Remaining life of main frame and extension of service life of shunting Locomotives on railways of Republic of Uzbekistan

Otabek Khamidov*, *Abdulaziz* Yusufov, *Shuxrat* Jamilov, and *Shohijakhon* Kudratov

Tashkent State Transport University, Tashkent, Uzbekistan

Abstract. The article is devoted to topical issues of control and calculation of the residual life of the main frame of shunting diesel locomotives operated on the railway of Uzbekistan. The article presents mathematical methods for calculating the residual life of locomotives. Also, it substantiates the expediency of extending the service life of shunting locomotives at the earliest stage of their development. The results were obtained with the help of the Solid works software environment, which allows you to analyze the calculations and identify the forces acting on the main frame of the locomotives. In addition, the 3-D model of the main frame was analyzed with effort. An analysis of the locomotive fleet of Uzbekistan Temir Yo'llari JSC was carried out; based on the fleet data, a detailed analysis of shunting locomotives was carried out. Methods for predicting the main frame's residual life and extending the shunting locomotives' service life have been studied.

1 Introduction

The volume of cargo and passenger transportation in the Republic of Uzbekistan is increasing year by year, which, in turn, is an important task to always maintain the traffic structure in technical conditions. TEM2 and ChME3 type shunting locomotives are used for sorting, distribution, and formation of the traffic structure of wagons at the railway station as an integral part of cargo and passenger transportation in the locomotive economy of JSC "Uzbekiston temir yo'llari" [1-3].

The assigned service life of locomotives (including the additional one) should be determined by the resource of their basic parts (bogie frame, main frame, load-bearing elements of the body). At the same time, the service life of mainline diesel locomotives should not exceed 45 years, shunting diesel locomotives and electric locomotives - 50 years.

Shunting locomotives of the locomotive fleet of JSC "Uzbekiston temir yo'llari" have exhausted their service life for thirty years; practically no new shunting locomotives have been purchased from the side of JSC "Uzbekiston temir yo'llari" [3-5].

*Corresponding author: otabek.rustamovich@yandex.ru

The operational wear and tear of shunting locomotives, on the one hand, and the steady upward trend in the volume of traffic in the railway transport of Uzbekistan (Uzbekiston Temir Yo'llari), on the other hand, prompted the search for radical ways to increase the number of traction units in operation. As one of the possible ways to solve this problem, it was proposed to carry out a major overhaul with a service life extension (including the additional one) of shunting locomotives after the expiration of the designated service life (more than 50 years)[5-8].

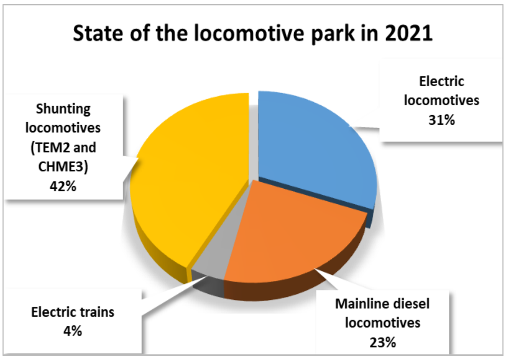
When carrying out the PSC, it is implied the implementation of deep modernization of a specific object of the railway transport of Uzbekistan, aimed at improving its operational properties and not worsening its main technical parameters (traction, etc.). This approach is effective provided that the modernized railway transport object pays off quickly enough; it entails the need to preserve its most labor-intensive and metal-intensive components (main frame, bogie frames, body, cabin, etc.), which determine all layout solutions and product identification numbers. Analysis of the locomotive fleet of JSC "Uzbekiston temir yo'llari".

The locomotive fleet of "Uzbekistan Temir Yo'llari" JSC is constantly replenished with modern electric locomotives for freight and passenger rolling stock. Table 1 shows an analysis of the number of locomotive fleets of "Uzbekistan Temir Yo'llari" JSC in 2021-2022 [8-10].

