Vol.3 №7 (2025). July

Journal of Effective Learning and Sustainable Innovation

innovativepublication.uz

INNOVATIVE PUBLICATION

MODELING OF A SPRING-FRICTION ENERGY-ABSORBING DEVICE FOR A FREIGHT CAR

Shokuchkorov Kurbannazar Salim ugli

D.Sc. (Tech.), Tashkent State Transport University

Kodirjonov Hasan Nodirjon ugli

Student, Tashkent State Transport University

Kodirjonov Husan Nodirjon ugli

Student, Tashkent State Transport University

Abstract. Energy-absorbing devices are designed to dissipate impact energy, thereby reducing the longitudinal tensile and compressive forces transmitted to the wagon frame through the coupler. In operational practice, the most common units are hexagonal spring-friction devices of types Sh-1-TM, Sh-2-V, Sh-6-TO-4 and others because of their simplicity and the possibility of designing them with satisfactory parameters.

The physical model of the spring-friction energy-absorbing device is shown in Fig. 1.

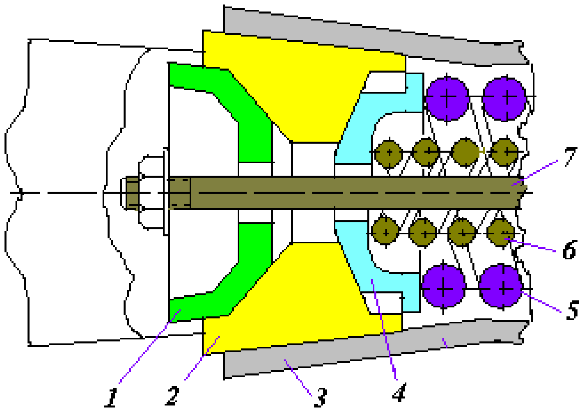


Figure 1. Spring-friction energy-absorbing device: 1 – pressure cone; 2 – friction wedge; 3 – device housing; 4 – pressure washer; 5 – outer spring; 6 – inner spring; 7 – tie bolt.

To identify the cause of non-uniform wear of the friction wedges, a model assuming full contact of the rubbing pairs along their inclined surfaces was examined, which made it possible to take the external reactions as applied at the mid-points of the contact surfaces [2]. Another model of the absorber that allows for possible edge contact of the rubbing bodies along individual faces was considered [3] according to the procedure in [4]; in that model the external reactions are replaced by four components instead of two, which contradicts the classical principles of theoretical mechanics [5, 6]. Consequently, the reasons for the non-uniform wear of the wedges in contact with the pressure cone, the housing throat and the pressure washer—taken together as friction pairs—remain unexplored. The reactions of the external connections of the wedges and the coordinates of their points of application with respect to a selected reference frame therefore have to be determined.

Methods. The study uses the release-from-constraints principle, the axiom of action and reaction, the theorem of three non-parallel forces and the conventional equilibrium conditions [5].

Vol.3 №7 (2025). July
Journal of Effective
innovativepublication.uz
Learning and Sustainable Innovation

Assumptions. The inclined surfaces of the pressure cone and a friction wedge are in contact at point A. At this point a force $\overline{F}$, acting from the pressure cone and taken by a single wedge, is applied. The coordinates x_A and y_A of point A with respect to the reference frame Oxy are assumed to be known. The projections of the reactions of the external connections of the wedge, $\overline{R}_1$ and $\overline{R}_2$, on the coordinate axes are assumed to be functions of the load from the pressure washer $\overline{F}$.

Solution. From the standpoint of theoretical mechanics the spring-friction absorber is a physical object, and from the standpoint of mechanism theory it is a wedge mechanism. Its three friction wedges 2, arranged concentrically in the hexagonal throat of housing 3, are in contact with only three rigid elements the pressure cone 1, the housing 3 and the pressure washer 4 (Fig. 1).

A single friction wedge is chosen as the object of study. According to the release from constraints principle [8] the contact surfaces of the wedge with the housing and the pressure washer considered as external connections are replaced by the reaction forces $\overline{R}_1$ (housing) and $\overline{R}_2$ (pressure washer) (Fig. 2). The coordinate axes Ox and Oy are taken as shown in Fig. 2.

