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Study on Trafficability of SL1400-Beach Vehicle

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Abstract—To solve the problem of SL1400 beach vehicle trafficability in Xiamen sand road condition, presented the formulas of tangential traction force and driving resistance, taking the pothook tractive force and the coefficient of traction as the evaluating indicator of trafficability. The research shows that SL1400 beach vehicle has better trafficability in Xiamen sand condition and can meet the demands of cleaning task.

Keywords-Trafficability; sand road condition; tire;

1. Introduction

As visitors leave the plastic bags, fruit skins, bottles and other garbage on the beach. In addition, storm and flood alluvial branches, white trash and other floating objects, which serious polluted local environment. It is very difficult to clean beaches rely on manual picking up so much garbage. In order to reduce the workload, someone landfill and incineration waste. Such an approach will only worsen the beach environment. To get rid of pollution, local governments have spent huge sums of money to purchase beach cleaning machine from abroad to save the beach.SL1400-Beach Vehicle is a compact structure, easy maintenance medium beach cleaning machinery. The trafficability of beach vehicle is the most important and most prominent problem for efficiently cleaning litter from beaches. Ordinary pneumatic tire on the shear capacity of poor loose sand, showing a large subsidence, a large rolling resistance, quite often slipping and difficult to drive. The tangential traction and the driving resistance from the theoretical calculation of SL1400 beach vehicle, predict whether the vehicle can finish the operation in the sand.

2. The structure of sl1400 beach vehicle

Figure 1 is the overall structure of the beach vehicle. A self-propelled (integral) vehicle, with cab and air conditioning, auxiliary power is about 55KW,chassis transmission system using all-hydraulic closed four-wheel drive, working device spilled by roller, belt conveyor. Screening all kinds of garbage on the beach, and collecting into the trash bucket. The volume of trash is 0.6 m^3 ,can containing about 600kg garbage. Poured Garbage into the dump truck through the lift, flip agencies, dumping height is about 2000mm. At the same time, smooth the sandy beach by scraping plate. SL1400 beach vehicle use low pressure off-road tires to prevent caught in beach, the major technical indicators of the vehicle as shown in Table 1.

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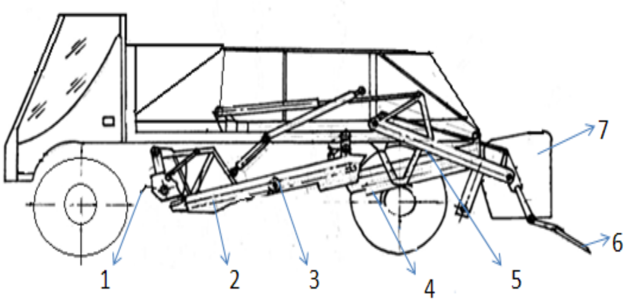

Fig.1. Structure of beach vehicle
1-Flexible gear;2-Cycle Screen;3- Cam ; 4-Tire;
5-Four-bar linkage;6- Scraping plate ; 7-Collection box

TABLE 1 TECHNICAL INDICATORS

Travel agencies	Four-wheel drive
Dimensions (mm)	6210*2000*2300
The largest total mass (kg)	4000
Operating speed ($km{\cdot}h^{-1}$)	15
Tire Size (mm)	400/60-15.5
Pattern height (mm)	15
Power (KW)	55

3. The Mechanical model between wheel and sand

In driving, the movement of the wheels, including the pure rolling, sliding and pure rolling and slip three states. Drive slip rate (when the wheels accelerating) relative to the ratio of the wheel speed and tangential velocity. The Settlement contains the static subsidence caused by axle load and the dynamic subsidence caused by wheel slip.

The compression of surface loose dry sand is small, plastic flow is the main deformation characteristics under loading. The flow path of sand particles under wheel as shown in Figure 2 . Each segments represents particle displacement size and direction in 0.1 second. From the chart, we know the sand under wheel produce two damaged regions, namely anterior and posterior areas. Envelope of the region similar to logarithmic spiral. In the damage area, everywhere combination of normal stress and shear stress over the shear strength of sand, causing sand particles to flow. In the former area, particle flow from the back to front, forming own soil, increase the bulldozing resistance; in the latter area, the sand particles flow from front to back, forming slip subsidence[1].

