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RESEARCH OF THE DRAW HOOK FAILURES ON RAIL VEHICLES IN SERBIA

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Abstract *– Draw hook failures present significant problems for railway safety and operational efficiency. Although failures on the draw gear are not frequent, they can induce serious problems on the vehicles and infrastructure when some elements break. This paper presents comprehensive research on the potential causes of these failures, aiming to provide insights for prevention measures related to materials, production process, geometry and manipulation practices during train operation. The draw hook, as one of the vital components in connections of wagons and locomotives, ensures the safety and reliability of trains during operation. By analyzing the historical failure data and relevant literature, this study identifies several key factors contributing to coupler failures. Material degradation emerges as a prominent concern, with factors such as fatigue, wear, and corrosion compromising the structural integrity of the coupler hook and other components over time. Overloading during starting, impacts, or improper coupling procedures further increase the risk of failures. Mechanical and physical characteristics of used material, as well as geometric inconsistencies, may also induce failure under operational conditions. Environmental factors, such as extreme temperatures, moisture ingress, and chemical exposure, pose additional challenges by accelerating material degradation and corrosion processes. Understanding the complex interaction of these factors is crucial for developing effective preventive maintenance strategies and for addressing and improving observed imperfections in draw gear elements. Implementing the results from this research can help railway operators and manufacturers of subjected elements mitigate the risk of failures, thereby ensuring the continued reliability and safety of rail transportation systems.*

Keywords – draw hook, failure, maintenance, rolling stock, rail vehicles.

1. INTRODUCTION

Rail transport has a crucial role in Serbia's economy, connecting major cities and facilitating the movement of goods and passengers. The efficiency and safety of rail operations depend on the proper functioning of each component of rail vehicles. Disruption in freight transport due to breaking some part of the draw gear assembly is one of the main reasons for excluding trains from traffic and delivery delays. The draw hook, as a main part, is essential for the secure connection between railcars, ensuring safe and reliable transportation.

Despite the importance of draw hooks, instances of failures have been observed in rail vehicles across Serbia (at the national and international trains), raising concerns about safety, reliability, and potential operational disruptions. These failures not only pose risks to the safety of passengers, goods, and personnel, but also bring significant economic costs and logistical challenges when vehicles or trains must be excluded from traffic.

Understanding the root causes of draw hook failures represents the key in lowering risks and enhancing the overall safety and efficiency of rail transportation systems in Serbia. Various factors such as material

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quality, design, maintenance practices, and operational conditions may contribute to these failures and warrant thorough investigation.

This paper aims to comprehensively present a few failures of draw hook and a preliminary analysis of the causes of failures on rail vehicles in Serbia. Analysis of the available data on the draw hook failure will indicate the potential problems that lead to them.

Analysis of the fatigue failure of draw hooks and identified the key factors contributing to this issue were presented in paper [1]. Results of these investigations showed that the draw hook fatigue failure resulted from the combined effect of three main factors: the material, manufacturing technology, and operating conditions. Investigation of the causes of a locomotive draw hook brittle failure pointed out that the fracture was due to the inadequate impact toughness of the used material [2]. The brittle fracture of the locomotive draw hook caused by the unsuitable material characteristics of the draw hook itself, and non-coaxial loading conditions during operation presented in paper [3] once again confirming the causes described in paper [1]. Study on the draw hook equipment fatigue life utilized in freight wagons was presented in paper [4]. This study explored fatigue in the draw hook body, examining various metallurgical and mechanical properties that impact fatigue through experimental and numerical methods. Although the draw gear assembly is designed with weaker elements, such as the coupling links, whose fractures are analyzed in the papers [5, 6], draw hook failures occasionally occur. The analysis of these failures is complex experimental work that is focused on mechanical and metallographic examination of the material, as well aa micro and macro analysis of the structure of the material. In this paper are presented examples of draw hook failures and the preparation for analysis of failures (breakages) of draw hooks in Serbia, through experimental research.

