Academic Journal of Management and Social Sciences
ISSN: 2958-4396 | Vol. 2, No. 3, 2023

Simulation Analysis of Track Transporter based on Recurdyn

Guangyu Xie, Guangzhong Hu

School of Sichuan, Sichuan University of Science & Engineering, Yibin 644000, China

Abstract: China has always been an agricultural country. The hilly area covers a large area and the road condition is poor. At present, it is difficult for agricultural transporters on the market to operate efficiently in this area, so it is necessary to improve their adaptability to the hilly landform. Crawler transporter is a main type of machine widely used in agricultural transportation. Compared with wheeled transporter, crawler transporter has good adhesion performance and is not easy to slip. When driving on soft clay road, its ground pressure and road subsidence are smaller, so crawler transporter is more widely used.

Keywords: Track; Climbing; Clay Pavement; Hills and Mountains.

1. Introduction

China has long been a country dominated by agriculture, but more than 43 percent of the country is hilly and mountainous, which is more than half of the arable area. Although hills and mountains are not suitable for cultivation of food crops, they are important land resources for cultivation of oil, tobacco, vegetables, melons and fruits, hemp plants and so on, playing a crucial role in China's food production [1][2].

However, due to the congenital natural environment, although the hilly and mountainous areas of China have advantaged natural conditions, the land area is small, irregular shape, the surrounding terrain is uneven, the field path is narrow, the gradient is steep, and the road surface is tortuous and bumpy, which causes difficulties for the efficient operation of large-scale agricultural machinery. However, the walking chassis of small agricultural machinery is not stable enough to facilitate operation [3][4][5]. As a result, it is difficult to transport and operate various agricultural products in hilly areas, and it is difficult for ordinary engineering vehicles to operate directly [6]. Therefore, it is a challenge to realize the smooth movement of the walking chassis under the complex landform. How to improve the adaptability of various engineering vehicles to the hilly landform has become an urgent problem to be solved.

2. Simulation Modeling of Tracked Transporter

2.1. Simplification of Car Body Geometry Model

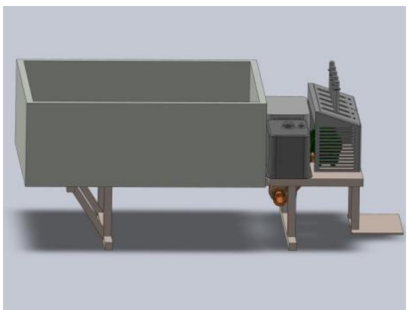

Fig 1. Simplified model of the car body

The chassis structure of agricultural tracked transporter is complex, so importing it directly into Recurdyn software for simulation will reduce the solving speed and affect the accuracy of simulation results. Therefore, it is necessary to simplify the chassis structure to improve the efficiency and accuracy of simulation calculation.

2.2. Simulation Model Related Values Set

Table 1. Defines constraints

Constraint type	definition
Rotating pair	The relative rotation between the two components is constrained and can be turned freely, but not translated
Fixed pair	The relative position and attitude between the two components are fixed
Translational pair	The relative translation between the two components is constrained and can be translated freely, but not rotated

Table 2. Constraints on components

Interlocking components		Constraint form
Driving wheel	Car body	Rotating pair
Guide wheel	Car body	Rotating pair
roadwheel	Balance elbow	Rotating pair
Tow wheel	Car body	Rotating pair
First and fifth roadwheels	Shock absorber component 1	Rotating pair
Balance elbow	Car body	Rotating pair, torsion spring
Shock absorber component 1	Shock absorber component 2	Moving pair, linear spring
Shock absorber component 2	Car body	Rotating pair

In order to ensure the accuracy of simulation results, corresponding constraints need to be added according to the actual situation after the completion of the three-dimensional model of the whole machine. These constraints include rotating pairs, fixed pairs and moving pairs. Among these constraints, the constraint of rotation pair involves the constraint of rotation, the constraint of fixed pair involves the constraint of some parts in the model, and the constraint of translation pair involves the constraint of some parts in the model. Table 1 and Table 2 provide specific definitions and forms.

