A Study on the Traveling Capability of Large Operating Buses on Mountainous Highways

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Abstract. This paper analyzes the pass principle and influencing factors of large operating buses. The dynamics model of large operating buses is constructed by TruckSim vehicle dynamics simulation software, and computer simulation is carried out. Finally, through the actual scene test of large operating buses and aerial photography observation by drone, the effectiveness of the method is verified. Results of this paper may have some referential significance for improving the safety ability of large operating buses on mountainous highway and reducing the risk of serious road traffic accidents.

1. Introduction

Through the statistical analysis of road traffic accidents with more than ten deaths from 2009 to 2017[1], 171 serious road traffic accidents occurred in China in the past nine years, of which 71 involved large operating buses, accounting for 41.5% of the total number of accidents. Of the 71 accidents, 41 accidents occurred while large operating buses were driving on mountainous highways, accounting for 57.7% of the total number of accidents involved with large operating buses. The driving safety problems of large operating buses on mountainous highway need to be solved urgently.

Traffic safety is a "safety ecosystem" composed of five elements-- people, vehicle, road, management and environment. Changes happen in any element of the system such as the behavior or nature, will have impact on traffic safety as a whole. Compared with passenger vehicles, large operating buses have poorer stability, larger turning radius, larger lane area occupied by turning, and might have some negative interaction effects between large operating buses and vehicles running in the same direction or opposite direction. Compared with ordinary highways, mountainous highways have sharp bends and steep slopes, which are more likely to cause problems such as poor road alignment conditions and the difficulty of roadside facilities to meet the safety requirements of large operating buses. When a large operating bus travels on mountainous highway, due to the inexperienced drivers the lateral stability of the large operating bus are poor. In addition, road factors such as water and cliffs, sharp bends, steep slopes are more likely to cause traffic accidents and serious consequences, especially when large operating buses are involved.

In this paper, a study is carried out on the traveling capability of large operating buses on mountainous highway, and the influence of road factors on the traveling capability of large operating buses is analyzed. The study focuses on the influence of road width, flat curve radius, super high and other factors on the traveling capability of large operating buses. The results of the study have application and reference value for the development of concrete application measures such as widening roads, controlling speed, optimizing alignment. It also has a guiding role in improving the
safe ability of large operating buses on mountainous highway and reducing the risk of serious road traffic accidents.

2. Main considerations for the traveling capability of large operating buses
The traveling capability of vehicles refers to the ability of vehicles to pass through certain road conditions. Specifically, it refers to the ability of a vehicle to pass through various poor condition highway and roadless areas (such as soft ground and rough areas) and various obstacles (steep slopes, side slopes, trenches, steps, bushes and water barriers) at a high enough average speed. However, when considering the special scene of large operating buses passing through mountainous highway, considering that mountainous highway is relatively flat, the chassis of large operating bus is relatively high, and the possibility of gap failure is relatively small, while the possibility of large operating bus deviating from the road surface through curves is relatively large, the influencing factors of large operating buses passing through curves are mainly considered[2-6]. These factors mainly include the following three aspects:

(1) Factors of geometric parameters of large operating buses
The geometric parameter factors that affect the traveling capability of large operating buses mainly include: turning channel, minimum turning radius, swing value, etc.

(2) Traffic control factors for large operating buses
The traffic control factors that affect the traveling capability of large operating buses mainly include: speed.

(3) The factors of traffic conditions for large operating buses
The road conditions that affect the turning pass of large operating buses mainly include: the width of lanes, the radius of curves and the superelevation.

3. Principle of Traveling Capacity of Large Buses
The goal of the study is driver safety and driving efficiency. Different roads have different requirements for large operating buses. Roads used by different large operating buses are also different. In addition to the requirements of pavement width, the minimum turning radius and passage width are the indicators for evaluating the traveling capability and curvilinear driving performance of large operating cars.

To analyzed the traveling capacity of large operating buses through out curves, it is necessary to determine the required area, width of curve passage and required width of road for the whole bus to turn. The turning process of a large passenger bus is shown in Fig. 1.

![Figure 1. Schematic diagram of large operating passenger buses passing through curve](image)

Among them:
A-front suspension of large operating buses;
B-wheelbase of large operating buses;
C-rear suspension of large operating buses;
H-width of large operating buses;
R₁—radius of inner circle of turning passage for large operating buses;
R₂—the radius of the outer circle of the turning passage for large operating buses;
R₀—turning radius of mass center of large operating buses;
W—width of turning passage for large operating buses.

\[
R_1 = \sqrt{\frac{V^2}{\mu g} - \frac{B}{2} - \frac{H}{2}}
\]

\[
R_2 = \sqrt{\left(\frac{V^2}{\mu g} - \frac{B}{2} + \frac{H}{2}\right)^2 + (B+C)^2}
\]

\[
W = \sqrt{\left(\frac{V^2}{\mu g} - \frac{B}{2} + \frac{H}{2}\right)^2 + (B+C)^2} - \sqrt{\left(\frac{V^2}{\mu g} - \frac{B}{2} + \frac{H}{2}\right)^2 + \frac{B}{2} + \frac{H}{2}}
\]

According to the above formula, the traveling capability of large operating buses passing through curves is influenced not only by the vehicle's own parameters, but also by the friction coefficient between the vehicle and the ground and the vehicle's running speed.

