Wheel pair, two-flange wheel, derailment, wheel flange, railway track.

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PROVIDING DERAILMENT PREVENTION BY APPLYING A WHEEL PAIR WITH THE COUNTER-FLANGE

Summary. The authors have proposed grounded engineering solution for design of wheel pair that has wheels with counter-flange that satisfy the existing standards of vertical and horizontal dynamics and movement stability index.

Improved profile of rail wheel with counter-flange has been developed. It provides the additional contact in horizontal plane while transverse vibrations of wheel pair relatively to rail track, makes carriage more stable and increase the resisting force of wheel against derailment when passing a curved part of line and in the case of spring deflection of rails due to force interaction.

Profile of wheel pair has the additional running track and counter-flange that prevents derailment when base flange of wheel rolls onto working surface of rail or there is way spacer due to rail spring deformation. Proposed design of wheel pair is covered by Ukrainian useful model patent.

ОБЕСПЕЧЕНИЕ ПРОТИВОДЕЙСТВИЯ СХОДА ЖЕЛЕЗНОДОРОЖНЫХ ЭКИПАЖЕЙ С РЕЛЬСОВ ПУТЕМ ИСПОЛЬЗОВАНИЯ КОЛЕСНОЙ ПАРЫ С КОНТГРЕБНЕМ

Аннотация. Предложено обоснованное техническое решение конструктивного исполнения колесной пары, которая имеет колеса с контргребнем, что соответствует существующим нормам по критериям вертикальной и горизонтальной динамики, а также показателям устойчивости движения.

Разработан усовершенствованный профиль железнодорожного колеса с контргребнем, что обеспечивает дополнительный контакт в горизонтальной плоскости при поперечных колебаниях колесной пары относительно рельсового пути и добавляет экипажу устойчивости и увеличивает силы сопротивления колес против схода с рельсов при прохождении криволинейных участков пути, а также при упругом отклонении рельсов в результате силового взаимодействия.

Профиль колесной пары характеризуется наличием дополнительной дорожки качения и контргребень, что обеспечивает противодействие схода колесной пары с рельсов в то время, когда основной гребень колеса вкатывается на рабочую поверхность рельса или имеет место распор пути в результате упругой деформации рельсов. Предложенная конструкция колесной пары защищена патентами Украины на полезную модель.

One of the main safety criteria for freight transportation by railway transport is derailment avoidance [16]. This is one of the most important problems at railway transport and it is a part of safety control problem. According to the works [4 – 7, 10 – 12], derailment event deduction is one of the main tasks in researching wheel-rail interaction.

The basic kinds of derailment include derailment due to the wheeling onto the rail and track thrusting – railhead is pressed-out by one wheel flange due to its spring decline and the other wheel fall off the other rail [1, 2, 13, 17].

Consequently, it is important to create such elements of truck (elements of wheel-rail system) that provide movement stability and preclude the possibility of wheel flange rolling onto railhead and have counteraction to derailment when spring rail deflection [3 – 9, 14, 15].

The article proposes a new design of wheel pair that provides protection against derailment due to counter-flange and makes possible its operation in the presence of track switches and other structural elements of track (fig. 1). The proposed idea of wheel pair design for special-purpose rolling-stock is covered by useful model patent of Ukraine [5, 6].

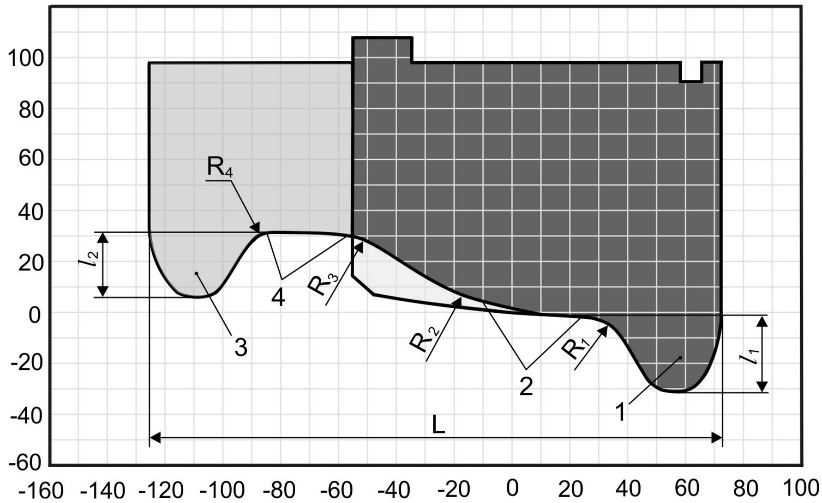

Fig. 1. Comparison of profiles of standard solid-rolled wheel and the proposed wheel:

