

JOURNAL OF TRANSPORT



ISSUE 2, 2026 vol. 3

E-ISSN: 2181-2438

ISSN: 3060-5164



RESEARCH, INNOVATION, RESULTS



**TOSHKENT DAVLAT
TRANSPORT UNIVERSITETI**
Tashkent state
transport university



JOURNAL OF TRANSPORT
RESEARCH, INNOVATION, RESULTS

E-ISSN: 2181-2438

ISSN: 3060-5164

VOLUME 3, ISSUE 2

JUNE, 2026



jot.tstu.uz

TASHKENT STATE TRANSPORT UNIVERSITY

JOURNAL OF TRANSPORT

SCIENTIFIC-TECHNICAL AND SCIENTIFIC INNOVATION JOURNAL

VOLUME 3, ISSUE 2 JUNE, 2026

EDITOR-IN-CHIEF

SAID S. SHAUMAROV

Professor, Doctor of Sciences in Technics, Tashkent State Transport University

Deputy Chief Editor

Miraziz M. Talipov

Doctor of Philosophy in Technical Sciences, Tashkent State Transport University

The “**Journal of Transport**” established by Tashkent State Transport University (TSTU), is a prestigious scientific-technical and innovation-focused publication aimed at disseminating cutting-edge research and applied studies in the field of transport and related disciplines. Located at Temiryo‘lchilar Street, 1, office 465, Tashkent, Uzbekistan (100167), the journal operates as a dynamic platform for both national and international academic and professional communities. Submissions and inquiries can be directed to the editorial office via email at jot@tstu.uz.

The Journal of Transport showcases groundbreaking scientific and applied research conducted by transport-oriented universities, higher educational institutions, research centers, and institutes both within the Republic of Uzbekistan and globally. Recognized for its academic rigor, the journal is included in the prestigious list of scientific publications endorsed by the decree of the Presidium of the Higher Attestation Commission No. 353/3 dated April 6, 2024. This inclusion signifies its role as a vital repository for publishing primary scientific findings from doctoral dissertations, including Doctor of Philosophy (PhD) and Doctor of Science (DSc) candidates in the technical and economic sciences.

Published quarterly, the journal provides a broad spectrum of high-quality research articles across diverse areas, including but not limited to:

- Economics of Transport
- Transport Process Organization and Logistics
- Rolling Stock and Train Traction
- Research, Design, and Construction of Railways, Highways, and Airfields, including Technology
- Technosphere Safety
- Power Supply, Electric Rolling Stock, Automation and Telemechanics, Radio Engineering and Communications
- Technological Machinery and Equipment
- Geodesy and Geoinformatics
- Automotive Service
- Air Traffic Control and Aircraft Maintenance
- Traffic Organization
- Railway and Road Operations

The journal benefits from its official recognition under Certificate No. 1150 issued by the Information and Mass Communications Agency, functioning under the Administration of the President of the Republic of Uzbekistan. With its E-ISSN 2181-2438, ISSN 3060-5164 the publication upholds international standards of quality and accessibility.

Articles are published in Uzbek, Russian, and English, ensuring a wide-reaching audience and fostering cross-cultural academic exchange. As a beacon of academic excellence, the "Journal of Transport" continues to serve as a vital conduit for knowledge dissemination, collaboration, and innovation in the transport sector and related fields.

Assessment of the residual life of shunting locomotive frame structures based on complex diagnostics and finite element method

A.M. Yusufov¹^a, Sh.Kh. Abdurasulov¹^b, A.P. Vohidov¹, J. Ulugov¹, A. Mahmudjanov¹

¹Tashkent state transport university, Tashkent, Uzbekistan

Abstract: This article scientifically evaluates the current technical condition and residual service life of the main frame of a TGM-23B shunting locomotive subjected to long-term operation. Using an industrial shunting locomotive as the research object, complex diagnostic procedures were carried out on its load-bearing frame structures using the ultrasonic thickness measurement method. Based on the actual dimensions and thickness indicators obtained, a digital 3D finite element model (FEM) of the frame was developed in the SOLIDWORKS Simulation software suite. The stress-strain state (SSS) and fatigue resistance characteristics of the structure were analyzed under the influence of the most unfavorable standard operational loads. Numerical calculation results proved that the static load-bearing capacity and the factor of safety of the frame remain at the required level.

