

# Study on Urban and Rural Ecotone Vehicles Acceleration Interference Model

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**Abstract**— In this paper, the status quo of urban and rural ecotone road accident-prone, through the analysis of changes in vehicles acceleration feature, choice of three-direction acceleration interference as road safety indicators. Three-direction acceleration interference models are established based on acceleration interference theory. To select urban and rural ecotone typical sections, to measure vehicle acceleration changes under different road conditions, to conclude the main rule of traffic accidents, and to verify the validity of the acceleration model.

**Index Terms**— Urban and rural ecotone, three-direction acceleration, discretization of the model, acceleration interference model.

## I. INTRODUCTION

Urban and rural ecotone is the combined the binary zone [1]. Because of more type vehicles, more serious pedestrian and vehicle mixed traffic, leading to urban and rural ecotone bad road traffic environment [2]. During vehicles running, speed change is more complex and more fluctuation, especially vehicle acceleration change has an important impact on traffic safety. In urban and rural ecotone section, the vehicle will be affected by the road alignment, road condition and traffic flow, and drivers tend to be more frequent braking or acceleration, in order to keep the continuity of the vehicle running speed. The running speed may change at any time, frequent acceleration and deceleration of the case [3]. Intensity of vehicle speed change, i.e., the acceleration is more objective indicator of the changes of vehicle traveling state [4]. Therefore, speed fluctuation of vehicles can be represented by acceleration standard deviation [5], see the Equation (1).

$$\left\{ \begin{array}{l} \sigma = \left\{ \left( \frac{1}{T} \right) \int_0^T [a(t) - \bar{a}]^2 dt \right\}^{\frac{1}{2}} \\ \bar{a} = \left( \frac{1}{T} \right) \int_0^T a(t) dt \end{array} \right. \quad (1)$$

Where:  $\sigma$  - acceleration interference,  $m/s^2$ ,  $T$ —the total running time of the vehicles,  $s$ ,  $a(t)$  -  $T$  moment acceleration,  $m/s^2$ ,  $\bar{a}$  - average acceleration,  $m/s^2$ .

## II. URBAN AND RURAL ECOTONE THREE-DIRECTION ACCELERATION INTERFERENCE MODEL

### A. Lateral Acceleration Interference Model

When vehicles traveling along the road horizontal curve, by centrifugal force and centripetal force. In order to improve the stability of the vehicles, set the ultra-high angle horizontal curve in the road at the general, to overcome the centrifugal force generated when the vehicle is cornering.

Centripetal force and centrifugal force:

$$F_n = mg \tan \alpha \approx mg \sin \alpha \quad (2)$$

$$F_r = \frac{mv^2}{R} \quad (3)$$

Where:  $m$ -car quality,  $g$ -acceleration of gravity,  $\alpha$  - the road is ultra-high tilt angle,  $R$ -flat curve radius.

By the Equation (2) and the Equation (3) the lateral force of the vehicle suffered:

$$F_h = F_r \cos \alpha - F_n = F_r \cos \alpha - mg \sin \alpha \quad (4)$$

$$\text{Where: } \sin \alpha = \frac{h_c}{\sqrt{b^2 + h_c^2}}, \quad \cos \alpha = \frac{b}{\sqrt{b^2 + h_c^2}},$$

$h_c$  is an elevation value,  $b$  is on the curve as a curve somewhere on the road width half, into the Equation (1) can be obtained:

$$a_h = \left( \frac{V^2(t)}{R} - \frac{g}{b} \right) \frac{b}{\sqrt{b^2 + h_c^2}} \quad (5)$$

Lateral acceleration interference model by the Equation (5) and the Equation (1) can be obtained:

$$\left\{ \begin{array}{l} \sigma_h = \left\{ \left( \frac{1}{T} \right) \int_0^T \left[ \left( \frac{V^2(t)}{R} - \frac{g}{b} \right) \frac{b}{\sqrt{b^2 + h_c^2}} - \bar{a} \right]^2 dt \right\}^{\frac{1}{2}} \\ \bar{a} = \frac{1}{T} \int_0^T a(t) dt = \frac{1}{T} \int_0^T \left( \frac{V^2(t)}{R} - \frac{g}{b} \right) \frac{b}{\sqrt{b^2 + h_c^2}} dt \end{array} \right. \quad (6)$$