2. DRAW GEAR ASSEMBLY

Draw gear assembly is formed from mechanical parts in a line with an energy absorber-elastic device mounted in the end beam on the railway vehicle, which works during operation, traction and braking, Figure 1. The draw gear assembly must have robust construction and be adequately sprung to minimize the impact loads from the starting jerks. Three characteristic breaking sections are presented in Fig 1. and will be explained in Subtitle 3.

2.1 Draw hook dimensions - EN 15566

Standard dimensions of draw hook which represents a part of draw gear assembly is shown in Figure 2.

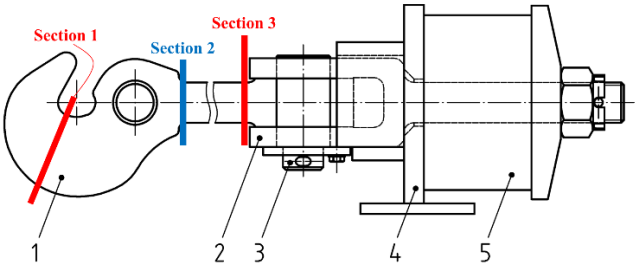

Fig. 1. Draw gear components: 1 - draw hook; 2 - drawbar; 3 - joint pin; 4 - support plate and 5 - elastic device [7]

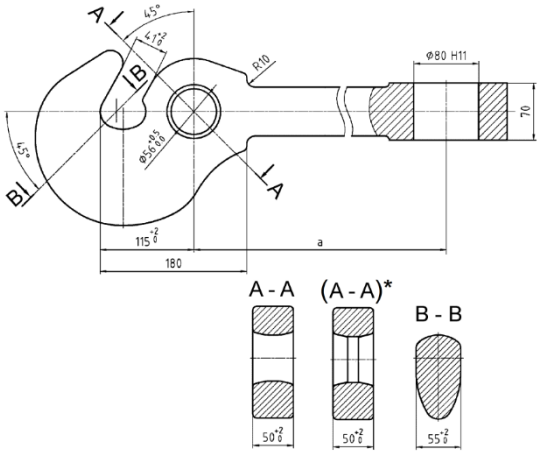

Fig. 2. Draw hook [7]

3. ANALYSIS OF DRAW HOOK FAILURE

The aim of this paper is to show and identify some of draw hooks failure on rail vehicles in Serbia, as well as to present method for determine causes that contribute to these failures. Surface of the broken locomotive draw hook (Section 3, Fig. 1) happened in 2020. in Serbia is presented in Figure 3 [8].

Fig. 3. Locomotive draw hook

Two more broken hooks in Serbia were presented in Figures 4 and 5. The first draw hook broke in March 2021. on the line Belgrade-Novi Sad, Figure 4. The place of break fits Section 2 in Figure 1. The draw hook

was a part of the draw gear of one of 29 freight wagons in the train with a gross weight of 1920t and a total length of 479 m.

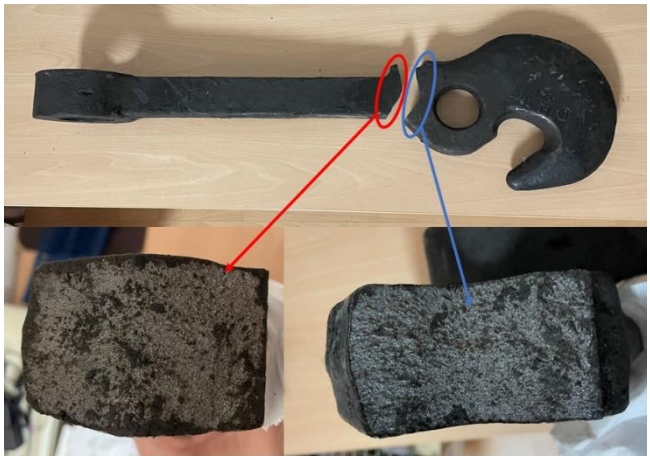

Fig. 4. Draw hook 1

The second draw hook accident happened in July 2021, Figure 5. This accident occurred when the train of mass 1662t was accelerating from 20 km/h to 30 km/h on an incline. Reaching the speed of 30 km/h, the train was stopped due to a loss of air from the main brake line. The place of the break fits Section 1 in Figure 1.