Keywords: TGM-23B locomotive, shunting locomotive, frame structure, residual life, complex diagnostics, ultrasonic thickness measurement, finite element method (FEM), factor of safety, stress-strain state (SSS), service life extension

Manyovr teplovozi rama konstruksiyalarining qoldiq resursini kompleks diagnostika va chekli elementlar usuli asosida baholash

Yusufov A.M.¹^a, Abdurasulov Sh.X.¹^b, Vohidov A.P.¹, Ulugov J.¹, Mahmudjanov A.¹

¹Toshkent davlat transport universiteti, Toshkent, Uzbekistan

Annotatsiya: Mazkur maqolada uzoq muddat ekspluatatsiya qilingan TGM-23B turidagi manyovr teplovozi asosiy ramasi joriy texnik holati va qoldiq resursi ilmiy jihatdan baholangan. Tadqiqot obyekti sifatida sanoat korxonasida foydalanilayotgan teplovoz olingan bo'lib, uning yuk ko'taruvchi rama konstruksiyalarida ultratovushli tolshinometriya usuli yordamida kompleks diagnostika ishlari amalga oshirilgan. Olingan faktik o'lchamlar va qalinlik ko'rsatkichlari asosida SOLIDWORKS Simulation dasturiy majmuasida ramaning raqamli 3D chekli elementlar modeli (ChEM) shakllantirilgan. Konstruksiyaning kuchlanganlik-deformatsiya holati (KDH) va toliqishga chidamlilik xususiyatlari amaldagi eng noqulay me'yoriy yuklamalar ta'sirida tahlil qilingan. Raqamli hisoblash natijalari ramaning statik ko'taruvchanlik qobiliyati va mustahkamlik zaxira koeffitsienti talab darajasida saqlanib qolganligini isbotladi.

Kalit so'zlar: TGM-23B teplovozi, manyovr lokomotivi, rama konstruksiyasi, qoldiq resurs, kompleks diagnostika, ultratovushli tolshinometriya, chekli elementlar usuli (ChEU), mustahkamlik zaxirasi, kuchlanganlik-deformatsiya holati (KDH), xizmat muddatini uzaytirish

1. Kirish

Bugungi kunda O'zbekiston Respublikasi temir yo'l transportida ekspluatatsiya qilinayotgan lokomotiv parkidagi TGM-23B turidagi manyovr teplovozlar muhim o'rin egallaydi. Mazkur turdagi teplovozlar sanoat korxonalari hududlarida yuk tashish jarayonlarini tashkil etish, vagonlarni saralash, tarkiblarni shakllantirish va boshqa manyovr ishlarini bajarishda keng qo'llaniladi. Shu bilan birga, mavjud lokomotivlarning aksariyat qismi uzoq yillar davomida ekspluatatsiya qilinishi natijasida ularning belgilangan xizmat muddati yakuniga yetib bormoqda yoki allaqachon tugagan [1].

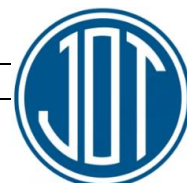
Shu munosabat bilan, mazkur turdagi teplovozlarining qoldiq resursini aniqlash, texnik holatini baholash hamda

xizmat muddatini ilmiy asoslangan holda uzaytirish masalasi dolzarb ilmiy-amaliy vazifa hisoblanadi. Lokomotivlarning xavfsiz ekspluatatsiyasi huquqiy-me'yoriy talablar, texnik diagnostika usullari hamda konstruktiv elementlarning mustahkamlik darajasini baholashga asoslangan kompleks yondashuvni talab qiladi [3].

TGM-23B turidagi manyovr teplovozlarining joriy texnik holatini baholash, ularning asosiy yuk ko'taruvchi elementlari, xususan rama konstruksiyalarining mustahkamligi, ishonchliligi va qoldiq resursini aniqlash transport vositasining yangidan belgilangan ekspluatatsiya muddatida xavfsiz ishlashini ilmiy jihatdan asoslash imkonini beradi. Teplovozlarining uzoq muddatli ekspluatatsiyasi jarayonida metall konstruksiyalarda charchash jarayonlari, qoldiq deformatsiyalar, payvand

^a <https://orcid.org/0000-0001-8310-8225>

^b <https://orcid.org/0000-0001-5581-507X>



choklarida mikro yoriqlar paydo bo'lishi kabi omillar kuzatilishi mumkin. Bu esa, o'z navbatida, lokomotivning umumiy texnik holatiga hamda uning xavfsiz ishlashiga sezilarli ta'sir ko'rsatadi.