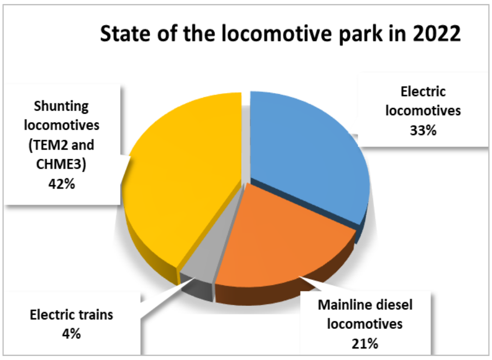
Table 1: an analysis of the number of locomotive fleets of "Uzbekistan Temir Yo'llari" JSC in 2021-2022 is given

№	Locomotive type	State of the locomotive fleet in 2021	State of the locomotive fleet in 2022
1	Electric locomotives	126	137
2	Mainline diesel locomotives	95	87
3	Electric trains	18	18
4	Shunting locomotives (TEM2 and CHME3)	173	173
5	Total locomotives	412	415

The first and second diagrams show the percentage share of traction rolling stock in 2021-2022.



1-diagram: state of the locomotive park in 2021



2-diagram: state of the locomotive park in 2022

Based on the state of the locomotive fleet of "Uzbekistan Temir Yo'llari" JSC for 2021, according to the first diagram, shunting locomotives account for 42%, electric locomotives 31%, mainline diesel locomotives 23% and electric sections 4%, and the second diagram in 2022 shunting locomotives 42%, electric locomotives 33%, mainline diesel locomotives 21% and electrical sections 4%.

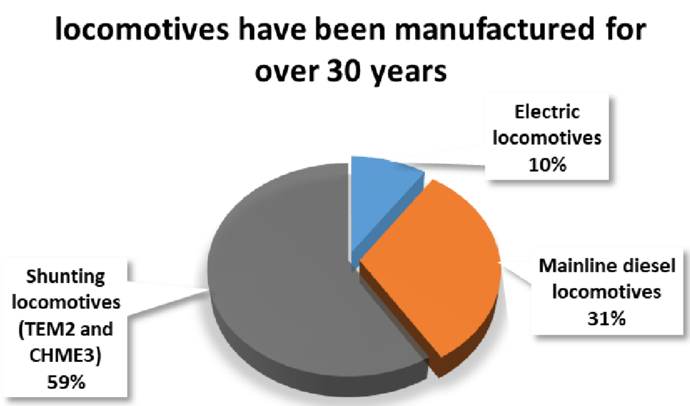
In the locomotive fleet in 2021-2022, shunting locomotives (TEM2 and ChME3) account for 42%, electric locomotives - for 4%, and we can observe that the figure has not changed. Most of the changes affected modern electric locomotives, which increased from 31% to 33% due to purchase, while diesel locomotives decreased from 23% to 21% due to end of life. The types and quantity of traction rolling stock make it possible to determine the average age of the locomotive fleet based on their close connection with the years of production (age).

Table 2 below presents an analysis of the types of structure of traction rolling stock in the current period of operation in the locomotive fleet of Uzbekistan Temir Yo'llari JSC by year (age) of production [1-6].

Table 2: an analysis of the age of traction rolling stock during the operation of the locomotive fleet of "Uzbekistan Temir Yo'llari" JSC is given

№	Type of traction rolling stock	up to 10 years	10 to 20 years	20 to 30 years old	Over 30 years	Total
1	Electric locomotives	44	12	30	30	116
2	Mainline diesel locomotives	45	7	9	99	160
3	Shunting locomotives (TEM2 and CHME3)	-	-	12	161	173
4	Total locomotives	89	19	51	314	473

Diagram 2 shows the percentage share of traction rolling stock over 30 years in the production of the locomotive fleet.



3-diagram: state by release

The production fleet of locomotives is more than 30 years old; rolling stock traction is performed by shunting locomotives (TEM2 and ChME3) 59%, mainline diesel locomotives 31% and electric locomotives 10%.

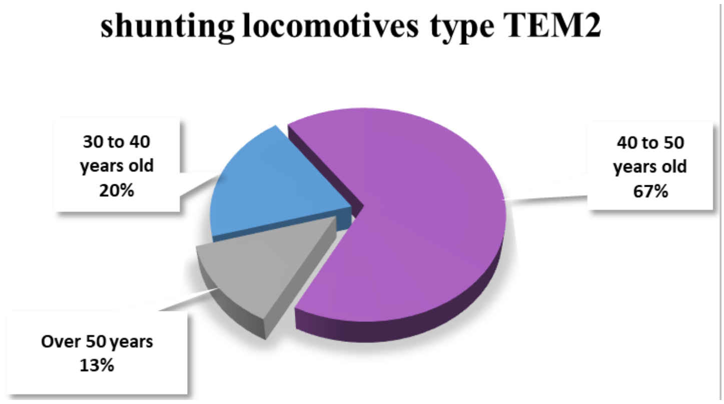
An analysis of the years of production of shunting locomotives of the TEM2 type in the locomotive fleet of "Uzbekistan Temir Yo'llari JSC is presented in Table 3.

