EURASIAN JOURNAL OF ACADEMIC RESEARCH
Innovative Academy Research Support Center
UIF = 8.1 | SJIF = 5.685 www.in-academy.uz

ALGORITHM AND METHODOLOGY FOR EVALUATING RELIABILITY INDICATORS OF A LARGE GEAR WHEEL OF A TRACTION GEARBOX FOR AN ELECTRIC LOCOMOTIVE

Radjibayev Davran Oktombaevich[1],
Khromova Galina Alekseevna[2],
Sobirov Nizamiddin Kahorjon ugli[3]
[1]candidate of tech. sciences, associate professor,
[2]doctor tech. sciences, professor, [3]master's student, Tashkent State Transport University,
Uzbekistan, Tashkent
https://www.doi.org/10.37547/ejar-v03-i02-p2-65

ARTICLE INFO

Received: 02nd February 2023
Accepted: 12th February 2023
Online: 13th February 2023

KEY WORDS

Electric locomotive, locomotive bogie frames, dynamic loads, stress-strain state of bogie frames, overhaul and repair of electric locomotive bogie frames VL-80.

ABSTRACT

This article presents experimental-theoretical research on strengthening the frames of VL-80 electric locomotive bogies during overhaul with service life extension in the conditions of UE "O'ztemiryo'lmashta'mir".

When an electric locomotive moves with a train, its vehicle part absorbs and transmits traction (braking) forces from the electric locomotive to the train (compressive, stretching), and also absorbs dynamic loads which arise when the electric locomotive passes curves and uneven sections of the track profile. At that, bogie frames of electric locomotives are subjected to the action of very significant in magnitude and different in direction dynamic loads, which along with natural wear and tear can cause damage of its individual components [1,2,3].

In the process of operation, the body supports, bogie joint parts, places of installation of brake and spring suspensions, balancers, traction engine suspensions, counter-axis devices and shock absorbers, etc. are subjected to intensive wear and tear. Apart from natural wear and tear, frame deformation in different planes and cracks in its elements are possible as a result of high forces.

The main damages of VL80 bogie frame are: local dents and deflections, fatigue cracks in the welds of axle brackets and cradle suspension brackets, as well as in the attachment points of sides and beams [2,3].

Electric locomotives of VL-80 series are operated in JSC "Uzbekistan Temir Yullari" in the Republic of Uzbekistan for more than 50 years. Due to the arisen need for electric locomotives of VL-80 series the overhaul with extension of useful service life by 8-10 years according to the "Instruction on bogie frame strengthening..." has been started. [4], developed by the authors of this article together with the employees of UE "O'ztemiryo'lmashta'mir". The use of this instruction [4] is caused by the appearance of fatigue cracks in separate sections of bogie frames of electric locomotives of VL-80c series during their operation, detected during scheduled types of overhaul at "Uzbekistan" locomotive depot.

This Instruction has been compiled taking into account the materials of calculation studies [5-8], based on the data of VL-80c electric locomotives operation according to failures, on the methods of material resistance, as well as dynamics and strength and generalization of the experience in repair of body frames and locomotive bogies at the locomotive repair plants of the Russian Ministry of Railways [2, 3] used at present, and it also takes into account specific features of previously performed types of overhaul of these units with welding reinforcing linings to the sections of bogie frames, in which repeated fatigue cracks have occurred in the process of operation. In addition, for numerical studies was made a program for quasi-static calculation on the strength of the bogie frame of electric locomotive VL-80, the novelty of which is protected by a certificate of official registration of software for the Republic of Uzbekistan № DGU 07664, 31.04.2020[9].

