Traveling Performance Simulation of Tracked Working Vehicle on the Soft Ground

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Abstract

Soft ground has significant effects on the raveling performance of tracked working vehicle for its particularity. The walking performance is an important evaluation index of its comprehensive operational capability. Aiming at the complex and difficult to test in situ of the tracked vehicle under the complicated soft ground conditions, a three-dimensional dynamic model and virtual prototype of the tracked vehicle are built by using the RecurDyn software, and the walking performance of the tracked working vehicle is simulated under the typical terrain conditions. The simulation results of the travelling performance on straight line travelling, turning, climbing and crossing the trentch conditions were respectively obtained, which provid a foundation for the further research on travelling performance evaluation and control and structural optimization of the soft ground terrain tracked working vehicle.

Keywords

Tracked Working Vehicle, Traveling Performance, Soft Ground, Simulation.

1. Introduction

The tracked working vehicle is the most important kind of working equipment in paddy field, swamp and seafloor for its traveling performance in the complex environment. However, the tracked working vehicle is easily to sink and slip while travelling on the soft soils with the characteristics of high slip rate and low strength and density [1]. Therefore, the tractive performance of the tracked vehicle is more importan. There are some reasearches on the tractive performance of tracked vehicle have been reported in literatures recently [2-8]. These researches are focused on the model establishing and partial simulation for special vehicles in different areas.

In this paper, take the seafloor mining tracked vehicle as an example to demonstration. A multi-body dynamics simulation model based on RecurDyn/Track tracked vehicle was established and the travelling performance on the typical terrain conditions were simulated and analized.

2. Multibody dynamics model establishing of the tracked working vehicle

In order to make a further analysis of the tracked working vehicle's traveling performance on soft ground, a model of multibody dynamics based on Recurdy is established. The 3-D model of the vehicle body, constructed by ProEngineer software based on the tracked working vehicle's strucural parameters (as shown in table 1), is loaded and corresponding constraints are defined in RecurDyn systems. On this basis, the track model suitable for soft gournd is established by using RecurDyn built-in Track/LM track module library.

Tab.1 Parameters of the track drive system component

Component	Radius (m)	Mass(kg)	Quantity
Driving wheel	0.28	50	2
Tensioning wheel	0.2	50	2
Supporting wheel	0.1	10	28
Carrier roller	0.1	10	6
Track shoe		15	150

The unilateral track is composed of 1 driving wheel and 14 supporting wheels and 1 tensioner and 3 carrire rollers. The center distance of the bilateral track is 3.5m and grouser height is 0.13m. The specific configuration parameters of the track as shown in table 2 [9].The geotechnical parameters of sediments were used in the simulation analysis are shown in table 3 [9-10].

Tab.2 Parameters of the track structure

Parameter/Unit	Symbol	Value
Total gravity of tracked vehicle/ N	W	1.15×10^5
Length of track on ground /(m)	L	6
Single track width /(m)	b	1.6
Track shoe pitch/(m)	l	0.2
Grouser thickness/(m)	d	0.045

Tab.3 Geotechnical parameters of sediments

Parameter/Unit	Symbol	Value
Sediments gravity/(N m^{-3})	γ_s	1.2×10^3
Sediments cohesion/(N m^{-2})	C	4000
Angle of internal friction/(°)	φ	5
Sediments residual shear stress/(Pa)	τ_{res}	1.4×10^4
Ratio of residual shear stress and maximum shear stress	K_r	0.28
Shear displacement of maximum shear stress/(m)	K_ω	0.035
Friction angle of grouser track shoe and sediments /(°)	δ	10

The multibody dynamics model establishing of the tracked working vehicle based on RecurDyn with the configration of simulation parameters as show in Fig 1.

