Passivity Analysis of Track Walking Device on Soft Road Condition

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Abstract. With wheel-track vehicle as the research object, the passivity of track walking device on soft road conditions have been studied, establishing the track walking device dynamic model and finishing the dynamic simulation. By the theoretical calculation and dynamic simulation analysis: the method of average ground pressure to represent the vehicle’s passivity on soft road condition has limitations, the average maximum pressure P_mm(MMP) evaluation method is more effective and more accurate; with the same track grounding length, the more wheels of the track walking device, the smaller the vehicle’s subsidence on soft road conditions and the better its passing performance. When a track walking device was increased from one single load wheel to three load wheels, the amount of subsidence on soft road conditions decreased by about 35%.

1. Introduction
Tracked vehicles have better passability on soft road conditions due to low ground pressure. Average ground pressure is often used to represent the passing performance of a tracked vehicle on soft road conditions. However, this calculation index is established on the premise that the pressure on the surface soil is approximately uniformly distributed within the range of track ground length, that is, this index is applicable to track with small wheelbase, small load wheel and long pitch[1]. With the increase of armored vehicles' speed, the design of tracked vehicles tends to adopt large load wheel and short pitch track plate, and the pressure varies greatly within the length of track grounding range -- the peak pressure at the load wheel can reach 2~3 times of the average ground pressure, while the pressure between two load wheels can be very low or even close to zero. Therefore, it is obviously inappropriate to use average ground pressure to represent the effect of tracked vehicle on the ground. Studies have proved that tracked vehicles with the same average ground pressure can have very different mobility performance on soft ground [2].

In order to improve the passability of soft road conditions, wheeled vehicles adopt external track on the tire, as shown in Figure 1. In the design of tracked vehicles, the size of load wheels is often reduced and the number of load wheels is increased, as shown in Figure 2.
In order to reduce the earthing specific pressure of a certain amphibious vehicle and improve its passability on soft beach road, a wheel-and-shoe composite walking scheme was proposed. The design of crawler walking device is shown in FIG. 3. This article for an amphibious vehicle as the research object, based on Roland (D. Rowland) the average maximum pressure P_mm (MMP) evaluation method for the crawler walking device grounding than the theoretical calculation [1, 3], at the same time based on RecurDyn to carry out the modeling and simulation analysis, mainly on different road wheel quantity and size for the crawler walking device grounding than the impact, this paper compares and analyzes the optimum design scheme of crawler walking device road wheel for crawler walking plan design to provide theoretical basis for vehicle.

\[ P_{mn} = \frac{1.285W}{2nb\sqrt{pd}} \]

W - vehicle weight, kg; N - number of load wheels per track; B - track width, cm; P - track plate pitch, cm; D - outside diameter of load wheel, cm.

The average maximum pressure values of track walking devices based on different number of load wheels are shown in Table 1. It can be seen from Table 1 that increasing the number of loading wheels significantly reduces the P_mm value.

2. Theoretical Calculation of Track Grounding Specific Pressure

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D. Rowland proposed that the average maximum unit pressure P_mm on the track (defined as the average value of the maximum pressure on all load wheels) should replace the nominal ground pressure as the index to evaluate the soft ground performance of tracked vehicles. P_mm was calculated according to the following formula [1,4]:

Figure 3. Schematic diagram of track walking device of an amphibious vehicle
Table 1. Calculation results of average maximum unit pressure

| Number of load wheels | Ground pressure (kPa) |
|----------------------|-----------------------|
| 2                    | 359.2                 |
| 3                    | 239.4                 |
| 4                    | 179.6                 |

Figure 4. Influence curve of the number of loading wheels on average maximum unit pressure

Figure 5. Impact curve of the ex-diameter of the load wheel on average maximum unit pressure
As can be seen from FIG. 4, with the increase in the number of load wheels, the average maximum unit ground pressure of the track walking device decreases. At the same time, it can be seen from FIG.5–FIG.6 that increasing the outer diameter of the load wheel and increasing the pitch of the track plate are also conducive to reducing the average maximum ground pressure. According to the average maximum unit ground pressure, the soil strength required by vehicles passing through soft road conditions can be estimated. The required soil strength can be calculated according to the following formula [5]:

\[
\text{Limiting CI} = 0.83P_{mm}
\]

3. Dynamic Simulation
A simulation model of the track walking device was built based on recurdyn, as shown in Figure 6. The dynamic simulation analysis was carried out, and the simulation analysis was carried out on the average maximum unit ground pressure of the load wheel on the front track walking device. The comparison analysis was focused on the average maximum unit ground pressure of the load wheel on different number of load wheel configurations.

Figure 6. Impact curve of track plate's pitch on average maximum unit pressure

Figure 7. Simulation model of track walking device
According to FIG. 7 and FIG. 8, when a single load wheel is set for crawler walking device on soft wet sand road, the settlement amount in soft section is about 140mm. After increasing from a single weight wheel to three weight wheels, the subsidence volume of the crawler walking device is about 110mm, reducing by 30mm. When the number of load wheels is increased to 4, the settlement amount of crawler walking device is about 100mm, which is reduced by 40mm and the performance is improved by 35%.

4. Conclusion
In this paper, the dynamic model of the track walking device was established and the dynamic simulation was carried out. According to the calculation and simulation results, it can be seen that:

1) The average ground pressure to represent the vehicle passing performance in soft road conditions has limitations, and the average maximum pressure P_mm(MMP) evaluation method is more effective and accurate.
2) The more weight wheels of the crawler walking device, the higher the passability of the crawler walking device in the soft section. On the premise of satisfying the weight and dimension space, increasing the number of loading wheels as far as possible can effectively improve the vehicle passability.

5. References
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