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ON INFLUENCE OF ADDITIONAL MEMBERS' MOVABILITY OF MINING ROLLING STOCK ON SAFETY CHARACTERISTICS OF THE MOTION

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Abstract. The paper is devoted to mining rail vehicle motion stability while motion on the rail track of steady and transient curvature. Several kinematical schemes of mining locomotives are studied. Assumed, that the most dynamically stable is locomotive with pin-joint coupling design. In addition, additional local movability of wheel set is studied subject to safety factor while motion on the mining rail track.

Keywords: mining locomotive, kinematics, safety factor.

О ВЛИЯНИИ ДОПОЛНИТЕЛЬНОЙ ПОДВИЖНОСТИ ЗВЕНЬЕВ ШАХТНОГО ТРАНСПОРТНОГО СРЕДСТВА НА ПОКАЗАТЕЛИ БЕЗОПАСНОСТИ ДВИЖЕНИЯ

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Аннотация. Работа посвящена определению параметров устойчивости при движении рельсовому пути переменной и постоянной кривизны. Изучено несколько кинематических схем и конструкций шахтного локомотива. Высказано мнение, что наиболее динамически устойчивым является конструкция шахтного локомотива шарнирно-сочлененной компоновки. Также, проанализирована роль дополнительной кинематической подвижности ходовой части вагонетки в увеличении устойчивости движения по шахтному рельсовому пути.

Ключевые слова: шахтный локомотив, кинематика, запас устойчивости.

Introduction. The tendency of increasing an adhesion weight of locomotives up to 10…14 (28) ton [1] in order to haul more heavy mining tub induced significant growth of static loads on the rail track. Due to the fact, that existing mining rail tracks have been design for much lower locomotives' weight, increased axial loading on the rail track elements rocketed up to 1.5…2.5 times and for mining tub 7 times more.

The force interaction character and coupling class of mining rollingstock elements suppose the usage of the lowest kinematical pairs. At the same time, the dimensions of machines' elements can vary owing to wear and gap adjusting within kinematical pair, elastic deformations, heat expansion, mistakes while mounting and repair, etc. Thus, it is obligatory to choose such mechanisms' scheme when the requirements for accuracy will be not so high.

The statically determined mechanisms requires the properties where member are self-excited, without odd joints. Such member linkage induces reduction of dynamical loading and growth of motion safety. It happens owing to additional movability of construction elements, while the linkages, with appear a kinematical pair, takes stable space position. They trace the variable trajectory and do not induce additional force disturbance.

As a output element of the mining rolling stocks' majority used to account a wheel, which develops a frictional pair with rail while motion. The wheel set parameter must meet the requirements of optimality both in wheel function as a support rod to take the weight of the locomotive and transmit it on the rail, and the tractive element for generating the traction force to overwhelm the motion reaction. These requirements are contradictory, that measures the design parameters both the chassis and mining vehicle in general [2].

At the other side, the wheel as an support rod, might trace the trajectory while motion on the rail track, which can not be linear in vertical surface, that induces dynamical load component in all vehicle components. An additional loading factor is that the wheel must trace horizontal trajectory either that causes constant lateral interaction (Garg & Dukkipaty, 1984). While the motion on the curvilinear rail track, the wheel roll on the rail can cause a significant lateral forces, which may result in stability loss of the mining vehicle. At the other side, the tractive effort realizes at the point of wheel-rail contact through friction, and it is limited by frictional properties of bonded surfaces and pressing force [3]. All these factors evoke unstable motion regime of mining vehicle.