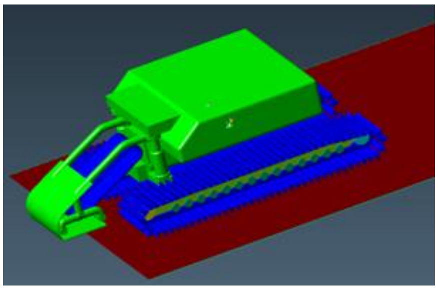
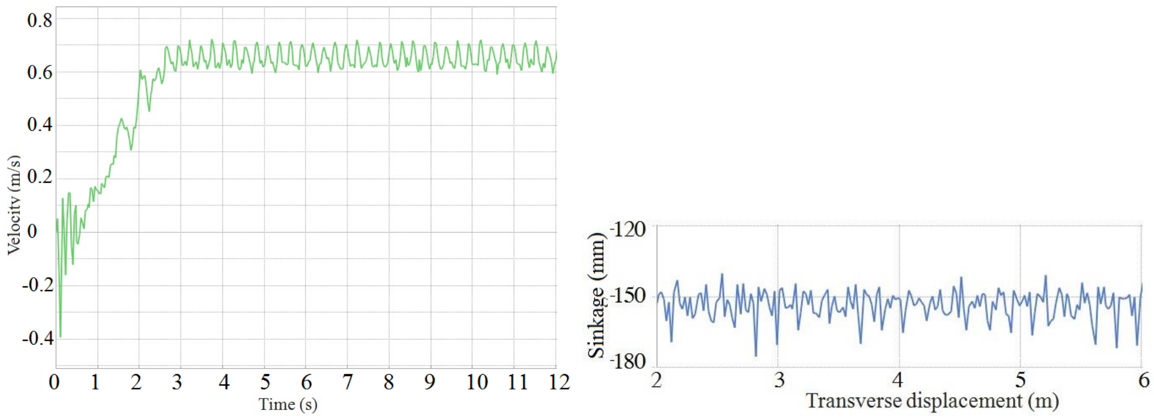


Fig.1 Simulation model of the tracked working vehicle based on RecurDyn

3. Walking performance simulation and analysis on the typical terrain conditions

3.1 Linear motion walking preformance simulation and analysis

According to the requirment of the crawler traveling speed undersea range 0.5-1.0 m/s, the driving wheel velocity is defined 0.5 m/s by the built-in STEP function. The linear motion simulation starts at the point of model dropping from about 20cm of the ground. The simulation result is shown in Fig 2.



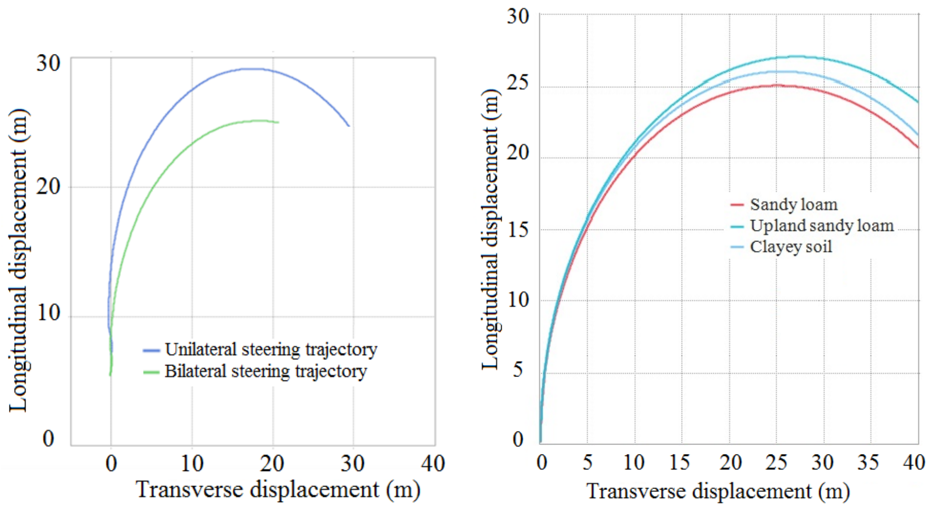
(a) Velocity - time curve (b) Sinkage with the transverse displacement

Fig.2 Curves of straight line travelling performanceche

The velocity of the vehicle fluctuated violently in the first second and then increased quickly to a steady fluctuation status with mean value of 0.65m/s after the third second. The sinkage of the vehicle, with the increasing of transverse displacement(straight line travelling), basically steady at a deepth of 155mm below the ground surface sinked in the sediments, fluctuated at the deepth of 155mm below the ground surface, which maximum fluctuation less than 20mm. The curves of straight line travelling performanceche show that the vehicle traveling with steady velocity and sinkage.

3.2 Steering preformance simulation and analysis

Considering the working vehicle with relatively wide track shoe and impeded great resistance during the course of steering walking on the seabed, the driving mode used in the simulation is differential steering, which bilateral track velocity differential steering ratio 1.2 and inner track velocity 0.5 m/s. The simulated steering trajectory curves of tracked vehicle obtained by different steering type and different sediments are shown in Fig 3.



