The use of energy saving technologies in the service of a rolling stock

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Abstract. The article deals with technical devices used at railway transportation for washing and cleaning of both rolling stock and its parts with a sufficiently large area of coverage of the product range which affect the treated objects or a jet of liquid with a detergent, or involve "bathing" of the object in the washing medium. At the same time the existing technology of cleaning and a design of washing machines do not allow to increase the efficiency of such devices, and the aggressive properties of liquids used in the process are not fully developed. The solution is seen in the intensification of technological processes of washing and cleaning of parts of the rolling stock by rational organization of the structure of the washing liquid flows to improve their performance. The article presents an assessment of the design features of traditional schemes of gas lift devices, the use of devices with forced gas supply for the implementation of technological processes in industrial production.

1. Introduction

Taking into account the fact that the development of transport communications is the basis of economic security of regions [1], Russia's transport strategy and development of competitive relations in transport [2] are associated with the use of new technologies, which is not limited to some specific fields (medicine, education, etc.). They can be used on railway transport for efficient management of logistics costs [3] as well as to minimize the negative impact on the environment. Furthermore, environmental and legal issues related to the use of environmental resources are already being considered [4] and environmental safety issues in the Russian Federation are being discussed [5].

JSC "Russian Railways" has adopted a Program to increase environmental responsibility. According to the adopted strategy, it was decided to reduce the burden on the environment from all types of activities 2 times by 2030. 2015 was declared the Year of waste management by the Company.

In recent years, systematic work on expansion of the landfill renewable energy project "smart station", a program for the elimination of coal-fired boilers, organized selective waste collection in office buildings and railway stations [6], development of approaches to creation of promising types of transport [7-11] have been also taken into account by today's demands for environmentally friendly projects.

In view of the above, the introduction of waste-free production and economical technological processes with the possibility of combining several technological operations attract much interest [12].

2. Discussion
In various industries, various systems are used in technological operations, which mainly use the principle of interaction of gas and liquid [13]. Chemical and/or physical absorption is successfully used to separate gas mixtures and separate valuable components [14]. Chemical reactions such as hydroformylation, alkylation, oxidation, etc. are also widely used [15]. These technologies are implemented in various types of reactors (mixing and displacement reactors, reactor cascades, and multicellular apparatuses).

Gas lift devices provide high contact interaction between gas and liquid, are characterized by low energy consumption, while the design provides ease of retrofitting with heat exchange systems and the absence of moving parts, and also they are indispensable for cleaning and recycling of generated emissions and wastes [16-18]. That is why they are widely represented in various industries.

Due to the large amount of waste water and, as a result, high economic losses, JSC "Russian Railways" faces the urgent issue of creating and applying closed water circulation systems. In addition, the rational use of water resources is required. Thus, the annual water consumption of the East Siberian railway followed by the formation of wastewater is about 25 million m$^3$, and widely used methods such as sedimentation and filtration do not provide the proper level of wastewater treatment.

The solution of the problem in this area is seen in the improvement of existing and development of new methods of wastewater treatment, in changing the technology of designing and creating machines that increase the level of their safe operation, including environmental protection of service personnel.

A wide variety of designs of devices and machines for carrying out technological processes of cleaning [19-21] of parts and assemblies allows us to distinguish among them the most common ones in railway transport.

![Figure 1. Rinsing apparatus MSP-1 for washing and drying roller bearings of box units of a rolling stock](image)

The MSP-1 rinsing apparatus (Figure 1) is used for cleaning and drying car and locomotive bearings of box units.

The rinsing apparatus can be operated independently, as well as together with the bearing pressing position and the box rinsing machine, and all cycle operations are performed automatically. The feed of processing objects to the device is carried out along two lines, while the box bearings cross the washing chamber, in which they are rotated and treated with a
washing medium by means of a jet system at a temperature of up to 95 °C. Then the box bearings are sent to the drying chamber for processing with compressed air.

A washing chamber is designed for cleaning the parts of the rolling stock crew (Figure 2). Cleaning of the surface of the wheel pairs is performed by means of metal brushes. The installation can be operated as an independent unit or as a part of an automated production line.

![Figure 2. A cleaning chamber of wheel pairs of a rolling stock](image)

Washing the surfaces of railway cars, wheel trolleys, components and parts of a rolling stock before their dismantling and disassembly is often carried out using a washing complex. The basis of it is a high-pressure hydraulic unit (30-150 barrels), which is an aggregate connected to the electrical network and the water supply network. The working parts of such installations are all kinds of spray heads. Water heating and a steam generator (heating boiler on diesel fuel) are provided, and there is some work with alkaline detergents for removal of especially heavy pollution.

The review of washing machines and devices for cleaning parts of a rolling stock given above shows that structurally they require an arrangement in a horizontal plane with the occupation of large production areas, which, in addition to the position directly for installing the washing machine, also require space for their maintenance and safe placement of maintenance personnel to prevent exposure to aggressive liquid media [22] during spray.