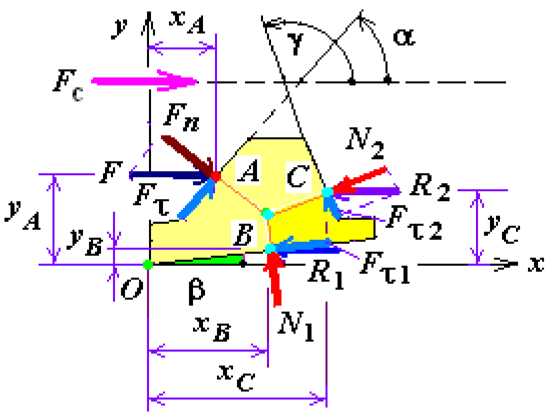
Figure 2. Calculated model of the friction wedge.

The following symbols are adopted:

- $\overline{F}_c$ – longitudinal compressive force from the coupler through the thrust plate;

INNOVATIVE PUBLICATION
Journal of Effective Learning and Sustainable Innovation
Vol.3 №7 (2025). July
innovativepublication.uz

- $\overline{F}$ – the share of force $\overline{F}_c$ acting from the pressure cone and taken by a single wedge, i.e. $\overline{F} = \overline{F}_c / 3$;
- $\overline{F}_n$ and $\overline{F}_\tau$ – the normal and tangential components of force $\overline{F}$;
- α – angle between the wedge face in contact with the pressure cone and the horizontal;
- β – angle between the wedge face in contact with the housing and the horizontal;
- γ – angle between the wedge face in contact with the pressure washer and the horizontal.



Moreover:

- $\overline{N}_1$ and $\overline{F}_{\tau 1}$ are the normal and tangential components of reaction $\overline{R}_1$ (housing);
- $\overline{N}_2$ and $\overline{F}_{\tau 2}$ are the normal and tangential components of reaction $\overline{R}_2$ (pressure washer);
- x_B, y_B and x_C, y_C are the coordinates of the application points of $\overline{R}_1$ and $\overline{R}_2$ with respect to the frame Oxy that are to be found.

Theoretical part. Because the coordinates x_A and y_A are known, the theorem of three non-parallel forces requires that the normal components $\overline{F}_n$, $\overline{N}_1$ and $\overline{N}_2$ of force $\overline{F}$

and reactions $\overline{R}_1$ and $\overline{R}_2$ intersect at a single point. Hence the coordinates x_B , y_B and x_C , y_C depend on x_A , y_A . For instance, when x_A increases (decreases), x_B increases (decreases) and x_C decreases (increases), which is feasible under edge contact along individual faces.

The equilibrium conditions of the wedge

$$\sum_{k=1}^{n} F_{kx} = 0:$$

$$F_n \cos(\alpha + \frac{3}{2}\pi) + F_\tau \cos(\alpha) + N_1 \cos(\beta + \frac{\pi}{2}) + F_{\tau 1} \cos(\beta + \pi) + \\ + N_2 \cos(\gamma + \frac{\pi}{2}) + F_{\tau 2} \cos(\gamma) = 0; \quad (1)$$

$$\sum_{k=1}^{n} F_{ky} = 0:$$

$$F_n \sin(\alpha + \frac{3}{2}\pi) + F_\tau \sin(\alpha) + N_1 \sin(\beta + \frac{\pi}{2}) + F_{\tau 1} \sin(\beta + \pi) + \\ + N_2 \sin(\gamma + \frac{\pi}{2}) + F_{\tau 2} \sin(\gamma) = 0 \quad (2)$$

$$\sum_{k=1}^{n} m_O(\overline{F}_k) = 0: \qquad -Fy_A + R_1 y_B + R_2 y_C = 0, \quad (3)$$

where $\overline{R}_1$ and $\overline{R}_2$ are the reactions of external connections, found by the dependencies:

$$\overline{R}_1 = \overline{N}_1 + \overline{F}_{\tau 1}, \qquad \overline{R}_2 = \overline{N}_2 + \overline{F}_{\tau 2} \quad (4)$$

In the three equations (1)–(3) there are five unknowns- $\overline{N}_1$ and $\overline{F}_{\tau 1}$, $\overline{N}_2$ and $\overline{F}_{\tau 2}$, y_B and y_C .

