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Influence Analysis of Structure Type on Turning Passing Ability of Car Transport Vehicle Combination

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Abstract

To analyze the influence of structure type on passing ability of car transport vehicle combination, the four basic vehicle combination models of two typical structure types, such as car transport semi-trailer road train and car transport vehicle combination with center axle trailer, have been built by using TruckSim. The turning circle test and the adaptability test on highway have been simulated on dry pavement to analyze the relationship between the structure type and the turning passing ability. The results show that the structure parameters have significant influence on the passing ability of car transport vehicle combination; three of the vehicle combination models can meet the requirements of GB 1589-2004"Limits of dimensions, axle load and masses for road vehicles"; all the four basic vehicle combination models will take up the lane beside itself when running on the up to and including third-grade highway/ramp.

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Keywords: Automobile Engineering; Car Transport Vehicle Combination; Passing Ability; Simulation

1. Introduction

Vehicle combination has been widely deployed in road delivery in large areas as Europe, U.S.A and Australia. Car transport vehicle combination, as a type of high-technological vehicle, is playing the roll of connection between vehicle manufacturers and dealers and consumers. In order to enhance efficiency, car transport vehicle combination usually functions in the types of car transport semi-trailer road train and car transport vehicle combination with

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center axle. Car transport vehicle combination with center axle has been widely used by many European vehicle manufactures (as DE BOOY、FVG、GROENEWOLD、LOHR and ROLFO), for their characters of simple flexible structures, low gravity centers and smaller tires. The passing ability of car transport vehicle combination refers to the ability of changing directions and rounding obstacles in harbors, freight yards, construction sites and narrow bend roads. In comparison with traditional freight vehicle, car transport vehicle combination has a longer body-structure and more degrees of freedom, while takes lager area in roads. It is rather necessary to study how the parameters affect passing abilities.

The limit of size and type of car transport vehicle combination are different in Europe, largely determined by road conditions and laws. Most countries defined the limit of lengths in both empty and fully loads, and allow an oversized distance. Germany defines the limit of vehicle length to 18.75m when empty loaded and 20.75 when full loaded, and front oversized distance to 0.5m and rear oversized distance to 1.5m. Most countries define the limit of vehicle length to 18.75 when empty. However, several counties define the limit of length to 25.25m, but allow only in modularity transport system.

Researches on passing ability of freight vehicles and semi-trailers has been conducted. Sanyal and Karmakar [1] made analysis on the influence of C-Double's parameters on stability under transport condition. Starr. Patrice [2] developed the system to evaluate the yaw stability of vehicle combination. Zhou Gang [3] studied the turning passing ability of double semi-trailer road train on curve according to China's current standard of highway. Lin Qingfeng [4] analyzed the influence of the trailer length on turning channel width of double semi-trailer road train with TruckSim. Han Houlu [5] built a model of semi-trailer road train by ADAMS/View, and analyzed the kinetic characteristics, steering principle, and steering behavior including minimum turning radius and channel width. A comparison of swept width of B-doubles with different overall lengths in low speed off-tracking has been made to give the overall dimension limit for B-Train by B. Pearson [6]. The Australian Performance Based Standards [7] defined the test procedure of quarter turn's forward swing and rear swing of both vehicles' and vehicle trains' passing abilities. Current China's GB 1589-2004, Limits of Dimensions Axle Load and Masses for Road Vehicles, required both vehicle and vehicle train to pass a round with 25m outer diameter and 10.6m inner radius [8].

Previous studies were concentrated on passing abilities of truck or semi-trailer road train, but there is less research about influence of structure type on passing ability of car transport vehicle combination. Therefore, in our research the turning process was simulated to analyze the relationship between the structure type and the turning channel width at low speed, by using TruckSim.

2. Test method

2.1. Models of Car Transport Vehicle Combination

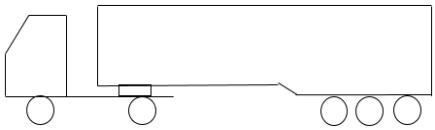

Fig. 1. Basic model of car transport semi-trailer road train.

