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This paper is devoted to the solution of the problem of freight car wheel wear reduction on 1520 mm gauge railways (the former USSR). The paper gives a brief description of the comprehensive retrofit of standard freight-car trucks (model 18-100) proposed at the Institute of Technical Mechanics of the National Academy of Sciences of Ukraine and the State Space Agency of Ukraine (ITM of NASU and SSAU) and introduced on the Ukrainian railways. The retrofit involves the use of US companies' devices adapted to the former USSR's countries and the ITM-73 wear-resistant wheel profile specially developed at the ITM of NASU and SSAU; it offers a several-fold increase in the life of critical running gear assemblies and makes it possible to reduce wheel and rail contact wear by a factor of 2–2.5.

The aim of the work was to refine the comprehensive retrofit of freight-car trucks, namely, to develop new

wear-resistant wheel profiles, in particular with account for the shape of worn rail heads. An approximate method was proposed for the solution of the wheel–rail interaction problem with the determination of the position and dimensions of nonelliptic contact patches, including the case of a conformal contact. Using this method, new wheel profiles were developed for worn wheel machining (ITM-73-01) and for new wheels for cars with an axle load of 23.5 tf (ITM-73-02) and 25 tf (ITM-73-03). Use was made of methods of mathematical simulation, numerical integration, oscillation theory, and statistical dynamics.

The data of theoretical and experimental studies presented in the paper show that the average wheel flange wear rate for freight cars with comprehensively retrofitted trucks whose wheels have the ITM-73-01 profile is 3.5 – 5 times lower than for a standard car with the standard wheel profile at the same kilometerage. According to predictive estimates, for cars with comprehensively retrofitted trucks the wear of wheels with the ITM-73-02 or ITM-73-03 profile will be still lower.

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$$B_j(x) = \sum_{i=1}^{n_j} a_{ji} \cdot \sin(2\pi \cdot x / l_{ji}) \,, \ \overline{j = 1,4} \,,$$

x –   ; n_j –
                                      ; a_{ji} l_{ji} –

a_{ji} , l_{ji} n_j ($\overline{j = 1,4}$, $\overline{i = 1,n_j}$)

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$$T = -F\varepsilon\left[\left(\frac{F\varepsilon}{\mu N}\right)^m + 1\right]^{-\frac{1}{m}},$$

$$F = 350m\sqrt{Nr},$$

$$m = 3{,}5,$$

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T ε – N –   -

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     ; r –   .

          ε -

       α ψ_{ws} :

$$\varepsilon = (\varepsilon_\psi^2 + \varepsilon_\alpha^2)^{1/2} = \left[(\varepsilon_x \sec\psi_{ws})^2 + (\varepsilon_y \sec\alpha)^2\right]^{1/2},$$

ε_x, ε_y –   .

                                       :

$$T_\psi = \frac{\varepsilon_\psi}{\varepsilon} T, \qquad T_\alpha = \frac{\varepsilon_\alpha}{\varepsilon} T .$$

$$N = N_z \sec\alpha ,$$

N_z –   ,   -

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$$\begin{cases} N_1\cos\alpha_1 + N_2\cos\alpha_2 = N_z \\ N_1\sin\alpha_1 + N_2\sin\alpha_2 = N_y, \end{cases} \tag{1}$$

N_y –

                   , N_z -

$N_y = N_z \Delta z'$; $\Delta z'$ –

        Δz -

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$$N_1 = \frac{N_z(\mathrm{tg}\alpha_2 - \Delta z')}{(\cos\alpha_1 \mathrm{tg}\alpha_2 - \sin\alpha_1)}, \qquad N_2 = \frac{N_z(\mathrm{tg}\alpha_1 - \Delta z')}{(\cos\alpha_2 \mathrm{tg}\alpha_1 - \sin\alpha_2)}.$$