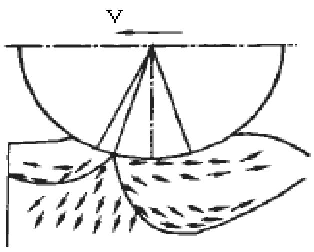

Fig.2. The flow path of sand particles

3.1. Tangential traction

Shear characteristics of soil is the most important features affect the trafficability of vehicle on soft ground. The maximum tangential traction limited by the anti-shear strength of soil when vehicles traveling on soft ground. Generally use the following equation describing the shear stress - shear deformation relationship [2]:

$$\tau = (c + ptg\varphi)\left(1 - e^{\frac{-j}{j_0}}\right)$$

In the formula, c denotes soil cohesion, φ denotes soil internal friction angle, p denotes the average pressure per unit area, j denotes r the shear displacement, j_0 denotes shear deformation modulus of soil. Under the driving torque, tire in contact with the sand will produce a driving force to promote the vehicles. Considered the height of the tire tread and wheel slip ratio when calculate the driving force. The shear stress τ on the contact area for integration, tangential traction caused by the single driving wheel can be drawn. The vertical load and contact area on front wheel is different from rear wheel. It is needed to respectively calculate driving force on the front and rear wheel, add to get vehicle driving force.

Tangential traction on the front wheel:

$$H_1=\left\{bl_1c(1+\frac{2h}{b})+W_1tg\varphi[1+0.64\frac{h}{b}arctg(\frac{h}{b})]\right\}\cdot[1-\frac{j_0}{\lambda l_1}(1-e^{-\lambda l_1/j_0})]$$

Tangential traction on the rear wheel:

$$H_2=\left\{bl_2c(1+\frac{2h}{b})+W_2tg\varphi[1+0.64\frac{h}{b}arctg(\frac{h}{b})]\right\}\cdot[1-\frac{j_0}{\lambda l_2}(1-e^{-\lambda l_2/j_0})]$$

Among above, c denotes soil cohesion, λ denotes wheel slip ratio, 'W' denotes the load, 'l' denotes the length of tire contact, subscript '1' and '2' denote the front and the rear wheel respectively, j_0 denotes shear deformation modulus of soil, h denotes pattern height. The length of tire contact is calculated as follow:

$$l_i=\sqrt{2r_0(r_0-r_k)-(r_0-r_k)^2}+\sqrt{2r_0(r_0-r_k+z_i)-(r_0-r_k+z_i)^2}$$

Among above, r_0 denotes free radius, r_k denotes the rolling radius, z denote rut depth.

3.2. Driving resistance

The roller does not cause working resistance, for roller rotation and wheel rotation in the same direction when SL1400 is working. There are various resistance when vehicle is moving, tangent traction generated by the driving wheel overcome these resistance. The total driving resistance mainly include compaction resistance F_R、 bulldozing resistance F_P [3] and resistance f generated by scraping plate. Ignore air resistance, for the beach vehicle moving in low speed.

- The resistance of calibrating sand

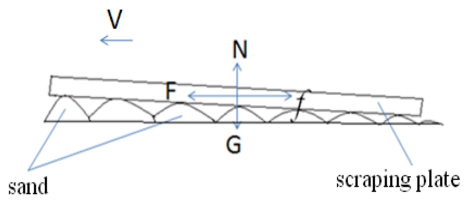

Fig.3. The force of scraping plate

Resistance generated by scraper is calculated as follows:

$$f=\mu N=\mu mg$$

Figure 3 shows the force of scraping plate. According to the theoretical mechanics, force balance in the vertical direction when the vehicle on the beach kept an even low speed in the driving, μ denotes coefficient of sliding friction, its value depends on physical state of contact surface, m denotes the mass of scraping plate, its value reference to Table2.

