

Methods of increasing the wear resistance with repairs of BDZ freight wagon bogies

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ABSTRACT

The increase in the time between various repairs of freight wagons determines the urgency of the problem of improving the wear resistance and service life for the restoration of supporting nodes and parts of the bogie for freight wagons due to excessive wear of the friction working surfaces. Most of the freight wagon bogie parts can be restored by subsequent processing. According to the existing technology and methods, the quality of freight wagon bogie repair does not provide the bogie mileage of specified kilometres necessary between repairs or in inter-repair periods. In this regard, to study the impact of surface restoration quality parameters on the wear process of parts in operation and after the repair is a priority task. The problem of providing methodology for various repairs of freight wagon bogies aims at increasing the wear resistance of bogie parts, which is a complex task and includes the use of modern methods to predict wear and technological warranty of the resource of repair parts.

KEYWORDS

Bogies, Freight wagons, Wear resistance, Repair, Hardfacing, Heat treatment, Railway transport.

1. INTRODUCTION

Railway transport represents a strategic sector for the Bulgarian economy. The reliability of freight wagons is directly linked to the technical condition of their running gear, particularly the bogies. The bogie is a primary structural component that absorbs dynamic loads during movement, ensuring the stability and safety of the wagon.

During operation, the bogie components are subjected to significant mechanical, vibrational, and contact loads, which lead to wear, material fatigue, and the initiation of cracks. Side frames, axle box openings, the suspension system, and wheelsets are particularly critical. Research indicates that defects exceeding 1 mm in size can sharply reduce the fatigue strength of bogie frames [1].

2. MAIN CAUSES OF BOGIE WEAR

The wear of freight wagon bogies is caused by several primary factors:

- High dynamic loads;
- Friction between contact surfaces;
- Insufficient or improper lubrication;
- Corrosion processes;
- Material fatigue;
- Low quality of welded joints;
- Operation on railway tracks in poor technical condition.

Cyclic loads are particularly hazardous, as they induce the propagation of fatigue cracks in load-bearing structures. Structural analyses of freight bogie frames demonstrate that stress concentration in the areas surrounding weldments is a major factor in structural failure [1].

The most widely used bogie type for freight wagons in BDZ (Bulgarian State Railways) is the Y25 type, distributed as the BT 6 two-axle bogie. The BT 6 is a Bulgarian analogue and is technically equivalent to the European Y25, specifically the Y25cs modification.

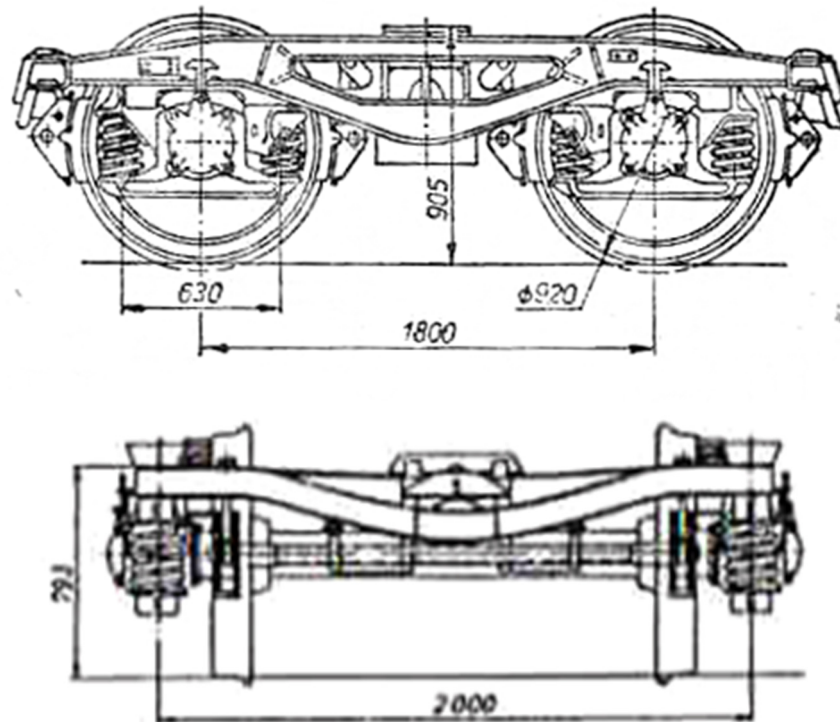


Figure 1: General view of the "Y 25Cs" (BT-6) bogie

During operation, bogies are subjected to intensive static and dynamic loads, resulting in frictional wear in the contact zones. Traditional repair methods involving standard weld hardfacing often lead to stress concentrators and the rapid recurrence of defects [2].