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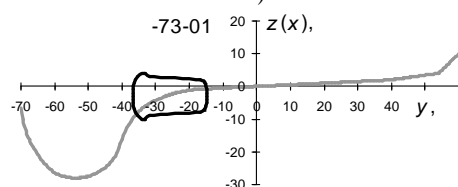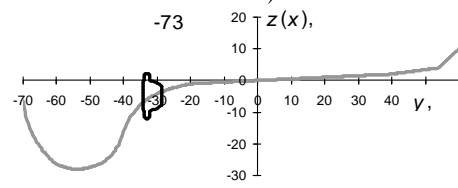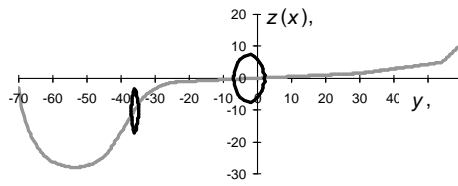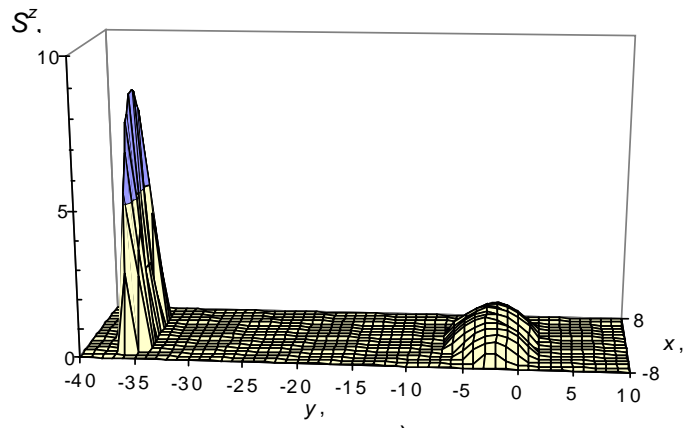[26].   -
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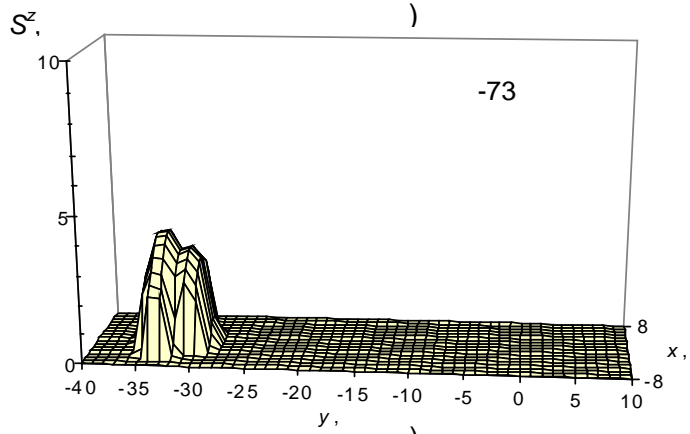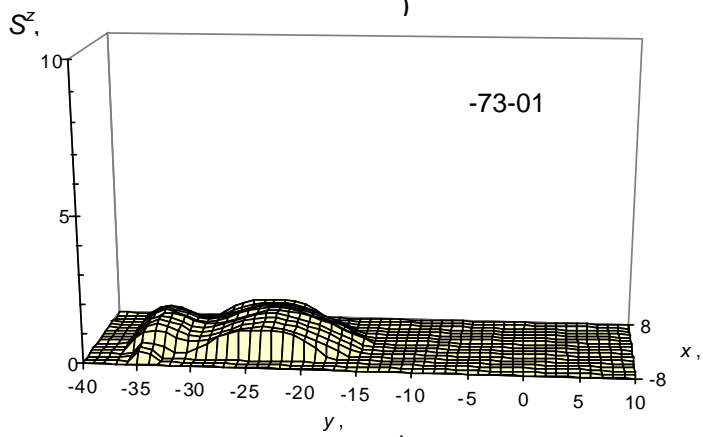   ,   ,