Teplovozlarning xavfsiz ishlashi ko'p jihatdan uning asosiy uzel va agregatlarining qoldiq resursi bilan belgilanadi. Ushbu muammoni hal qilish uchun texnik diagnostika ishlarini muntazam amalga oshirish, aniqlangan nosozliklarni o'z vaqtida bartaraf etish, zarur hollarda uzel va agregatlarni ta'mirlash yoki almashtirish talab etiladi [3]. Shu sababli, metall konstruksiyalar hamda asosiy uzel-agregatlar xizmat muddati davomida o'z funksional vazifalarini jiddiy shikastlanishlarsiz bajarishi zarur.

2. Tadqiqot metodologiyasi

Manovr teplovozinining diagnostika tekshiruv va texnik holatini baholash metodologiyasi

TGM-23B manovr teplovozlarning ekspluatatsion ishonchligini baholashda ularning joriy texnik holatini aniqlash hal qiluvchi bosqich hisoblanadi. Diagnostika ishlari Toshkent davlat transport universiteti "Lokomotivlar va lokomotiv xo'jaligi" kafedrasida qoshidagi "Temir yo'llarning harakatlanuvchi tarkibi" ilmiy markazi mutaxassislari tomonidan xalqaro standartlar va O'zbekiston Respublikasi "Texnik jihatdan tartibga solish" agentligi tomonidan sertifikatlangan o'lchov vositalari yordamida amalga oshiriladi. Quyidagi 1-rasmda TGM-23B turidagi Sanoat manovr teplovozinining umumiy ko'rinishi keltirib o'tilgan.

Teplovoznining tashqi va ichki ko'rigidan o'tkazishdan maqsad loyiha hujjatlariga nomuvofiqliklarni, ekspluatatsiya jarayonidagi shikastlanishlarni, yoriqlarni, korroziyalni hududlarni hamda jihozlarning to'liqligini aniqlashdan iborat [4-5]. Tekshiruv jarayonida quyidagi tizimlar qamrab olinadi:

- Rama konstruksiyasi va ekipaj qismi;
- Kuzov va mashinist kabinasi;
- Zarba-tortuv va avtortirkama uskunalar;
- Tormoz va elektr jihozlari hamda yordamchi uskunalar.



1-rasm. TGM-23B turidagi teplovoznining umumiy ko'rinishi

Aniqlangan har bir nosozlik teplovoznining texnik holatini tekshirish kartasida qayd etiladi. Nuqsonlarning tasnifi va o'lchamini aniqlashda 4-20 marta kattalashtiruvchi optik asboblardan hamda zamonaviy putur yetkazmaydigan nazorat usullari qo'llaniladi:

➤ Vizual va o'lchov nazorati: Qismlarning eskirish darajasi o'lchov xaritalari talablari asosida $\pm 0,3$ mm gacha bo'lgan aniqlikda o'lchanadi.

➤ Putur yetkazmaydigan nazorat: Payvandlangan bo'g'inlar va asosiy metallarda yoriqlar, g'ovaklik yoki shlak qo'shimchalarini aniqlash uchun ultratovushli, magnit yoki rangli nuqsonlarni aniqlash usullari tanlab olinadi.

➤ Laboratoriya tahlillari: Metallning mexanik xususiyatlari, metallografik tahlili va kimyoviy tarkibi o'rganiladi. Bu tadqiqotlar asosiy va payvandlash materiallarining yaroqliligini aniqlashda muhim ilmiy asos bo'lib xizmat qiladi.

Tekshiruvlar natijasida har bir qismning keyingi ekspluatatsiyaga yaroqliligi yoki uni tiklash imkoniyatlari belgilanadi. Aniqlangan barcha nosozliklar va laboratoriya tadqiqotlari natijalari mutaxassislar tomonidan imzolangan xulosa shaklida rasmiylashtiriladi [6]. Ushbu ma'lumotlar teplovoznining qoldiq resursini hisoblash va uni uzaytirish masalalarini ilmiy asoslash uchun asosiy kirish ma'lumoti hisoblanadi.

Rama konstruksiyalarining korroziya omilini hisobga olgan holda ultratovushli tolshinometriya sxemasini ishlab chiqish

