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The effect of the track plan on the damage to rails by contact fatigue crambling

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Abstarct. An analysis of foreign and domestic experience in improving traffic safety while extending the service life of rails and improving their interaction with the wheels of rolling stock shows that the working conditions of rails are much more difficult in curved sections of the track, especially in the outer thread, due to the intense impact of the ridges of the wheels of rolling stock on the lateral working

One of the reasons for the formation of contact fatigue stains on the lateral working surface of the rail head is the presence of tangential stresses that occur in the absence of perpendicular pressure of the wheel on the rail head. In addition, the movement of the wheels on the rails is accompanied by slippage, which appears due to the taper of the wheels and the occurrence of the wheel crest on the rail head. A typical case of the wheel crest running over the rail head is the movement of the crew along curved sections of the track. In this case, the guide axle runs over one of the wheels on the rail head. As a result, there is a transverse slip of the wheel on the rolling surface and friction forces between the wheel and the rail are appropriately oriented to the axes. These processes, enhanced by an increase in dynamic action, cause more intense damage to the rail heads by defects 11 in the curves, while defects mostly appear on the outer rail thread.

Keywords: defect, rail, rail crambling, rail head.

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Introduction

As the radius of the curves decreases, the number of rails removed from the track due to defects and damage increases. In areas with small radius curves, especially in the presence of steep ascents and descents, the intensity of lateral and vertical wear is so high that there is no removal of rails due to contact fatigue defects [1, 2]. From this it can be concluded that the nature and level of damage to rails in curves are greatly influenced by operating conditions. Numerous observations on the roads confirm that with a decrease in the longitudinal slopes of the track, the number of rails removed from the track with excess wear of the head decreases, and the intensity of removal of severely defective rails with contact fatigue damage increases, i.e. two interdependent processes are observed.

An analysis of domestic rail operation experience indicates that external rails in curves with a radius of R = 351-650 m at longitudinal slopes are particularly intensively damaged by defects 11 –7o/oo<1 < +7o/oo, and in curves with radii R =651-1000 m at longitudinal slopes –10o/oo <1<+10o/oo.

The wheels, when moving the carriage, have the ability to press the ridge against the side face of the rail head ("wag"). The probability of such a pinch increases dramatically when the crew enters the curve. Under certain, quite normal conditions, up to 50-100% of the wheels rolling along this thread can be pressed against the outer thread.

When pressing the wheels, having an average or more rolling value, with a ridge to the rail head, a so-called "single-point" contact occurs. As a result, the zone of vertical force influences on the head shifts from the middle band to the main working face of the rail head. The greater the wheel wear, the greater the offset. Therefore, in the outer thread of the curves, the probability of wheels contacting in the area of lateral rounding of the head is much higher than in straight sections, and even more so than in the inner thread of the curves. Accordingly, the probability of rail failures is distributed according to contact fatigue stains.

Despite the variety of rail operating conditions in the outer thread of the curves, the area of accumulation of the observed centers of origin of internal longitudinally inclined cracks (defect 11) is mainly located within the boundaries of 4-14 mm from the side face of the rail head.

In other words, this zone practically coincides with the zone of the so-called "single-point" contact of worn wheels with the head of an unworn rail. This zone, according to statistical data on failures of elements of the upper structure of the track in modern conditions, makes up 3/4 of all failure zones.

Therefore, when predicting the intensity of the formation of dents and discolorations, an analysis of defects 11 should be carried out taking into account the curvature of the line. The analysis of the track plan consists in the fact that it is necessary to assess the intensity of the total removal of rails according to defect 11 in sections with different radii and compare it with the length of these sections.

The methodology

The correlation between the curvature and the damage to the track can be quantified using the coefficient λ_{R1}^{11}, which is generally calculated using the formula:

$$\lambda_{R1}^{11} = \frac{N_{Ri}^{11}}{L_{Ri}}, \tag{1}$$

where N_{Ri}^{11} – the proportion of 11 rails seized due to a defect in sections of the i-th radius; L_{Ri} – the proportion of curves of the i-th radius in this section.

