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ASPECTS REGARDING BRAKING FLAT WAGONS WITH SMALL WHEELS

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Abstract: *This paper presents several problems related to braking at the limit of adherence of the platform wagons with lowered ceiling, the wheel diameter ranging from 335 to 760 mm. The paper also deals with aspects related to the modification of the dimensions of the contact area due to the variation of the rated diameter and the vertical load on the wheel, as well as aspects related to the stresses in the contact area and the pseudo-sliding coefficients.*
Key words: *contact area, stresses in the contact area, pseudo-sliding coefficients.*

INTRODUCTION

The combination between road and railway transportation constitutes a present-day problem of the freight transportation. Under this consideration a series of platform wagons with lowered ceiling (414…625 mm to the rail level) were developed; these wagons are meant to transport containers or motor trucks without weight-related problems. An important characteristic of these wagons is the decrease in the rolling rated diameter and the increase in the number of axes on the wagon for the purposes of maintaining a constant net load.

The paper deals with aspects on the influence of the main parameters on the dimensions of the contact area, stresses in the contact area, parameters, which can also determine variations of the pseudo-sliding coefficients. The study is carried out while taking into account that the rated diameter of the wheel ranges between 335…760 mm and the vertical load on the wheel ranges between 36,78…10 kN, however it is mainly extended to the wagons in the Saadkkms and Sdgmss series.

Another problem that has been dealt with and presented in the paper refers to the braking system used for the above mentioned vehicles. In this sense we conducted an analysis of the advantages and disadvantages it implies.

CHARACTERISTICS OF THE WAGONS WITH SMALL WHEELS

Wagon series Saadkkms

Wagon length:……………….. ……..20200 mm;
Wagon axle base:…………………… 12730 mm;
Height from the rail to the ceiling:……..454 mm;
Automatic brake type……………….. KE-GP-A;
Bogie type:………………………………… 2+3;
Bogie axle base: ……………………...4x700mm;
Diameter of the wheels – as new:……... 370 mm;
Diameter of the wheels - as fully worn:..335 mm;
Dead weight:…………………………… …21,3t;
Maximum load on axle:…………………… 7,5t;
Net load of the wagon:………………... ….53,7t;
Max. constructive speed:……………..120 km/h.

Wagon series Sdgmss

Wagon length: ………………………23460 mm;
Wagon axle base: ……………………17600 mm;
Maximum width of the wagon:……….2892 mm;
Height from the rail to the ceiling: ……625 mm;
Bogie axle base: ………………………1800 mm;
Automatic brake type:………………. KE-GP-A;
Bogie type:………………………………… 2+3;
Bogie axle base:…………………….. 4x700mm;
Wheel diameter – as new: ……………..760 mm;
Wheel diameter - as fully worn: ……….335 mm;
Dead weight:…………………………….. ….22t;
Maximum load on axle:……………………. 16 t;
Max. constructive speed:…………. ….120 km/h.

USED BRAKING SYSTEMS

Considering that the studied vehicles are used for freight transportation and have maximum constructive speed of 120 km/h, the sheet UIC 546 recommends the use of the shoe brake. Due to the extremely low dimensions of the wheels, these vehicles can only be equipped with automatic air brakes – disk brake. Due to the very low distance of the ceiling as to the rail plane and the standardization of the axle necks, the used solution is that the wheel membrane should also be brake disk.

The disks mounted "on the wheel" are made of two simple disks mounted on one side and the other side of the wheel. Regularly there are two constructive types. The used type implies the use of brake disks directly mounted on the wheel membrane, in which case it is flat and processed. Fixing occurs by bolts with countersunk head [2], which go though the wheel membrane. From this point of view the disk is practically a common part with the wheel, which increases the metal mass participating in warmth distribution, but there is no cooling by forced ventilation at the disk level.

Mounting the brake disks onto the wheel generally presents a series of advantages, among which: the solution is quite handy as it does not imply the creation of special axles, with additional wheel seats, which should have higher diameter than the wheel diameter; for a certain wheel dimension, the maximum diameter of the disk mounted on the wheel is higher than the diameter of the fitted on the axle, thus permitting, at least in theory, to obtain better braking performances.

It is well known that mounting the brake disk on the wheel also has a series of disadvantages, among which the most important is masking its membrane, which prevents timely detection of any possible cracks [2]. This system is not recommended to be used unless in special cases, provided that both from the constructive, and from a functional point of view no other constructive solutions may be used.

