ORIGINAL ARTICLE
DOI: https://doi.org/10.30932/1992-3252-2024-22-4-3

World of Transport and Transportation, 2024,
Vol. 22, Iss. 4 (113), pp. 149–152

Improving Quality of Guide Rods for Rail Vehicles' Suspension Systems by Changing Technology of their Manufacture

Tatiana A. POPOVA **Vladimir M. FEDIN** **Alexander P. POPOV**

Tatiana A. Popova [1], Vladimir M. Fedin [2], Alexander P. Popov [3]

[1, 2, 3] Russian University of Transport, Moscow, Russia,
[1] ORCID: https://orcid.org/0000-0002-6620-2292; Scopus Author ID: 57215115792; Russian Science Citation Index SPIN-code: 8517-7756; Russian Science Citation Index AuthorID: 706166.
[3] ORCID: https://orcid.org/0000-0002-4618-4154; Scopus Author ID: 57215127911; Russian Science Citation Index SPIN-code: 5652-9525; Russian Science Citation Index AuthorID: 705561.
✉ *[1] tatiana241187@gmail.com.*
✉ *[2] vmfedin@yandex.ru*
✉ *[3] pap60@bk.ru.*

ABSTRACT

Dependability of the suspension of metro coaches is directly determined by the parts included in the axle box (primary) suspension system.

The paper considers the spring suspension using guide rod. The guide rod presents a round steel rod that is attached through a bushing to the bogie bolster with its upper part, while its lower end is inserted into the axle box eye. The central section of the guide rod serves as a kind of guidepost for the suspension springs.

The operating principle is based on the ability of guide rods to distribute loads that occur during movement of a metro train. This technology can significantly reduce the wear of rails and wheel sets, thereby increasing safety and reducing the cost of rolling stock maintenance.

Today, there are a few problems caused by guide rods failures, the service life of which does not match the time parameters of failures of car bogie frames. Among other things, many items are rejected at the stage of production tests due to internal defects. Since dependability issues are the most acute, it is extremely important to find ways to increase the durability of the primary suspension systems using guide rods. The study is aimed at finding optimal technological solutions for manufacture of the items based in the analysis of the material and possible methods of processing guide rods.

The study has resulted in a conclusion on promising character of quenching cooling with a fast-moving water flow, since the achievement of all the required parameters was proven during the relevant tests.

Keywords: metro, guide rod, axle box suspension, strengthening of parts, heat treatment, steel quenching, steel 40X, steel 35.

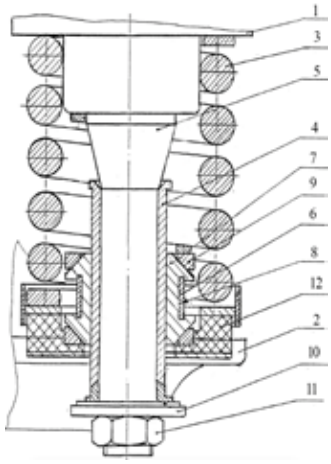
For citation: Popova, T. A., Fedin, V. M., Popov, A. P. Improving Quality of Guide Rods for Rail Vehicles' Suspension Systems by Changing Technology of their Manufacture. World of Transport and Transportation, 2024, Vol. 22, Iss. 4 (113), pp. 149–152. DOI: https://doi.org/10.30932/1992-3252-2024-22-4-3.

The original text of the article in Russian is published in the first part of the issue.
Текст статьи на русском языке публикуется в первой части данного выпуска.

INTRODUCTION

The design of Russian metro coaches widely used a link suspension system and a spring suspension system using guide rods, the latter being considered most dependable. This unit is used to ensure stability and comfort in coaches. The guide rod itself is the central element of the vibration damper, which in turn is a mechanism designed to reduce the amplitude of vertical movements of the body that occur during movement of coaches and works in tandem with the suspension's springs. The essence of the operation of the guide rod is to create dissipative (dispersive) forces that are activated when interacting with the springs for effective vibration damping. The structural layout of the guide rod unit is shown in Pic. 1.

During operation, the guide rod is exposed to a wide range of loads – both dynamic and static ones. This circumstance emphasises the importance of the *objective* to determine its dependability and durability.



Pic. 1. Guide rod unit of a metro coach: 1- bogie frame, 2- axle-box body, 3- spring, 4- plastic sleeve, 5- guide rod, 6 – ring, 7 – blocks, 8 – tapered groove stem. 9- V-ring, 10- disk spring, 11- nut, 12 – rubber damper [3].