(a) Turning radius of different steering type (b) Turning radius on different sediments

Fig.3 Steering trajectory of simulation

The turning radius with bilateral steering is obviously less than that with unilateral steering especially in the longitudimal displacement direction. The U-turn distance of the former is shorter than the latter one. Similarly, the turning radius ordering by value from small to large is respectively sandy loam, upland sandy loam and clay soil. All the steering paths are approximately circular. Therefore, the steering radius has close contact with the steering mode and sediment properties.

3.3 Climbing and crossing trench performance simulation analysis

According to the walking terrain features of seafloor in mining region and requirements of mining vehicle's operating performance, the tracked vehicle has good adaptability to the terrain (climbing height less than 0.5m, slope less than 15 degrees, obstructive ocean trench width less than 1m). Therefore a virtual soft terrain (slope=15°, height=0.5m, followed by a trench width=1m, depth =0.3m) was established in RecurDyn as shown in fig 4. The tracked vehicle is travelling smoothly through the soft sediments and steadily in simulation. Its gravity center position and velocity curves are shown in Fig 5.

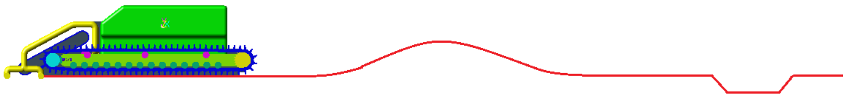


Fig.4 Climbing and crossing trench simulation

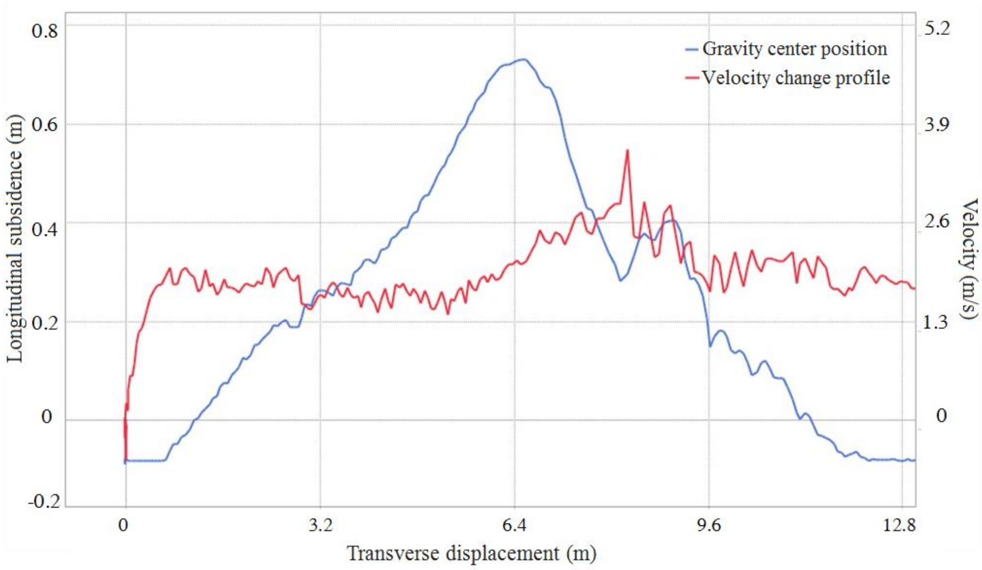


Fig.5 The gravity center position and velocity curves in climbing and crossing trench

In the upward climbing travelling process, the tracked vehicle's gravity center position rose gently while its velocity changed in significantly. In the downward travelling process, the tracked vehicle's velocity suddenly increased to a peak and then gradually restored to a steady status after flatten fluctuations. In the crossing trench process, the gravity center position and velocity did not change significantly. This shows that the narrow trench has no significant effect on the travelling performance. Therefor the big trench travelling process can be decomposed as climbing process and straight line process. The simulation results shows that the tracked vehicles have stable travelling performance in the typical deep-sea terrain conditions.

4. Conclusion

According to the structural parameters of deep-sea tracked mining vehicle, a multi-body dynamics simulation model based on RecurDyn/Track tracked vehicle was established. The dynamic simulation results of the travelling performance of straight line travelling, turning, climbing and crossing the trench conditions were respectively obtained by the simulation model, through which setting the seabed mechanical parameters and custom wheels motion functions. The results obtained provided a foundation for the further research on travelling performance evaluation and control and structural design optimization of the deep-sea tracked mining vehicle.

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