TABLE2 LOAD OF MAIN COMPONENTS

Load name	Mass (kg)
Cab	400
Frame	400
Engine and accessories	400
Working device	400
Trash bucket and	400
Hydraulic system	420
Scraping plate	50
Amount of waste	600

- Compaction resistance

Vehicle at low speed, you can ignore the tire slip on impact of the subsidence. According to rut formation theory, using the model proposed by Bekker: $P = kz^n$, soil compaction resulting resistance can be drawn[4,5]:

$$F_{Rd} = Kb\left(\frac{z_0^{n+1}}{n+1}\right) = \frac{b(p_1 + p_c)^{\frac{n+1}{n}}}{(n+1)K^{\frac{1}{n}}}$$

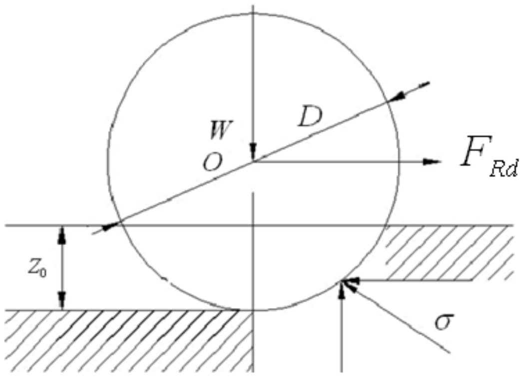

Fig.4. Stress Analysis

Among above, p_1 denotes tire inflation pressure, p_c denotes tire wall stiffness(at a certain load, kept constant), k denotes modulus of deformation， n denotes index of deformation. As long as the soil parameters k and n measured before the adoption of the wheel each time, the compaction resistance of each wheel can be calculated. All wheel compaction resistance add to the compaction resistance of vehicle.

- Bulldozing resistance.

Rolling resistance caused by a single wheel vertical over soil is called bulldozing resistance. In terms of sandy soil(c=0), often using the following formula:

$$F_P = \frac{b\sin(\alpha+\varphi)}{2\sin\alpha\cos\varphi}(2zck_c + \gamma z^2 k_\gamma) + \frac{\pi l^3\gamma(90^\circ - \varphi)}{540} + \frac{c\pi l^2}{180} + cl^2 tg(45^\circ + \frac{\varphi}{2})$$

Among above, N_c and N_γ denote bearing capacity factor, can be obtained by look-up table. Measured soil parameters c 、 φ, and the sand density value γ, the value of bulldozing resistance can be calculated using the formula.

3.3. Trafficability evaluation

Beach vehicle take drawbar pull DP as the trafficability evaluation index. When the whole driving force H that the soil acting on the vehicles greater than the vehicle driving resistance ΣP ,beach vehicles can travel on the beach, the difference between H and ΣP called the drawbar pull DP.

In engineering, commonly used the drawbar pull of unit weight, namely traction coefficient Π, as the trafficability evaluation index[6,7].

$$\Pi = \frac{DP}{W} = \frac{H - \Sigma P}{W}$$

When the DP or Π greater than zero, soil thrust force that travel agencies received, in addition to overcoming the soil resistance, there is also part of the thrust force, **f**or acceleration, hill climbing and traction of vehicles driven part.

4. Simulation and Analysis of Results

Soil parameters[6]: n=0.97, j_0 =0.005m， c=0, φ =26.3°， γ =16345.8N/m^3,K=1945KN/m^{n+2} , bearing capacity factor N_c=41, N_γ=17. Tire wall stiffness take 45KPa, tire inflation pressure 100KPa, coefficient of sliding friction μ take 0.7 according to experience. Free radius and the rolling radius of tires respectively were r_0=43.7cm and r_k =41.5cm.

Figure 5 shown that modulus of deformation impact on load – Subsidence. Modulus of deformation respectively $K=2500KN/m^{n+2}$, $K=2000KN/m^{n+2}$, $K=1500KN/m^{n+2}$from the bottom. As figure 5 shows, bearing capacity increase with modulus of deformation improve, namely subsidence reduced in the same pressure. So the increase in modulus of deformation can increase the loading capacity. Figure 6 shown that compaction resistance changes with tire inflation pressure and wheel width. As figure 6 shows, compaction resistance increase with tire inflation pressure and wheel width improve.

