the wheelset is accepted and declared fit for further use.

When carrying out defect detection of incoming products (delivery of new spare parts and materials), in case of identified inconsistencies in the elements, primary information is generated on the reasons and quantity of rejected parts for the subsequent drawing up of a complaint report form VU-41[1] and the return of products to the supplier based on initiation of complaint and claim work. If during defect detection the components do not fall under the complaint procedure, they are disposed of.

After defect detection of the wheelset, it is transferred to the disassembly position, where, after dismantling axle box units, they are transferred to the roller unit, the remaining elements are sent for washing and repair and defect detection inspection positions, as well as for non-destructive testing. In the roller department, repairs and subsequent sorting of rollers, separators, outer and inner rings are carried out. After repair and flaw detection, the bearing assemblies are transferred to the mounting unit. At the same time, repair work is carried out on the wheelset and other elements by turning the rolling surface, followed by flaw detection, defect detection and repair of axle box housings. In the mounting unit, bearings are installed on the wheelset, final diagnostics of the wheelset is performed, and final acceptance of the repaired wheelset is carried out.

When repairing a wheelset with a gearbox of the middle part of the axle, after installing the

axle box units, it is sent to the gearbox unit, where standard routine work on repairing the gearbox and testing under load is carried out.

Medium and major repairs of a wheelset follow the same sequence of actions as shown in Pic. 3, after which the wheelset is recognized as suitable and allowed for use. The completion of the repair is assumed to be the time of acceptance of the wheelset.

Thus, digitalisation of the passenger coach's wheelset repair process results in a final report that is generated for the selected period in conformity with economic and technological parameters (Pic. 4). Based on the results of the analysis, it is possible to evaluate such indicators as the actual load, the work performed by each repair bay's employee, the cost per unit of repaired products by type (current, medium and major repairs), the range of spare parts and materials used, the time spent on the corresponding repair of one wheelset.

CONCLUSIONS

The implemented software-analytical model for managing the technological process of repairing a passenger coach's wheelset ensures the step-by-step implementation of technological operations, accounting for the spent time of personnel, spare parts and materials, the structure of damageability of the wheelsets, and is also the key to improving the entire quality of coaches' repairs. This system is a universal platform that allows building technological operations at other workshops of a passenger coaches' repair enterprise, controlling technological discipline at each stage of repair, and monitoring the actual load of equipment, personnel, as well as financial and material resources in real time per each repaired unit.

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Article received 03.11.2023, approved 27.12. 2023, accepted 29.12.2023.