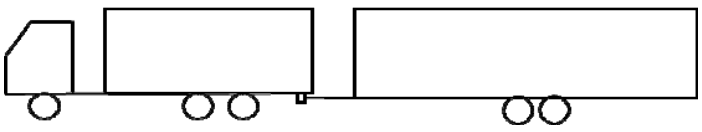

Fig. 2. Basic model of car transport vehicle combination with centre axle trailer.

In TruckSim, the vehicle combination model consists of body, steering system, braking system, power transmission system, wheels, axles and suspension subsystems. Basic model of car transport vehicle combination were selected from TruckSim (Fig. 1 and 2). The structure parameters of basic tractor and trailer in this research are shown in Table 1. Other parameters of car transport vehicle combination were designed with the default setting of TruckSim.

2.2. Simulation Test Design

(1) The Turning Circle Test

The turning circle test is based on the requirement of "Limits of dimensions, axle load and masses for road vehicles" in GB1589-2004 standard. The tractor's and the trailer's vertical axes are overlapped. In the test, the vehicle first runs straight and then runs along with a right-angle circular arc whose radius is 12.5m. The length of the circular arc is at least half of the circumference, the road adhesion coefficient is 0.85, and the speed is 5km/h (see Fig. 3).

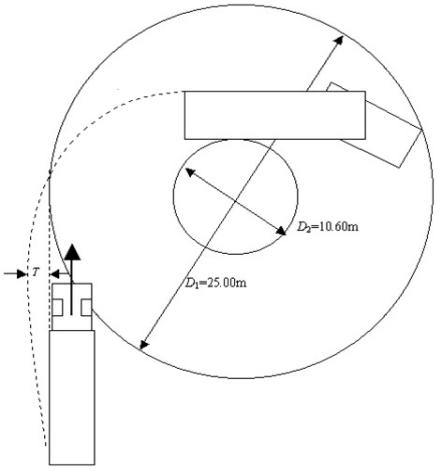

Fig. 3. Turning channel circle test.

Table 1. Structure parameters of car transport vehicle combination. Unit: mm

Basic Model		Car transport semi-trailer road train		Car transport vehicle combination with centre axle trailer	
		Model A	Model C	Model C	Model D
Length (mm)		16500	18700	18700	22000
Width (mm)		2550	2550	2550	2550
Power Type		4×2	4×2	4×2	4×2
Wheel Base (mm)	Tractor	3805	3790	3300	6815
	Trailer	6820+1310+1310	8340+1310+1310	5880+1500	5865+1300

(2) The Road Adaptability Test

The adaptability test on highway is based on JTG D20-2006 standard [9] of "Design Criterion of Highway Route". We conducted the simulation on the road adaptability of car transport vehicle combination using TruckSim. The parameter of highway is the extreme minimum radius (see Table 2&3). The tractor's and the trailer's vertical

axes are overlapped. The vehicle first runs straight and then runs along with a highway curve whose radius is extreme minimum.

Table 2. Highway linear and extreme minimum radius.

Road Level	Highway			1st			2nd		3rd		4th
Speed(km/h)	120	100	80	100	80	60	80	60	40	30	20
Lane Width(m)	3.75	3.75	3.75	3.75	3.75	3.50	3.75	3.50	3.50	3.25	3.00
Extreme Minimum Radius(m)	650	400	250	400	250	125	250	125	60	30	15

Table 3. Highway ramp and extreme minimum radius.

Road Level	Ramp					
Speed (km/h)	80	70	60	40	35	30
Lane Width (m)	3.50	3.50	3.50	3.50	3.50	3.50
Extreme Minimum Radius (m)	230	175	120	50	35	25

2.3. Indexes

The indexes are of the car transport vehicle combinations from the simulation, including the turning circle and the turning swept width. The output data is the wheel trajectories of vehicle combination, and then the parameters of turning passing abilities of the vehicle combination were acquired according to the geometrical relationship between the wheel and the outer profiles of vehicle combination.