The wagons with low diameter constitute one of the above mentioned situations, and if - from a constructive point of view – the wheel membrane is used directly as brake disk, the previously mentioned disadvantage is also eliminated.

DIMENSIONS OF THE CONTACT ELLIPSE

Due to the deformation of the metal materials the wheels and rails are made of, the contact regularly occurs on an elliptic area. Generally, according to the specialty literature for this situation the dimensions of the contact ellipse are determined based on Hertz's theory [1]. This theory applies subject to the observance of the following suppositions:

- the dimensions of the contact ellipse are very low as compared to the dimensions of the two objects that come into contact;
- in the contact area only occur compressing stresses and no tangential stresses;
- the material in the contact area remains within the limit of proportionality of the elastic deformations.

Based on Hertz's theory, if we consider a and b as semi axes of the contact ellipse, their dimension may be established based on the formulas

$$(a/m)^3 = \frac{3N(1-\upsilon^2)}{E(A+B)}; \tag{1}$$

$$(b/n)^3 = \frac{3N(1-\upsilon^2)}{E(A+B)}, \tag{2}$$

where N[kN] is the normal load on the contact area, E[kN/mm^2] the coefficient of elasticity, ν Poisson's coefficient, and m and n coefficients are dimensions depending on the report (A-B)/(A+B), defined by cosβ=(A-B)/(A+B). A and B constants, as defined by Hertz, are dependant on the main curves of the contact surfaces, and for the wheel – rail system, if we consider ρ_r and ρ_s as transversal radiuses of the wheel profile, respectively of the rail and r the rolling radius of the wheel, the dimension (A-B) and (A+B) are determined as follows

$$A + B = \frac{1}{r} + \frac{1}{\rho_r} + \frac{1}{\rho_s}; \quad (3)$$

$$A - B = \frac{1}{r} - \frac{1}{\rho_r} - \frac{1}{\rho_s}. \quad (4)$$

As in general, the railway administrations use wear profiles, regularly in concave shape, the relations (3) and (4) become [1]

$$A + B = \frac{(\rho_s + r)}{r\rho_s} - \frac{1}{\rho_r}; \quad (5)$$

$$A - B = \frac{(\rho_s - r)}{r\rho_s} + \frac{1}{\rho_r}. \quad (6)$$

For the calculation of the pseudo-sliding coefficients we use a method based on Kalker's theory [1]. Thus, on longitudinal direction χ_x and transversala direction χ_y, Kalker defines the pseudo-sliding coefficients as follows [1]

$$\chi x = \left[\frac{Gab}{N}\right] C_{11}; \quad (7)$$

$$\chi y = \left[\frac{Gab}{N}\right] C_{22}, \quad (8)$$

where: C_{11} and C_{22} – represent coefficients calculated by Kalker and depend on the relation of the dimensions of the contact ellipse a/b or b/a [1]; N – represents the normal load on the wheel; G – represents the transversal coefficient of elasticity; G is determined depending on the longitudinal coefficient of elasticity E

$$G = \frac{E}{2(1+\nu)}, \quad (9)$$

where $\nu = 0{,}3$ represents Poisson's coefficient.

STUDY ON THE WAGON IN THE SERIES Saadkkms

For this study was elaborated a calculation program that permitted the determination of the dimensions of the contact ellipse, of the stresses in the contact area, as well as of the pseudo-sliding coefficients. The paper intends to conduct an analysis of the dimensions indicated under the conditions given by the variation of the rated diameter of the wheel and of the vertical load on the wheel. The following situations have been studied: wheel diameter in the plane of the nominal rolling circle, ranging between 335…370 mm, and the vertical load on the wheel between 10…37 kN.

The main results obtained with the help of the elaborated calculation program are summarized in the diagrams figures 1…6.

As we can observe in fig. 1, 2 and 3 the dimensions of the semi axes a and b and the extent of the contact area present a slight decrease simultaneously with the decrease in the diameter, but a significant decrease for the decrease of the load on the wheel.

In order to establish the pressures on the contact area wheel – rail the following formulas have been used [1]:

$$Z_{max} = 3Q_0/(2\pi ab); \quad (10)$$

$$Z_{adm} = 3\sigma_c; \quad (11)$$

$$Z_{0adm} = 4{,}5\sigma_c, \quad (12)$$

where: Z_{max} [kN/cm^2] constitutes maximum stress on the contact area, Z_{adm} [kN/cm^2] – maximum permitted stress and Z_{oadm} [kN/cm^2] is defined as average admitted stress.