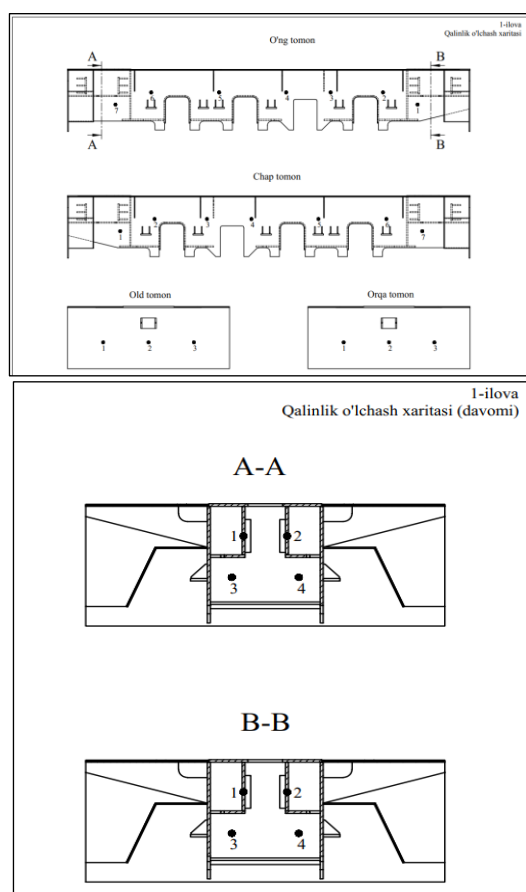
Teplovozlarning xizmat muddatini uzaytirishda rama konstruksiyalarining texnik holatini baholash hal qiluvchi ahamiyatga ega. Tadqiqot jarayonida teng taqsimlangan korroziya omilini hisobga olgan holda, rama elementlarining qoldiq qalinligini aniqlash uchun ultratovushli tolshinometriya usuli ishlab chiqildi [7-9].

Teplovozlarning rama konstruksiyalarining joriy texnik holatini aniqlash quyidagi ishlarni o'z ichiga oladi. Qoldiq xizmat muddatini uzaytirishga bevosita ta'sir ko'rsatadigan omillardan biri uning rama konstruksiyalarining texnik holatini tekshirishdir. Texnik holatni tekshirish jarayonida xizmat muddati tugagan TGM-23B turidagi manovr teplovozlarning rama konstruksiyalarining qalinligini o'lchash (tolshinometrik tahlil) sxemasi ishlab chiqildi [10].

Asosiy rama kesimlarga ajratildi va asosiy ramani qalinligini o'lchash sxemasi 1- rasmda keltirib o'tilgan.

Sanoat korxonalari infratuzilmasida uzluksiz manovr operatsiyalarini bajaruvchi lokomotivlar resursini tasdiqlash murakkab muhandislik yechimlarini talab etadi. Shu sababli, respublika temir yo'llari tarmog'iga tutash "Kvars" AJ hududida og'ir sharoitlarda ekspluatatsiya qilinayotgan №355 inventar raqamli TGM-23B teplovozinini kapital ta'mirlash jarayonida qoldiq xizmat muddatini uzaytirish maqsadida uning asosiy yuk ko'taruvchi ramasi to'liq diagnostikadan o'tkazildi [11].

Texnik holatni shunchaki vizual baholashdan voz kechilib, aniq sonli ko'rsatkichlarga tayanish uchun rama fazoviy konstruksiya sifatida tarqalgan dinamik yuklamalar (tortish, tormozlanish va manovr zarbalari) ta'siriga qarab qat'iy kesimlarga differensiallashtirildi. Har bir kritik zona bo'yicha metall yemirilishi va korroziya qatlamini qayd etishga qaratilgan maxsus koordinatali tolshinometriya xaritasi ishlab chiqildi.



1-rasm. TGM-23B turidagi manyovr teplovzorlarining rama konstruksiyalarining qalinligini o'lchash xaritasi

Ekspluatatsion eskirish oqibatida asosiy metallda yuzaga keladigan yashirin degradatsiya jarayonlarini aniqlashda zamonaviy ultratovushli qalinlik o'lchash usuli qo'llanildi. Ushbu amaliyot konstruksiya yaxlitligini buzmaganda, bo'ylama va ko'ndalang balkalarning faktik qalinlik parametrlarini bevosita o'lchash imkonini berdi. Asosiy rama kesimlari bo'yicha o'tkazilgan mazkur o'lchov jarayonining yakuniy natijalari tizimlashtirilib, keyingi mustahkamlik hisoblari uchun tayanch ma'lumot sifatida mos ravishda 1-jadvalda keltirilgan.

