

OPTIMISATION OF TRACK STIFFNESS



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Abstract:

The railway track does hard work in difficult conditions. Being under the influence of mobile loads and natural phenomena, ensuring the continuity and safety of train traffic, it should serve at any time of the year, day or night. The railway track is considered as a structural system that is designed to withstand the combined effects of traffic and the environment, so that maintenance and safety costs for passengers are in the first place, and the subgrade is stable, reliable, and durable. If appropriate and timely maintenance is not carried out, speed limits may be imposed on areas of variable stiffness, which will lead to corresponding financial costs and delays for passengers and also because of the high stiffness, defects arise that shorten the life cycle of wheelsets. It is necessary to study the influence of track stiffness for the design and technical content of the railway.

Key words:

Track stiffness, optimization, strain energy, rail strain energy, rail pad.

Introduction.

To develop reliable track maintenance and design solutions, appropriate measures must be taken to improve track performance. Typically, two types of measurements are taken to determine track quality: functional and structural. Functional dimensions relate to how the track works from the perspective of the researcher. Relevant measures include track geometry and ride comfort. Measurements of the structural condition are related to the structural integrity of the track system and include deflection and stiffness, as well as related to the stability of the railway track [1].

The effect of track stiffness on performance can be divided into two groups, which are either degradation due to high track stiffness or degradation due to low railway track stiffness. To effectively monitor and control track stiffness, the optimum track stiffness value must meet design and maintenance standards. Several attempts have been made in the past to develop an optimum value for the stiffness of the track; however, recent studies [2] concluded that the optimization of the stiffness value of the track depends on the technical characteristics and no specific decision was made. Therefore, the goal of this work is to develop an optimal value of track stiffness, using numerical modeling, for Russian railways to facilitate efficient design and maintenance.

The stiffness of a vertical track is a function of the modulus of elasticity of the various layers and components in the rail track system. There are a number of methods that can be used to mathematically represent the stiffness of a railroad track, depending on various factors such as isolation of the stiffness of certain components, frequency excitations, and nonlinearity of the track stiffness. The overall stiffness of the track is the ratio of the dynamic load applied to the elements of the superstructure of the track; however, it is difficult to determine the applied dynamic loads. Therefore, to overcome this problem, the stiffness of the rail track can also be expressed in a simplified approach in terms of: superstructure module, under-rail module and rail bend as shown

in equations 1 and 2 [4].

$$k_g = 2x(u_s)^{0.75} \cdot x(4EI)^{0.25} \quad (1)$$

k_g – overall track stiffness;
 u_s – modulus of elasticity of the rail;
 $E-I$ tracking system module;

$$\frac{1}{u_s} = \frac{1}{u_{pad}} + \frac{1}{u_{bed}} \quad (2)$$

u_{pad} – modulus of elasticity of the rail pad;
 u_{bed} – modulus of elasticity of the path;

Influence of low rigidity of the track on the railway track. Low stiffness of the track leads to high deflection of the track, which, in turn, generates high bending stresses (see Fig. 1) in the rail base, intense wear (see Fig. 2) and high stresses on intermediate bonding [4]. [five]. One of the first studies of the influence of track stiffness on track geometry was carried out by British Rail (BR) in 1990 [6]. The BR study analyzed a section where approximately 10% of the route had low track rigidity and the rest had high track rigidity. The study showed that sections with low track stiffness had 50% more wear compared to sections with more rigid tracks. In another study [7], to determine the effect of low stiffness on the structural and functional state of the path of the system, several performance measures were used to compare performance with low stiffness of the path versus relatively higher stiffness. The analysis was normalized for traffic and the results are shown in Table 1..

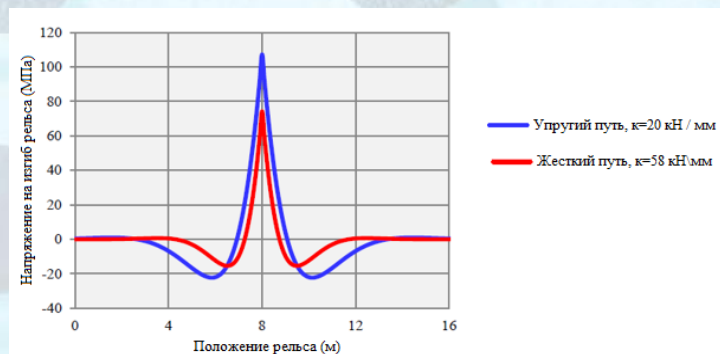


Figure 1. Bending stress of a rail for an elastic and rigid track under a wheel load moving at a speed of 100 km / h

**Table 1
Impact of low track stiffness (from Ebersohn et al, 1993)**

Path type	Study path	Elastic path
Overall rigidity of the track	52	32
Functional performance indicators		
Estimated (mm)	28	45,6
Ride quality (mm)	2,34	3,78
Structural performance indicators		
Ballast Pollution Index	1,1	4,7
Maintenance entry (number of rammed sleepers)	160	452



Figure 2. Intense deterioration of track geometry as a result of low track stiffness

Previous studies [5] and [8] have shown that with high track stiffness, less displacement and bending stresses will occur, but the load is distributed over fewer sleepers (see Fig. 3), which increases the dynamic forces applied to the track, which leads to ballast draft and contact fatigue.