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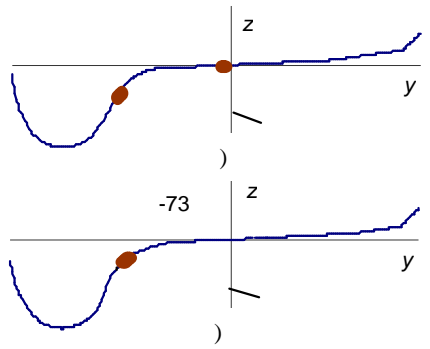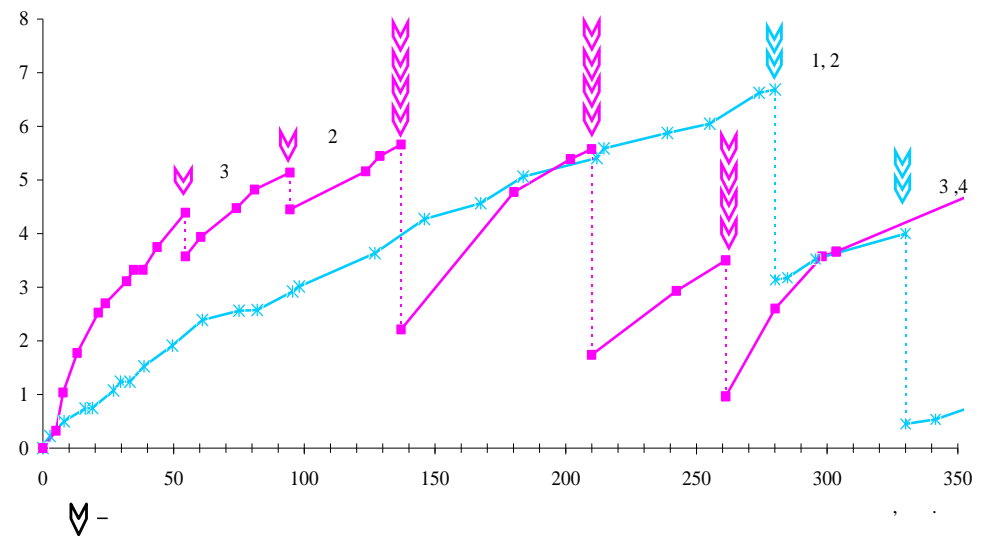
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$$T_{\psi k} = \frac{\varepsilon_{\psi k}}{\varepsilon_k} T_k, \qquad T_{\alpha k} = \frac{\varepsilon_{\alpha k}}{\varepsilon_k} T_k.$$