### B. Axial Acceleration Interference Model

Axial acceleration is generated in the axial acceleration and deceleration of the traveling vehicle, the axial acceleration direction with the vehicle traveling direction, the acceleration

size depends on the dynamic performance of the vehicle and the running resistance can be expressed as:

$$a_z = \frac{\lambda g}{\delta} (D - f - i) \quad (7)$$

Where:  $\lambda$  - altitude load correction factor,  $\delta$  - inertia force coefficient,  $D$  - automotive power coefficient,  $f$  - rolling resistance coefficient,  $i$  - vertical slope.

$$i = \frac{dy}{dx} = i_1 \pm \frac{l}{R_s} \quad (8)$$

The power coefficient  $D$  as:

$$\begin{cases} D = \frac{KT_0 - K'V^2(t)}{G} \\ K = \frac{i_g i_0 \eta_T}{r} \\ K' = \frac{C_D A}{21.15} \end{cases} \quad (9)$$

Where:  $i_g$  - the vehicle transmission speed ratio,  $i_0$  - the main reduction gear rotation ratio,  $\eta_T$  - inertia coefficient,  $r$  - wheel radius,  $C_D$  - air resistance coefficient,  $T_0$  - loading rate, the paper take 100%,  $A$  - vehicles traveling direction of the projection area.

By the Equation (7), the Equation (8) and the Equation (9) known, the axial direction of the straight slope segment acceleration is:

$$a_z = \frac{\lambda g}{\delta} \left( \frac{KT_0 - K'V^2(t)}{G} - f - i \right) \quad (10)$$

By the Equation (10) and the Equation (1) axial acceleration interference model is:

$$\begin{cases} \sigma_z = \left\{ \left( \frac{1}{T} \right) \int_0^T \left[ \frac{\lambda g}{\delta} \left( \frac{KT_0 - K'V^2(t)}{G} - f - i \right) - \bar{a} \right]^2 dt \right\}^{\frac{1}{2}} \\ \bar{a} = \frac{1}{T} \int_0^T a(t) dt = \frac{1}{T} \int_0^T \frac{\lambda g}{\delta} \left( \frac{KT_0 - K'V^2(t)}{G} - f - i \right) dt \end{cases} \quad (11)$$

### C. Vertical Acceleration Interference Model

Vehicles traveling on a vertical curve generate the vertical centrifugal force, which produce vertical acceleration. This is due to the vertical section on the vertical curve caused, different vertical curve radius different vertical acceleration, namely:

$$a_s = \frac{V^2(t)}{3.6^2 R_s} = \frac{V^2(t)}{12.96 R_s} \quad (12)$$

Where:  $R_s$  - radius of curvature at the largest radius of curvature, m.

Can be obtained by the Equation (12) and the Equation (1) vertical acceleration interference model is:

$$\begin{cases} \sigma_s = \left\{ \frac{1}{T} \int_0^T \left[ \frac{V^2(t)}{12.96 R_s} - \bar{a} \right]^2 dt \right\}^{\frac{1}{2}} \\ \bar{a} = \frac{1}{T} \int_0^T a(t) dt = \frac{1}{T} \int_0^T \frac{V^2(t)}{12.96 R_s} dt \end{cases} \quad (13)$$

### D. Model Discretized

Using equipment to consecutive time intervals ( $\Delta t$ ) detecting the vehicle running acceleration, acceleration interference model is:

$$\sigma = \left\{ \left( \frac{1}{T} \right) \sum [a_i - \bar{a}]^2 \Delta t \right\}^{\frac{1}{2}} \quad (14)$$

Where:  $T$  is the observation time,  $a_i$  for time acceleration,  $\bar{a}$  average acceleration,  $\Delta t$  time equal-length sampling.

