Discussion on the Prediction Method of the Running Resistance of Tracked Vehicle

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Abstract: This paper first analyzes the caterpillar vehicles on various resistance, influenced the vehicle is the main factors of resistance. And through the tracked vehicles driving resistance established the theoretical analysis of soil work includes compaction, earth-moving work caterpillar vehicles driving resistance, the mathematical model. In K.K Rowland and ogure baker, based on the study of such people, further calculus out more accurate and practical caterpillar vehicle resistance prediction method calculation formula. For each parameter is determined and puts forward some methods to determine them.

1. Analysis of All Kinds of Resistance of Tracked Vehicles

1.1. Ground to the Running Resistance of the Track.

The ground resistance to track refers to the ground resistance caused by ground deformation, which is related to the ground pressure of track, the position of vehicle center of mass and the ground situation. As the engineering vehicles generally have to operate on the relatively harsh ground, the selection of operating ratio resistance coefficient should fully consider all kinds of working environment, and select the appropriate resistance coefficient. For some common road conditions, the resistance coefficient of muddy ground, fine sand and cultivated land is the largest.

According to the experience, in the case of flat driving, this resistance accounts for 93% of the total resistance. Therefore, this resistance will be emphatically analyzed in the following paper.

1.2. Internal Resistance.

Internal resistance mainly refers to the walking resistance caused by the friction force inside the walking mechanism. Generally, caterpillar type walking mechanism is composed of drive mechanism, track, supporting wheel, guide wheel, supporting sprocket or supporting chain plate. When walking, the friction between these mechanisms must produce certain internal resistance, which generally consists of five parts :(1) the friction resistance between the track pin and the track pin when the track plate bypasses the guide wheel and the drive wheel. This resistance is related to the diameter of the track pin and the friction coefficient between the track pin and the pin suite. (2) friction resistance at support wheel. This resistance is related to the external diameter of the supporting wheel, the diameter of supporting wheel, the gravity of transferring the supporting wheel to the crawler plate and the friction coefficient between supporting wheel and axle. (3) friction resistance at the guide wheel. This resistance is related to the friction coefficient between the guide shaft and the bearing, the diameter of the guide wheel and the diameter of the guide wheel raceway. (4) friction resistance at the driving wheel. This resistance is related to the friction coefficient of the driving wheel bearing, the diameter of the driving wheel shaft, the diameter of the driving wheel joint circle and the taut edge tension of the track. (5) friction resistance at the sprocket or chain plate. This resistance is mainly related to the weight, contact area and friction coefficient of the crawler plate supported by the sprocket or the supporting chain plate. Internal resistance generally accounts for about 16% of the resistance to walk, so sufficient consideration should be given to the design.

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1.3. Slope Resistance.

Slope resistance refers to the walking resistance caused by the component of gravity when a vehicle climbs a slope. The general construction site is uneven, which requires the crawler engineering vehicles must have a certain climbing ability. The slope resistance formula is F=mgsina. It can be seen that the slope resistance is mainly determined by the vehicle's gradient and self-weight, and is proportional to both. This resistance generally accounts for about 60% of the whole driving resistance and is the most important factor affecting the driving performance of tracked engineering vehicles.

1.4. Turning Resistance.

There are two main types of turning resistance: (1) in-place turning resistance. In-place turning resistance refers to the resistance generated when the two sides of the track are reversed at the same time, which is mainly related to the proportion coefficient of vertical load and friction resistance, the length of track ground and gauge. (2) single track steering resistance. One side track steering resistance refers to one side of the track brake and the other side of the unilateral steering resistance. This resistance is mainly related to flow resistance coefficient, steering resistance coefficient, track ground length and gauge. In addition, the size of these two kinds of resistance is also related to the whole vehicle's center of mass. If the mechanical center of mass falls in the center of the crawler frame (i.e. the ground pressure of the crawler is uniformly distributed), the turning resistance is smaller than that of the non-uniform distribution of the ground pressure of the crawler, so the whole vehicle's center of mass should fall in the center of the crawler frame as far as possible.

1.5. Wind Resistance.

The magnitude of wind resistance is mainly related to the windward area of the vehicle, the filling rate of the structure and the wind speed. For medium and large crawler engineering vehicles, the drag force is relatively high, while the wind resistance is generally very small, accounting for only about 0.1% of the drag force, so the wind resistance can only be used as a reference factor.

1.6. Inertia Resistance.

Inertial resistance is the walking resistance caused by the acceleration when the vehicle starts, and its size is mainly related to the gravity and starting acceleration, and is directly proportional to it. For some engineering vehicles with slow driving speed and no requirement of fast starting, this factor can only be used as a reference factor.