Figure 2 shows the unilateral track model after constraint definition:

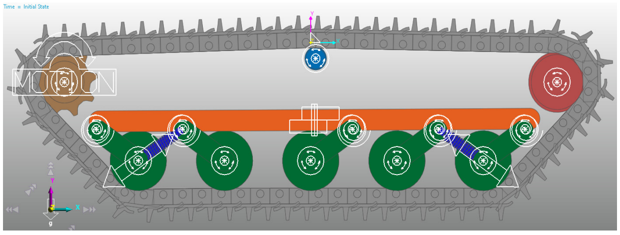

Fig 2. Constraint model of track walking mechanism

3. Multi-condition Simulation Analysis

In order to explore the influence of hilly terrain environment on transport vehicles, multi-condition coupling analysis was carried out with reference to Optimal Test Design [7]. The maximum longitudinal climb was taken as the evaluation index, and orthogonal experimental analysis was carried out with lateral slope, driving speed, different loads and different road surfaces as factors. Simulation factors and levels are shown in Table 3 below.

Table 3. Simulation factors and levels

level	factor			
	Lateral grade	Pavement parameter	Travel speed	Load mass
1	3°	Dry sand	3km/h	No load (0kg)
2	8°	Sandy soil	5km/h	Half-load (750kg)
3	13°	clay	7km/h	Full load (1500kg)

According to the factors and levels in Table 3 above, the maximum vertical climb is taken as the index of the test, and the orthogonal table of 3 levels and 5 factors is also selected and treated by the pseudo-horizontal method. Table 4 below is the scheme and results of the orthogonal test.

Table 4. simulation schemes and results

Test number	factor				Maximum climbing grade
	a	b	c	d	
1	1	1	1	1	52°
2	1	1	2	2	44°
3	1	2	1	3	44°
4	1	2	3	1	50°
5	1	3	2	3	42°
6	1	3	3	2	44°
7	2	1	1	3	38°
8	2	1	3	1	50°
9	2	2	2	2	44°
10	2	2	3	3	39°
11	2	3	1	2	42°
12	2	3	2	1	46°
13	3	1	2	3	36°
14	3	1	3	2	41°
15	3	2	1	2	44°
16	3	2	2	1	50°
17	3	3	1	1	46°
18	3	3	3	3	38°

In Table 4, a, b, c and d respectively represent lateral slope, different road surfaces, driving speeds and different loads. According to the above table, the maximum climbing slope is 52° and the minimum climbing slope is 36° . The primary, secondary and optimal combinations of range analysis factors are performed, as shown in Table 5.

Table 5. Range analysis

K_{1j} (1level data sum)	276	261	266	294
K_{2j} (2level data sum)	259	271	262	259
K_{3j} (3level data sum)	255	258	262	237
k_{1j} (1Mean level)	46	43.5	44.33	49
k_{2j} (2Mean level)	43.17	45.17	43.67	43.17
k_{3j} (3Mean level)	42.5	43	43.67	39.5
$R_j(k) = k_{ij\max} - k_{ij\min}$	3.5	2.17	0.66	9.5
Primary and secondary factors	d>a>b>c			
Optimal level	a1, b1, c1, d1			

In Table 5, K_{1j}, K_{2j} and K_{3j} respectively represent the sum of maximum climbing slope of each factor at level 1, 2 and 3. K_{1j}, K_{2j} and K_{3j} correspond to the mean value of level 1, 2 and 3 data and respectively. R_j is the range of each factor a, b, c and d, which can determine the influence degree of the influencing factors on the test index. According to Table 5-4 above, the factors affecting the maximum gradient are listed in the order of main and secondary: different load > lateral slope > different road surface > driving speed. Now, variance analysis is carried out to further understand the influence of each factor on the test indicators, as shown in Table 6 below.

Table 6. Analysis of variance

Source of variance	Sum of squares	Degree of freedom	Mean square sum	F	Significance level
model	544.5	1	544.5	753.923	0.000**
a	13	2	6.5	9	0.007**
b	4.333	2	2.167	3	0.1
c	1.333	2	0.667	0.923	0.432
d	65.333	2	32.667	45.231	0.000**
error	6.5	9	0.722		

According to the variance analysis table, different load and lateral slope have significant influence on maximum climb, while road type and driving speed have little influence on maximum climb. The F value also intuitively shows that the influence of four factors on the maximum obstacle height is d>a>b>c.

4. Summary

Taking the longitudinal maximum climb slope as the test index, the simulation tests were carried out respectively with the transverse slope, road type, driving speed and different loads as the main factors. It is found that different loads and lateral slope have a greater impact on the longitudinal climb slope, while the road type and driving speed have a smaller impact. The order of influencing factors was: different load > lateral slope > different road surface > driving speed.

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