Of  $\sum [a_i - \bar{a}]^2 \Delta t$  transformation:

$$\sum [a_i - \bar{a}]^2 \Delta t = \sum a_i^2 \Delta t - \sum 2a_i \bar{a} \Delta t + \sum \bar{a}^2 \Delta t = \sum a_i^2 \Delta t - 2\bar{a} \sum a_i \Delta t + \bar{a}^2 T = \sum a_i^2 \Delta t + \bar{a}^2 T$$

Substituting acceleration interference Equation is:

$$\sigma = \left\{ \left( \frac{1}{T} \right) \sum a_i^2 \Delta t - \bar{a}^2 \right\}^{\frac{1}{2}} = \left\{ \frac{\Delta t (T - \Delta t)}{T^2} \sum a_i^2 \right\}^{\frac{1}{2}} \quad (15)$$

The Equation (15) into the Equation (6), the Equation (11) and the Equation (13) obtained:

$$\sigma = \begin{cases} \left\{ \frac{\Delta t (T - \Delta t)}{T^2} \sum \left[ \left( \frac{V^2(t)}{R} - \frac{g}{b} \right) \frac{b}{\sqrt{b^2 + h_c^2}} \right]^2 \right\}^{\frac{1}{2}} \\ \left\{ \frac{\Delta t (T - \Delta t)}{T^2} \sum \left[ \frac{\lambda g}{\delta} \left( \frac{KT_0 - K'V^2(t)}{G} - f - i \right) \right]^2 \right\}^{\frac{1}{2}} \\ \left\{ \frac{\Delta t (T - \Delta t)}{T^2} \sum \left[ \frac{V^2(t)}{12.96 R_s} \right]^2 \right\}^{\frac{1}{2}} \end{cases} \quad (16)$$

## III. MEASURED ACCELERATION ANALYSIS

Test sections selected in Harbin, two sections of urban and rural ecotone. First experimental section for isolation fence section, second experimental section for un-isolation fence section. During the test, the vehicle is running possible speed. Good road condition means the road surface is clean, smooth, and not consider the snow, icing and snowfall, good traffic condition is free stream running state, does not consider cross, pedestrians and non-motorized interference, the driver who is skilled is able to skillfully driving a vehicle is in good health, tend to travel at higher speeds, but not risky. Consider security reasons, the principles of the above possible speed corresponding prediction model calculation, under certain conditions, can be obtained by actual measurement. This paper refers to possible speed to meet the basic road condition, traffic condition, and driver quality premise vehicle maximum safe running speed.

The experimental data of the vehicle traveling in the 1st section is shown in Fig. 1, Fig. 2, Fig. 3.