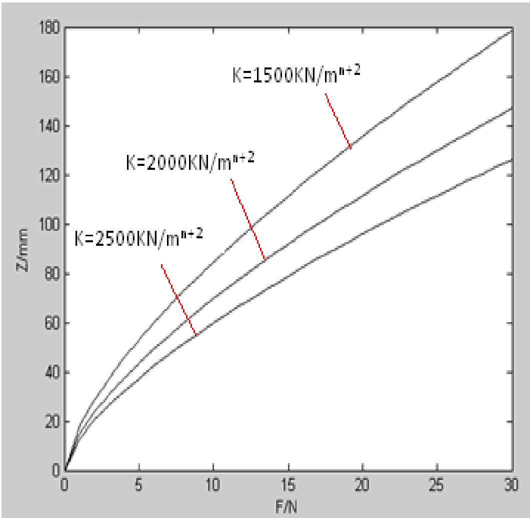

Fig.5. Modulus of deformation impact on load - Subsidence

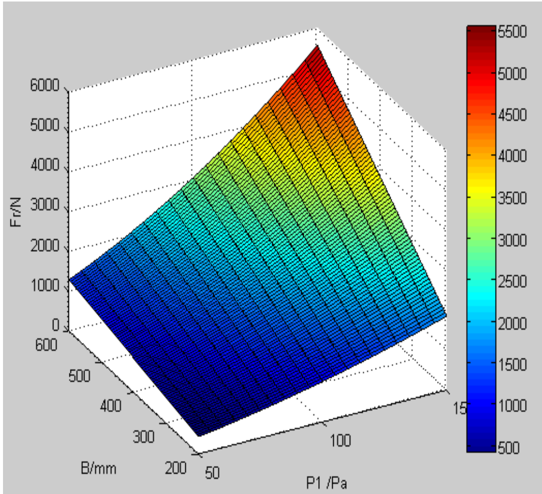

Fig.6. Compaction resistance changes with tire inflation pressure and wheel width.

Take the above data into the formula to obtain the curves on vehicle tangent traction and slip, the total vehicle travel resistance, drawbar pull DP and traction coefficient Π. The surface in Figure 7 shown subsidence changes with the wheel diameter and wheel width. It is known that subsidence decreased when the wheel width and wheel diameter increasing from Figure 7. The wheel width impact on subsidence is greater than the wheel diameter. It is shown tangential traction increase with the slip rate increases in Figure 8. Tangential traction is close to 0 when the slip rate close to 0. When the slip rate reaches 100% tangential traction reaches its maximum 19.55KN. The total vehicle drag is 16.429KN, at this time the vehicle slip rate is10%.

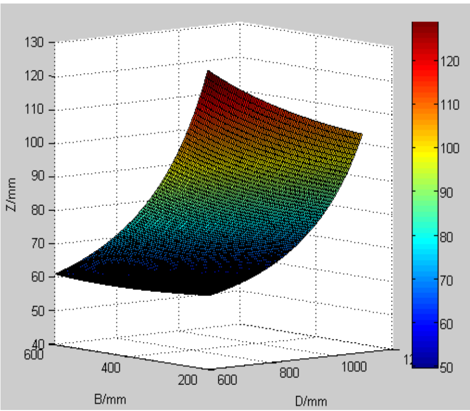

Fig.7. Subsidence changes with wheel diameter and wheel width.

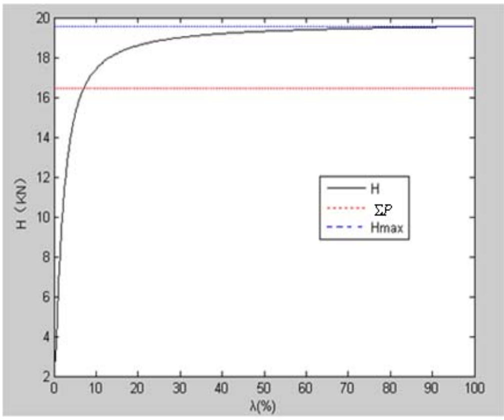

Fig.8. The curve of ΣP\H and λ

5. Conclusions

It is shown that SL1400 beach vehicle have better traction. Tangential traction has increased with the slip rate increase. The maximum tangential traction as to 19.55KN, and vehicle resistance to 16.43 KN . At this point driven roller slip is 10%, basically to meet its operational requirements. Therefore, select the type 400/60-15.5 tires is reasonable.

SL1400 beach vehicle can improve trafficability on sandy off-road, such as using large width section of ultra-low pressure tire, and further increase the contact area, reducing ground pressure. Using the methods and formulas to predict whether the vehicle meet the requirements of regional cross-country in theory, reference for the user purchase, to avoid major economic losses caused by blind acquisition.

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