Applying Coulomb's law of friction

$$\overline{F}_{\tau} \leq f\overline{N}, \qquad (5)$$

where f – is the coefficient of sliding friction ($f = 0{,}7\, f_{\text{сц}}$ taking into account that $f_{\text{сц}}$ – is the coefficient of adhesion friction between the contacting surfaces of the cargo and the floor of the car, taken from reference data).

Rewrite (1) and (2) taking into account (5)

$$F_n \cos(\alpha + \frac{3}{2}\pi) + F_{\tau} \cos(\alpha) + N_1\left(\cos(\beta + \frac{\pi}{2}) + f \cos(\beta + \pi) \right) +$$
$$+ N_2\left(\cos(\gamma + \frac{\pi}{2}) + f \cos(\gamma) \right) = 0; \qquad (6)$$

$$F_n \sin(\alpha + \frac{3}{2}\pi) + F_{\tau} \sin(\alpha) + N_1\left(\sin(\beta + \frac{\pi}{2}) + f \sin(\beta + \pi) \right) +$$
$$N_2\left(\sin(\gamma + \frac{\pi}{2}) + f \sin(\gamma) \right) = 0 \qquad (7)$$

and substituting it into the equilibrium equations yields expressions (6)–(7), which are then reduced to the linear system

$$N_1 a + N_2 b = A_0 ;$$

$$N_1 c + N_2 d = B_0 , \qquad (8)$$

with the dimensionless coefficients a, b, c, d

$$a = \cos(\beta + \frac{\pi}{2}) + f\cos(\beta + \pi); \quad b = \cos(\gamma + \frac{\pi}{2}) + f\cos(\gamma);$$

$$c = \sin(\beta + \frac{\pi}{2}) + f\sin(\beta + \pi); \quad d = \sin(\gamma + \frac{\pi}{2}) + f\sin(\gamma); \qquad (9)$$

and the force-dimension coefficients A_0, B_0

$$A_0 = -F_n\left(\cos(\alpha + \frac{3}{2}\pi) + f\cos(\alpha)\right);$$

$$B_0 = -F_n\left(\sin(\alpha + \frac{3}{2}\pi) + f\sin(\alpha)\right). \qquad (10)$$

Using Cramer's rule [6], we find the unknowns from system (8)

$$N_1 = \frac{A_0 d - B_0 b}{ad - bc}; \quad N_2 = \frac{B_0 a - A_0 c}{ad - bc}. \qquad (11)$$

References:

1. Lukin V.V., Anisimov P.S., Fedoseyev Yu.P. Carriages. General course: Textbook for higher education institutions of railway transport / Ed. V.V. Lukin. - M.: Route, 2004. - 424 p.

2. Vinokurov M.V., Shadur L.A. Cars. – M.: Transzheldorizdat, 1953. – 704 p.

3. Pryanikov S.A. Increasing the reliability of the automatic coupling device of freight cars based on improving the monitoring of the technical condition of spring-friction absorbing devices during repairs. Abstract of Cand. Sci. (Eng.). – Ekaterinburg: Ural State Transport University, 2008. – 22 p.

4. Glushko M.I., Antropova A.N. Operation of the Spring-Friction Assembly of a Freight Wagon Bogie. Vestnik VNIIZhT, 2004, No. 5, pp. 41–44.

5. Khurmatov, Ya.A., Khaydarov, O.U., Abdullaev, B.A., Djabbarov, Sh.B., Inagamov, S.G. Evaluation of the efficiency of the friction tread brake of the diesel motor car / E3S Web of Conferences. – International Scientific Siberian Transport Forum - TransSiberia 2023. – Vol. 402. – 04009. – pp. 1–8; DOI: 10.1051/e3sconf/202340204009.14.

6. Abdullaev, R., Adilov, N., Juraeva, D., Makhmudov, A., Avdeeva, A. Mathematical modeling of the rolling speed of a car on the first profile site of the slide E3S Web of Conferences, 2023, 460, 06025

7. Ortiqov M., Adilov, N., Juraeva, D., Kamilov, K., Dehkonov, M.. Modeling of Forces Acting on a Wagon During Hump Rolling. E3S Web of Conferences, 2023, 458, 10018.

8. Abdullaev R., Adilov, N., Juraeva, D., Makhmudov, A., Ergasheva, V. Development of a Mathematical Model of Wagon Motion. E3S Web of Conferences, 2023, 460, 06009.