Fig. 5. Draw hook 2

The experimental investigations of the failures of these two draw hooks will focus on the analysis of the material properties and the operational conditions.

Next to the analysis of material properties and micro and macrostructure of the broken draw hooks, additional tests, and analysis will be conducted of the new draw hooks (unused). Results and characteristic parameters obtained by tests of broken and new draw hooks will be compared. Also, these experimental results will be used for the development and validation of the numerical model. A 3D model of draw gear assembly will be formed in the software package SolidWorks, while the development of the numerical model and finite element analysis (FEA) will be done by using the ANSYS software package. The FEA will be employed to simulate load distributions, stress analysis and uncover the potential failure points. This comprehensive approach will provide a detailed understanding of the factors leading to draw hook failures.

Tensile tests will be conducted on failed and new draw hooks to measure their mechanical and physical characteristics and chemical composition, providing insights into the material's performance under load. Also, the Charpy impact test will be conducted on different temperatures to analyze the impact of low or high temperatures on the material properties and toughness. The testing samples will be prepared according to standard [7]. Figure 6 shows the exactly defined positions on the hook for cutting samples.

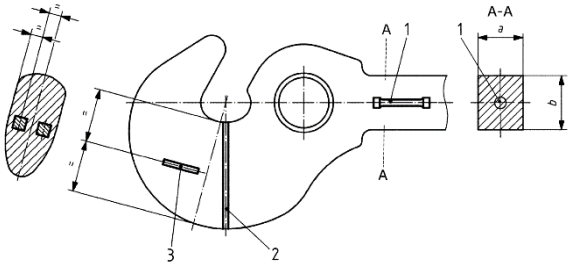

Fig. 6. Draw hook tensile position: 1 - tensile test sample normalized; 2 - macrographic and micrographic examination sample and 3 - impact test sample [7]

In addition, to the mentioned tests, hardness tests of the material will be performed to get the useful parameters for evaluation. The plan is to carry out fatigue tests to assess the endurance limit and fatigue life of the draw hooks under cyclic loading conditions. These mechanical tests are crucial for understanding the properties contributing to draw hook failures and will inform the development of more robust designs. Material characterization will involve analyzing the chemical composition of the draw hook material using techniques such as optical emission spectroscopy (OES) to detect any deviations in alloy composition that might affect performance. Additionally, the microstructure of the material will be examined using optical microscopy to identify defects such as inclusions, voids, or grain boundary issues that could contribute to failure. These analyses will provide a comprehensive understanding of the material properties and potential factors leading to draw hook failures. A developed and validated numerical model will be used for different analyses of draw hooks with a significant reduction in research costs. In this way easily change the material properties and geometry of the draw hook and analyze their impact on strength and operational reliability. Also, experimental and

numerical research will be useful for improving production processes and maintenance and reducing their costs.

4. CONCLUSION

This paper aims to lay the groundwork for research on the causes of draw hook failures on rail vehicles in Serbia, critical components ensuring the safe and efficient operation of rail transport.

Experimental and numerical research will provide a comprehensive understanding of the causes that contribute to drawing hook failures in Serbian rail vehicles. Analysis of key factors, it is possible to improve the safety, reliability, and efficiency of rail transportation systems in Serbia, ultimately reducing risks and operational disruptions.

The developed and validated numerical models will present a base for significantly more extensive research and analysis with low investigation costs.

Future research should explore advanced materials and innovative design solutions to further enhance the performance of draw hooks and other critical rail vehicle components.

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