RESULTS

Analysis of the material of the guide rod

The initial stages of using guide-rod type bogies revealed a problem of fatigue cracks in the area of intersection of the annular welds of the inner guide rods' bushings with the longitudinal welds of the longitudinal beams. This led to negative consequences. Several design and technological measures, such as welding a special pad on the upper shelf in the weld zone of the bushing and double-sided edge preparation for the annular weld, made it possible to only partially solve this problem.

New methods of treatment and research of materials allow developing effective technical and technological solutions to prevent further damage and ensure safe operation of bogies.

Most guide rods today are manufactured according to the requirements of design documentation from grade 40X steel. This material, which meets GOST [Russian state standard] 4543 requirements, is enriched with chromium in the range of 0,78…1,15 %, which provides the product with high dependability in terms of operational characteristics [1]. This type of structural steel is considered to be the best due to its resistance to damage and durability, although it is associated with a high cost. Despite this, a significant number of guide rods are subject to rejection due to the presence of non-metallic inclusions. They are defects of the original metal, which can manifest themselves both on the surface and in the subsurface layer of the product [2]. Such defects are found using the magnetic method of non-destructive testing. It should be noted that even high-quality steels can contain non-metallic inclusions, which does not exclude their use in production, but requires careful monitoring.

To improve economic efficiency, alternative solutions are proposed, including replacing the original material with one similar in its characteristics. Steel with comparable physical properties is considered. To optimise the choice of material, an analysis and comparison of all proposed alternatives is carried out according to several criteria, including cost, availability and compliance with technical production requirements [1]. This approach allows not only to guarantee the high quality of the final product, but also to ensure the economic efficiency of the production process.

Making final selection of materials involves considering operating conditions and external factors such as mechanical loads and environmental influences [3]. If necessary, issues of improving the mechanical properties of parts by introducing additional strengthening treatment are developed [2].

Several suitable materials are considered, including carbon steels: steel 35, steel 45 and steel 47GT.

Conducting a comparative analysis of the composition of metals allows us to understand their mechanical properties and processability. In addition, this helps to optimise production processes and improve the quality of finished products. The analysis of the chemical composition of steel grade 40X is shown in Table 1.

The analysis of the results given in Table 1 shows that the actual composition of 40X steel complies with the requirements of GOST 4543.

[1] Recommendations for the use of low-alloy high-strength steels for welded structures: research report. E. O. Paton Electric Welding Institute. Kyev, 1977, 77 p.

[2] GOST [State Standard] 1050–2013 Metal products made of non-alloy structural quality and special steels.

[3] Savinov, S. Yu. Patent RU 16722 U1. Russian Federation. Resonance oscillations' damper, No 2000119297/20, appl. 15.02.2000: publ. 02.10.2001. Federal unitary state enterprise «Central design bureau of transport mechanical engineering, 8 p. [Electronic resource]: https://patents.s3.yandex.net/RU16722U1_20010210.pdf. Last accessed 10.10.2020.

Table 1

Chemical composition of guide rod made of steel 40X [compiled by the authors]

Object of study	Element, mass fraction, %							
	C	Si	Mn	S	P	Cr	Ni	Cu
Guide rod, steel 40X	0,42	0,23	0,67	0,001	0,005	1,05	0,09	0,05
Requirements of GOST 4543–71	0,35–0,45	0,15–0,39	0,48–0,82	no more than		0,78–1,15	no more than	
				0,035	0,035		0,30	0,30

Table 2

Chemical composition of guide rod made of steel 35 [compiled by the authors]

Object of study	Element, mass fraction, %							
	C	Si	Mn	S	P	Cr	Ni	Cu
Guide rod, steel 35	0,33	0,24	0,62	0,001	0,005	0,11	0,09	0,06
Requirements of GOST 1050–2013	0,31–0,41	0,15–0,39	0,47–0,83	no more than				
				0,040	0,035	0,25	0,30	0,30
Guide rod, steel 35 (select)	0,38–0,41	0,35–0,39	0,79–0,83	no more than		0,21–0,25	0,25–0,30	no more than 0,30
				0,040	0,035			

Steel 35 is considered an alternative material for production of guide rods. It is a medium-carbon steel, which is used after normalisation, improvement and surface hardening for various machine parts [4]. The chemical composition of steel 35 is given in Table 2.

The analysis of the results of the study of steel 35, shown in Table 2, allows us to make sure that its chemical composition complies with the standards of GOST 1050.