1-jadval

TGM-23B turidagi №355 teplovzoning asosiy ramasining qalinligini o'lchash natijalari, mm

Chap tomon							
1	2	3	4	5	6	7	
25,21	25,13	25,11	25,02	25,09	25,02	25,12	
Old tomon				Orqa tomon			
1	2	3		4	5	6	
19,85	20,16	19,78		19,85	19,71	20,00	
A-A				B-B			
1	2	3	4	1	2	3	4
15,2	15,43	15,16	15,03	15,21	15,13	15,22	15,17

1-jadvalda keltirilgan qalinlik o'lchash (tolshinometriya) natijalari TGM-23B turidagi №355 raqamli manyovr teplovozi rama konstruksiyasining joriy

texnik va fizik holatini kompleks baholash uchun asosiy empirik baza bo'lib xizmat qildi. Olingan aniq o'lchamlar va faktik qalinlik ko'rsatkichlari asosida zamonaviy SOLIDWORKS dasturiy majmuasida ramaning yuqori aniqlikdagi 3D chekli elementlar modeli (ChEM) ishlab chiqildi [12]. Bunda raqamli modelga kiritilgan geometrik parametrlar shunchaki ideal holatdagi chizmalarni emas, balki bevosita ekspluatatsiya jarayonidagi haqiqiy qoldiq qalinliklarni o'zida aks ettiradi. Bu yondashuv navbatdagi mustahkamlik va kuchlanganlik-deformatsiya holati (KDH) hisob-kitoblarning ilmiy ishonchligini keskin oshiradi.

Eksperimental o'lchovlar natijalarining qiyosiy tahlili shuni ko'rsatdiki, ramani tashkil etuvchi asosiy po'lat listlarning faktik qalinligi dastlabki me'yoriy konstruktorlik hujjatlariga va ishlab chiqaruvchi zavod chizmalariga to'liq muvofiq keladi. Uzoq muddatli ekspluatatsiya sharoitlariga va muntazam dinamik yuklamalarga qaramay, yuk ko'taruvchi bo'ylama va ko'ndalang balkalarda, shuningdek, kritik o'tish zonalarida metallning sezilarli darajada yemirilishi, xatarli korroziya o'choqlari yoki qatlamlarga ajralish nuqsonlari aniqlanmadi.

Ushbu holat metall konstruksiyaning o'z ko'taruvchanlik qobiliyatini hamda belgilangan mustahkamlik zaxirasini to'la saqlab qolganligini isbotlaydi. Olingan mazkur xulosalar teplovoznining qoldiq resursini aniq baholash, xizmat muddatini uzaytirishni ilmiy asoslash hamda keyingi ekspluatatsiya jarayonida harakat xavfsizligini ta'minlash bo'yicha yakuniy muhandislik qarorlarini qabul qilish uchun ishonchli zamin yaratadi].

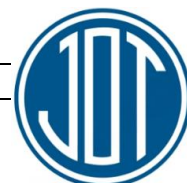
3. Natija va muhokamalar

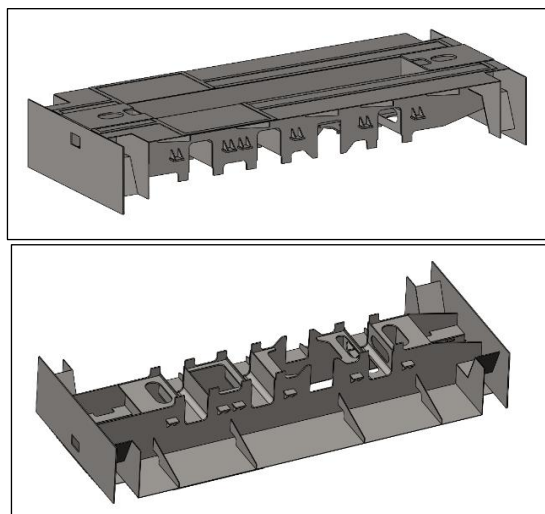
O'lchov ma'lumotlari asosida rama konstruksiyasining chekli elementlar usuli orqali mustahkamlik tahlili

Tolshinometriya tahlili orqali tasdiqlangan faktik o'lchamlar asosida TGM-23B manyovr teplovozi asosiy ramasining raqamli modeli SOLIDWORKS Simulation dasturiy majmuasida shakllantirildi. Metall konstruksiyaning ishonchligi ikkita fundamental mezon: statik yuk ko'tarish qobiliyati (oquvchanlik chegarasiga nisbatan) va davriy yuklanish sharoitidagi toliqishga chidamlilik zaxirasi bo'yicha baholandi [13].

Rama konstruksiyasiga ta'sir etuvchi kuchlanishlar ekspluatatsiya jarayonidagi eng noqulay yuklanish kombinatsiyalari – og'irlik kuchi, avtotirkama apparati orqali uzatiladigan tortish-tormozlash zarbalari hamda yo'lning egri uchastkalarida yuzaga keladigan kvazistatik kuchlar asosida jamlandi. Amaldagi me'yoriy talablarga muvofiq, ruxsat etilgan kuchlanishlar ish rejimining og'irlik darajasiga qarab material shartli oquvchanlik chegarasining $0.6\sigma_{0.2}$ dan $0.9\sigma_{0.2}$ gacha bo'lgan diapazonida qat'iy chegaralandi.