Under the established conditions, respectively variation of the diameter and the load on the wheel within the stated limits, the calculation program lead to a series of results that are presented in diagrams in fig. 4. Considering the stresses in the contact area and analyzing the obtained values, we could discover that including under the application of the maximum admitted load on the axle (36,78 kN), the material in the contact area remains entirely within the limit of elasticity with no plastic deformations [1]. This final discovery needed to be mentioned as the conducted study refers to wagons with small wheels which obviously imply a much smaller contact area as compared to the contact area of the ordinary wagon wheels. The fact that there are no plastic deformations if the dimensions of the contact ellipse are increased may be explained by the distribution of the total vertical load on several axles, so in this context the use of a large number of axles and the disk brake – disk mounted on the wheel membrane - is justified.

While analyzing figures 5 and 6 we can see that pseudo-sliding on transversal direction is close in value to the one on longitudinal direction and increases considerably with the increase in the vertical load on the wheel, while the variation of the rated diameter of the wheel has rather reduced influence.

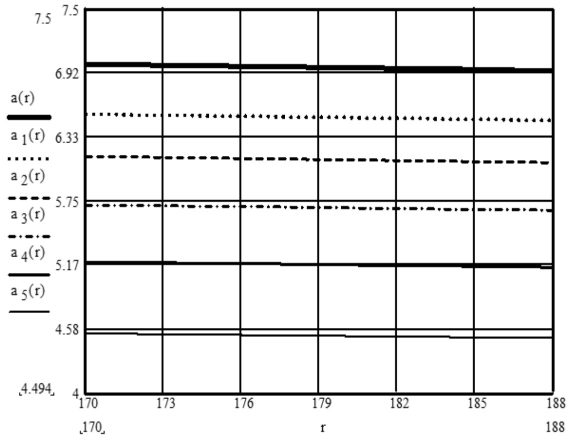

Fig. 1. Variation of the semi-axis a[mm] of the contact ellipse wheel – rail according to the wheel radius and the load on wheel Q for the wagon in the Saadkkms series

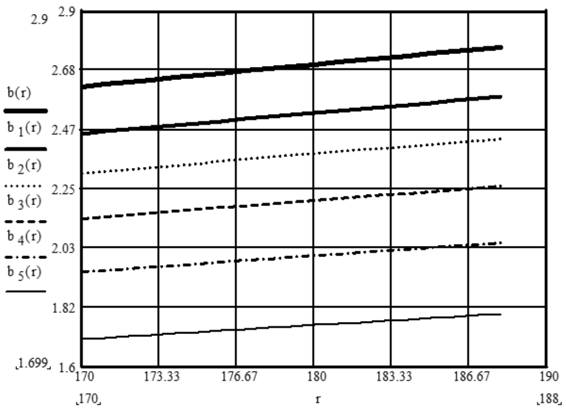

Fig. 2. Variation of the semiaxis b[mm] of the contact ellipse wheel – rail according to the radius of the wheel and the load on the Q wheel for the wagon in the Saadkkms series

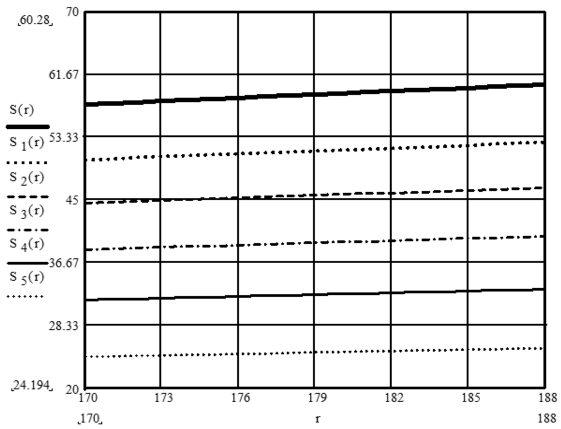

Fig. 3. Variation of the contact area [mm^2] depending on the wheel radius and load on Q wheel for the wagon in Saadkkms series

