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SOME ASPECTS REGARDING THE TRIBOLOGY OF THE WHEEL-RAIL CONTACT

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Abstract: *Tribology is the science and technology of interacting surfaces in relative motion. It includes the study and application of the principles of friction, lubrication and wear. For the particular railway engineering issues, the tribology of the wheel-rail contact deals with the interaction between the wheel and rail surfaces with or without macroscopic relative displacement, plastic deformations, material flows, micro-cracks and exfoliations that might modify the shape of the rolling surfaces and damage the geometric guiding capability of the rim. The fundamental issue that ensures the development of the rolling stock is the wheel-rail contact.*

Key words: *tribology, longitudinal slip, track torsion, dynamic overloads.*

The railway vehicles are mainly characterized by the fact that they roll smoothly on the rails and are self-guided by the contact forces occurring between the rail and the wheel rims.

The metal wheels and the rails, as well, offer the capability of supporting loads that are superior to any other terrestrial transportation system. Together with the self-guiding, this feature enables today's trains to carry very heavy payloads to various destinations. The small mechanical drag determines outstanding energy efficiency, compared to other transportation systems. Moreover, the self-guiding enables high operating speeds and safety, no matter the weather conditions.

Because of these technical characteristics and important economic benefits of the wheel-rail system, the railway developed continuously becoming the main terrestrial transportation mean in the world (our country included). The railway networks with their dedicated infrastructure are one of the most important national assets.

During operation, the railway vehicle is subjected to various external perturbations that generate unwanted vibrations, which might cause serious damage in guiding safety.

When running in straight line, the wheel (using a corrected circular arc tread) doesn't need much guidance due to the specific tread profile. In this particular case, the rims act strictly as an additional safety precaution. Thus, with the wheel and rail profiles known, the coordinates of the contact points should result on both wheels, depending on the transversal gap (of course, limited by the gauge). When running in a curve, the problem might be reduced to a 2D system, by defining the so-called "apparent wheel tread". Once the speed increases, inertia forces occur. As they become superior to the one generated by the wheel-rail friction, will generate the transversal slide of the wheel set and the transfer of the entire guiding force to the wheel rim.

The important dynamic forces that occur at the wheel-rail contact point may damage the wheel tread and/or the rail flange, including the rim's geometric guiding capability.

The form and the dimensions of the contact patch affect the reliability of the wheel-rail system – the adhesion either in traction, or braking mode.

Taking a close look at the wear of the classic conic wheel treads, one may observe that due to the local displacement of the contact point, the wear modifies the profile in the same area following a concave pattern with different gradients. On their turn, those will generate, consequently, the random displacement of the actual contact points on the rail flange and - therefore - an extended contact patch.

As time goes by, the conic wheel tread reaches a state of ”self-sufficient” wear, which stops progressing. In addition, the dual contact disappears and the wear of the wheel rim stops.

This suggested that - not only for safety reasons - the use of the so-called ”corrected circular arc tread” (which follows the exact pattern of the wear) is much reliable and ensures even from the beginning the desired contact patch. One of the most important advantages of the corrected circular arc tread is that even when the axle is in brakeage status, the wheel keeps rolling like a linear bearing. In these particular conditions the lubrication of the rim and the rail flange is not required any more, as it may become totally inefficient (might reduce or even cancel the adhesion force).

Other complex studies performed on small diameter wheels revealed that the wear (for both systems - wheels and track) is self-adapting and leads to a constant worn tread profile. The external active part of the rim doesn't actually follow a defined pattern. Thus, if neglected, may seriously affect the safety especially at switches and crossings.

The short wavelength defects generate important dynamic rail overloads, particularly at high speeds. The shortest wavelengths reside from the elastic deformations occurring in the contact patch. In order to reduce the overloads, it is mandatory that for unsuspended masses to be as light as possible.

On the other hand, the axle's vertical vibrations might unload the external wheel and, also, increase the Y/Q ratio (Y - the guiding force, Q - the vertical load) and eventually lead to derailment.

The suspension has to ensure the dynamic stability for both situations, running in straight line and in curves, plus maintain the wheel-rail interaction forces in the acceptable range. It is important that all the elements of the suspension system (springs, dampers and guide arms) are adapted to the specific operating conditions (rail, speed) and capable of offering the so-called ”controlled independence” between the vehicle's apportioned masses.

Rail torsion leads to an uneven load of the wheels. If the most unloaded wheel is an external one (compared to the curvature centre), it might derail when the axle loses its guiding capability. The vehicle's torsion capability must compensate the unloading of the external wheel due to the rail torsion. This correlation is mandatory not only for safety reasons but also in order to prevent the dynamic overloads to damage the vehicle or the rail.