2. Analysis of the Driving Resistance of the Ground to the Track

The driving resistance of crawler vehicle is mainly caused by energy consumption caused by the rut formed by compaction soil. Therefore, the calculation method of function conversion can be used. When the advance distance of crawler vehicle is L (L is the track ground length), the work P consumed by vehicle compaction soil is:

$$P = \int_0^{z_0} 2bLpdz \tag{1}$$

b--track width;

p--the load applied on the soil unit supported area;

Z_0 -- rut depth;

When the driving distance of the vehicle is L, the work to overcome the driving resistance F_c should be equal to the work done $F_c \cdot L$ by the vehicle in compacting the soil. so

$$F_C \cdot L = P = 2Lb\int_0^{Z_0} pdz \tag{2}$$

$$F_C = 2b\int_0^{Z_0} p dz \tag{3}$$

According to the pressure settlement formula of Soviet scholar luria

$$p = Kz^n \tag{4}$$

K--soil deformation modulus;

N--soil deformation index;

Suppose interest rate with grounding pressure is not uniformly distributed, Let the transverse eccentricity be c and the longitudinal eccentricity be e:

$$F_C = \frac{b}{(n+1)K^{\frac{1}{n}}}\left[p_{cp}(1+\frac{6e}{L})\right]^{\frac{n+1}{n}}\left[\left(1+\frac{2c}{B}\right)^{\frac{n+1}{n}}+\left(1-\frac{2c}{B}\right)^{\frac{n+1}{n}}\right] \tag{5}$$

Driving resistance coefficient refers to the ratio of external driving resistance to machine gravity (including vertical load):

$$f = \frac{F_C}{W} \tag{6}$$

$$f = \frac{\left(bP_{cp}\right)^{\frac{1}{n}}}{(n+1)K^{\frac{1}{n}}}\left[p_{cp}(1+\frac{6e}{L})\right]^{\frac{n+1}{n}}\left[\left(1+\frac{2c}{B}\right)^{\frac{n+1}{n}}+\left(1-\frac{2c}{B}\right)^{\frac{n+1}{n}}\right] \tag{7}$$

In order to predict the driving resistance of tracked vehicles more accurately, k.k. ogure of Japan made a detailed modification to the calculation method of driving resistance. His amendments mainly include three points:

(1)It can predict the driving resistance by using the work consumed by soil compaction in the vertical direction under the action of crawler. However, it is more practical to think that the direction of soil compaction is not vertical direction, but inclined forward compaction.

(2) The ground pressure distribution is not uniform under the action of the vehicle. The following figure shows the typical results of testing ground pressure distribution, which is obtained by the test vehicle measuring external driving resistance. As can be seen from the figure, the maximum ground pressure occurs under the roller. If the average value of the maximum pressure under each wheel p_{mm} is used, then Rowland puts forward:

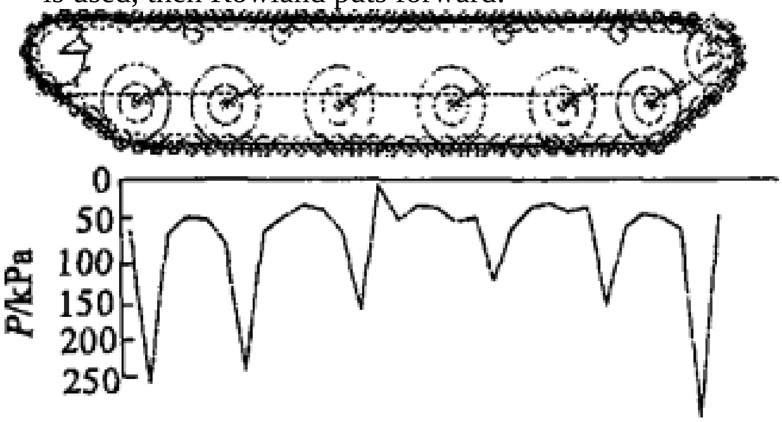

Figure 1 Pressure curve

$$H = Z_0, q = 0, B = b, \ p_{mm} = \frac{1.25W}{2nd\sqrt{td}} \tag{8}$$

Where: w--vehicle weight, N;
n--the number of supporting wheels on a track;
d--outer diameter of wheel, cm;
b--track width, cm;
t--caterpillar pitch, cm;

In the soft condition, the failure mode is local failure, and the bulldozing resistance can be calculated by the following formula:

$$F_b' = 0.5\gamma Z_0^2 b K_\gamma' + 0.67 b Z_0 C K_{pc}' \tag{9}$$

Type in the:

$$K_{pc}' = \left(N_c' - \tan\varphi'\right)\cos^2\varphi' \tag{10}$$

$$K_\gamma' = \left(\frac{2N_\gamma'}{\tan\varphi'} + 1\right)\cos^2\varphi' \tag{11}$$

$$\tan\varphi' = \frac{2}{3}\tan\varphi \tag{12}$$

N_c' and N_γ' is the bearing capacity coefficient of local shear failure.