3. Result

3.1. Turning Circle Test

The test results of the four models are shown in Table 4, including the out value and the inner radius at the trailer's passing angle of 90°, 180°, 270° and 360°. Three of the models can meet the GB 1589-2004 requirements stating that the vehicle and vehicle combination must be able to pass a turning circle, with the outer radius of 25.00m and the inner radius no less than 10.60m, with the outer value no less than 0.80m. The results show that, the car transport combination vehicle with center axle, with the same length, has a better passing ability than Car transport semi-trailer road train.

Table 4. The Turning Circle Test Results of Car Transport Vehicle Combination models.

Model	Axle Distance (mm)		Inner Radius(m)				Out Value(m)
	Tractor	Trailer	90°	180°	270°	360°	
Model A	3805	6820+1310+1310	6130	5490	5330	5310	330
Model B	3790	8340+1310+1310	5100	4300	4000	3750	350
Model C	3300	5880+1500	6270	5625	5453	5370	650
Model D	6815	5865+1300	6225	5670	5500	5495	530

3.2. The Highway Adaptability Test

According to the current standard of 'Design Specification for Highway Alignment'(JTG D20-2006), the highway curve radius includes 650m, 400m, 250m, 125m, 60m, 30m and 15m, and the ramp radius includes 230 m, 175 m, 120 m, 50 m, 35 m and 25m respectively. The speed on highway, level 1st&2nd road, is set at 60km/h in

accordance with the safe speed at each level; the speed is set at 30km/h on other roads and ramp. The results of turning swept width have been shown in Table 5 and Table 6.

The results imply that the road adaptability of car transport semi-trailer road train is similar to the car transport vehicle combination with center axle trailer. When the models run on the highway, level 1st&2nd road and the ramp with the radius more than 50m, all the models can pass the curve within one lane; when the models runs on the level 3rd&4th road and the ramp with the radius less than 50m, all the tracks will take up the lane beside them.

The turning channel width is mainly affected by the curve radius, but the influence of structure on the road adaptability is not obvious.

Table 5. The turning channel width on the highway and ramp with the radius≥50m.

		Highway					Ramp			
Extreme Minimum Radius(m)		650	400	250	125	60	230	175	120	50
Lane Width(m)		3.75	3.75	3.75	3.50	3.50	3.50	3.50	3.50	3.50
Turning Channel Width (m)	Model A	2.63	2.71	2.74	2.81	2.87	2.74	2.78	2.80	2.92
	Model B	2.61	2.70	2.73	2.82	2.89	2.76	2.77	2.81	2.94
	Model C	2.63	2.70	2.76	2.86	3.05	2.78	2.80	2.86	3.06
	Model D	2.62	2.71	2.79	2.84	3.07	2.79	2.83	2.87	3.08

Table 6. The turning channel width on the highway and ramp with the radius≤50m.

		Highway		Ramp	
Extreme Minimum Radius(m)		30	15	35	25
Lane Width(m)		3.25	3.00	3.50	3.50
Turning Channel Width(m)	Model A	3.78	6.98	3.73	4.63
	Model B	3.96	7.02	3.86	4.88
	Model C	4.27	7.23	4.25	5.17
	Model D	4.33	7.41	4.26	5.22

4. Conclusion

The car transport vehicle combination models have been built by using TruckSim. The results show that three of the models can meet the GB 1589-2004 standard of “Limits of dimensions, axle load and masses for road vehicles”, but the car transport vehicle combination with center axle trailer, with the same length, can meet the requirements with better passing ability; all the models will take up the lane beside themselves when running on the up to and including third-grade highway/ramp. The structure type have significant influence on the passing ability of car transport vehicle combination, while the influence of structure type on the road adaptability is not obvious. This research results can provide theory basis and technical support for the design of car transport vehicle combination and the development of car transport.

Acknowledgment

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