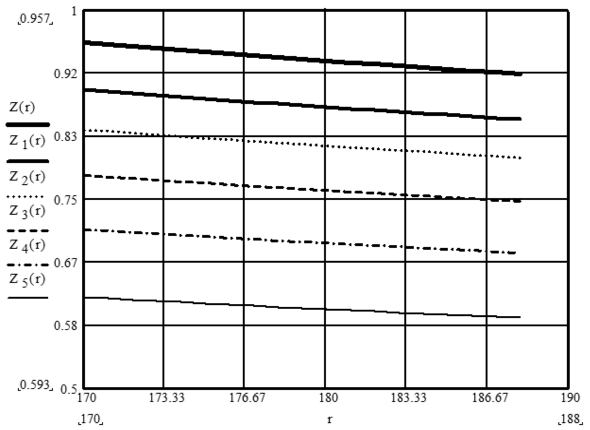

Fig. 4. Variation of the stresses on the contact ellipse wheel – rail [kN/cm^2] according to the wheel radius and the load on the Q wheel for the wagon in the Saadkkms series

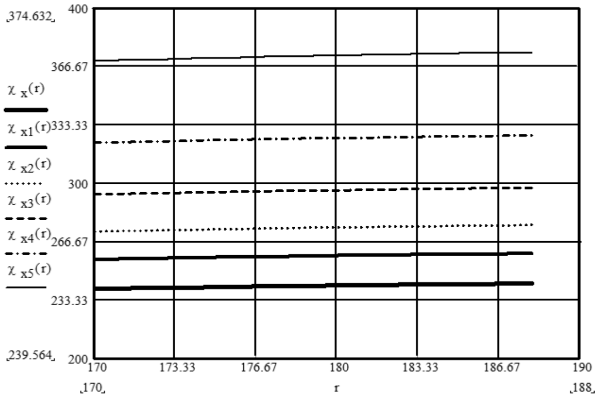

Fig. 5 Variation of the coefficients of pseudo-sliding on longitudinal direction acc. to the wheel radius and the load on Q wheel for the wagon in the Saadkkms series

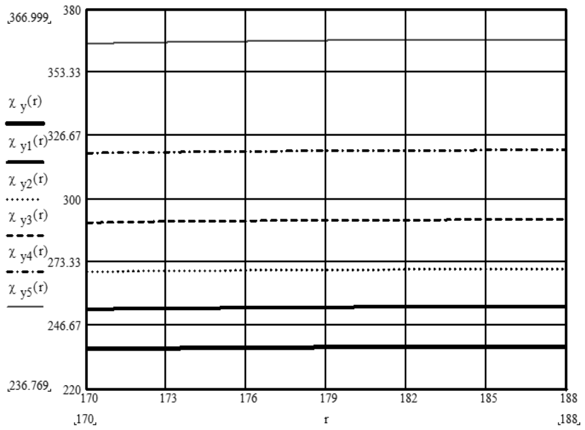

Fig. 6. Variation of the pseudo-sliding coefficients on transversal direction acc. to wheel radius and load on Q wheel for the wagon in the Saadkkms series

STUDY ON THE WAGON IN Sdgmss SERIES

Based on the same principle as in the case of Saadkkms wagon, for the wagon in the Sdgmss series was applied the elaborated calculation program, the aim being to determine the variations of the semiaxes a and b of the contact ellipse, the stresses on the contact ellipse and the pseudo-sliding coefficients on longitudinal and transversal direction. As in the previous case, we mentioned the established conditions, respectively the variation of the diameter and load on wheel within properly determined limits. Thus were studies and analyzed the following cases: wheel diameter in the plane of the rolling nominal circle ranging between 660…760 mm, and the vertical load on the wheel between 28…79 kN

The main results obtained with the help of the elaborated calculation program are recorded in the diagrams in figures 7…12.

As can be observed in fig. 7, 8 and 9, the dimensions of the semiaxes a and b, implicitly the extent of the contact area records a slight decrease with the decrease in the wheel diameter. In return, a significant decrease in the dimensions of the contact area can be observed as the load on wheel decreases.

Fig. 10 present the results obtained after the determination of the stresses in the contact area – by again using the formulas (6)…(8).

After making the calculations it resulted that in the interval given by the maximum admitted load on the wheel, respectively 78,48 kN and the minimum load of 28,2 kN, the material in the contact area remains entirely within the limit of elasticity without plastic deformations [1], when the contact area is very low as compared to the corresponding wheels at the usual wagons. This observation may be explained by the fact that in this situation, although the number of axles is much lower, the rated diameters in the plane of the rolling circle they are double as compared to the preceding case.