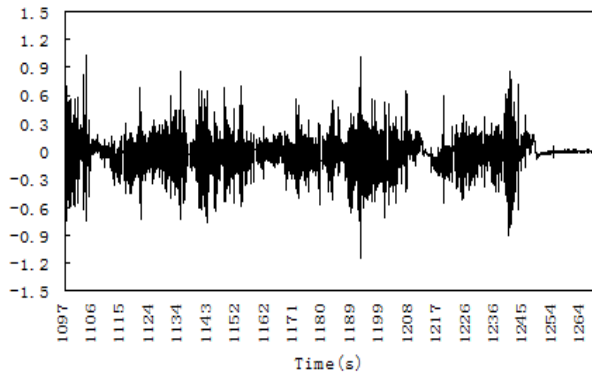


Fig.1 Longitudinal acceleration

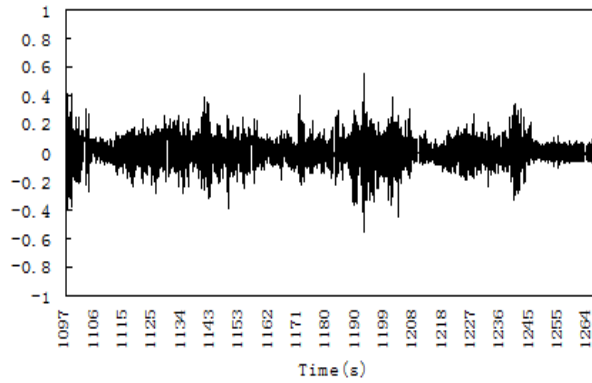


Fig.2 Lateral acceleration

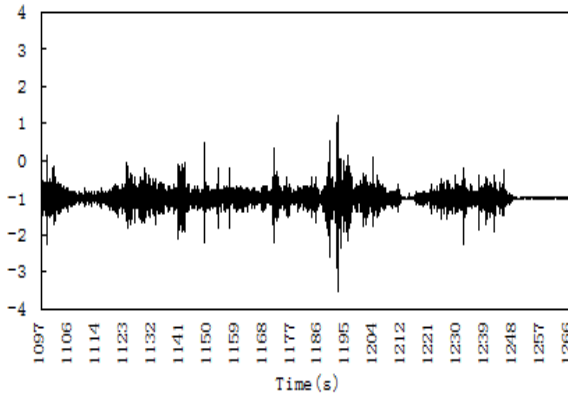


Fig.3 Vertical acceleration

The experimental data of the vehicle traveling in the 2nd section is shown in Fig. 4, Fig .5, Fig .6.

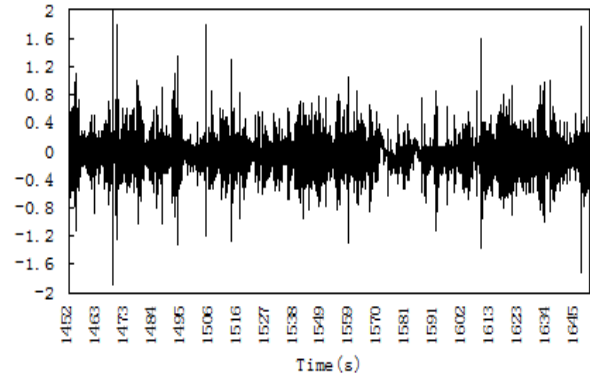


Fig. 4 Longitudinal acceleration

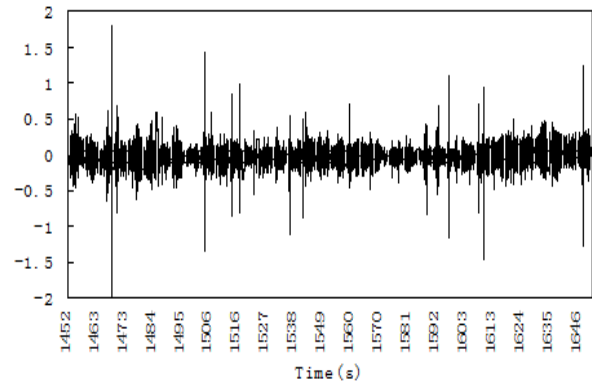


Fig.5 Lateral acceleration

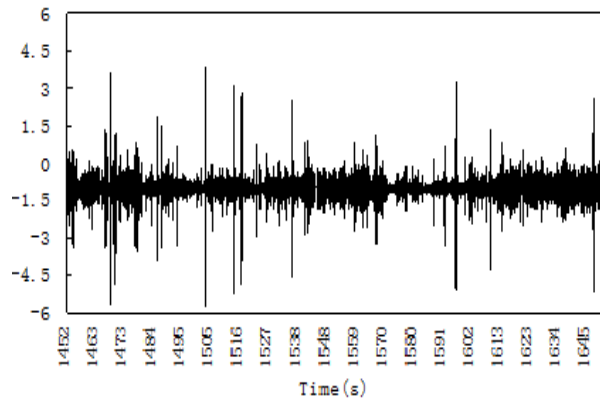


Fig.6 Vertical acceleration

## CONCLUSION

Use of urban and rural ecotone roads measured experimental data, the combination of these models can be calculated in the urban and rural ecotone with the changes in the characteristics of the different sections of the vehicle in speed. Through analysis of two types of urban and rural ecotone respectively measured the resulting data , found that the types of road traffic accidents are significant difference in different urban and rural ecotone sections. On the isolation fence section, vehicles lateral acceleration larger, vehicles scraping a high proportion of traffic accidents, without the

isolation fence section, vehicles longitudinal acceleration larger, vehicles rear-end accidents a high proportion.

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