Mathematical Modeling of Continuous Tossing of the Brush with the Gap from the Commutator

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***Abstract*—The proposed study is related to the development of the theoretical foundations of the dynamics of the contact group of the elements of the brush-commutator unit. Dynamic interactions of the brush with the commutator under the vibration applying from the side of the corpus of traction motor are considered. A special feature of the study is the possibility of breaking the not-holding brush-commutator contact as a result of the vibrational effects of internal and external force factors. A method is proposed for constructing mathematical models based on the use of the generalized gap function, which represents the analytical apparatus for accounting for unilateral constraints. The construction of the mathematical model assumes, at the primary stage, the permissibility of reducing the design scheme to the interaction of a material particle with a vibrating surface in a gravitational field. Within the framework of the model under consideration, non-standard force factors are taken into account by introducing an additional quasi-constant force applied to the brush. The influence of force factors on the modes of continuous tossing of the brush is shown. Peculiarities of the interaction of the brush on the interval of ascent and fall on the commutator surface are obtained in analytical form**

***Index Terms*—the brush-commutator unit, traction motor, not-holding ties, unilateral constraints, the gap of contact, the function of the gap, continuous tossing**

I. Introduction

Modern requirements to the speed of the railway train and cargo volume draw attention to the problem of ensuring the reliability of the components of traction motor of an electric locomotive. This is reflected in the papers on the dynamics of the brush-commutator unit and stability of current collection processes [1], [2]. The efficiency of the collector-brush unit is determined by the vibrational modes of the external force effects. An important factor is the condition of contact interaction between the brushes and commutator surface [3], [4].

Contact interaction with unilateral constraints in problems of dynamics of technological machines and vibration processes has been well studied and is reflected in the works [5]-[7]. "Not-holding ties" in processes of interaction in the contact wheelset-track is investigated slightly. Separate the dynamic aspects of contact failure was reflected in the works on the dynamics of the rolling stock when passing the rail joints [8]. Not-holding ties are characteristic of switching processes implemented in the brush-commutator unit of traction motors. One of the first works in this direction were the results of the first studies published in articles [9], [10]. The possibility of contact failure in the work of the brush-commutator unit are considered in the famous works [11]-[14]. The practice provides many examples of the occurrence of failures of traction motors, when, unilateral constraints of the bonds, including the rebound of the brushes, are essential. In the staging plan Influence of oscillation of the traction motor on the dynamic properties of the interaction of brush-commutator are considered in work [15].

The dynamic interactions features of elements of mechanical vibrating systems with «not holding» ties on the example of model problems with the implementation of periodic regimes with a gap are considered in the publications [16]-[18].

However, the issues of development of dynamic representations about the violation of the conditions of contact, forms of possible processes of dynamic interaction with continuous tossing with the definition of conditions of non-infringement of contact in the detailed view of analytical approaches are not considered.

This article examines the approach to determining the dynamic characteristics of the brush-commutator unit depending on custom force factors on the basis of the mathematical model taking into account «not holding» ties including analytical way.

II. Main Provisions: Statement of the Problem Research

The interaction of the brushes with the commutator surface can be represented by a model of unilateral constraints of contact, when the vertically moving material particle is interacting with vibrating horizontal surface [19], [20]. The surface roughness and curvature of the commutator are approximated by a harmonic function with a fixed amplitude and a frequency. The commutator surface is imagined by a horizontal surface, which makes the vertical harmonic vibrations in a point contact. Features of the interaction of the brush with the retaining device and corpus of the traction motor are provided as the additional force. The frictional force of

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the brushes against the walls of the sockets of the brush holder may be play the role of additional force. Also influence from the spring element to brush may be play the role of additional force too. Additional forces may depend on the phase state. For example, the additional force is valued as f_1 during the time interval of process of vertical lift brush in the phase of free motion, and additional force is valued as f_2 in a phase of lowering of the brush to the surface. The possibility of gap is formatted by various parameters of amplitude A, frequency ω and force factors. The contact of the brush with the commutator, assuming that the contact reaction is positive, sets the phase of the goods wait. The phase of the goods wait phase transits to a critical phase state characterized by a zero contact reaction. The critical phase may transit to the gap phase. The phase of gap is characterized by a positive value of clearance. The gap is measured by the distance between the brush and surface of the commutator. The presence of gravitational force and additional force factors lead to the impact of brushes on the commutator. It is believed that absolutely inelastic impact take a place. The phase of interaction of brush with the commutator surface with gap and the group of phase states (goods wait phase, boundary phase, impact phase) are presented as schematic and design schemes in Fig. 1. The combination of power factors can lead to realization of the modes with a periodic gap [20].