Fig. 11 and 12 show that pseudo-sliding on transversal direction is close to the value of the one on longitudinal direction. It is considerably decreased with the increase in the vertical load on the wheel, while the variation of the nominal diameter in the plane of the rolling circle has relatively reduced influence on the size of the pseudo-sliding.

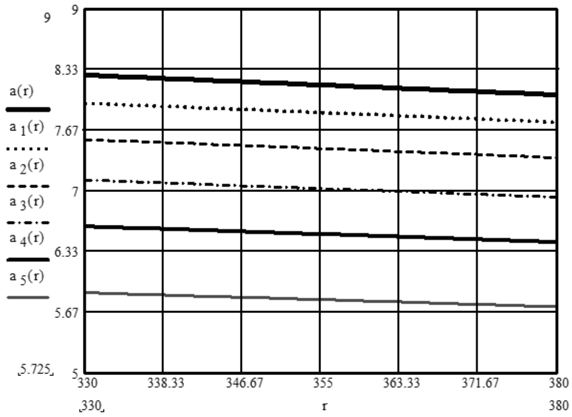

Fig. 7. Variation of the semi-axis a[mm] of the contact ellipse wheel – rail acc. to the radius of the wheel and the load on Q wheel

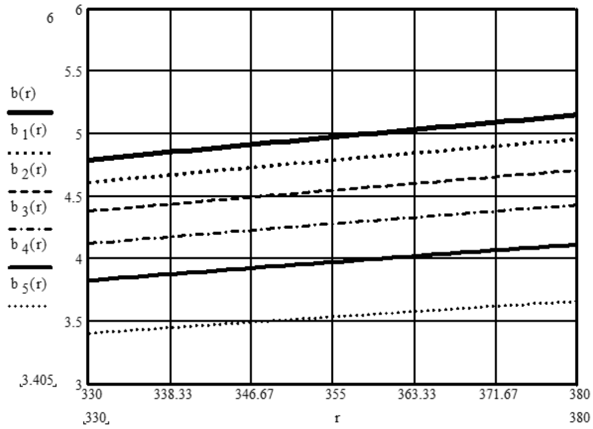

Fig. 8. Variation of the semi-axis b[mm] of the contact ellipse wheel – rail acc. to the radius of the wheel and the load on Q wheel for the wagon in Sdgmss series

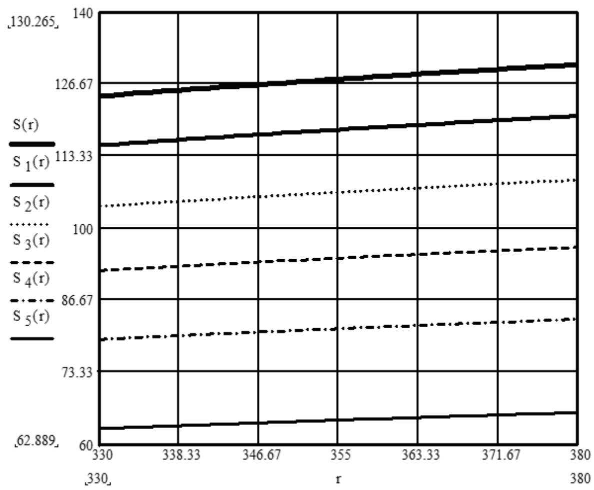

Fig. 9. Variation of the contact area [mm^2] acc. to the radius of the wheel and the load on Q wheel for the wagon in Sdgmss series

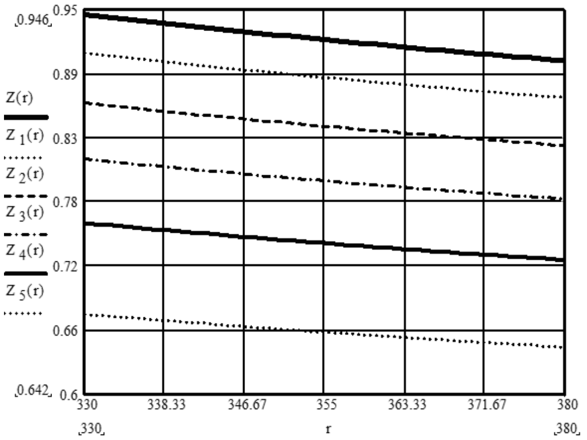

Fig. 10. Variation of the pressures on the contact area [kN/cm^2] acc. to the radius of the wheel and the load on Q wheel for the wagon in Sdgmss series