Toliqishga qarshi zaxira koeffitsiyentini aniqlashda standart po'lat namunaning chidamlilik chegarasi, sikl asimmetriyasi ta'sirini tavsiflovchi koeffitsiyenti, nazariy kuchlanish konsentratsiyasi va detal ko'ndalang kesimining o'lcham omilini hisobga oluvchi murakkab empirik funksiyalardan foydalanildi. Analitik baholashlar bilan bir qatorda, 3-rasmda ko'rsatilgan 3D modeli ishlab chiqildi.

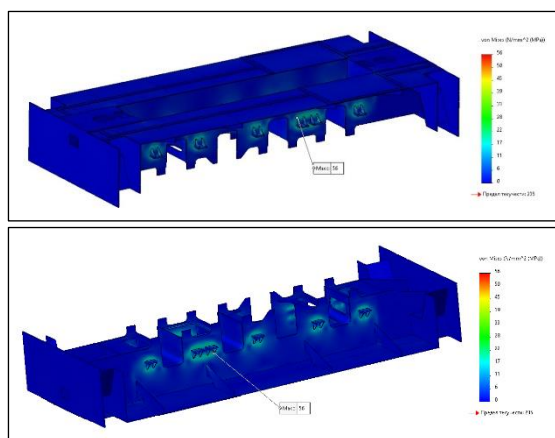




3-rasm. TGM-23B turidagi teplovoz ramasining 3D modeli

Chekli elementlar modeliga o'rnatilgan chegaraviy shartlar va yuklamalar ta'sirida konstruksiyaning kuchlanganlik-deformatsiya holati (KDH) generatsiya qilindi.

Olingan ekvivalent kuchlanishlarining taqsimlanish epyurasi (4-rasm) asosiy mexanik kuchlanishlar bo'yama balkalar hamda ressa osmalari o'rnatiladigan o'tish uzellarida konsentratsiyalanishini ko'rsatdi. Tahlil qilinayotgan kritik zonalaridagi maksimal kuchlanish amplitudasi ruxsat etilgan material oquvchanlik chegarasidan past darajada barqarorlashgan.



4-rasm. TGM-23B turidagi teplovozning kuchlanganlik-deformatsiya holati

Yuqoridagi 4-rasmda keltirilgan TGM-23B teplovozi asosiy ramasining kuchlanganlik-deformatsiya holati (KDH) epyurasi ekspluatatsion yuklamalarning murakkab ta'sirini vizual namoyon etadi [14]. Chekli elementlar usuli orqali olingan ushbu tahlil shuni ko'rsatadiki, maksimal mexanik kuchlanishlar asosan bo'yama balkalar va ressa osmalari o'rnatiladigan kritik o'tish uzellarida jamlangan. Shunga qaramay, qayd etilgan eng yuqori kuchlanish amplitudasi konstruksiyada qo'llanilgan po'lat materialining ruxsat etilgan oquvchanlik chegarasidan sezilarli darajada past ekanligi aniqlandi. Mazkur holat ramaning statik yuk ko'tarish qobiliyati to'liq saqlanganligini hamda metallning toliqishga chidamlilik zaxirasi yetarli ekanligini ilmiy

jihatdan isbotlaydi. Olingan raqamli natijalar xatarli plastik deformatsiyalar xavfi yo'qligini tasdiqlab, xizmat muddatini xavfsiz uzaytirish uchun asosiy muhandislik kafolati bo'lib xizmat qiladi.

4. Xulosa

O'tkazilgan kompleks diagnostika va raqamli modellashirish tadqiqotlari natijasida sanoat korxonalarida ekspluatatsiya qilinayotgan TGM-23B turidagi manyovr teplovozi asosiy ramasining joriy texnik holati va qoldiq resursi ilmiy jihatdan baholandi. Olingan natijalar asosida quyidagi yakuniy muhandislik xulosalari shakllantirildi:

Birinchidan, "Kvars" AJ hududida ishlovchi №355 raqamli teplovoz misolida o'tkazilgan ultratovushli tolshinometriya tahlillari shuni tasdiqladiki, uzoq muddatli ekspluatatsiya va murakkab dinamik yuklamalarga qaramay, rama metall listlarining faktik qalinligi zavod konstruktorlik hujjatlari me'yorlariga to'liq mos keladi. Konstruksiyada ko'taruvchanlik qobiliyatiga putur yetkazuvchi xatarli korroziya o'choqlari va qatlamlarga ajralish nuqsonlari aniqlanmadi.