Thus, using the obtained data and the results of structures and calculations, it is possible to more accurately predict work on replacing rails damaged by defect 11 on specific sections of the path. For example, if there is a track with non-hardened rails of the P65 type on the site with a load of 70 million tons.t km gross / km per hour 40% of curves with a radius of 450-650 m, it is necessary to plan to include in the per-kilometer reserve an additional 1 Rail per 3 km of track.

Studies confirming the presence of mutual correction between the depth of occurrence of internal longitudinal cracks, the intensity of formation of protrusions and the level of impact on the path of axial loads are devoted to the work of many authors [3]. In general, the higher the axial load value, the greater the depth of the VPT. The process of changing the geometric dimensions of the notches formed after the VPT enters the rail surface, depending on the level of impact of the maximum axial loads, requires research and an appropriate assessment of the impact of these changes on the durability of the rails. For this purpose, the actual materials and primary data on measurements of geometric dimensions (length and depth) of defects 11 formed on rails of type P65 of mass production at the time of their removal from the path along this damage when traveling along Ring paths of mobile composition with ROS=230, 250 and 270 kN. operating tonnage to harvest from 50 to 660 million tons. t gross. The sample consisted of 268 rails obtained at Ros=230 kN, 398 rails at Ros=250 kN, and 532 rails at Ros=270kn

Findings/Discussion

The main results of the statistical analysis of the geometry of defects 11 are shown in Table 1. It follows from the analysis of Table 1 that when the rail loading mode is weighted, the geometry of the defect changes, which consists in the fact that with an increase in the axial carriage load acting on the track, the length decreases and at the same time the depth of the gouges increases[4,5]. Such a mechanism for changing the geometric characteristics of the defect 11 indicates an increase in the force loading of the rail and, as a result, a decrease in the level of resistance to damage to the rails at high loads.

Table 1. Dependence of the geometric dimensions of the defect 11 on the axial ones

The indicator of the defect geometry	Unit of measurement	Values of indicators at axial load, кN		
		230	250	270
The maximum possible length	мм	194	163	159
Maximum possible depth	мм	8,3	8,1	7,6

The angle of inclination of the defect to	degree	4,5	2,6	5,9

For example, at Ros = 230 kN, the number of defects with a length of more than 150 mm is 20% of the total, whereas at Ros = 270 kN – 12%. Accordingly, the number of defects with a depth of more than 7 mm at an axial load of 230 kN is 20%, and when exposed to a load of 270 kN, this amount increases to 59%, and 12% of them have a maximum depth of 10 mm. Thus, the kinetics of changing the geometry of rail damage by defect 11 with an increase in axial load is characterized by an increase in the effect of "concentration" or "wedge", as a result of which the stress concentration in the area of rail damage increases, and, as a result, the resistance of rail steel to the development of contact fatigue cracks decreases[6,7].

To quantify the degree of resistance of rail steel to the development of defect 11, a classical physics problem was used to assess the resistance to movement of a rigid wedge in an ideal elastoplastic medium, which is not characterized by dissipative properties. Such a medium, as is known in mechanics, is classified as potential (conservative), for which the following ratio between normal pressure (stress) is valid and some potential function[8,9,10], which can be considered as the potential for the rate of development of the defect 11 and must be determined:

$$\sigma_y = \frac{\partial \varphi}{\partial t} \rho, \tag{2}$$

where ρ – the density of rail steel.

For the potential, we use the following Laplace equation, which is used for conservative media:

$$\frac{\partial^2 \varphi}{\partial x^2} + \frac{\partial^2 \varphi}{\partial y^2} = 0. \tag{3}$$

In the analysis under consideration, equation (4) is solved under the following boundary conditions: on the deformable surface *(-C: C)* of the rail head (wedge) along the axis *OX* at some point in time *t* at *-C X C,* the ratio takes place

$$\frac{\partial \varphi}{\partial n} + \frac{\partial \varphi}{\partial y} = V_0, \tag{4}$$

where n – normal to the surface of the defect 11;

On the remaining, undamaged chipped working surface of the rail head, the speed potential is zero *(φ=0): X<-C u X>C*

If, along with the velocity potential, according to the wedge continuity equation, another harmonic and, therefore, necessarily conjugate function is introduced, then the problem of the "concentration" or "wedge" effect posed in the analysis under consideration can be solved in the complex plane $Z=x+i$ and in this plane the analytical function W, called in the theory of elasticity by a complex potential. At the same time:

$$W=\psi+i\psi \quad \frac{dW}{dz}=V_x\text{-}iV_y. \tag{5}$$

Conclusion

In the course of the study, the task was set to determine how much the GDP growth rate changes with an increase in the axial carriage load. The time of crack growth was considered from the moment of its detection to the formation of a chink and it was assumed that its growth occurs evenly as tonnage is passed.