The most common breakdowns by type and number in
BDZ for 2025

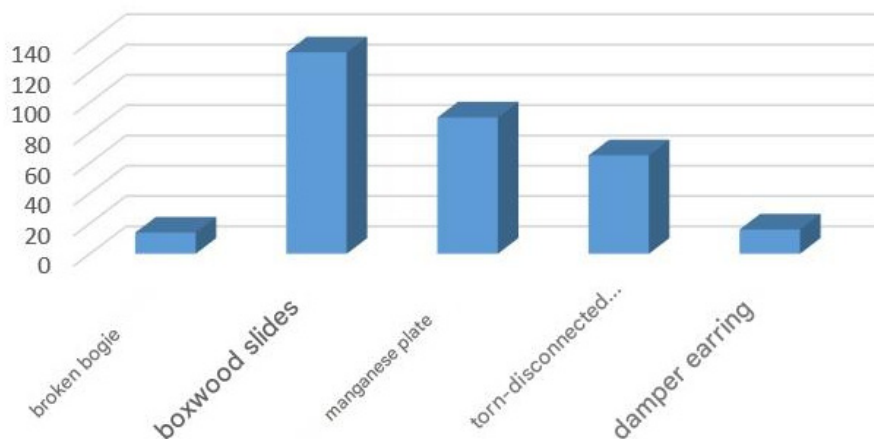


Figure 1: Most common defects in freight wagon bogies

3. METHODS FOR INCREASING WEAR RESISTANCE

3.1. Heat Treatment

Heat treatment is utilized to enhance the mechanical properties of steel components. Quenching and tempering are applied to increase:

- Hardness;
- Fatigue resistance;

- Wear resistance;
- Surface layer strength.

In bogie repair, localized induction hardening is frequently applied to highly loaded surfaces, such as axlebox openings and support elements.

3.2. Hardfacing and Component Restoration

Weld hardfacing is one of the most widespread methods for repairing worn components. Electric arc or plasma hardfacing is employed to restore the dimensions of worn surfaces.

The advantages of this method include:

- Extension of operational lifespan;
- Reduction of expenditures on new components;
- Increase in surface layer hardness.

Modern technologies utilize alloyed electrodes with high chromium, nickel, and molybdenum content, which provide superior resistance to abrasive wear.

3.3. Application of Wear-Resistant Coatings

The application of protective coatings significantly reduces the wear rate. The following are applied:

- Chromium coatings;
- Carbide layers;
- Cermets coatings;
- Polymer composite materials.

These technologies enhance resistance to friction and corrosion, particularly when operating in aggressive environments.

3.4. Non-Destructive Testing

Modern diagnostics play a key role in accident prevention. Non-destructive testing (NDT) methods include:

- Ultrasonic testing;
- Magnetic particle testing;
- Eddy current testing;
- Liquid penetrant testing.

These methods enable the detection of microcracks and internal defects at an early stage. NDT methods represent a fundamental approach to extending wagon service life and enhancing operational safety [3].

3.5. Robotic Welding

In recent years, robotic welding systems have been implemented in railway mechanical engineering. They provide:

- Higher weld seam quality;
- Minimization of human error;
- Reduced residual stresses;
- Higher reproducibility of the repair process.

Studies on robotic welding cells for bogie frames indicate an improvement in operational reliability and a reduction in defect probability [4].

4. MODERN ENGINEERING APPROACHES

4.1. High-Strength Steels

The utilization of low-alloy high-strength steels allows for:

- Reduction of the bogie tare weight;
- Increase in load-carrying capacity;
- Improvement of fatigue resistance.

4.2. Computer Modeling

The Finite Element Method (FEM) optimizes the repair of freight bogies by simulating stresses and wear within friction zones (side sliders, center pivot, axleboxes). The implementation of FEM in the repair cycle is based on fundamental mathematical contact stiffness matrices (5) and proceeds through the following six sequential stages:

- Scanning and CAD Defect Detection: 3D laser scanning of the actual geometry of the worn frame jaws to create a volumetric model in compliance with the nominal dimensions specified in the UIC 510-1 regulations [6].

- Discretization (Mesh Generation): Utilizing fine volumetric SOLID elements (hexahedrons), which provide greater accuracy per unit of computational time compared to tetrahedrons—especially when simulating bending and linear stresses in contact friction zones—ensuring high computational accuracy and smooth mesh transitions toward non-critical zones [5].
- Definition of Boundary Conditions and Loads: Applying forces in accordance with BDS EN 13749 [7], which defines the methodology to be followed to achieve a satisfactory design for bogie frames and includes design procedures, evaluation methods, verification, and manufacturing quality requirements. It is limited to the structural requirements of bogie frames, including pads and axlebox housings. For the purposes of this document, these terms encompass all functional applications, such as damper brackets.
- Contact FEM Analysis: Defining frictional contact with a realistic friction coefficient ($\mu = 0.15 - 0.4$). Computing Von Mises equivalent stresses and contact pressure distribution.
- Simulation of Repair Models: Conducting comparative analysis within the FEM environment between standard hardfacing, installation of manganese liners, and the use of non-metallic composites based on Archard's mathematical wear criterion [8].
- Optimization: Selection of a technology that ensures maximum mitigation of contact stress peaks.

5. CONCLUSION

Enhancing wear resistance during the repair of freight wagon bogies is a critical factor for the reliable operation of railway transport in Bulgaria. The best results are achieved through the combined application of heat treatment, hardfacing, wear-resistant coatings, robotic welding, and modern diagnostic methods.

The integration of FEM simulations into railway repair practices enables a scientifically substantiated transition from classical welding to the utilization of modern materials and methodologies.

The implementation of modern technologies in the maintenance and repair operations of the Bulgarian State Railways will result in an extended operational lifespan of the wagons, enhanced traffic safety, and reduced financial maintenance expenditures.

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