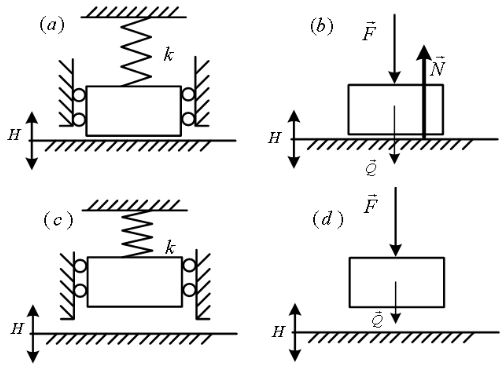

Fig. 1. The phases of brush-commutator interaction: (a) schematic diagram of contact phase, (b) calculation scheme of contact phase, (c) schematic diagram of free phase, (d) calculation scheme of free phase.

The objective of the study is to develop a method of estimating the influence of configuration of additional forces on the characteristics of the modes of motion of the brush-commutator interaction subject to unilateral constraints. A mathematical model of the interaction of material particles with the vibrating surface is used to solve this problem [16]. In particular, duration of the approach of the material point is resulted on the basis of the developed model [20].

III. Mathematical Model of the Interaction of the Brushes with Collector

Introduction of the generalized gap function. The mathematical model of the brush-commutator interaction within the framework of the problem of assessing the characteristics of dynamic modes with separation is formed on the basis of consistent detailing of ideas about the features of the brush movement taking into account the unilateral connections. At the initial stage of the study, a model of free movement of the brush in isolation from the surface of the collector taking into account only gravity is developed, provided that at the initial time the brush is in forced contact with the surface of the collector. To take into account the forms of brush breaks, the concept of a generalized form of free movement of the brush is introduced. A comparison of the generalized free motion form of the brush with the shape of the collector motion leads to a similar concept to account for the gap – the generalized gap function, which is used to construct the gap criterion in the analytical form. Force factors are taken into account by introducing coefficients reflecting the connection of the weight force with additional constant forces acting on the brush in the process of alternating phase states.

A mathematical model of the interaction of the brushes with the collector. The model of free movement of the brush is based on the assumption of the possibility of constructing the shape of the brush movement from the points of forced contact of the brush with the surface of the collector for arbitrary moments of time. The forms of free motion of the brush are determined from the set of all solutions of differential equations taking into account the initial conditions characterizing the forced contact moment:

$$\begin{cases} \dfrac{\partial^2 X_H(t,t_0)}{\partial t^2} = -g,\ t \ge t_0 \\ \left.\dfrac{\partial X_H(t,t_0)}{\partial t}\right|_{t=t_0} = \left.\dfrac{\partial H(t)}{\partial t}\right|_{t=t_0} \\ \left. X_H(t,t_0)\right|_{t=t_0} = \left. H(t)\right|_{t=t_0}, \end{cases} \tag{1}$$

where the generalized form X_H of brush motion is a family of free motion forms with initial conditions given by the commutator surface whose vertical motion is approximated by a harmonic function $H(t)=A\sin(\omega t)$.

Comparison of the system (1) of the generalized free movement of the brush with the surface movement $H(t)$ allows to localize the point of separation of the brush from the commutator surface.

The value of exceeding by the form of free movement of a brush of a collector surface represents a gap, formal consideration of which as a difference between the generalized form of free movement and a commutator surface, leads to the concept of the generalized function of a gap:

$$R_H(t,t_0) = X_H(t,t_0) - H(t) \tag{2}$$

where $X_H(t, t_0)$ is a family of forms of free movement of the brush under the condition of forced contact at the time $t=t_0$, $H(t)$ is the form of vertical movement of the commutator surface.