$$T_x = \sum_{k=1}^{n} T_{\psi k} \cos \psi_{ws}, \qquad T_y = \sum_{k=1}^{n} T_{\alpha k} \sin \alpha_k,$$

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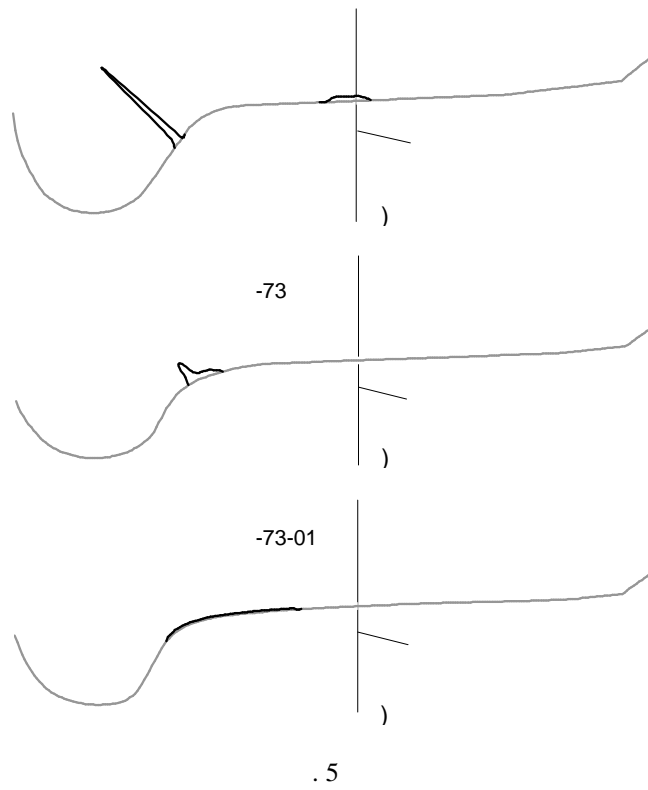,   -
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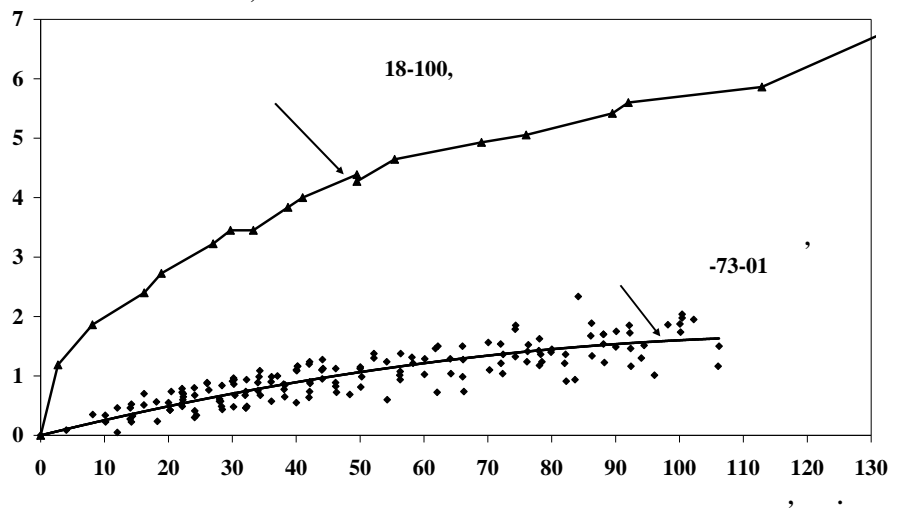
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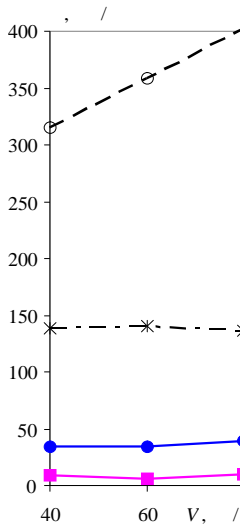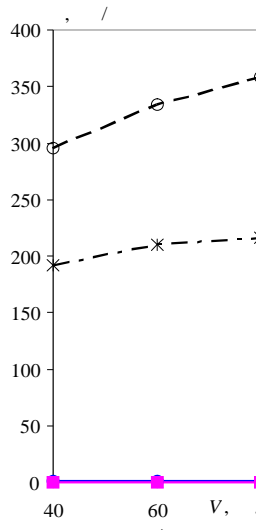
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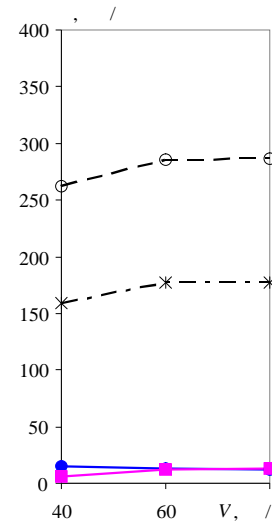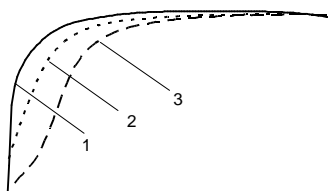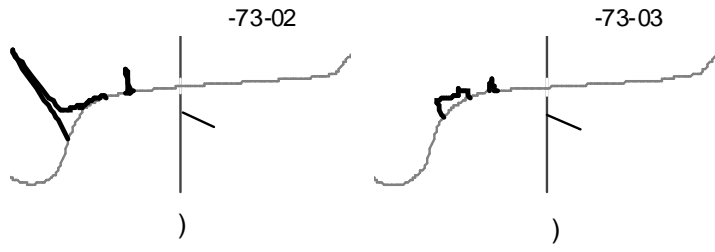.   ,   -
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                . 1992.   12.   . 30–34.
3.   .   .   .
            . 1995.   10.   . 36–40.

4. *Ushkalov V. F.* Wheelset and Rail Wear on Ukrainian Railways. Proceedings of the 2nd Mini Conference on Contact Mechanics and Wear of Rail/Wheel Systems. Budapest, Hungary. 1996. . 250–258.