The choice in favour of steel 35 is based on several advantages over other similar materials: products made from it can withstand high impact loads. The material is characterised by the absence of a tendency to crack formation. In addition, steel 35 is characterised by a combination of low plasticity and hardness. Among the advantages, we can also name the cost characteristics: the simplicity of the production process affects the relatively low price of the product. There is also no need to introduce expensive alloying additives. Steel 35 is characterised by a fairly wide temperature range of application from –40 to +425^{0}C.

Modernisation and optimisation of guide rod manufacturing technology

Processing of parts requires carefully selected methods to achieve optimal properties of products[4]. The most rational technological process for processing guide rods consists of the following stages: a blank obtained by stamping, normalisation, shot cleaning, which ensures removal of burrs and other surface defects [5]. The next stage is mechanical treatment for precise finishing of the shape and dimensions of the part. Next comes heat treatment, including heating, quenching cooling and tempering.

In the basic version, to eliminate quenching cracks on a guide rod made of steel 40X, it is necessary to carry out simultaneous intensive quenching cooling with heat removal from all parts of the item [6–8]. The quenching medium is oil. To solve the problem of environmental friendliness of production, which will become increasingly relevant over time, it is proposed to replace the quenching medium of oil with water. This will reduce the negative impact on the environment. A fast-moving stream of water is used to cool the material considering the flow rate, pressure and temperature to achieve the desired characteristics of the hardened product [9].

The quality indicator is ensuring uniform hardness along the entire perimeter of the product without the need to resort to additional operations such as induction heating [10; 11].

Analysis of operational damage to a guide rod made of steel 40X shows that damage most often occurs in the «210» zone (see Pic.2), which is caused by a change in the strength properties of the metal in the transition area from the high-strength zone hardened by induction to the zone with an improved structure.

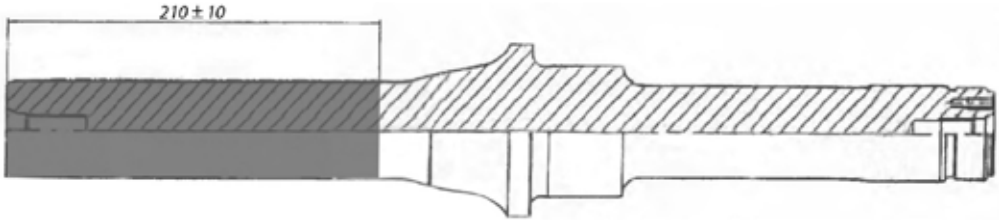
When testing guide rods to assess the quality of products, it is necessary to evaluate the hardness, mechanical properties of the section of the parts, impact toughness and to conduct metallographic studies.

When selecting optimal temperature exposure modes (the effect of exposure duration and temperature on the quality parameters of products is shown in [12–14]) in the process of quenching with a fast-moving water flow and subsequent tempering, it is possible to achieve uniform hardness over the entire section of the guide rod at a level of 45–50 HRC.

CONCLUSIONS

Spring suspension systems using guide rods are an important technical solution in the field of railway engineering and metro rolling stock. The development of new approaches to quenching cooling technology

[4] GOST 2999–75. Metals and alloys. Vickers hardness measurement method. Introduced 1976.01.07. Moscow, USSR State Committee on Standards, 1975, 31 p.



Pic. 2. Scheme of the zone «210» of a guide rod [developed by the authors].

in guide rod manufacturing is important for increasing dependability and durability of products. The proposed quenching cooling technology with a fast-moving water flow suggests the following advantages:

– improving the environmental situation due to the transition from quenching in oil to water;

– reducing the cost of parts when using steel 35 instead of steel 40X.

Thus, the new technological process for guide rod manufacturing will not only improve the quality and accuracy of the manufactured parts but will also be significantly beneficial in terms of economic efficiency and environmental safety, which in turn will ensure a high degree of comfort and safety of passenger transportation but will also open up new prospects for development and improvement of metro trains.

REFERENCES

1. Baranov, I. V., Ermolin, Yu. A., Reva, V. F. Some issues of design and manufacturing technology of elements and units of rolling stock's bogie frames associated with increasing fatigue strength [*Nekotorie voprosy konstruirovaniya i tekhnologii izgorovleniya elementov i uzlov ram telezhek podvizhnogo sostava, svyazannie s povysheniem ustalostnoi prochnosti*]. *Trudy MIIT*, 1968, Iss. 296, pp. 3–20.

2. Guschin, A. N., Gusev, Yu. B., Sozinov, S. V. Behaviour of low-carbon preliminarily deformed steel under static and cyclic load // Trudy NGTU im. R.E. Alekseeva, 2013, Iss. 5 (102), pp. 168−176. [Electronic resource]: https://www.nntu.ru/frontend/web/ngtu/files/nauka/izdaniya/trudy/2013/05/2013-05pdf [full text of the issue]. Last accessed 28.03.2024.