The problem of selecting the shape of separation from the family of possible forms of free movement of the brush can be reduced to the problem of determining the shape of the generalized gap, which takes a positive value after separation on the basis of the differential criterion presented in [20]. In particular, the use of a differential criterion for the harmonic form of vertical movement of the collector surface shows the possibility of implementing two different types of brush separation from the commutator. The brush separation, which is carried out during the transition of the decaying phase to the boundary phase of the zero contact reaction, can be determined by their conditions of positivity of the third derivative of the gap function [18]:

$$\begin{cases} R_H(t,t_0)\big|_{t=t_0} = 0, \\ \dot{R}_H(t,t_0)\big|_{t=t_0} = 0, \\ \ddot{R}_H(t,t_0)\big|_{t=t_0} = 0, \\ \dddot{R}_H(t,t_0)\big|_{t=t_0} > 0, \end{cases} \tag{3}$$

where the differentiation is carried out by variable t.

At the same time, within the framework of the model under consideration, it is possible to detach the brush from the commutator surface only on the basis of the forced contact characteristics, if the conditions are met:

$$\begin{cases} R_H(t,t_0)\big|_{t=t_0} = 0, \\ \dot{R}_H(t,t_0)\big|_{t=t_0} = 0, \\ \ddot{R}_H(t,t_0)\big|_{t=t_0} > 0. \end{cases} \tag{4}$$

The differential criterion for determining the separation points can be used as a classification feature of the separation points on the basis of the order of the derivative taking positive values after the previous zero derivatives. So the condition (4) defines the points of separation of the second order, and the condition (3) determines the points of separation of the third order.

In [20] it is shown that the account of the order of the separation point creates the preconditions for the development of the theory of trajectory regimes of periodic contact disruption.

A significant factor in the formation of local peculiarities of infringement of contact of the brushes with the surface, and extending to the characteristics of the modes with a periodic separation are of force on the brush, manifesting itself in a number of cases, as additional constant force. As part of the assessment of the effectiveness of the brush-commutator unit, the effect of additional forces on the duration of the contact between the brush and the commutator surface is of interest. Details of the study are presented in [18], [20].

IV. Duration of the Gap Depending on the Force Configuration: The Direct Problem

Duration of the gap contact for continuous flipping a brush is discussed. Force is switched at the moment of reaching the maximum value of the gap. Analytical configuration entry forces f_1 and f_2 is determined by the expression $f_2 = \alpha f_1$ for the configuration parameter α.

1. Variant $\alpha > 1$. This means that when the brush is decreasing in the collector slot, the additional force, co-directed with the weight force, increases. The analytical expression of duration of the gap, depending on additional force f_1, is following:

$$\Delta T = \left(1 + \sqrt{\frac{1+\dfrac{f_1}{mg}}{1+\dfrac{\alpha f_1}{mg}}}\right)\left(\frac{A\omega}{g\left(1+f_1/mg\right)} - \frac{1}{\omega}\right) \tag{5}$$

The range of forces shaping the phase of gap of finite duration has the form:

$$\frac{-mg}{\alpha} < f_1 < -mg + mA\omega^2 \tag{6}$$

If $A\omega^2 - g > 0$, then configuration parameter α of the considered range of forces is not empty. If $A\omega^2 - g < 0$, then consideration of interval α is needed:

$$1 < \alpha < \frac{g}{g - A\omega^2} \tag{7}$$

2. Variant $0 < \alpha < 1$. This option means that during the brush fall process, the additional force weakens compared to the force during the lifting process after the separation. The simultaneous fulfillment of the conditions of the finite duration of gap and conditions of gap are expressed as:

$$-mg < f_1 < -mg + mA\omega^2 \tag{8}$$

3. Variant $\alpha < 0$. This option reflects the effect of changing the direction of the additional forces at the moment of reaching the maximum brush height of gap. The joint condition of finite duration of the gap and conditions of gap is represented as the interval for modules of additional force:

$$-mg < f_1 < \frac{mg}{\alpha} \tag{9}$$

The presented condition for the considered configuration parameter sets a non-empty set of additional forces acting on the brush in the separation process at the lifting stage. It should be noted that the proximity of additional forces to the boundary points of the interval (9) means an increase in the duration of the gap. However, the duration of the gap is reduced to zero in case the magnitude of the additional force goes to the critical value $f_0 = m(A\omega^2 - g)$. Fig. 2 presents the plots of the durations of the gap for case the value of the critical force exceeds the maximum range of the finite duration of the gap for certain configuration parameter α:

$$-\frac{mg}{\alpha} < m(A\omega^2 - g) \tag{10}$$

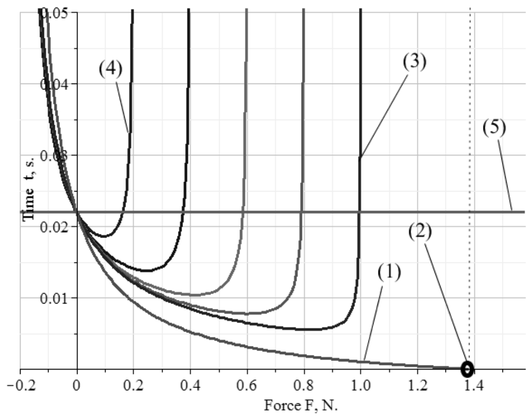

Fig. 2. The duration of the breach of contact for the configuration parameters α<0: A=0.0002 m, ω =100 Hz, m = 0.02 kg, (4) is the curve for a parameter $\alpha = -1$; (3) is the curve for option $\alpha = -0.2$; (1) is the curve of duration of gape when the switching of force does not occur and the force kept the intensity throughout the period of movement of the brushes, (5) is the curve of duration of gap in the absence of additional forces, (2) is the magnitude of the suppression of gap T.

V. Configuration of Forces, Providing a Permanent Duration of the Gap: The Inverse Problem

The configuration of additional forces providing a fixed duration of the gap of brushes with commutator surface is discussed.

1. The following equation relative to the unknown variables f_1 and f_2 is considered to determine the configuration of forces in which the duration of the breach of the contact amounts to T_0:

$$\left(1+\sqrt{\frac{1+\dfrac{f_1}{mg}}{1+\dfrac{f_2}{mg}}}\right)\left(\frac{A\omega}{g\left(1+f_1/mg\right)}-\frac{1}{\omega}\right)=T_0 \qquad (11)$$

The solvability condition for this equation (11) implies the condition in the form of inequality:

$$\sqrt{\frac{1+\dfrac{f_1}{mg}}{1+\dfrac{f_2}{mg}}}=T_0\Big/\left(\frac{A\omega}{g\left(1+f_1/mg\right)}-\frac{1}{\omega}\right) \qquad (12)$$

It can be shown that an additional force f_1 must lie in the interval:

$$-mg+\frac{1}{T_0\omega+1}mA\omega^2 < f_1 < -mg+mA\omega^2 \qquad (13)$$

If condition (13) is true, then the required additional force is uniquely represented in the form of fractionally rational function.

2. There is the option of independent values f_1 and f_2. It is believed the forces f_1 and f_2 act on the brush in the gap phase in the up and down movement, respectively. It is assumed that forces can have an arbitrary fixed value.

The plane YOX with a Cartesian coordinate system is presented in Fig. 3.

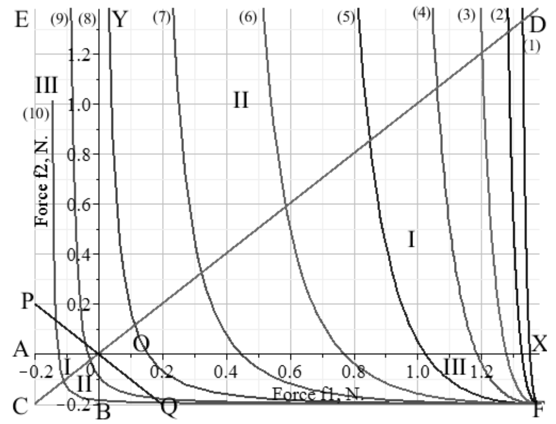

Fig. 3. The set of tossing regimes with a fixed duration of the gap: C – point with coordinates ($-mg$, $-mg$), F–point with coordinates ($-mg+mA\omega^2$, $-mg$). Curves (1)-(10) are the lines of level for the duration of gaps to the brushes equal to values respectively 0.0001 s. 0.0002 s, 0.0004 s., 0.0008 s., 0.0016 s.,.. 0.0512 s.