■ + □ – solid-rolled wheel profile (National State Standard 9036-76);

■ + ■ – proposed wheel with counter-flange;

1 - inner solid-rolled flange of wheel; 2 - the main rolling profile; 3 - counter-flange; R_1, R_2, R_3, R_4 - curve radius in transition sections of curved surface that connects counter-flange and the wheel; 4 - extra rolling profile

Рис. 1. Сравнение профилей стандартного цельнокатаного колеса и предложенного колеса:

■ + □ – цельнокатаный профиль колеса (ГОСТ 9036-76);

■ + ■ – предложенное колесо с контргребнем;

1 – внутренний цельнокатаный гребень колеса; 2 – основной профиль качения; 3 – контргребень; R_1, R_2, R_3, R_4 – радиусы кривизны в переходных участках криволинейной поверхности, который сочетает контргребень с ободом колеса; 4 – резервный профиль качения

Profile of new wheel pair incorporates the following feature – it has the counter-flange in addition to the main flange. Rolling surface is connected with the counter-flange by ease curve with curve radius in transfer points R_2, R_3 and creates extra rolling profile. Overall width of the rim of wheel is increased due to rail width and free split. Extra-profile allows wheel return to standard position at tread circle due to curved surface. The height of counter-flange that is less relatively to wheel tread circle does not allow a wheel to contact track switch and other equipment of rail track.

In the case of emergency, when one wheel of the wheel pair rolls onto railhead by its inner flange, the other wheel contacts the outer side due to the counter-flange and creates a force that reacts against derailment (fig. 2).

It is intended that contact of flange and rail is the second contact point of wheel and the first one is a contact at the main rolling profile.

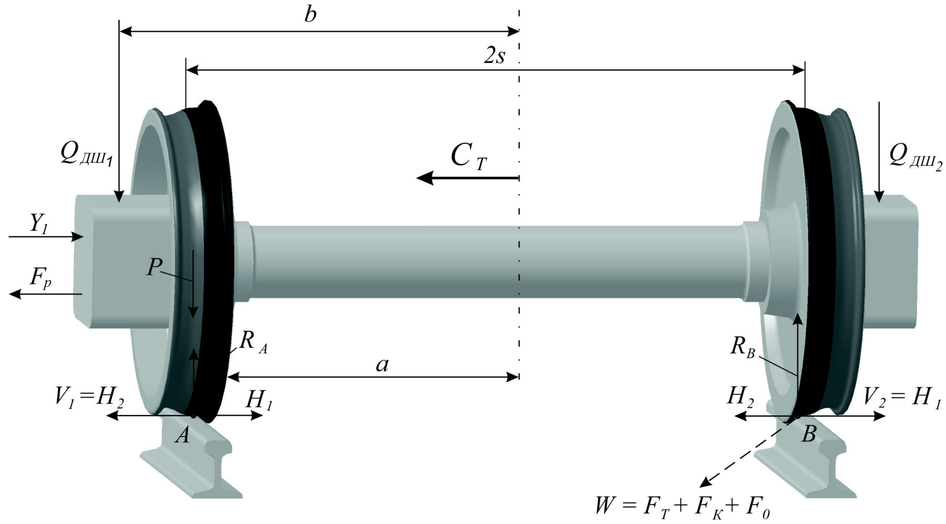

Fig. 2. Analytical model of wheel pair that has the wheels with counter-flange loaded with static and dynamic components of forces:
– main profile of the wheel; – extra profile of the wheel;
H_1 – side pressure on the wheel that guides (overruns);
H_2 – component of frictional force;
V_1, V_2 – the forces generated when counter-flange contact;
$2s$ – distance between wheel pair rolling circles;
C_T – centrifugal force of inertia;
Y_1 – forcing on the side of outside rail;
R_A, R_B – reactions of outside rail to car wheels;
$Q_{дш1}$ and $Q_{дш2}$ – dynamic vertical force acting on the neck of axle;
F_p – force acting from the frame;
b – half of the distance between the axles of spring groupings of the car;
a – distance between wheel flanges of wheel pair.
Рис. 2. Расчетная схема колесной пары, которая имеет колеса с контргребнем, нагруженной статическими и динамическими составляющими сил:
– основной профиль колеса; – резервный профиль колеса;
H_1 – боковое давление на направляющее (набегающее) колесо;
H_2 – составляющая силы трения;
V_1, V_2 – силы, возникающие при контакте контргребня;
$2s$ – расстояние между кругами катания колесной пары;
C_T – центробежная сила инерции;
Y_1 – усилия со стороны наружного рельса;
R_A, R_B – реакции наружного рельса на колеса вагона;
$Q_{дш1}$ і $Q_{дш2}$ – динамические вертикальные силы, действующие на шейку оси;
F_p – сила, действующая от рамы;
b – половина расстояния между осями рессорных комплектов вагона;
a – расстояние между гребнями колес колесной пары

Presence of the additional counter-flange at the conical part of the wheel provides the additional contact point between wheel pair and rail. Additional contact point between wheel pair and rail is modelled as spring contact with applying spring element. Spring element is used because of the fact that this contact is transitory and happens to be for a short while.