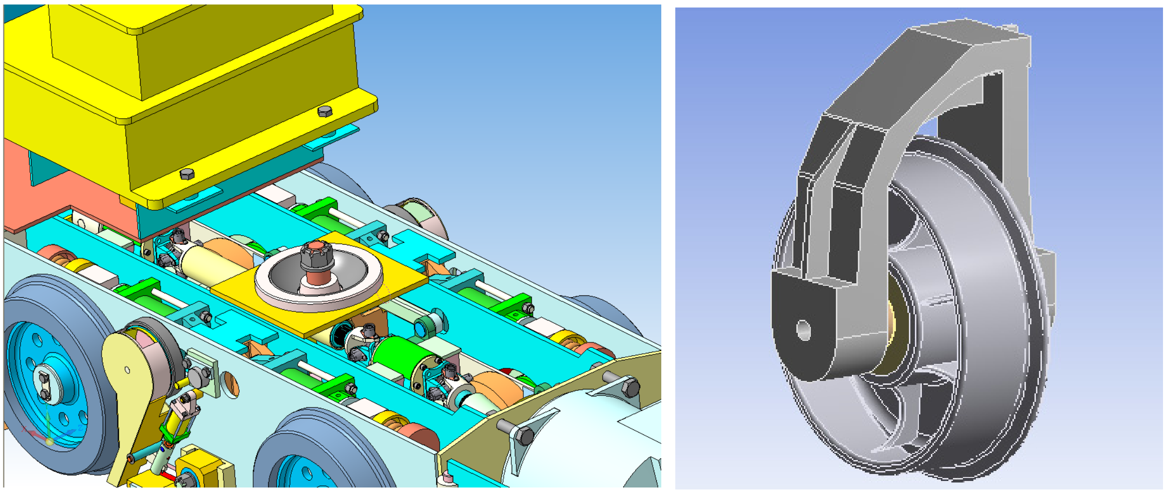
The modern design methods [4], which base on the scientific approach of mining machines simulation and research, facilitate to define the location and character of arising dynamical loading and prevent their growth while forming at the mining vehicle chassis. This prevents the following dynamical loads transmission on the bolster structure. Thus, the structure selection and selection of mining machines parameters, which bases on the detail analysis of running processes, might be an essential part of energy-mechanical system and its scheme development on the design stage [4].

The **study purpose** is determination of qualitative and quantitative influence of mining vehicle coupling on the stability while motion on the ail track with constant and variable radius.

The main material. It is well known, that odd coupling are such connection type, which removal do not increase the total mechanism movability [4]. The limited line displacement causes the necessity of force transmission within the kinematical pair between member, and limited angular displacement – the torque between members of the pair. The kinematical pair must be designed for these forces and torques. To check the odd linkages within the mechanism we can use constructional formula. We might take into account the quantity of known odd couplings. The quantity p_i of kinematical pairs of i-th class, that applies ip_i constraining conditions, and all kinematical pairs $\sum_{i=1}^{i=5} ip_i$ constrained conditions.

There can be general or local (passive) mechanism movability. The local movability is such one that does not influence on the total mechanism movability. The local movability has rollers (because of the possible slipping), pulley, band wheel, bushing and pin, cylindrical sliding bar with ball end. The kinematical pair coupling defines without clearances, if kinematical pair produced like ball bearing, where the clearance is very small or even can be tightness. While clearance existence an additional kinematical movability arises, which can be used in machine operation. These clearances can occur because of frictional wear of the coupled kinematical members, and grow uncontrollable. Such growth evokes additional dynamical components of operational loadings and reduces machine's exploitation indexes. However, it is possible to revise the machine design and additional kinematical movability either to reduce the duration of nonstationary motion regime. This is essential for mining conditions, which is marked by lots of unfavorable factors of numerous nature [3]. To provide the smooth wear of coupled kinematical members a coupling with local movability can be applied [5].

The authors of the paper proposed and implemented on the industrial enterprises new technical solutions of mining vehicle components and machines. For example, locomotive of the module scheme, that includes a few sections. It allows for development of the vehicle with different trailing weight, energy supply system and necessary exploitation indexes. The distinguish feature of such locomotives is kinematical coupling between bogie and tractive section (Figure1).



a) b)

Figure 1. (a) locomotive joint; (b) mining wagon's wheel set.

Such connection provides necessary relative movability and transmits vertical loading from frame to bogie, horizontal lateral forces – centrifugal force, reaction of overrunning rail, which has geometrical imperfections in all surfaces. Movability around the vertical axis is necessary for tractive bogie turn and in order to avoid odd couplings, because the pin does not carry the chassis weight; around lateral axis – for correct weight distribution between locomotive axles and reduction influence on the rail track; longitudinal movability is absent because the tractive effort transmits in this direction.