Table 3. The service life of diesel locomotives of the TEM2 series of the locomotive fleet of Uzbekistan Temir Yo'llari JSC has expired.

№	Type of shunting locomotive	30 to 40 years old	40 to 50 years old	Over 50 years	Total
1	ТЭМ2 (locomotive with electric transmission, shunting)	26	89	17	132

In the coming years, several problems may arise: on the one hand, the cost of using an outdated traffic structure and constantly maintaining it in a suspended state; on the other hand, due to the low traffic content, it is impossible to maneuver in the locomotive economy[11-14].

Due to limited investment opportunities, replacing new generation shunting locomotives with new ones is very difficult. Therefore, in addition to the gradual renewal of the fleet through the acquisition of new maneuverable locomotives, it is also desirable to extend the locomotive's life by overhauling part of the fleet[7].



4- diagram: Analysis of shunting locomotives of the TEM2 series in the locomotive fleet JSC "Uzbekiston temir yo'llari" for the years of production

The fourth diagram shows the service life from the date of issue; we can notice that the TEM2 series shunting diesel locomotives are from 30 to 40 years - 20%, from 40 to 50 years - 67%, and 13% - over 50 years. The service life during the overhaul of locomotives of the TEM2 type is increased based on regulatory documents, and this period should not exceed 50 years. It can be seen from the fourth diagram that a fifth of the units of shunting diesel locomotives of the TEM2 series in the locomotive fleet of "Uzbekistan Temir Yo'llari" JSC have passed their service life, and in the worst case, this figure increases from year to year[1-10].

2 Results and Discussion

The determination of the residual service life of the main frame of shunting locomotives is carried out using diagnostics. During the diagnostic process, however, control is without damage (non-destructive testing) and is carried out in a position where the main frame of the locomotive is divided into parts.

This work is devoted to studying the features during the PSC, which implies the implementation of deep modernization of a specific railway transport facility in Uzbekistan, aimed at improving its operational properties and not worsening its main technical parameters (traction, etc.). This approach is effective provided that the modernized railway transport object pays off quickly enough; it entails the need to preserve its most labor-intensive and metal-intensive components (main frame, bogie frames, body, cabin, etc.), which determine all layout solutions and product identification number [11-14].

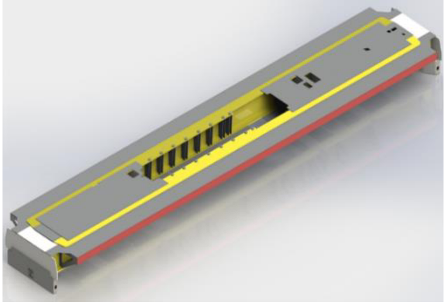
During the overhaul, most of the units of diesel locomotives of the TEM2 series can be repaired and replaced, with the help of these operations, the performance of the units is partially preserved, and the efficiency of traction parameters is increased. The main part

https://doi.org/10.1051/e3sconf/202336505008

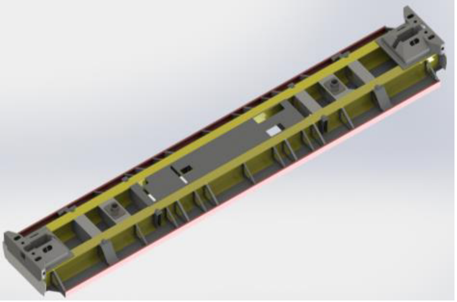
showing the state of the residual life of diesel locomotives of the TEM1, TEM2, and TEM2A series is the main frame and the bogie frame.

The main frame of the shunting locomotive bearing the metal structure takes over and transfers vertical, traction, shock, braking, and inertial forces to the main components of the undercarriage, such as frames, bogies (axles), and shock-traction devices [15-17].