At that, the ingoing wheel will have one contact point with the rail. And non-ingoing wheel will have two contact points: at the rolling surface and on the outside at the external flange. The first contact point will be at the rolling surface of the wheel and wheel-rail interaction force in this point (

P_1) will show no specifics. Moreover, due to a small taper of rolling surface of the wheel, we may consider that the force P_1 (fig. 3) acts true-vertical. In the second contact point that is at the cam surface of external flange there is force generated that prevents further movement of wheel pair to the right (P_2). This force includes two components: lateral (P_{2y}) and vertical (P_{2z}).

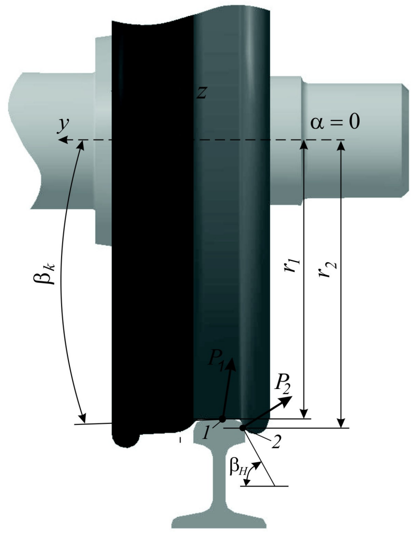

Fig. 3. Contact forces acting on the wheel in two contact points:
P_1 - wheel-rail interaction force; P_2 - counter-force to wheel movement
Рис. 3. Контактные силы, которые действуют на колесо в двух точках контакта:
P_1 - сила взаимодействия колеса с рельсом; P_2 - сила противодействия перемещению колеса;

Forces P_1 and P_2 and loading Q acting on the wheel are in quasi-static equilibrium.

$$P_1 = \frac{Q - P_2\left(\mu\, f_{y2}\, sin\,\beta_н + cos\,\beta_н\right)}{\mu\, f_{y2}\, sin\,\beta_к + cos\,\beta_к} =$$

$$= \left(Q - sin\beta_н + \mu\, f_{y2}\cdot\alpha\right) \Bigg/ \left(\begin{array}{l} \mu\, f_{y2}\, sin\,\beta_к + cos\,\beta_к + \\ + \left(\mu\, f_{x1}\, cos\,\beta_к - sin\,\beta_к\right)\cdot f_{y2}\, sin\,\beta_н + \\ + \left(\mu\, f_{x1}\alpha + \mu\, f_{y1}\, cos\,\beta_к - sin\,\beta_к\right) cos\,\beta_н \end{array}\right)$$

$$P_2 = \frac{\mu P_1 f_{x1}\cdot\alpha + \mu P_1 f_{y1}\, cos\,\beta_к - P_1\, sin\,\beta_к}{sin\beta_н + \mu\, f_{y2}\cdot\alpha}$$

where f_{xi} and f_{yi} – normalized sliding forces;
$\beta_{кол}$ – angle of the conical part of extra profile;
$\beta_н$ – slope angle of additional flange to horizontal plane;
Q – vertical loading of the wheel.

Fig. 4 presents mutual positions of wheel and rail in normal state - in one-point contact at the tread circle of the wheel. Contact point of wheel and rail at the tread circle is indicated by spot.

As we can see from the considered figure, the wheel without the additional flange is moved about 16 mm in cross direction when moving in the curved line. And it takes the position relatively to the rail presented at fig. 5.

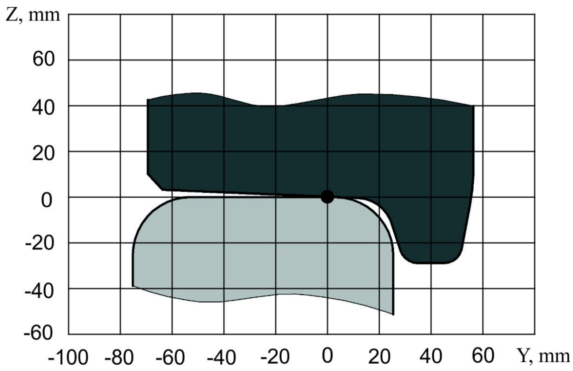

Fig. 4. Mutual positions of wheel and rail in normal state at the tread circle
Рис. 4. Взаимное расположение колеса и рельса при одноточечном контакте по кругу катания колеса