Such a technical design of washing machines limits the possibility of using the energy of the liquid medium flow in order to increase the efficiency of the technological process, since it mainly involves the impact on the treated objects either by a jet of liquid with a detergent, or by "bathing" the object in the washing medium. The existing cleaning technology and the design of washing machines do not allow increasing the efficiency of such devices, and the aggressive properties of liquids used in the technological process are not fully developed. Occasional attempts to introduce recycling cannot improve the current situation, which is complicated by the need for additional energy costs. The result is a large volume of toxic industrial effluents in the form of aggressive fluids.
At the same time, washing machines used for cleaning units and parts of a railway rolling stock often have a low degree of unification, which leads to an increase in the cost of equipment, often represented by piece production.

3. Results
The solution of the problem is seen in the intensification of technological processes for washing and cleaning parts of a rolling stock by organizing rationally the structure of the washing fluid flows to increase their productivity.

The achievement of this goal is based on the study of the influence of hydrodynamic factors and design parameters of gas-lift devices on the performance of the cleaning and rinsing process.

The classical design schemes of gas-lift reactors [19, 23] differ in generalized design features, such as: a vertically located container (reactor), usually cylindrical in shape with a partition that creates zones of ascending and descending gas-liquid flows (upstream zone (USZ) and downstream zone (DSZ)) with the possibility of communicating ascending and descending zones in the upper (above the partition) and lower (under the partition) parts of the reactor. Without a structural partition (material boundary) in the reactor the interaction of ascending and descending flows occurs throughout the entire volume of the reactor. A bubbling located at the bottom of the reactor in the downflow zone is supplied with gas (steam), which creates a moving circulation circuit of the gas-liquid mixture.

Schematic diagrams of gas-lift reactors are shown in Figure 3.

![Figure 3. Schematic diagrams of gas-lift reactors: 1 - upstream zone; 2 - downstream zone; 3 – partition; L – liquid; G – gas](image)

The best technical solutions, which originality is confirmed by patents for the invention and issued author's certificates [24-26], are presented collectively in the schematic diagrams of classical structures, and the increase in the intensity of the liquid flow is traditionally car-
ried out by using various types of flow elements and heads with technological holes in them and other modifications.

The recognized advantages of reactors made according to traditional schemes are: technical simplicity of the design; ease of its modification by adding additional elements to the reactor design that allow the device to be used for a wide range of needs in various industries; the ability to regulate smoothly the gas content by changing the intensity of gas (steam) supply; immobility of the basic design of elements; the ability to develop aggressive properties of the working fluid due to the optimal choice of its number of circulation cycles in the gearbox design.

The offered improvement of traditional schemes of gas-lift reactors is based on the experience of inefficient use of energy of descending liquid flows in the DSZ, which is known from experience, to ensure a high-quality impact on processing objects, and, thus, increase the productivity of this process [27, 28].

In order to eliminate the considered shortcomings, constructive measures are suggested to introduce "passive" elements into the reactor device, i.e., elements that do not require additional energy consumption for their operation, which contribute to the intensification of mass exchange processes by changing the structure of gas-liquid flows.

Increase in the intensity of mass transfer processes in the downstream zone is provided, in addition to the open jet stream, by additional design changes, such as:

1. an additional low-flow bubbler is added to the downstream zone (at the bottom of the device), the capacity of which is about 15% of the total gas capacity (taking into account the bubbler located in the upstream zone).

2. a "passive" element is introduced into the design of the device, which is a horizontal partition with through holes in the form of jet nozzles for creation of an open jet flow of a gas-liquid mixture in the downstream zone. The passage of gas in the DSZ is carried out due to the valves made in the horizontal partition. The offered changes are reflected in the diagram of the reactor with an open jet flow in Figure 4.

Laboratory tests performed with the reactor corresponding to the diagram in Figure 4 showed an increase in the level of gas saturating, compared with traditional schemes, in the area of downstream at about 15% to equalize the level of the gas-liquid mixture in the zones of upward and downward flows, taking into account the gas content of \(\phi_g = 0.4\) in DSZ.

When testing, the intensity changes of the adsorption rate of oxygen with a solution of sodium sulfate are in dependence on the geometric parameters of flow holes \(F_c\) in the horizontal partition and the area \(F_{DSZ}\) sectional area downstream. And depending on the level of placement of horizontal partitions in the zone, the downward flow was determined.
Figure 4. Schematic diagram of a reactor with an open jet flow in the downstream zone: 1 - chamber; 2 - circulation pipe; 3 - bubbler; 4 - horizontal partition

The obtained data on changes in the oxygen sorption rate are shown in tables 1 and 2, where the number of rows is the number of measurements, and the columns reflect structural changes in the classical scheme.