4. Computer Simulation of Traveling capability of Large Operating Buses

4.1 Large Buses for Simulation and Actual Scene Test
The simulation selects the common large operating buses in China. The models are shown in Table 1:

| Vehicle parameter information | ZK6105CHEVNPG4 | braking distance | ≤10m(v=30km/h) |
|-------------------------------|----------------|------------------|-----------------|
| Gross weight                  | 16500kg        | Maximum grade ability of the automobile | 12%             |
| Curb weight                   | 11900kg        | Minimum turn radius of Vehicle | ≤24m            |
| Bodywork Length               | 10500mm        | Engine Location  | Rear            |
| Body width                    | 2500mm         | Engine Type      | YC6J210N-52     |
| Height of the vehicle body    | 3200mm         | Power Rating     | 155/2500(kW/rpm)|
| Number of Axles               | 2              | Maximum power    | 146/2500(kW/rpm)|
| Wheelbase                     | 5200mm         | Rated Torque     | 710/1500(N-m/rpm)|
| Front Overhang                | 2235mm         | Displacement     | 6.494L          |
| Rear Overhang                 | 30655mm        | Emission Standard| State V         |
| Front Tread                   | 2067mm         | Rated passenger  | 76/10-36,       |
|                               |                |                  | 70/10-36        |
|                               |                |                  | (conditioned)   |
| Rear Tread                    | 1860mm         | Maximum Speed    | 69km/h          |
| Minimum Gap                   | 200mm          |                  |                 |

4.2 Computer Simulation and Analysis of Traveling Capacity of Large Operating Passenger Buses
According to the main parameters in Table 1, the dynamics model of large bus is built by using Trucksim vehicle dynamics simulation software. Based on the actual route design parameters, a simulation environment with a circular curve radius of 13m, a road surface width of 7m and a driving speed of 15km/h as shown in Fig. 2 is established to analyze the traffic of large operating bus.
The left diagram and the right diagram of Fig. 3 show the running track and speed of the simulated vehicle on a circle curve with a radius value of 13m at 15km/h respectively. The right diagram of the figure shows that the simulated vehicle runs at a speed of about 15km/h in the whole process. The cyan curve on the left diagram is the ideal curve (i.e. lane center line) and the red curve is the actual curve of the vehicle. As can be seen from the figure, the vehicle can pass through a circular curve with a radius of 13m at a speed of 15km/h.
Fig. 4 is a lane offset value of a simulated vehicle running on a circular curve with a radius of 13m at a speed of 15km/h. Fig. 5 is a simulated screenshot of the simulated vehicle running on a circular curve with a radius of 13m at a speed of 15km/h. As can be seen from the figure, the lane deviation of the vehicle near the end of the curve reaches the maximum value of 0.62m, and encroaches on the opposite lane area during driving.

Fig. 6. Speed lateral force coefficient of 13m radius of 15km/h
Fig. 6 shows the lateral force coefficients of the front axle, rear axle and the whole vehicle running on a circular curve with a radius of 13m at the speed of 15km/h. The yellow line and the red line are the lateral force coefficient thresholds of 0.15 and 0.2 respectively, which are more uncomfortable and uncomfortable for drivers and passengers. It can be seen from the figure that the transverse force coefficient is the largest at the starting point of the curve, but the transverse force coefficient is all in a more comfortable area during the curve driving process.

4.3 Practical Scene Testing of Traveling Capacity of Large Operating Buses
In order to further verify the traveling capability of large operating buses passing through curves, the road in Wan Xian Mountain Scenic Area of South Taihang, Xinxiang is selected as the measured road. The measured road length is 5.7km, the minimum horizontal curve radius for sharp bends is 13m, and the measured road width of curves is 7m.

Through aerial observation by drone, the road flat curve radius of Wan Xian Mountain scenic spot is 13m, and the road surface width is 7m. During observation, vehicles all use the opposite lane to pass through the curve, as Fig. 7 shows. The measured results can well confirm the accuracy of the passing results of simulation analysis.

5. Conclusion
Based on the research on the traveling capability of large operating buses on mountainous highway, this paper analyzes the traveling capability principle and influencing factors of large operating buses, establishes the dynamic model of large ordinary buses by using Trucksim vehicle dynamics simulation software, and carries out computer simulation. Finally, the validity of the method is verified through the actual scene test of large operating buses and aerial photography observation by drone. The results of this paper have certain practical significance for analyzing the influence of road surface width, flat curve radius, super high and other factors on the traveling capability of large operating buses, as well as for improving the safe traffic capacity of large operating buses on mountainous highway and reducing the risk of serious road traffic accidents through measures such as widening roads, controlling speed and optimizing alignment.

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