To prevent accidents and irreversible destruction of shunting locomotives operated by "Uzbekiston Temir Yo'llari" JSC, the main priority is to extend the service life and ensure the safety of shunting locomotives through early prediction and troubleshooting. The remaining resource of the shunting locomotive is determined by the node that has the smallest residual resource, this node of the moving unit is the main frame [19-21].



a)



b)

Fig. 5. Three-dimensional model of the main frame of the diesel locomotive TEM2. *a)* view from above, *b)* view from the bottom

Let us consider the main methods for determining the residual resource of the main frame of a shunting locomotive [12]. To identify the residual resource, the supporting structure of the main frame of the shunting locomotive is used. The supporting structure of the main frame must ensure during the operation of the shunting locomotive reliability, functionality, and traffic safety following the requirements of the rules of technical operation on the railway [6]. Shunting locomotives are not operated at full capacity during operation; therefore, it can be assumed that the residual resource has not yet been fully developed. International practices show that the actual term of an operated shunting locomotive on the railway may exceed the manufacturer's term.

Let us consider estimating the residual life of the main frame based on the TEM2 shunting locomotive. Shunting is an integral part of the transportation process. The main type of locomotives designed to perform heavy shunting work on the railways of Uzbekistan is shunting locomotives of the TEM2 type [4].

When calculating complexly stressed elements, equivalent stresses are determined, which should not exceed the allowable ones established for the corresponding design mode [10-14].

3 Preparation of initial data for performing a static calculation

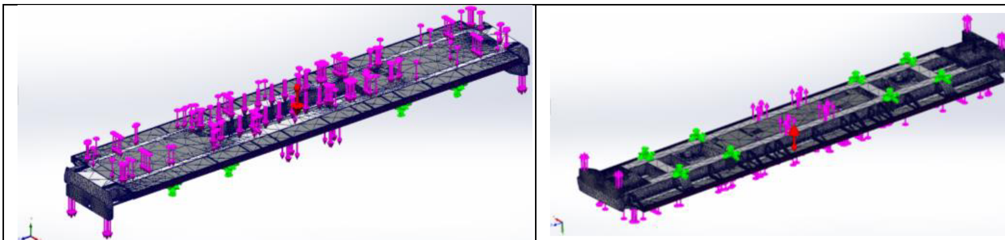
As is known, the reliability of the calculation largely depends on the choice of the scheme of application of loads, places of fastening, and the level of loads applied in the zones of application of forces acting on the object under consideration. To assess local stresses in the areas of installation of support brackets, it was assumed that the floor surface was motionless. The bending forms of deformation of the longitudinal beams of the frame are excluded from consideration in this case. This is justified by having a short length and high cross-sections (significant bending stiffness characteristics). The calculation begins with the

https://doi.org/10.1051/e3sconf/202336505008

choice of the calculation scheme of the structure. The design scheme should reflect the main design features that significantly impact its behavior under load. On the design scheme, the zones of application of the load must be indicated; its level must be determined. In other words, a calculation scheme is an idealized object that does not consider insignificant, in terms of influence on the stress-strain state, fragments of the structure. Figure 6 shows a view of such a design scheme for the frame of shunting locomotive TEM2. As mentioned above, the calculations aim to determine the nature of the stress distribution from vertical loads since, based on them, dynamic additional loads will be determined, and ultimately the fatigue strength will be evaluated.

When calculating a volumetric body by the finite element method, it is necessary to model a spatial geometric model. The simulation was carried out using the above software product SolidWorks. Static calculation of the main frame of the shunting locomotive TEM2[11-17].

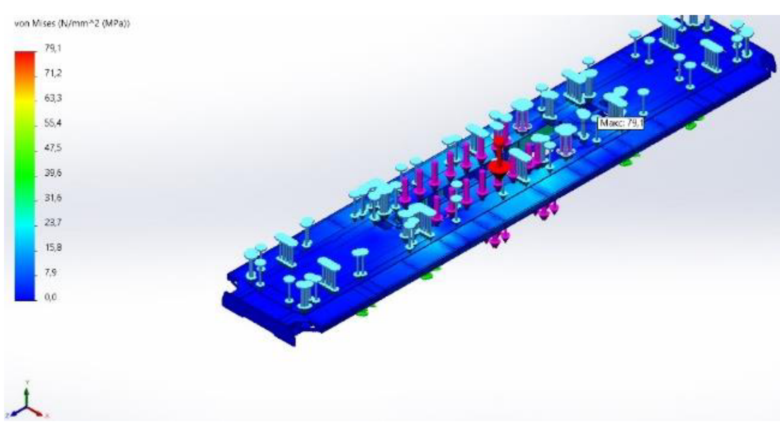
When creating the mesh, volumetric finite elements were used.



