Improving track vehicle trafficability

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Abstract. The article is focused on estimating internal resistance forces impact on track vehicles trafficability over-the-snow. It has been proved that adjustable track tension can significantly decrease resistance force to motion and considerably increase track vehicles trafficability over-the-virgin-snow. Mathematical model of the vehicle movement with adjustable track tension, dependence of external and internal resistance forces on track tension have been obtained.

When moving upon the snow road bed (Figure 1) a track vehicle as a dynamic system is affected by the snow cover, being the disturbance factor.

To build a mathematical model of the track assembly, plane motion of track vehicle is considered (Figure 1).

Having studied connections overlaid on the system, an equation system (1) is obtained after several transformations, describing the vehicle track assembly motion.

Figure 1. Model of track vehicle motion along the bearing surface
Equations (1) describe the vehicle center-of-mass motion, idler center-of-mass motion, characterize inertia moment balance applied to the driving sprocket, the moment driven from the transmission, reaction forces moment of caterpillar tracks about the sprocket spindle, balance of moments on the idler; describe lower track wheels rotation mode, lower track wheels center-of-mass motion about balance beams spindles.

\[ M \ddot{X}_c + X_c^2 = \sum_{j=1}^{2N} \mu_{x_j} \]
\[ M(\ddot{X}_c + \dot{g}) = \sum_{j=1}^{2N} \mu_{x_j} \]
\[ J_0 \ddot{\phi} + \sum_{j=1}^{2N} [m_{1j} K_j^2 \ddot{\phi} + m_{2j} K_j \dot{b}_j (\ddot{\xi}_j \sin(\varphi + \xi_j + A_{k_j}) + \ddot{\xi}_j \cos(\varphi + \xi_j + A_{k_j})) + m_{3j} \dot{g} (\ddot{X}_c \cos(\varphi + \xi_j + A_{k_j}) - C_{\xi_j} (\xi_{oj} - \varphi - \xi_j) + 2m_s (H_0 + Q_0 \ddot{\phi} - 2 \ddot{\phi}) \sin(\theta + A_s) + (\theta - 2 \dot{\phi}) \cos(\theta + A_s) Q_0 H_0)] - m_{3j} \dot{g} [X_0 \cos(\varphi + \xi_j + A_{k_j}) - Z_0 \sin(\theta + A_s) + Q_0 \sin(\theta + \varphi)] + \sum_{j=1}^{2N} \mu_{x_j} (P_2 (\phi + \xi_j) - 2 (D_{\phi, b} + D_{\phi, n}) + \sum_{j=1}^{2N} \mu_{x_j} (Z_0 \cos(\varphi - X_0 \sin(\xi_j)) + \mu_{x_j} (X_0 \sin(\xi_j)) + Z_0 K_j \sin(\varphi + \xi_j) \sigma_j (\theta - \dot{\phi}) + \phi^2 \cos(\theta + A_s) Q_0 H_0 + 1 + m_s g Q \sin(\theta - \varphi) + F_1 + 2 F_2 (\theta - \theta_c - \sum_{k=N+1}^{n+2} [\lambda_{x,k} Q_0 \cos(\theta - \varphi) + \lambda_{z,k} Q_0 \sin(\theta - \varphi)])] = (-1) \mu_{x_j} \dot{P}_2 \dot{\theta} \sin[\dot{\theta}] + \delta \dot{F}_2 \dot{F} \sin[\dot{\theta}] \]

\[ I_{1j} \ddot{\phi}_1 = M_{B,x} + M_b \]
\[ I_{2j} \ddot{\phi}_2 = M_n \]
\[ J_{kN} \ddot{\phi}_N + R_N (\lambda_{x,m+\alpha_3} \cos(y_{m+1} + \lambda_{z,m+1} \sin(y_{m+1})) = (-1) (a_1 R_1 + c_1 f_{kN}) \]

The obtained equation system (1) is closed, all necessary values determined.

This mathematical model was implemented using ECM. The vehicle design parameters and the bearing surface properties are given as initial data. The following processes can be printed out: travel and speed, body and lower track wheels, idlers and driving sprockets acceleration; lower track wheels load, tensile strains in the track chain.

When estimating track vehicles trafficability over-the-snow it is necessary to know the resistance to motion force and the track vehicle drag force.

Track vehicle resistance to motion force can be presented as:
where $P'_f$ - force of resistance due to the engine internal losses, $P_f$ - external resistance force.

Force of resistance due to the engine internal losses has a considerable impact on track vehicles trafficability.

Up to now, among specialists there is no consensus in general concerning preliminary static track tension impact on the vehicles trafficability over the snow.

With static track tension increase, loads on lower track wheels are redistributed, loads on end lower track wheels decrease. At this caterpillar drive maximum peak pressure on the snow increases (Figure 2), resulting in resistance to motion increase and deterioration of the vehicle trafficability.

Alternatively, with the static track tension increase, track bending stiffness increases, which decreases its bulging and lowers the resistance force due to additional snow deformation, snow being pressed into the lower track wheels interspace (Figure 3), which is likely to result in improving the vehicle trafficability.

It is these contrary tendencies that determine resistance to motion. Theoretical computation research of various vehicles has shown that with static tension increase the track vehicles resistance to
motion over the snow can be raised or lowered. Thus the answer to the problem of preliminary static track tension impact on the vehicles-over-the-snow trafficability depends on the analysis of individual subject of research. Figures 4, 5 show results of such an analysis for Transport and Technological Vehicles (TTV) 34016 «Ветлуга-Арктика» (Vetluga-Arctica). External resistance to motion force variation range (Pf) for different types of snow is marked by dashed lines in the diagram (Figure 4). Internal resistance force variation (Pf') by static tension force (Tc) is marked by a solid line. At Tc low values, external resistance to motion force constitutes the biggest proportion (80-85%) of total resistance to motion. Static tension increase results in internal resistance increase in track assembly. With Tc increase, resistance force contribution in total resistance to motion also increases; it is comparable to external resistance and, at larger Tc values, even exceeds it (Figure 4). As soon as Pf' changes more rapidly than Pf, total resistance to motion (Pc) increases with Tc increase (Figure 5).

![Figure 4](image1.png)

**Figure 4.** Dependence of external and internal resistance forces on track tension

![Figure 5](image2.png)

**Figure 5.** Dependence of resistance force on track tension

Consequently to sustain the vehicle motion it is necessary to increase the driving sprocket force which at certain Tc values becomes larger than the drag force, realized at caterpillar drive-to-snow
contact (Figure 5); snow breakdown takes place, skidding is rapidly developed which results in drag force decrease and the vehicle trafficability worsens. Thus, the answer to the problem for the track vehicles is the following: with static tension increase the vehicle trafficability over the snow deteriorates.

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