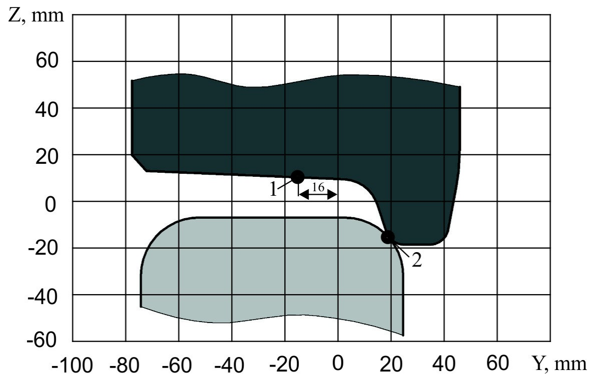

Fig. 5. Position of the wheel without the additional flange relatively to the rail when maximal side assignment
Рис. 5. Положение колеса, не оборудованного дополнительным гребнем, относительно рельса при максимальной боковом отнесении

Contact point at standard rolling circle is indicated as figure 1 and new point of contact between wheel flange and side surface of the rail - as figure 2. Referring to the figure, it is seen that in this case the left wheel is in critical state and the derailment is more than possible.

If the car with the wheels equipped with the additional flanges is in the same sort of situation, the maximal value of lateral motion is approximately 10 mm and the wheel takes the position relatively to the rail presented at figure 6.

At first glance, difference between lateral motions in these situations is not big. But, in the latter case, when the wheel is equipped with the additional flange, the wheel pair is in less hazardous situation. The contact is in the point (spot 2 at figure 6) that is located on the side surface of the rail. And in this case there is some distance between complete wheeling onto the rail.

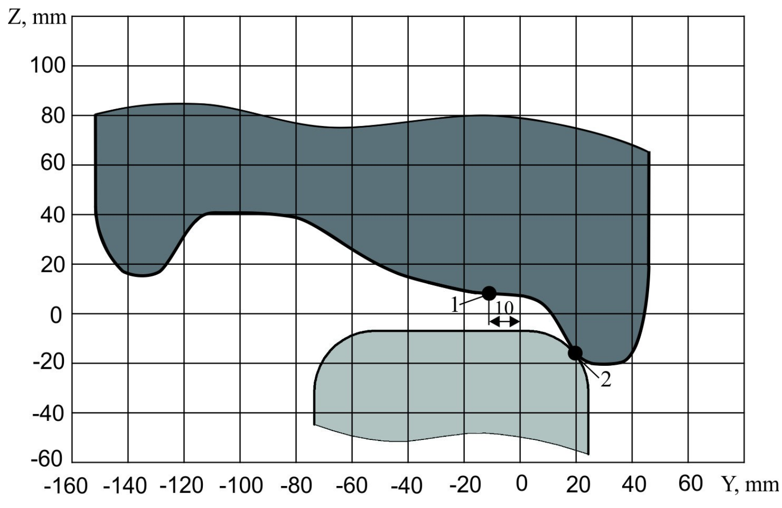

Fig. 6. Position of the wheel equipped with the additional flange relatively to the rail at maximum lateral motion
Рис. 6. Положение колеса, оборудованного дополнительным гребнем, относительно рельса при максимальной боковом отнесении

The effects of force interaction can be powered down due to structural measures that makes possible creating alternative design of wheel pairs. Such alternative to the design of traditional profiles of wheel pair provides possibility to create special-profile rolling surface and obtain the lateral forces of interaction that allows truck to increase stability and prevent derailment.

CONCLUSIONS

1. The authors have developed a wheel pair that profile has the additional running track and counter-flange that provides the additional contact in a horizontal plane while lateral vibrations of wheel pair relatively to the track, provides the stability and increases the resistance against derailment when passing curved part of the rail and in the case of spring deflection of the rail as a result of force interaction. Design of wheel pair that has the additional counter-flange is covered by Ukrainian useful model patent.
2. Providing stable wheel movement on the rail requires taking into account interdependence of geometrical, frictional and dynamical parameters of wheel-rail interaction at the stage of design. It is necessary to take into consideration redistribution of forces due to presence of the wheels with counter-flange in addition to classic distribution of forces in wheel-rail contact zone.
3. Implementation of the proposed wheel pair that has counter-flange to special-purpose rolling stock will provide improving safety of movement and carriage integrity and will provide social and economic effect due to emergency decrease and decrease of disastrous consequences.

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