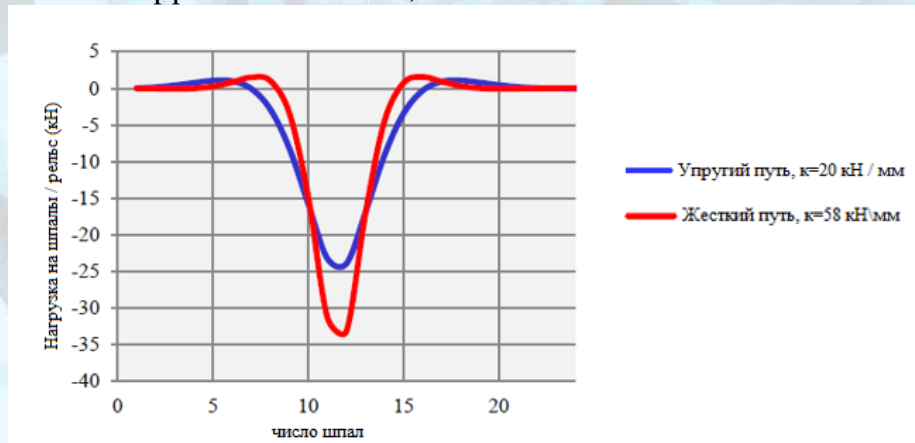


Figure 3. Load on sleepers / rail for an elastic and rigid track at a typical wheel load (165 kN) moving at a speed of 100 km / h

Various studies have been carried out to determine the optimum rail track stiffness value, the track was not too stiff to cause contact fatigue and ballast abrasion, or too elastic to cause bending fatigue and ballast settlement. The study [8] examined the relationship between track stiffness and total cost (construction and maintenance of the track) and estimated that the optimal track stiffness at which the total minimum is 70 kN / mm to 80 kN / mm.

However, more recent studies have shown that the optimal track stiffness can vary depending on the characteristics of the line [3]. It is also important to note that most of the previous studies did not take into account the effect of rail stiffness on train movement, i.e. wheel damage. Therefore, in order to develop an individual optimal value of track stiffness for Russian railways, the optimization process should take into account the effect on wheel damage. One possible approach to achieving this goal is to study the total cost of track construction and maintenance of tracks and trains, taking into account different track stiffnesses. Unfortunately, this approach is impractical because it is very difficult to estimate the cost of maintaining railways and trains. An alternative approach to finding the optimal stiffness of the path can be the concept of the total energy of elastic deformation. Elastic energy is defined as the energy released when materials are deformed [9] and is a function of stress, strain and volume of the material, as shown in Equation 3. Studies show that the strain energy generated in a material is largely related to material damage and fatigue, therefore, studying the effect of track stiffness on the total deformation energy in the entire railway track system can serve

as a good optimization function. Minimizing the deformation energy for the entire railroad track system will: minimize the total damage caused by stress, hence maximize the service life of trains and tracks, depending on the stiffness of the track (see equation 4). To assess the optimal stiffness of a rail track, finite element modeling (FEM) is used to calculate the total deformation energy of a rail system at various stiffness of the rail track and conditions of loading. The stiffness of the track is changed by changing the Young's modulus of the ballast.

$$\partial = \frac{1}{2} V \varepsilon \sigma^2 \quad (3)$$

∂ - is the energy of elastic deformation of the material.

V -is the volume of the material.

σ - material stress.

ε - material deformation

$$\min(\partial_T) = \min[\partial_r(k_{Gi}) + \partial_s(k_{Gi}) + \partial_b(k_{Gi}) + \partial_{sg}(k_{Gi}) + \partial_w(k_{Gi}) + \partial_p(k_{Gi})] \quad (4)$$

∂_T - is the total elastic deformation energy of the system.

$\partial_r(k_{Gi})$ - deformation energy of the rail at the i-th rigidity of the track.

$\partial_s(k_{Gi})$ - is the deformation energy of the sleeper at the i-th rigidity of the track.

$\partial_b(k_{Gi})$ - is the deformation energy of the ballast at the i-th rigidity of the track.

Conclusion

The aim of the study was the following conclusions:

1. Earlier, the value of the stiffness of the railway track was recognized and it was determined that there is an optimal value of the stiffness of the rail track, which depends on the technical characteristics of the railway track.
2. The concept of total deformation energy can be used to determine the optimal value of the stiffness of the path.
3. From the point of view of economics, engineers should take into account optimization in the design to obtain an acceptable optimum value of the track stiffness.

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