5.   . .
                                                    .   :   , 1997. 207 .

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7.   . .   .
                . 2011.   9.   . 18–21.

8.   . .,   . .,   . .   .   -
                    . 1993.   8.   . 37–38.

9. *Magel E., Tajaddini A.*   .   . 2007.   10.
   . 62–64.

10. *Zakharov S., Goryacheva I., Bogdanov V., Pogorelov D., Zharov I.* Problems with Wheel and Rail Profiles Selection and Optimization. Wear. 2008. V. 265, issues 9, 10, 30. P. 1266–1272.

11. *Gerlici Yu., Lack T.* Railway Wheel and Rail Head Profiles Development Based on the Geometric Characteristics Shapes. 8 Intern. Conf. on Contact Mech. and Wear of Rail/Wheel Systems, Florence, Sept. 2009. // Wear. 2011. 271, No. 1–2. P. 246–258.

12.   . .   . ., ...
                        :   . .   .   «   ».   .
    2013.   . 204–211.

13. *Ushkalov V. F., Lashko A. D., Mokriy T. F.* Upgrade of Freight Car Bogies As An Option for Freight Rolling stock Running Gears Renovation. VNIIZhT Bulletin. 2014.   1.   . 7–12.

14 *Gregg Hansen W. M.,*   . .,   . .,   . .,   . . .   -
                                        18-100   -
                        . .   . 2004.   . 5.   . 215–219.

15.   . .,   . .,   . .   -   -

          . .   .
                                        . . .   . 2008.   . 23.   . 76–82.

16.   18-7020   2. URL http://test.kvsz.com/index.php/ru/produktsiya/ gruzovoe-
vagonostroenie/khodovye-chasti/telezhki/item/833-dvukhosnaya-telezhka-model-18-7020.

17.   . .,   . .,   . .   -
                                            .   . 2012.   1.   . 38–41.

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                        .   .   . 2013.   . 4 (46).   . 135–144.

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21. *Piotrowski J., Kalker J. J.* The Elastic Cross-Influence Between Two Quasi-Hertzian Contact Zones. Vehicle System Dynamics. 1988. V. 17. P. 337–367.

22. *Pascal J. P., Sauvage G.* New Method for Reducing the Multicontact Wheel/Rail Problem to One Equivalent Contact Patch / The Dynamics of Vehicles on Roads and on Tracks : Proceedings of 12th IAVSD-Symposium. France, Lyon. 1991. P. 475–490.

23. *Anyakwo A. A.*, *Pislaru C., Andrew B.* New Method for Modelling and Simulation of the Dynamic Behavior of the Wheel-Rail Contact. International Journal of Automation and Computing. 2012. No. 9 (3). P. 237–247.

24. *Ushkalov V., Malysheva I.* On a Vehicle Wheel-Rail Interaction. Ninth World Congress on the Theory of Machines and Mechanisms : Proceedings. Italy, Milan: Politecnico di Milano. 1995. V. 2. P. 941–945.

25. *Ushkalov V., Alexandrov* . The Creep Force Model for Different Conditions of Wheel-Rail Rolling Contact. ASME Winter annual Meeting. 1989. P. 189–196.

26. *William J. H., Ebersöhn W., Lundgren J., Tournay H., Zakharov S.* Guidelines to Best Practices for Heavy Haul Railway Operations : Wheel and Rail Interface Issues. USA: International Heavy Haul Association. 2001. 482 p.

27. *Kovalev R., Yazykov V. N., Mikhalchenko G. S., Pogorelov D. Yu.* Railway Vehicle Dynamics: Some Aspects of Wheel-Rail Contact Modeling and Optimization of Running Gears. Mechanics Based Design of Structures and Machines. 2003. No. 31 (3). P. 315–335.

28.   . .   «   -
          ».   . .   . 2013.   18 (207), . .
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29.   . .,   . .,   . .   -
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      . 2014.   4.   . 23–27.
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32.   . .,   . .   -
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34.   18-9817   25   . URL http://
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35.   . .,   . .,   . .,   . .
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