The Comfort Measurement of Urban Railway Train Based on UIC513 Standard

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Abstract: Combining with the characteristics of train operation of rail transit, this paper adjusted the measuring point and measuring time in the UIC513 standard, so as to apply it to calculate the vibration comfort of urban railway train. On this basis, the data acquisition equipment was made to implement the test of practical carrying operation on Chengdu Metro Line 1. Meanwhile, by means of the UIC513 standard and the improved method, the acquired data was used to calculate the comfort level respectively; finally, the results were compared.

1 INTRODUCTION

Due to the constant increase of passenger flow volume in urban rail transit, most passengers will have to face the situation of taking the train by standing; that is to say, the vibration and impact during train operation will greatly influence their travel experience. For this reason, the comfort of train operation has become another research emphasis in the ATO system following safety, punctuality and energy conservation. The UIC513 standard in International Union of Railways renders a model of calculating passengers' comfort through collecting the vibration acceleration of railway train. Because of convenient calculation and explicit output result, this standard is widely applied to the train operation optimization of interurban railway. Nowadays, the researches on comfort of urban rail transit in China are few and they mostly adopt the UIC513 standard directly. For example, via the UIC513 standard and the Sperling stationarity calculation model, Professor Zhu Jianyue from Tongji University implemented experiment on Shanghai Metro Line 1 and obtained the data concerned on comfort and stationarity. According to the operation characteristics of urban rail transit, this paper adjusted the comfort calculation method in the UIC513 standard and obtained an approach to measure comfort of urban rail transit. Through practical tests on Chengdu Metro Line 1, the comfort data using the UIC513 and the adjusted method was calculated and acquired. After comparing the above results, the conclusion showed that the adjusted method is more significant.

2 CALCULATION MODEL

2.1 Calculation Model of Comfort in UIC513 Standard

UIC513 standard classifies the measurement of comfort into three conditions, which include simplified measurement method in sitting or standing position, complete measurement method in sitting position and complete measurement method in standing position. This paper adopts the simplified method applicable to both sitting and standing positions, whose comfort calculation formula is as follows:

$$N_{MV} = 6\sqrt{(a_{XP95}^{W_d})^2 + (a_{YP95}^{W_d})^2 + (a_{ZP95}^{W_b})^2} \qquad (1)$$

Where, N_{MV} is a comfort index; a reoresents effective acceleration and its superscript W_i is a weight parameter; $i, i=(b,c,d)$ represents weight curve, among which b is vertical weighing mode, c is seat backrest weighing mode, d is horizontal weighing mode and the subscript $\sigma, \sigma=(X,Y,Z)$

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means the direction of axis measured by sensor; the superscript $j, j=(A,P,D)$ stands for measurement position, among which A is seat surface, P is floor and D is seat backrest; and the subscript k is the confidence parameter, $k=(50,95)$ means to implement probability process based on confidence coefficient of 50% or 95%. The ratings of comfort indexes acquired by calculation are shown in Table 1.

Table 1: Comfort Level and Evaluation of UIC513.

Comfort level	Evaluation scale	Comfort Description
1	N<1	Very good comfort
2	1<N<2	Good comfort
3	2<N<4	Moderate comfort
4	4<N<5	Poor comfort
5	N>5	Very poor comfort

With respect to the railway train in suburbs, N shall not be greater than 4; for common railway train, N shall not be greater than 3, and the luxury train shall be less than 2.

2.2 Acceleration Data Acquisition and Processing Method in UIC513 Standard

The calculation flow chart of each unit in digital method is shown in figure 1.

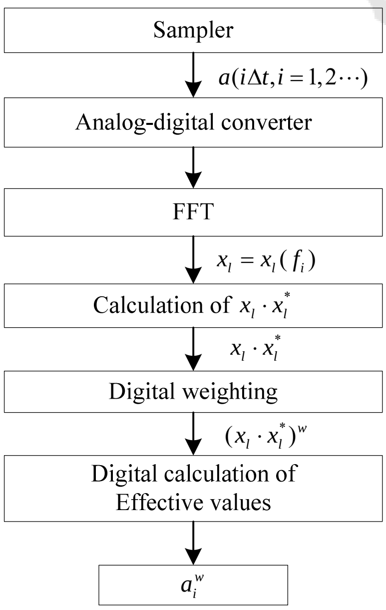

Figure 1: Digital method of comfort calculation.

The sampling process was divided into multiple 5-minute continuous time quantums, where the data in time length of 5 seconds was regarded as one unit for calculation of weighed effective value; based on the weighing calculation (see the Fig. for weighing curve) of data in three directions of axis, the weighting effective value was obtained. By taking the confidence points with complete effective value of 50% or 95% in single time quantum, the acceleration in three directions was induced into the formula (1) to obtain comfort value; finally, through taking arithmetic mean of comfort value corresponding to all continuous time quantms, the comfort index of entire test railway section were obtained.