a)	*b)*

Fig. 6. Finite element model of the frame of the TEM2 shunting diesel locomotive. a) view from above, b) view from the bottom

Figures 7-11 show the results of static calculation from the action of vertical loads. The results of these calculations served as the starting material for determining the residual resource, considering the fatigue strength of the main frame of the shunting locomotive TEM2.



https://doi.org/10.1051/e3sconf/202336505008

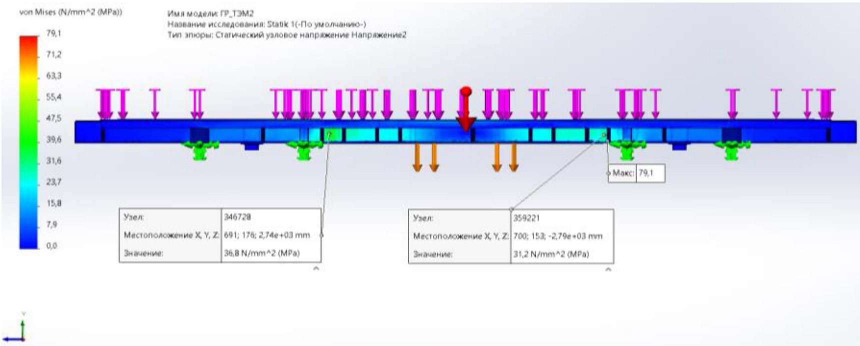


Fig.7. General view of the distribution of equivalent stresses in the main frame from the action of static loads