Total external resistance shall be:

When the soil is hard:

$$F = F_C + F_b = \frac{2bp_0^2\cos\theta}{K}\left(\frac{p_{mm}}{p_0 - p_{mm}} - \ln\frac{p_0}{p_0 - p_{mm}}\right) + 0.5\gamma Z_0^2 b K_\gamma + b Z_0 C K \tag{13}$$

When soft soil is:

$$F = F_C + F_b' = \frac{2bp_0^2\cos\theta}{K}\left(\frac{p_{mm}}{p_0 - p_{mm}} - \ln\frac{p_0}{p_0 - p_{mm}}\right) + 0.5\gamma Z_0^2 b K_\gamma' + 0.67 b Z_0 C K_{pc}' \tag{14}$$

3. Analysis of Other Factors on Track Resistance

In addition to the driving resistance of the track, there are internal resistance, breaking resistance, turning resistance, wind resistance, inertia resistance and so on. As these resistance are not conducive to the calculation formula, only qualitative analysis can be made according to the empirical formula. In this case, because the breaking resistance and turning resistance change greatly and the conditions change, the analysis is not done here. Due to the complexity of the influencing factors, it is difficult to give the derived formula, and some experiments can be used as references. Therefore, the empirical formula is generally recommended as the design estimation. There are three empirical formulas:

$$\eta_x = 0.95 - 0.003\, v_i \text{ [8]}$$
$$\eta_x = 0.97 - 0.003\, v_i$$
$$\eta_x = 0.95 - 0.0017\, v_i \tag{15}$$

These formulae are all linear expressions. The first formula is for the steel pin track, which was proposed in the 1950s based on partial low-speed experiments. The author of the second formula used the pin to hang the rubber track, referring to the first formula and to correct. The third formula according to the machine speed is greater than or equal to 30 km/h reference first correction formula based on the experiment: the same 14 t tell caterpillar car, engine power 235 kw, design a maximum speed of 65 km/h, steel pin crawler drive on cement road surfaces, can only achieve 60 km/h, change pin ears hanging plastic track, can reach more than 65 km/h, is still in the car, when the engine power up to 265 kw, with Shanghai pin track, also can achieve more than 65 km/h, the third formula after the comprehensive conversion, their graphics as shown in figure.

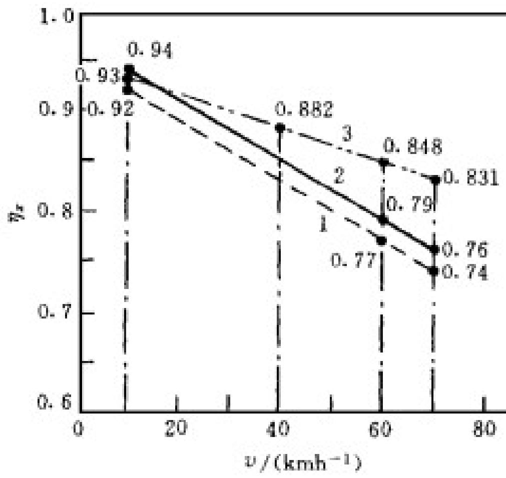

Figure 2 Graphics

From the above figure, the efficiency of the second formula is 2% higher than that of the first one at different speeds. The third formula is significantly improved after v>30km/h, and when v=70km/h, the efficiency is 8.5% higher than the second formula. It's 10.95% higher than the first formula; V =60km/h is 6.84% higher than the second expression and 9.2%.

In addition, the relation curve between the driving resistance F of different track structures and the speed v is shown below.

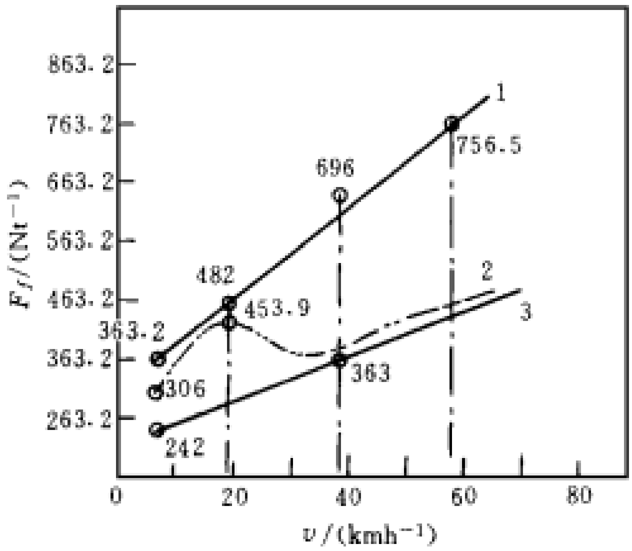

Figure 3 The relation curve

1--empirical formulas in general cases;
2--rubber bushing track;
3-half-track rubber track;

4. Conclusion

(1)The driving resistance of vehicles facing the track on the ground can be calculated according to the following formula:

$$F = F_C + F_b = \frac{2bp_0^2\cos\theta}{K}\left(\frac{p_{mm}}{p_0 - p_{mm}} - \ln\frac{p_0}{p_0 - p_{mm}}\right) + 0.5\gamma Z_0^2 bK_\gamma + bZ_0 CK \tag{12}$$

(2)The ratio of the drag force to the total driving resistance can be calculated according to the empirical formula.

(3)Different speeds and different tracks also affect driving resistance.

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