When running in curves at higher speeds, the unloading of the external wheels are limited by the uncompensated centrifugal forces and, therefore, the rail torsion is less important. In exchange, the importance of the variation speed of the torsion gradient becomes a priority because the dynamic overloads that occur might produce premature damages to both, rail and vehicle, through fatigue stresses.

Back to the wheel-rail contact, one has to mention that the so-called ”pure rolling” cannot be achieved in reality. Due to the longitudinal slides, the wheel tread usually wears following a steep conic pattern, which is not suitable for running in straight line. The longitudinal slides also generate heat, noise and additional energy consumption. The pure conic rolling eliminates the longitudinal slides. The transversal slides depend on the external wheel's angle. A steering axle will efficiently solve this issue.

The additional slides generate a rough abrasive wear, including major material pieces that fall apart from the wheel rim and rail flange.

When the driving axle has wheels with corrected circular arc treads, the friction forces will cause the decrease of the wheel angle, thus steering the axle into a radial position and cancelling the tangential and transversal friction forces.

The tangential contact forces are determined by the size of the contact patch, considered as elliptical. Some dedicated theories aim to solve the wheel-rail interaction issues and improve the dynamic performances of the vehicles.

The clear up of the issue regarding the friction coefficients is very important in order to ensure the adhesion and enhance the traction/braking capabilities close to that limit. In case of the subway power-cars, the maximal traction force equals the adhesion, which decreases as the speed goes up. On the other hand, the drag amplifies along with the speed, especially its aerodynamic component.

The wheel slip is accompanied by the so-called ”stick-slip” movement, which may cause severe damage to the axle gear.

The hunting movement is specific for railway vehicles and their maximal speed is limited due to hunting instability, which generates transversal stresses that might endanger the safety.

The axles hunting movements are transmitted to the bogie frame and to the car body through the traction transfer device. The anti-yawing dampers (situated on both sides of the car body and bogie frame) are playing a key role, especially when the hunting frequencies of the bogie and the car body are significantly close. The achievement of a friction momentum between the bogie and the car body reduces the hunting but, in return, increases the transversal stresses transmitted to the rails when running in curves. It is essential for the suspension to ensure the maximum reduction possible for both, the hunting movement and the combined shaking-rolling movements of the car body. In order to achieve this, it is essential to ensure a" controlled independence" between the bogie and the car body.

By adopting sufficiently lower frequencies for the car body – secondary suspension system, compared to the frequency of the hunting movement at the bogie level, a reduction in hunting effects occurs and, in addition, the risk of resonance at high speeds is avoided.

Another important role in extending the stability domain associated with the hunting movement is given by the longitudinal and transversal flexibilities of the primary suspension.

At higher speeds, the elastic guiding systems are much reliable because they enable the axle to gain a radial orientation, which is preferable when running in curves. The new generation of steering-axle bogies fulfil the essential requirements for hunting when running in straight line and the extension of vehicle capabilities for negotiating the curvature radiuses as well.

CONCLUSIONS

The result of the wheel-rail interaction is crucial in providing the passenger comfort and freight integrity plus safety.

The lubrication of the rail flange may have a significant influence in reducing the wear, especially for small curvature radiuses (below 300 m).

The form and the dimensions of the contact patch affect the reliability of the wheel-rail system – the adhesion either in traction, or braking mode.

The vehicle's torsion capability must compensate the unloading of the external wheel due to the rail torsion. This correlation is mandatory not only for safety reasons but also in order to prevent the dynamic overloads to damage the vehicle or the rail.

The maximum dynamic forces due to wheel-rail interaction may be determined either by calculating the track deformation, or the vehicle's derailment limit.

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НЯКОЛКО АСПЕКТА НА ТРИБОЛОГИЯТА НА КОНТАКТА МЕЖДУ КОЛЕЛОТО И РЕЛСАТА

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РУМЪНИЯ

Ключови думи: *трибология, надлъжно плъзгане, усукване на релсовия път, динамично претоварване*

Анотация: *Трибологията е науката и технологията за взаимодействащите повърхности в относително движение. Тя включва изучаването и приложението на принципите на триене, смазване и износване. В железопътното инженерство трибологията на контакта между колелото и релсата изучава взаимодействието между повърхностите на колелото и релсата при наличието или не на макроскопско относително изместване, пластични деформации, изтичане на вещество, микропукнатини и обелвания. Контактът между колелото и релсата е от фундаментално значение за развитието на подвижния състав.*