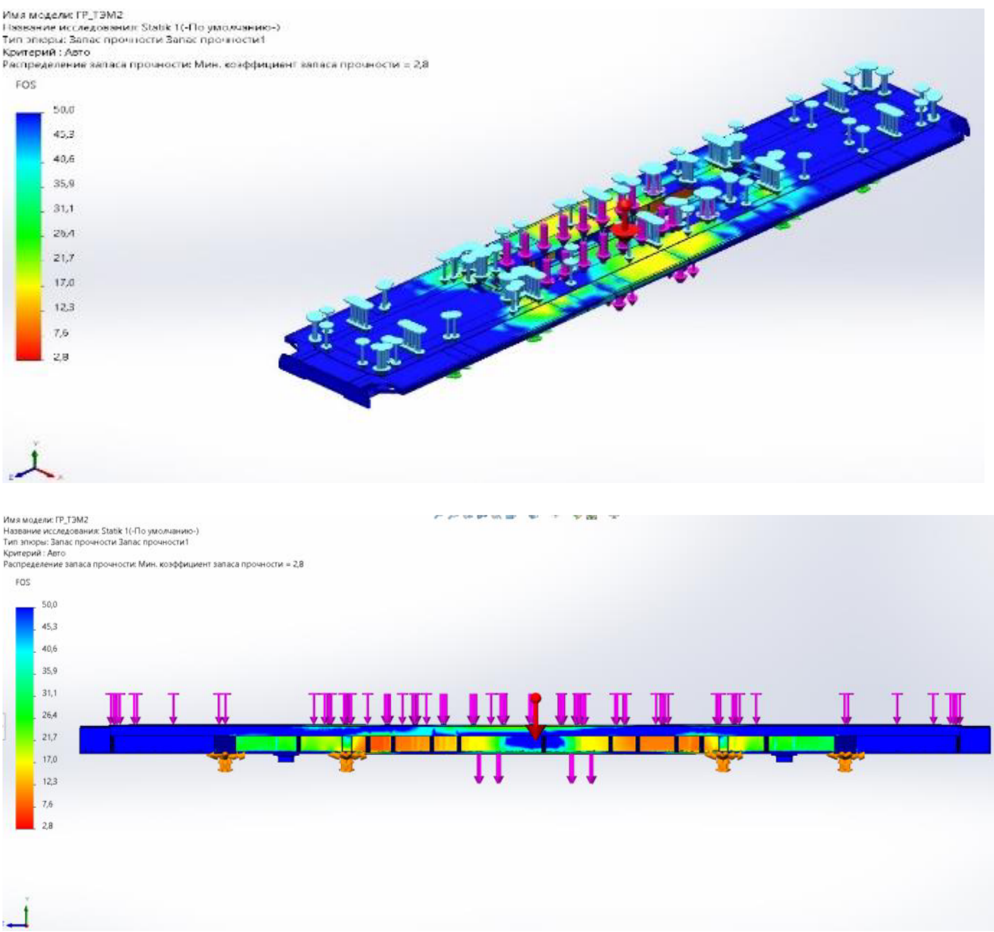


Fig. 8. Safety margin of the main frame of the locomotive TEM2

https://doi.org/10.1051/e3sconf/202336505008

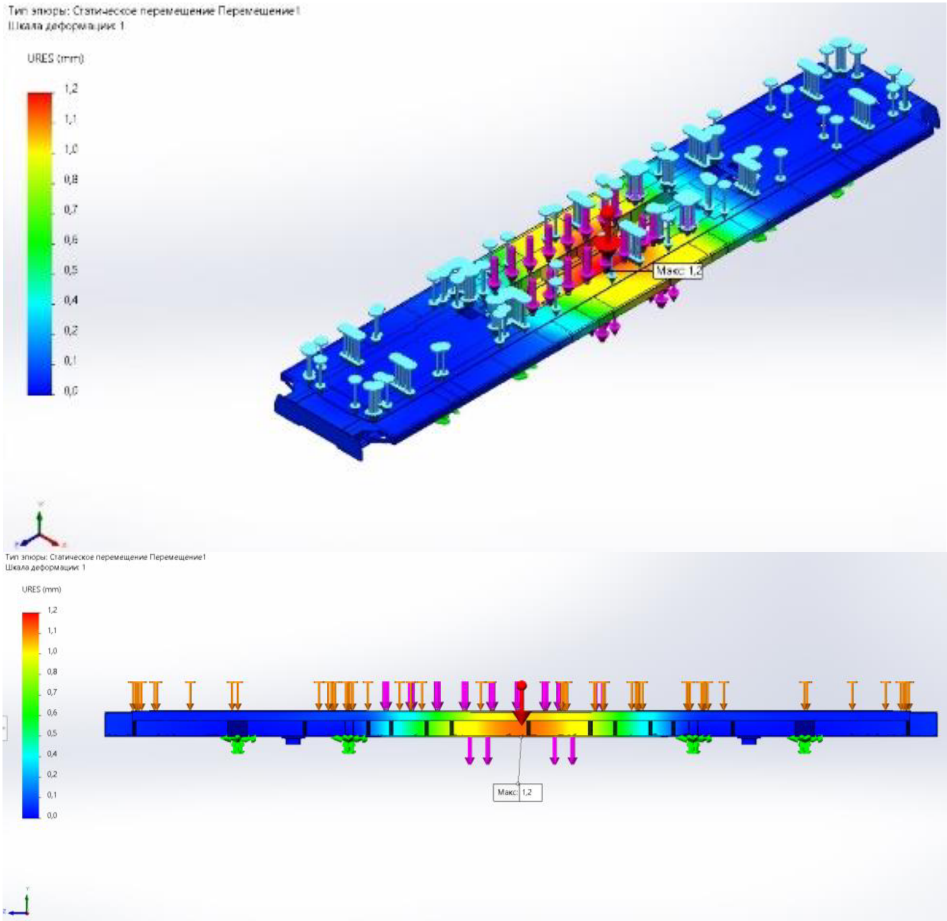


Fig. 9. Moving the main frame of the locomotive TEM2

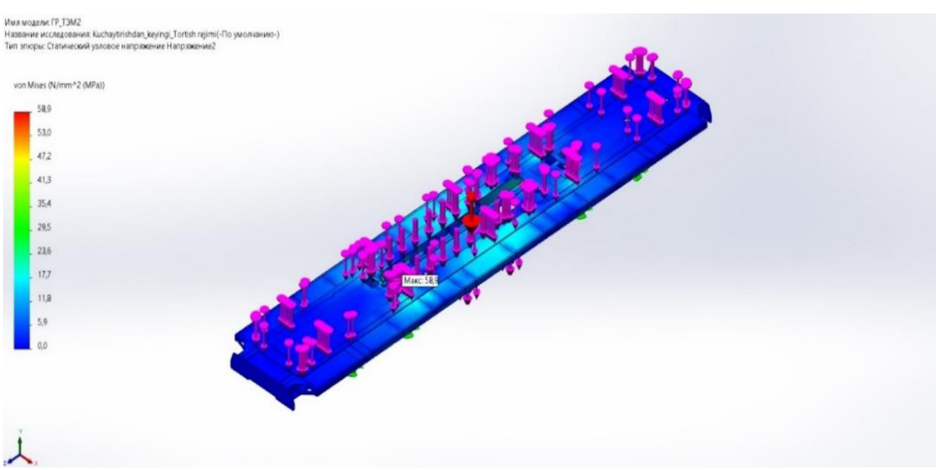


Fig. 10. Tension of the main frame of the locomotive TEM2 in traction mode

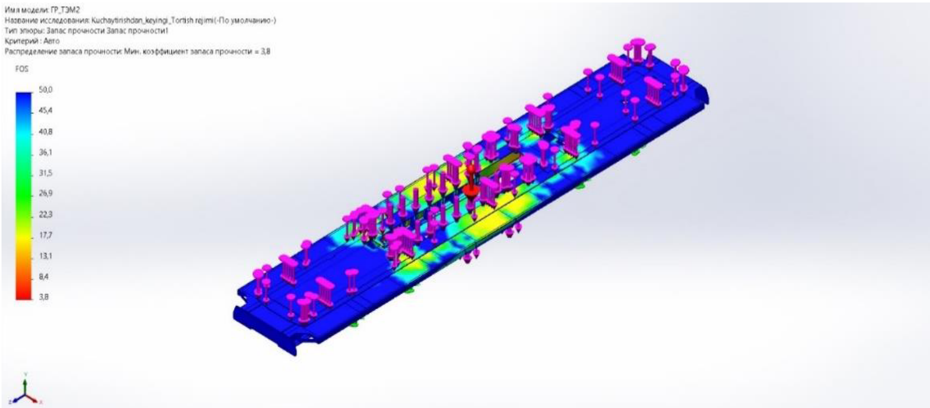


Fig. 11. Safety margin of the main frame of the locomotive TEM2 in traction mode

The maximum internal stress of the main frame in dangerous sections was 79.1 MPa. During the work, the main frame is taken as the main bearing unit responsible for the safe operation of the locomotive. Unlike replaceable units, the frame (and other load-bearing units) cannot be replaced when performing planned types of work. One of the criteria for assessing the frame's durability should include the moment of the appearance of fatigue cracks in the most stressed nodes of the structure[19-23].

4 Conclusion

Thus, it has been shown that timely detection of defects in locomotive units extends the service life. It is shown that the state of the main frame determines the intensity of the locomotive and its durability and performance. The