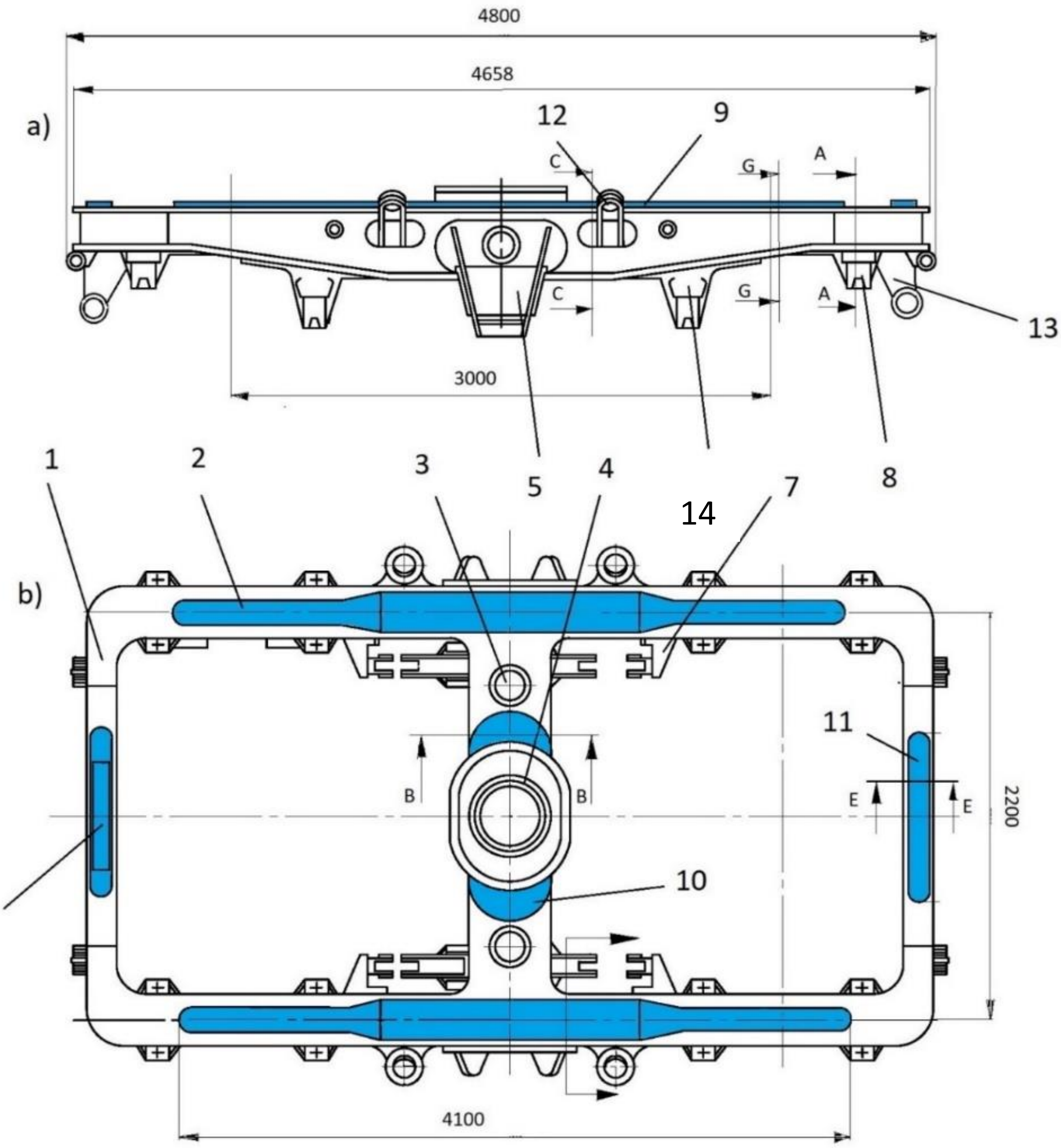

Figure 1. Upgraded bogie frame
of electric locomotive VL-80 with design sections with reinforcing overlays:

a). cross section; b). plan view,
1 - frame end-bar; 2 - reinforcing plates on the frame sidewall 50x12; 3 - kingpin bar; 4 - kingpin ball-joint box; 5 - kingpin;6 - reinforcing pad under the roller of the unloading device,
7 - bracket for suspension of brake lever gear; 8 - small axle-box bracket; 9 - reinforcing pad on frame sidewall 50x12; 10 - reinforcing pad on the ball link box of the kingpin; 11 - reinforcing pad on the frame sidewall 50x12; 12 - bracket under the cradle suspension rod of the body; bracket for attachment of brake cylinder; 13 - bracket for attachment of hydraulic dampers; 14 - big axle bracket.

Implementation of this Instruction [4] will help to reduce the probability of accidental destruction of bogie frames and body frame parts of electric locomotives of VL-80c series and increase their useful service life by 8-10 years after overhaul. At that, a properly calculated process of modernization of electric locomotive bogie frames with installation of reinforcing pads can increase their reliability and durability, as well as prolong the useful service life.

Instruction [4] is compiled on the basis of calculation studies, performed in MATHCAD 15 programming environment, to determine actually achieved stresses in the material of welded seams of bogie frame parts, in which fatigue cracks occurred. On the basis of theoretical and numerical calculations, rational dimensions for reinforcing pads with complex configuration for bogie frame parts of electric locomotives VL-80 were selected in it [5,6,7].

Figure 1 (figure 1) shows a cross section of the modernized bogie frame of electric locomotive VL-80 with design cross-sections with reinforcing plates and its view in plan, the drawings of which are proposed for modernization during overhaul with the extension of useful life.

As a result of the theoretical and numerical studies [5,6,7] the following generalizing conclusions can be made:

1. According to quasi-static calculation of the frame of electric locomotive VL-80 it was found that the most stressed sections are ***B – B*** *,* ***D – D*** *,* ***E – E*** *(figure 1). And after 30 years and more of exploitation (the given period of exploitation at the present day the VL-80 electric locomotives of JSC "Uzbekistan Temir Yullari" have, according JSC locomotive operation service department) these sections cannot stand the calculated modes on dynamic fatigue durability. It is necessary to strengthen (modernize) these sections by installing reinforcing shaped overlays of steel plates St3 and corners.*

2.To determine the frame *strength in the dangerous section* ***D – D*** of the longitudinal frame beam of VL-80 electric locomotive bogie at the junction of longitudinal and transverse beams at the most unfavorable combinations of loads, summation of all arising stresses in statics and dynamics was performed by the superposition principle. Numerical calculation results are summarized in Table 1. The design speed of VL-80 electric locomotive is V_{EK} = 110 km/hour [2,3].