Ikkinchidan, o'lchov natijalari asosida SOLIDWORKS Simulation dasturiy majmuasida shakllantirilgan 3D chekli elementlar modeli (ChEM) yordamida o'tkazilgan kuchlanganlik-deformatsiya holati (KDH) tahlili eng noqulay yuklanish kombinatsiyalarida ham maksimal mexanik kuchlanishlar ruxsat etilgan oquvchanlik chegarasidan barqaror ravishda past ekanligini ko'rsatdi. Asosiy mexanik kuchlanishlar bo'yama balkalar va ressa osmalari kabi kritik uzellarda to'plamsa-da, ularning amplitudasi plastik deformatsiyalarni keltirib chiqarmaydi.

Uchinchidan, hisoblab chiqilgan mustahkamlik zaxira koeffitsiyenti va toliqishga chidamlilik ko'rsatkichlari rama konstruksiyasining amaldagi davlat standartlari va xalqaro me'yorlarga to'liq javob berishini isbotladi. Metallning charchoqlik zaxirasi navbatdagi ekspluatatsiya davri uchun yetarli darajada saqlanib qolgan.

Foydalangan adabiyotlar / References

- [1] Abdurasulov S. et al. Structural strength evaluation of the main frame in the PE2U industrial traction unit control electric locomotive //AIP Conference Proceedings. – AIP Publishing LLC, 2026. – T. 3447. – №. 1. – C. 070005.
- [2] Yusufov A., Taiwen Y. Service life extension through retrofit of the TEM2 shunting locomotive bogie frame //AIP Conference Proceedings. – AIP Publishing LLC, 2026. – T. 3447. – №. 1. – C. 070008.
- [3] Yusufov A. et al. Modernization strategies for the main frame structure of TEM2 shunting locomotives to prolong service life //AIP Conference Proceedings. – AIP Publishing LLC, 2026. – T. 3447. – №. 1. – C. 070007.
- [4] Raxmiddinov I. et al. Experimental and finite element analysis of the structural durability of special self-propelled rolling stock frames //Vibroengineering Procedia. – 2025. – T. 60. – C. 186-192.
- [5] Ivanov, D. Big Data Analytics and Fatigue Life Assessment in Railway Freight Transportation. Procedia Computer Science, – 2019. Vol. 159, pp. 1086-1095.

[6] Anderson, D. Optimization Techniques in Logistics and Transportation Maintenance". Operations Research Journal, – 2019. Vol. 16, Issue 2, pp. 100-115.

[7] Wang, L., & Zhang, X. Optimizing Data Flow and Maintenance Strategies in Supply Chain Management Using AI Techniques. International Journal of Supply Chain Management, – 2021. Vol. 6, Issue 3, pp. 23-35.

[8] Abdurasulov S. et al. Evaluation of mean stress under load cycle of PE2M (U) industrial traction unit motorized dumpcar underframe using finite element method //Vibroengineering Procedia. – 2025. – T. 60. – C. 731-737.

[9] Kosimov K., et al. Experimental evaluation of residual deflection and structural stiffness of the UzTE16M locomotive frame under static loading conditions //Vibroengineering Procedia. – 2025. – T. 60. – C. 579-585.

[10] Kudratov S. et al. Diesel locomotives-Fault analysis and problem solving //AIP Conference Proceedings. – AIP Publishing LLC, 2025. – T. 3256. – №. 1. – C. 060013.

[11] Abdurasulov S. et al. Stress-strain state analysis of cross beam of main frame of industrial electric locomotives PE2M and PE2U //AIP Conference Proceedings. – AIP Publishing LLC, 2025. – T. 3256. – №. 1. – C. 060011.

[12] Jamilov S. et al. Mathematical modelling of heat exchange process of locomotive traction electric motors //AIP Conference Proceedings. – AIP Publishing LLC, 2025. – T. 3256. – №. 1. – C. 060012.

[13] Yusuf A. Reliability analysis of asynchronous traction electric motors of O'Z-EL series locomotives and ways to improve their operational reliability //Acta of Turin Polytechnic University in Tashkent. – 2025. – T. 15. – №. 1. – C. 65-69.

[14] Jamilov S. et al. Research of Factors Affecting the Heating and Cooling of Locomotive Traction Electric Machines //ICTEA: International Conference on Thermal Engineering. – 2024. – T. 1. – №. 1.

[15] Yusuf A. Analysis of the state and prospects for the development of the locomotive fleet JSC "O'zbekiston temir yo'li" //Acta of Turin Polytechnic University in Tashkent. – 2023. – T. 13. – №. 1. – C. 16-21.