presented mathematical model for calculating loads of locomotive main frames makes it possible to describe the physical processes in case of damage and malfunctions as reliably as possible. With the help of the proposed diagnostic model, work can be carried out to extend the service life of locomotives.

References

1. 1. Khamidov O.R. Otsenka ostatochnogo resursa glavnykh ram manevrovykh teplovozov. Universum, 2022. 2(95)
2. 2. Khamidov O.R. Prognozirovaniye ostatochnogo resursa glavnoy ramy i prodleniye srokov sluzhby manevrovykh lokomotivov NA AO “UTY”. Universum 2022. 4(97).
3. Abdulaziz Yusufov | Sabir Azimov | Shukhrat Jamilov "Determination of Residential Service of Locomotives in the Locomotive Park of JSC "Uzbekistan Railways"" Published in International Journal of Trend in Scientific Research and Development Volume-6, Issue-3, April 2022, pp.413-417
4. 4. Volokhov G.M., Tikhomirov V.P. Ostatochnyy resurs nesushchikh konstruktsiy tyagovogo podvizhnogo sostava zhe-leznykh dorog: monografiya. Orel: OrelGTU, 2006. — 158 s.
5. 5. Normy dlya rascheta prochnosti nesushchikh elementov, dinamicheskikh kachestv i vozdeystviya na put' ekipazhnoy chasti lokomotivov zheleznykh dorog kolei 1520 mm. – M.: VNIIZHT, 1998. – 145 s.