The continuous tossing of the brush with the additional forces f_1 and f_2 is brought into correspondence with each point F=(f_1, f_2) plane YOX. A positive value corresponds to an additional force codirected to gravity. Similarly, a negative value corresponds to a force directed in the opposite direction to gravity. The area is considered within the two lines CE and FD parallel to the y-axis in the Fig.3. The periodic gap of the brush is implemented for each point in a designated area [20].

In Fig. 3, this configuration set is indicated by $ECFD$. As you approach the boundary of the area CE and CF duration of violation of commutator contact with the brush increases without limit. At the same time, as we approach the FD boundary, the duration of the contact violation decreases to zero. If the point of force configuration F lies outside this area, the brush is either in the zone of impossibility of contact with the commutator surface, that is, to the right of the straight FD, or in the area of "infinite duration of contact", that is, or to the left of the straight EC, or below the straight CF and at the same time to the left of the straight FD. The area of periodic contact disruption can be divided into sub-areas depending on the regimes under consideration.

Region inside the triangle OBC and DYO determine the configuration of additional forces, with the property that on the interval of lowering of the brush in the mode with continuous tossing the intensity of the force, keeping its direction, increases the force acting on a range of lifting brushes. In Fig. 3, this area is indicated by the number II.

The area inside the triangles CAO and ODX defines the configuration of forces, the intensity of which is lowered by the change of the direction of the brush in the phase of detachment from the surface. In Fig. 3, this area is indicated by the number I.

The area inside the rectangles $AOYE$ and $BOXD$, indicated in Fig. 3 by number III, determines the configuration of forces changing their direction as a result of changing the direction of the brush movement in the separation phase. The set of modes for which the additional force at change of the direction keeps the module, is designated in Fig. 3 by the piece PQ. At the ends of the segment, namely at points P and Q, conditions are created for the implementation of the regime with a violation of the contact of "infinite" duration. For this mode, you can find a combination of forces that minimize the brush's approach height, provided that point F lies to the right of point Q. This condition is equivalent to inequality $mg<-mg+mA\omega^2$. In the further movement along the straight line PQ is the transition of interaction in the irrevocable mode of separation of the brush.

With a more detailed consideration of the collector-brush unit, it can be noted that the brush, having a non-restraining connection, interacts not only with the surface of the collector, but also with the elements of the brush holder, in particular, with a spring, which, in turn, has certain mass-inertial properties. With this approach, the dynamics of interaction of elements of the brush-commutator unit is complicated due to the possibility of the influence of the second unstoppable bond.

The presented variants of the modes allow us to consider the additional force as a factor of possible regulation of the dynamic state of the contact interaction of the brush with the surface of the commutator.

VI. Conclusion

The following conclusions are generated on the basis of the conducted researches:

1. The new mathematical model of interaction of elements of the brush-commutator unit is developed so, that the possibility of contact in the complex interaction with the gap of the brushes with the collector is taken into account.

2. Periodization of contact interaction is proposed with following phase states: phase goods wait, boundary condition of the contact, phase with gap, phase with the beat on the surface of commutator.

3. A new concept of a generalized function of the gap is introduced. The function of gap predetermines the details of views on the various forms of gap and one setups the classification criterion based on a differential criterion of the breakaway of brush.

4. It is shown that an additional force determines the duration of the gap of brushes with commutator surface and affects the features of the formation of modes with continuous tossing.

5. The analytical result of the solution of the inverse problem can be used to develop devices control modes of contacting the brush with the surface of the commutator.

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References

[1] V. I. Bocharov, V. I. Zaharov, and L. F. Kolomejcev, *Traction Motors of Electric Locomotives*, V. G. Shcherbakov Ed., Novocherkassk: Nautilus, 1998 (in Russian).

[2] A. I. Orlenko, M. N. Petrov, and O. A. Teregulov, *Complex Diagnostics of Traction Motor of Electric Locomotive*, Krasnoyarsk, 2016 (in Russian).

[3] V. D. Avilov, *Optimization of the Switching Process in the Commutator Electrical Machines DC*, Omsk: Omsk Scientific Bulletin, 2013 (in Russian).

[4] V. V. Kharlamov, "Improvement of methods and means of diagnosing the technical condition of collector and brush-commutator unit of traction electric motors of rolling stock," Ph.D. dissertation, Omsk: Omsk State Transport University, 2002 (in Russian).