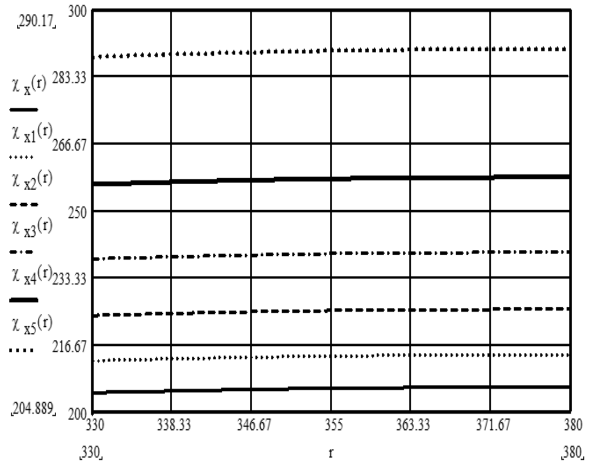

Fig. 11. Variation of the longitudinal pseudo-sliding coefficients acc. to the radius of the wheel and the load on Q wheel for the wear profile DB II

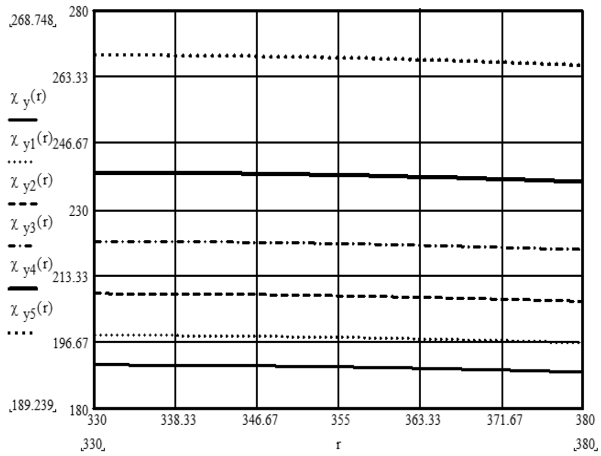

Fig. 12. Variation of the transversal pseudo-sliding coefficients acc. to the radius of the wheel and the load on Q wheel for the wear profile DB II

CONCLUSIONS

In this study we dealt with aspects related to the modification of the dimensions of the contact area wheel-rail as a consequence of the variation of the rated diameter of the wheel and of the vertical load on the wheel. Special attention was directed to determining the values of the stress in the contact area, when the load on the wheel takes on values within a limited range of minimum and maximum admitted values. Based on a method on the basis of Kalker's theory the pseudo-sliding coefficients were established on longitudinal and transversal direction.

The study shows that due to the very loaw values of the rated diameter and vertical load, for the Saadkkms wagon the size of the contact area is reduced, ranging between 24…55 mm^2. This required the verifications of the stresses in the contact area. The calculations revealed that the material in the contact area remains entirely within the limit of elasticity with no plastic deformations. The calculation of the pseudo-sliding shows that pseudo-sliding on transversal direction is close to the value of longitudinal pseudo-sliding, and it decreases considerably with the increase in the vertical load on wheel, while the variation of the rated diameter in the plane of the rolling circle has relatively reduced influence.

For the wagon in the Sdgmss series, the values of these parameters are practically double, which can be explained due to the much higher rated diameters and loads on wheel, when the number of axles is much lower.

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АСПЕКТИ НА СПИРАНЕТО НА ПЛОСЪК ВАГОН С МАЛКИ КОЛЕЛА

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Резюме: *Докладът разглежда някои проблеми, които се отнасят до спирането при ограничение на сцеплението на платформени вагони със снижен покрив, като диаметърът на колелото е с обхват от 335 до 760 mm. Представени са и някои аспекти, които се отнасят до модифицирането на измеренията на контактната повърхност поради варирането на диаметъра и вертикалното натоварване на колелото, както и проблеми на напрежението в контактната зона и коефициентите на псевдо-плъзгане.*
Ключови думи: *контактна повърхност, напрежение в контактната зона, коефициенти на псевдо-плъзгане.*