6. 6. Polozheniye «Lokomotivy. Poryadok prodleniya naznachennogo sroka sluzhby» P.15.01.-2009 : [Utverzhdeno pyat'desyat tret'im Sovetom po zheleznodorozhnomu transportu gosudarstv-uchastnikov sodruzhestva. Protokol ot 20-21 oktyabrya 2010 g.]. – M.: 2010, – 24 s.
7. 7. Grigor'yev, P.S. Opredeleniye dinamicheskoy nagruzhennosti nesushchego uzla manevrovogo lokomotiva [Tekst] / P.S. Grigor'yev // Transport Rossiyskoy Federatsii. – 2015. – №3(58). – S. 44 – 46.
8. 8. A. V. Grishchenko, V. V. Grachev, F. YU. Bazilevskiy, M.A. Shrayber, YU. M. Ganiyeva, V. V. Mel'nikova., Otsenka ostatochnogo resursa nesushchikh konstruktsiy lokomotivov promyshlennogo transporta UDK 629.4.
9. 9. Ogan'yan E.S. Napryazhenno-deformirovannoye sostoyaniye konstruktsiy ekipazhnoy chasti teplovozov teplovozov pri soudareniyakh i avariynykh stolknoveniyakh // Tr. VNITI. — Vyp. 79. — Kolomna, 1999. — S. 76—81.
10. 10. Khamidov O.R, Yusufov A.M, Kudratov SH.I, Abdurasulov A.M, Azimov S.M. (2022). Otsenka srednikh napryazheniy tsikla v nesushchikh ramakh teplovozov na osnove konechno-elementnogo rascheta ot staticheskikh nagruzok. https://doi.org/10.5281/zenodo.6720495
11. 11. Khamidov O.R, Yusufov A.M, Kudratov SH.I3 Abdurasulov A.M, Zhamilov SH.M. (2022). Obsledovaniye tekhnicheskogo sostoyaniya manevrovogo teplovoza serii TEM2. https://doi.org/10.5281/zenodo.6720581
12. J. Mallikat. Der Eisenbahningenieur, Modernizatsiya teplovozov v Germanii. // Zheleznyye dorogi mira 1996 №8 str.6-9.
13. V. Spiryagin, Improvement of dynamic interaction between the locomotive and railwaytrack, PhD Thesis, East Ukrainian National University, Lugansk, Ukraine, 2004.
14. Volokhov, G.M. Ostatochnyy resurs nesushchikh konstruktsiy tyagovogo podvizhnogo sostava zheleznykh dorog: monografiya / G.M. Volokhov, V.P. Tikhomirov. – Orel: Orel GTU, 2006. – 158 s
15. Ogan'yan E.S Deformatsionnyye kriterii nagruzhennosti ram lokomotivov/Tyazholoye mashinostroyeniye 2004 №11.
16. Oganyan E.S. Primeneniye metodov raschota nesushchey sposobnosti i malotsiklovoy ustalosti dlya otsenki resursa otvetstvennykh uzlov lokomotivov. / Sbornik trudov PGUPS SPb-2000g.
17. 17. Strekopytov V.V., Grishchenko A.V. / Povysheniye nadozhnosti lokomotivov i effektivnosti ikh raboty. // Sbornik nauchnykh trudov PGUPS SPb-2003 s 3-7
18. 18. Bunin B.B., Ogan'yan E.S., Ponomayova T. M., Shevchenko V. G., Otsenka dolgovechnosti i ostatochnogo resursa ram telezhek lokomotivov. // Tyazholoye mashinostroyeniye. 2007 №11. s. 31-33
19. Spiryagin, C. C ole, Y.Q. S un, M . McClanachan, V. Spiryagin, T. McSweeney, Design and Simulation of Rail Vehicles, Ground Vehicle Engineering Series, CRC Press, Boca Raton, FL, 2014.
20. S. Simson, Three axle locomotive bogie steering, simulation of powered curving performance: Passive and active steering bogies, PhD Thesis, Central Queensland University,Rockhampton, Queensland, Australia, 2009.