[16] Abdurasulov S., Zayniddinov N., Yusuf A. Requirements for the strength of load-bearing structures of locomotives //Acta of Turin Polytechnic University in Tashkent. – 2023. – T. 30. – C. 44-48.

[17] Khamidov O. R. et al. Investigation of the stress-strain state of the bogie frame of shunting locomotives using the finite element method //Железнодорожный подвижной состав: проблемы, решения, перспективы. – 2023. – С. 504-509.

[18] Abdurasulov S. X. et al. O'zbekiston respublikasi tog'- kon sanoatida foydalanilayotgan tortish agregatlari parking tahlili //Academic research in educational sciences. – 2023. – T. 4. – №. 8. – C. 146-157.

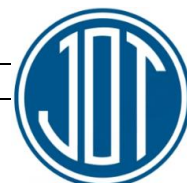
[19] Кодиров Н. С. и др. Разработка метода для определения динамической нагруженности узлов подвижного состава с применением неразрушающего контроля //Приборы и методы измерений, контроля качества и диагностики в. – 2022. – С. 98.

[20] Хамидов О. Р. и др. Оценка средних напряжений цикла в несущих рамах тепловозов на основе, конечно-элементного, расчета от статических нагрузок //Academic research in modern science. – 2022. – Т. 1. – №. 9. – С. 118-124.

[21] Абдурасулов Ш. Х. и др. Вестник транспорта поволжья //вестник транспорта поволжья Учредители: Приволжский государственный университет путей сообщения. – №. 1. – С. 7-11.

Mualliflar to'g'risida ma'lumot/ Information about the authors

Yusufov Abdulaziz / Abdulaziz Yusufov	Toshkent davlat transport universiteti "Lokomotivlar va lokomotiv xo'jaligi" kafedrasida dotsenti, t.f.f.d., (PhD), E-mail: abdulazizyusufovv@bk.ru Tel.: +99894 308 88 08 https://orcid.org/0000-0002-1651-5493
Abdurasulov Sherzamin / Sherzamin Abdurasulov	Toshkent davlat transport universiteti "Lokomotivlar va lokomotiv xo'jaligi" kafedrasida katta o'qituvchisi, t.f.f.d., (PhD), E-mail: shezamin.tstu@gmail.com Tel.: + 99890 021 04 93 https://orcid.org/0000-0001-5581-507X
Vohidov Azizbek / Azizbek Vohidov	Toshkent davlat transport universiteti "Lokomotivlar va lokomotiv xo'jaligi" kafedrasida tayanch doktranti Tel.: +99891 233 00 55
Ulugov Javoxir / Javokhir Ulugov	Toshkent davlat transport universiteti "Lokomotivlar va lokomotiv xo'jaligi" kafedrasida magistranti Tel.: +99890 947 18 08
Makhmudjanov Abbos / Abbos Makhmudjanov	Toshkent davlat transport universiteti "Lokomotivlar va lokomotiv xo'jaligi" kafedrasida magistranti Tel.: +99890 628 11 31



M. Miralimov, Sh. Akhmedov, B. Mukhitdinov, A. Menglibaev	
<i>Effective technologies for protecting bridge cones using gabion structures.....</i>	160
A. Antonov, V. Struk, M. Rakhmatov, A. Riskulov, Kh. Nurmetov	
<i>Modelling of thermophysical characteristics and analysis of interfacial interaction in nanocomposites based on polymer matrices.....</i>	164
M. Sobirov	
<i>Heating of car brake discs and measures to eliminate it.....</i>	169
R. Dadaboev, T. Olimov	
<i>Theoretical foundations of the mass customization concept in the automotive industry.....</i>	174
A. Yusufov, Sh. Abdurasulov, A. Vohidov, J. Ulugov, A. Mahmudjanov	
<i>Evaluation of the operational reliability of metro car bogie frames based on finite element method and optimization models</i>	178
A. Yusufov, Sh. Abdurasulov, A. Vohidov, J. Ulugov, A. Mahmudjanov	
<i>Assessment of the residual life of shunting locomotive frame structures based on complex diagnostics and finite element method</i>	183
D. Shodmonov	
<i>Integration of case-based reasoning and the k-nearest neighbours algorithm for classification tasks in intelligent decision support systems.....</i>	188
E. Kamalova, A. Kholmatov	
<i>Scientific interpretation of the essence, classification, and evaluation indicators of logistics efficiency.....</i>	192
E. Kamalova, A. Kholmatov	
<i>The role and specific features of logistics efficiency in the transport system within the national economy.....</i>	198