Additional kinematical wheel movability is realized in cylindrical joint of mining wagon's axle box. It allows for reduction of the angle of attack of the wheel on the rail without additional force disturbance [7].

To determine the relations between kinematical and dynamical characteristics of mining vehicle we need to provide an analysis of force interaction relations in dependence on rail track parameters and subject to mining vehicle output members. The obtained data allows for assessment of the safety index, which is used to describe by safety coefficient:

$$K_y = \frac{\operatorname{tg}\chi - \mu}{1 + \mu \cdot \operatorname{tg}\chi}\left(\frac{P_v}{P_l}\right) > 1 \quad (1)$$

where χ – angle of wheel flange; μ – friction coefficient; P_v – normal rail reaction under ongoing wheel, N; P_l – guiding force on the ongoing wheel, N.

Local and regular rail imperfections lead to additional growth of guiding force P_b, that can cause the derailment at some certain critical value. Reduction of guiding force can improve stability and predict derailment.

The most complex motion regime is driving through curvilinear rail track with wheel flange climbing by both rear and front axles. This induces the rotation of tractive bogie in relation to mass center (Figure 2). Simultaneously, the middle section rotates around pin joint. At axial displacement of the wheels, a reaction force arises at the point of flange contact, which acts flatwise to motion direction. A sudden growth of these forces appears while wheel misalignment. To reduce reactive forces an additional local movability of kinematical pair coupling is necessary.

Thus, we have obtained several relations of dynamic forces and safety factor (SF) indexes (Figure 2).

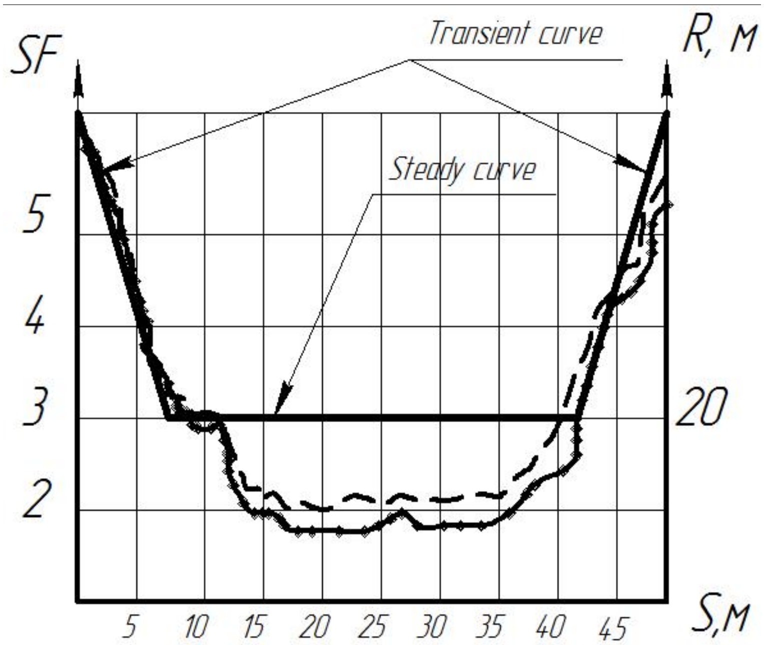


Figure. 2. – Safety factor relation to track curvature subject to structural scheme.
V=4 m/s - - - - sectional locomotive; ——— conventional locomotive.

Analysis of the dependences (Figure 2) shows that the rigid connection of the traction bogie section with a body provokes unsteady hunting and lateral displacement, which amplitude continuity growths until the wheel flanges touch the rail. If locomotive's connection is rough, then energy of the impact will be more significant, due to traction bogie mass influence and mass of the middle section partially. In order to avoid this, it is more appropriate to apply kinematical coupling with local movability, which allows for reduction of the middle section inertia influence on the rail track through bogie.

Conclusions. To enhance the stability and safety, reduce load on the vehicle's chassis and on the track, reduction motion resistance is possible while the usage of a new kinematical design where the kinematical pairs will have an additional local movability. Thus, it will reduce the number of redundant links with shortage the unnecessary weight. To determine the appropriate value of mobility, providing the necessary performance, we can use modern means of computer simulation interoperability of mine transport and track.

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