[5] I. I. Blehman, *The Theory of Vibration Processes and Devices. Mechanical Vibration and Vibration Engineering*, SPb.: Ore and metals, 2013 (in Russian).

[6] G. J. Panovko, *Dynamics of Vibrating Processes*, Moscow-Izhevsk: RHD, 2006 (in Russian).

[7] Yu. R. Kopylov, *Dynamics Vibro-Hardening Process*, Voronezh: Nauchnaja kniga, 2011 (in Russian).

[8] M. P. Pakhomov, N. P. Bujnov, and I. I. Galiev, "Estimation of the level pulse impact rail joints on the locomotive wheel," *The Interaction of Rolling Stock and Path, the Dynamics of Locomotives*, Omsk, pp. 9-16, 1971.

[9] S. V. Eliseev, V. P. Paramsin, and I. V. Senkevich, "To the question of the influence of mechanical factors on commutation," *Proceedings of Omsk Institute of Railway Transport Engineers*, Omsk, pp. 91-104, 1966 (in Russian).

[10] M. F. Karasev, V. P. Belyaev, V. N. Kozlov, A. M. Trushkov, V. D. Avilov, and S. V. Eliseev, "Further development of the theory of optimal switching," in *Proc. Scientific Works of Omsk Institute of Railway Transport Engineers*, vol. 78, Moscow: Transport, 1967, p. 175.

[11] V. V. Kharlamov, D. I. Popov, and A. P. Afonin, "Influence of local mechanical defects of the commutator on the distribution level of sparking of brushes on the commutator," in *Proc. Materials XI Int. Scientific-Technical Conference on Automation and Energy Efficiency Engineering and Metallurgical Industries, Technology and Reliability of Machines, Devices and Equipment*, 2016, pp. 180-182.

[12] V. V. Kharlamov, D. I. Popov, and M. F. Bayazitov, "Estimation of the impact of the profile of the commutator of machines DC on work of sliding contact," *Omsk Scientific Bulletin*, no. 4, pp. 62-65, 2016.

[13] V. V. Kharlamov, P. K. Sadun, A. V. Dolgov, and D. A. Akhunov, *Improvement of the Technology of Diagnosing the Technical Condition of Brush-commutator unit of Traction Electric Motors of Locomotives*, Omsk: Omsk State Transport University, 2015.

[14] Sh. K. Ismailov, *Increase the Resource of Insulation of Electric Machines of Rolling Stock*, Omsk: Omsk State Transport University, 2007.

[15] V. V. Kharlamov, A. V. Nekhaev, P. K. Skadun, and D. A. Akhunov, "Estimation of the effect of the irregularities of railway track on the work of the brush-commutator unit of a traction motor," in *Electromechanical Energy Converters*, V. D. Avilov Ed., Omsk, 2014, pp. 31-36.

[16] A. V. Eliseev, A. I. Artyunin, and S. V. Eliseev, "Generalized gap function in the dynamic interaction problems of elements of vibrational technological machines with 'not holding' ties," in *Vibroengineering, Procedia*, pp. 495-500, October 2016.

[17] A. V. Eliseev, A. I. Artyunin, N. P. Sigachev, and I. S. Sitov, "Unilateral constraints in vibrating technological processes: mathematical models, features of interaction of elements," in *Proc. Fifth Int. Symposium on Innovation and Sustainability of Modern Railway*, Nanchang, China, October 20-21, 2016, pp. 261-269.

[18] I. S. Sitov and A. V. Eliseev, "The theoretical basis of the interaction of the material particle with a vibrating surface with not-holding ties," *System, Methods, Technology*, Bratsk: Bratsk State University, no. 16, pp. 19-29, 2012 (in Russian).

[19] A. V. Eliseev, "The peculiarities of interaction between material particle with a vibrating surface, depending on the additional force taking into account not-holding ties," *Int. Journal of Applied and Fundamental Research*, no. 3, pp. 9-15, 2013 (in Russian).

[20] A. V. Eliseev, V. V. Selvinskij, and S. V. Eliseev, *The Dynamics of a Vibratory Interaction of Elements of Technological Systems Subject to Not-holding Ties,* Novosibirsk: Nauka, 2015 (in Russian).

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