**Table 1.** Dependence of the change in the oxygen sorption rate on the diameter of the flow hole in the horizontal partition in the downstream zone

| No. n / a | $F_c / F_{DSZ}$ | Without a partition in DSZ |
|-----------|------------------|---------------------------|
|           | 0.01  | 0.02  | 0.03  | 0.04  | 0.05  | 0.06  |
| 1         | 2.8   | 4.5   | 4.6   | 4.6   | 4.2   | 4.1   | 3.6   |
| 2         | 2.9   | 5.0   | 4.9   | 4.8   | 4.2   | 4.2   | 3.8   |
| 3         | 2.7   | 4.5   | 4.6   | 4.7   | 4.4   | 3.9   | 3.8   |
| 4         | 3.2   | 5.2   | 5.1   | 4.9   | 4.6   | 4.5   | 3.7   |
| 5         | 3.1   | 5.2   | 5.0   | 5.0   | 4.8   | 4.5   | 4.1   |
| 6         | 3.2   | 5.1   | 5.3   | 4.9   | 4.5   | 4.6   | 4.3   |
| 7         | 3.1   | 5.2   | 5.1   | 4.9   | 4.7   | 4.5   | 4.1   |
| 8         | 3.3   | 4.5   | 4.5   | 4.4   | 4.3   | 3.9   | 4.2   |
| 9         | 2.9   | 4.4   | 4.6   | 4.2   | 4.3   | 3.8   | 3.8   |
| 10        | 2.7   | 4.4   | 4.3   | 4.2   | 4.0   | 3.8   | 3.5   |
| in average| 3.0   | 4.8   | 4.8   | 4.6   | 4.4   | 4.2   | 3.9   |
| $\Delta\%$| -23   | +23   | +23   | +18   | +13   | +8    | –     |
Table 2. Dependence of changes in the oxygen sorption rate on the level of placement of the horizontal partition in the downstream zone

| No. n/a | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 |
|---------|-----|-----|-----|-----|-----|-----|-----|
| 1       | 2.1 | 3.9 | 4.1 | 4.7 | 4.8 | 3.3 | 2.6 |
| 2       | 2.3 | 4.0 | 4.2 | 5.0 | 5.1 | 3.5 | 2.8 |
| 3       | 2.3 | 3.7 | 3.9 | 4.7 | 4.8 | 3.5 | 2.8 |
| 4       | 2.2 | 4.3 | 4.5 | 5.2 | 5.3 | 3.4 | 2.7 |
| 5       | 2.6 | 4.3 | 4.5 | 5.1 | 5.2 | 3.8 | 3.1 |
| 6       | 2.8 | 4.4 | 4.6 | 5.4 | 5.5 | 4.0 | 3.3 |
| 7       | 2.6 | 4.3 | 4.5 | 5.2 | 5.3 | 3.8 | 3.1 |
| 8       | 2.7 | 3.7 | 3.9 | 4.6 | 4.7 | 3.9 | 3.2 |
| 9       | 2.3 | 3.6 | 3.8 | 4.7 | 4.8 | 3.5 | 2.8 |
| 10      | 2.0 | 3.7 | 3.9 | 4.4 | 4.5 | 3.2 | 2.5 |
| in average | 2.4 | 4.0 | 4.2 | 4.9 | 5.0 | 3.6 | 2.9 |
| Δ%     | -38 | +23 | +6.9 | +25 | +27 | -8.4 | -27 |

The results of the experiment are shown in Figure 5. The absence of a partition in the downstream zone (the classical scheme) shows an average oxygen sorption rate which is close to the recommended value [29].

The results of the measurements of sorption of oxygen in Table 1 correspond to a fixed position of the horizontal partition in the DSZ in height (\(h_p / h_{vp}=0.6\)) in Table 2 corresponds to a constant cross-sectional area of the flow hole in the horizontal partition (\(F_c / F_{DSZ}=0.02\)). The last line of Tables 1 and 2 informs about the percentage change in the oxygen sorption rate compared to the device operating according to the traditional scheme (the "+" sign corresponds to an increase in the rate of oxygen dissolution; "–" – to a decrease).

Figure 5. Change in the rate of oxygen sorption rate (Sr) a) depending on the diameter of the flow hole in the horizontal partition in the DSZ; b) depending on the level of placement of the horizontal partition in the DSZ.
4. Conclusion
The results of comparative mass transfer studies allowed us to formulate recommendations for choosing the relative area of the flow hole in the horizontal partition of the $F_c/F_{DSZ}=0.025$ and the level of its placement $h_p/hvp=0.55$. Gas-liquid reactors with a modified flow structure of the gas-liquid mixture, made by introducing additional structural elements into the design, allowed increasing the productivity of the technological process by up to 30% compared to the traditional scheme.

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