Total stresses in the dangerous (most stressed) section
D - D **of the longitudinal girder of bogie frame of electric locomotive VL-80**

Таблица 1.

№	*Type of load*	*motion start (at $V_E = 0$ km/h)*	*Movement in a curve with no elevation*	*Moving in a curve with elevation*	*Motion at construction speed*
1.	*Weight load*	48,425	48,425	48,425	48,425
2.	*When moving in a curve*	0	13,984	41,292	55,276
3.	*Operating in traction mode*	8,76	6,168	6.54	5,626
4.	*Cosymmetric load*	3,464	3,464	3,464	3,464
5.	*Dynamic vertical load*	0	7,958	9,131	10,921
6.	***Total load***	**60,654**	**80,376**	**108,48**	**123,71**

According to the results of numerical calculation data for the modernized section ***D - D*** of the longitudinal frame beam of electric locomotive VL-80 bogie it was found that the total stress in the most stressed section does not exceed the strength limit and is equal to σ_{sum} = 123,71 MPa at design speed V_{EK} = 110 km/hour,

and the *tensile strength* for this section is

$$n = \frac{[\sigma_{add}]}{\sigma\ sum} = \frac{240}{123{,}71} = 1{,}94. \quad (1)$$

The safety factor of the calculation is greater than 1.6, i.e. this section passes the safety factor condition.

In this case, even if the aging of the bogie frame sidewall material is taken into account, the resulting total stresses must be

$$(\sigma_Y + \sigma_{CT}) \leq [\sigma] = 218{,}18\ MPa,$$

the safety factor, taking into account the aging of the material, will be

$$n_{aging} = \frac{[\sigma]}{\sigma\ sum} = \frac{218{,}18}{123{,}71} \approx 1{,}764. \quad (2)$$

3.When testing the fatigue strength, it was taken into account that the elements of the bogie frame subjected to alternating asymmetric stress should have an additional safety margin due to the presence of stress concentrators and a number of other reasons. In this case, the endurance limit is reduced due to a k_σ-fold decrease in the variable component of the ultimate allowable stress. The coefficient of reduction of fatigue strength of the part in comparison to the sample k_σ = 2.4. Coefficient of material sensitivity to cycle asymmetry

$$\psi_\sigma = \frac{2\sigma_T - \sigma_0}{\sigma_0} = 0{,}6, \quad (3)$$

where $\boldsymbol{\sigma}_T = 200$ MPa, $\boldsymbol{\sigma}_0 = 250$ MPa, $\boldsymbol{\sigma}_m = 69{,}778$ MPa

At the same time, the *endurance limit*

$\boldsymbol{\sigma}_{\text{Bendur}} = \frac{\boldsymbol{\sigma}_{\text{T}}}{\boldsymbol{k\sigma}} + \left(1 - \frac{2\boldsymbol{\sigma}_{\text{T}} - \boldsymbol{\sigma}_0}{\boldsymbol{\sigma}_{\text{T}}\boldsymbol{k\sigma}}\right)\boldsymbol{\sigma}_m$, (4),

where according to the numerical calculation $\boldsymbol{\sigma}_{endur} = 131{,}36$ MPa.

Fatigue safety factor, taking into account maximum stress

$n_\sigma = \frac{\boldsymbol{\sigma}_{endur}}{\boldsymbol{\sigma}_m + \boldsymbol{\sigma}_{ampl}} = 1{,}427,$ (5)

where $\boldsymbol{\sigma}_{ampl} = 22{,}216$ MPa is the reduced amplitude stress, which is calculated by the formula $\boldsymbol{\sigma}_{ampl} = 2{,}17\sqrt[6]{(\sum_i R_i)},$ (6)

where R_i is the reduced amplitude stress of the calculated asymmetric cycle of dynamic loading of the frame parts, it is calculated according to the numerical calculation in the program compiled for MathCad 15 programming environment [5,6,7].

As a result of the conducted numerical investigations on the frame sections of electric locomotive VL-80 bogie frame it was found that taking into account the modernization performed by installing reinforcing plates the fatigue strength is sufficient, as it exceeds the minimum value of 1.4.

4. On the basis of train tests, which are planned to be conducted in 2023 - 2024 on JSC "Uzbekistan Temir Yullari", results of theoretical calculations on selection of rational parameters of reinforcement plates with complex configuration for frame parts of electric locomotives VL-80 bogies will be specified.

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