Ozturk Maira – text writing, data collection, data sorting, trend analysis and technology application of additive technologies in the automotive industry

Rafal Burdzik – checking the analysis and data, summarizing, concluding, checking the integrity of the article.

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Жол жоспарының рельстердің контактілі-шаршау бояуларының зақымдалуына әсері

Аннотация. Анализ зарубежного и отечественного опыта повышения безопасности движения при одновременном продлении срока службы рельсов и улучшении их взаимодействия с колесами подвижного состава показывает, что условия эксплуатации рельсов значительно усложняются на криволинейных участках пути, особенно на внешней резьбе, из-за интенсивного воздействия гребней из колес подвижного состава на боковой рабочей поверхности

Одной из причин образования пятен контактной усталости на боковой рабочей поверхности головки рельса является наличие касательных напряжений, возникающих при отсутствии перпендикулярного давления колеса на головку рельса. Кроме того, движение колес по рельсам сопровождается проскальзыванием, которое появляется из-за конусности колес и появления гребня колеса на головке рельса. Типичным случаем, когда гребень колеса проходит по головке рельса, является движение экипажа по криволинейным участкам пути. В этом случае направляющая ось проходит по одному из колес на головке рельса. В результате происходит поперечное скольжение колеса по поверхности качения, и силы трения между колесом и рельсом соответствующим образом ориентируются по осям. Эти процессы, усиливаемые увеличением динамического воздействия, приводят к более интенсивному повреждению головок рельсов из-за дефектов 11 в изгибах, в то время как дефекты в основном проявляются на внешней поверхности рельсовой нити.

Ключевые слова: дефект, рельс, заедание рельса, головка рельса.

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Жол жоспарының рельстердің контактілі-шаршау бояуларының зақымдалуына әсері

Аңдатпа. Рельстердің қызмет ету мерзімін ұзарту және олардың жылжымалы құрамның доңғалақтарымен өзара әрекеттесуін жақсарту кезінде қозғалыс қауіпсіздігін жақсарту бойынша шетелдік және отандық тәжірибені талдау рельстердің жұмыс жағдайлары жолдың қисық учаскелерінде әлдеқайда қиын екенін көрсетеді., әсіресе сыртқы жіпте, жылжымалы құрам дөңгелектерінің жоталарының бүйірлік жұмыс механизміне қатты әсер етуіне байланысты.

Рельс басының бүйірлік жұмыс бетінде контактілі шаршау дақтарының пайда болу себептерінің бірі рельс басындағы дөңгелектің перпендикуляр қысымы болмаған кезде пайда болатын тангенциалды кернеулердің болуы болып табылады. Сонымен қатар, дөңгелектердің рельстердегі қозғалысы сырғанаумен бірге жүреді, бұл дөңгелектердің тарылуына және рельстің басындағы доңғалақ жотасының пайда болуына байланысты пайда болады. Рельстің басынан өтіп бара жатқан доңғалақ жотасының типтік жағдайы-бұл экипаждың жолдың қисық учаскелері бойымен қозғалуы. Бұл жағдайда бағыттаушы ось рельстің басындағы дөңгелектердің бірінің үстінен өтеді. Нәтижесінде дөңгелектің жылжымалы бетінде көлденең сырғуы байқалады және доңғалақ пен рельс арасындағы үйкеліс күштері осьтерге сәйкес бағытталған. Динамикалық әрекеттің жоғарылауымен күшейтілген бұл процестер қисықтардағы 11 ақаулармен рельстердің бастарына үлкен зақым келтіреді, ал ақаулар негізінен рельстердің сыртқы жіптерінде пайда болады.

Түйін сөздер: ақау, рельс, рельстің бұзылуы, рельстің басы

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