3. Bhadeshia, H. K. D. H., Honeycombe, R. W. K. Steels: Microstructure and Properties. 4th ed., 2017. ISBN 978-0-08-100270-4.

4. Pickering, F. B. Physical metallurgy and the design of steels [*Ed. in Russian: Fizicheskoe metallovedenie i razrabotka stalei*]. Moscow, Metallurgy publ., 1982, 184 p.

5. Zaides, S. A., Vu Van, H., Doan Thanh, V. Developing installation to increase cylindrical part surface hardness // iPolytech Journal, 2020, Vol. 24, Iss. 2, pp. 262−274. DOI: https://doi.org/10.21285/1814-3520-2020-2-262-274.

6. Wang, Li, Speer, J. G. Quenching and Partitioning Steel Heat Treatment. *Metallography, Microstructure, and Analysis*, 2013, Vol. 2, pp. 268–281. DOI: https://doi.org/10.1007/s13632-013-0082-8.

7. Inoue, T., Raniecki, B. Determination of thermal-hardening stress in steels by use of thermoplasticity theory. *Journal of the Mechanics and Physics of Solids*, 1978, Vol. 26, Iss 3, pp. 187–212. DOI: https://doi.org/10.1016/0022-5096(78)90008-X.

8. Shepelyakovsky, K. Z. Hardening of machine parts by surface hardening under induction heating [*Uprochenie detalei mashin poverkhnostnoi zakalkoi pri induktsionnom nagreve*]. Moscow, Mashinostroenie publ., 1972, 288 p.

9. Kuznetsova, N. Yu. Study of the cooling capacity of a flow of fast-moving water during volume-surface hardening of steel [*Issledovanie okhlazhdayushchei sposobnosti potoka bystrodvizhushcheisya vody pri obemno-poverkhnostnoi zakalke stali*]. *XI International Scientific and Technical Ural School-Seminar of Young Scientists-Metallographers*. Yekaterinburg, 2010, pp. 43–45.

10. Kolmogorov, G. L., Kuznetsova, E. V., Tiunov, V. V. Technological residual stress and its impact on durability and dependability of fabricated metal products. Monograph. Perm, Perm National Research Polytechnic University, 2012, 226 p. ISBN: 978-5-398-00840-1.

11. Khvorostukhin, L. A., Shishkin, S. V., Kovalev, A. P. [*et al*]. Increasing the load-bearing capacity of machine parts by surface hardening [*Povyshenie nesushchei sposobnosti detalei mashin poverkhnostnym uprocheniem*]. Moscow, Mashinostroenie publ., 1988, 144 p.

12. Kobasko, N. I., Prokhorenko, N. I. Effect of cooling rate during hardening on crack formation in steel 45 [*Vliyanie skorosti okhlazhdeniya pri zakalke na obrazovanie treshchin v stali 45*]. *Metal science and heat treatment of metals*, 1964, Iss. 2, pp. 53–54.

13. Wu, B. W., Chen, G. X., Lv, J. Z., Zhu, Q., Zhao, X. N., Kang, X. Effect of the axlebox arrangement of the bogie and the primary suspension parameters on the rail corrugation at the sharp curve metro track. *Wear*, Vol. 426–427, Part B, 2019, pp 1828–1836. DOI: 10.1016/j.wear.2019.01.038.

14. Iwnicki, S. Handbook of Railway Vehicle Dynamics (1st ed.). CRC Press. 2006. DOI: https://doi.org/10.1201/9781420004892. ISBN-13: 978-0-8493-3321-7. [Access for subscribers only].

Information about the authors:

Popova, Tatiana A., *Senior Lecturer at the Department of Transport Mechanical Engineering and Rolling Stock Repair Technology of Russian University of Transport, Moscow, Russia, tatiana241187@gmail.com.*

Fedin, Vladimir M., *D.Sc. (Eng), Professor at the Department of Transport Mechanical Engineering and Rolling Stock Repair Technology of Russian University of Transport, Moscow, Russia, vmfedin@yandex.ru*

Popov, Alexander P., *Ph.D. (Eng), Associate Professor at the Department of Transport Mechanical Engineering and Rolling Stock Repair Technology of Russian University of Transport, Moscow, Russia, pap60@bk.ru.*

Article received 05.12.2023, approved 21.04.2024, accepted 23.04.2024.