2.3 Improvement Based on Operation Characteristics of Urban Rail Transit

There are prominent differences between urban rail transit and interurban railway in vehicle type, operation mode and passengers' travel mode. Therefore, the direct application of the UIC513 standard in calculating the operation comfort of urban rail transit could result in deviations without sufficient reference significance. For this purpose, the measurement method recommended by the UIC513 standard is adjusted as follows.

2.3.1 Adjustment of Measurement Time

The length of run time between two stations in most of interurban railways is within 1-2 minutes, which is shorter than 5 minutes. So train stopping for passengers to get on and off will definitely appear during the acquisition of vibration acceleration in 5 continuous minutes, whose data in calculation will greatly influence the practical significance of calculation result. For this reason, the complete run time from the starting station to the next stop station is set as the length of test time, where the data in every second is regarded as one calculation unit.

2.3.2 Adjustment of Measurement Position

Different from interurban railway, most of passengers have to take the urban rail transit by standing, so the arrangements of test points are in standing position (fixed on train floor). According to the passenger distribution regularity in rush hour of Chinese urban rail transit, the test points are adjusted to the intersection points of each pair of doors and the axle wire of carriage.

3 EXPERIMENTAL PROCESS AND RESULT ANALYSIS

After communicating with operator, the practical test was implemented on the south extension line of Chengdu Metro Line 1, and then the test results were analyzed briefly.

3.1 Experiment Process

The experimented train is a standard type B metro vehicle, the test line is Chengdu Metro Line 1 South extension line, whose starting point is the Guang Du station, and its terminal is the Century City station, the total mileage is 5.53 kilometers, and the running time is about 8 minutes. The test time was at 9:00 a.m. The train was under the ATO AM mode. In order to reduce disturbance to passengers, the test was carried out in the end of experimented train (carriage number 1011206). The test apparatus were 4 vibration acceleration gathering boards, which were powered by dry cell and pasted on train floor through packing tape before departure, as shown in figure 2 The MPU6050 motion sensor was used to collect the acceleration of three axes. After frame encapsulation of data via the ARM Cortex-M4 processor, the HC-05 Bluetooth module sent the data frame to laptop for digital weighing and comfort calculation. Each axial sampling rate was set at 250Hz and the position is shown in figure 3. The acceleration gathering boards kept working during the entire experiment process. When calculating comfort under the adjusted model, it is necessary to distinguish train operation status based on the variation acceleration data of X axle direction, so as to introduce all acceleration data into the calculation formula when the train is running but remove it when the train is stopping for passengers to get on or off from calculation.

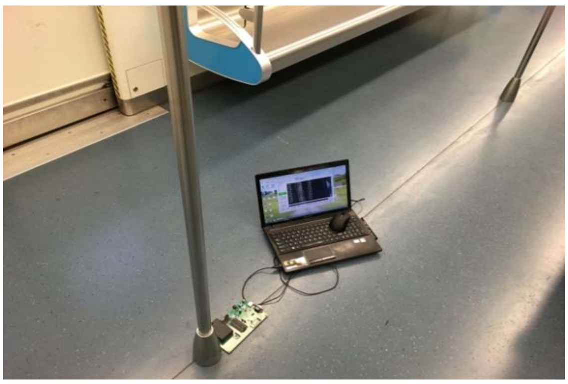

Figure 2: Acceleration measuring device.

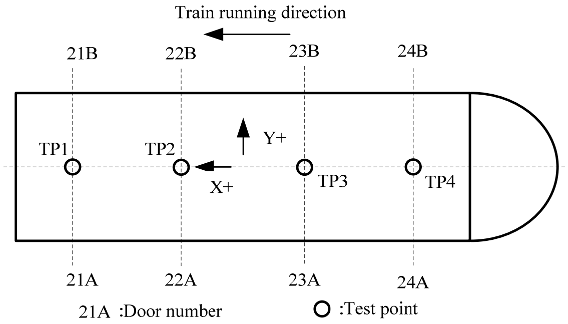

Figure 3: Sampling point distribution.

3.2 Result Analysis

After computing the average of vibration acceleration measured at the same time in four test points, the comfort is calculated according to the method in the UIC513 standard. Considering acceleration data in 5 continuous minutes as a group of samples and data in every 5 seconds as one computing unit, the whole recording period of 480 seconds can generate 36 groups of comfort data, which are shown in figure 4. This indicates that the comfort of this travel is evaluated as good comfort.

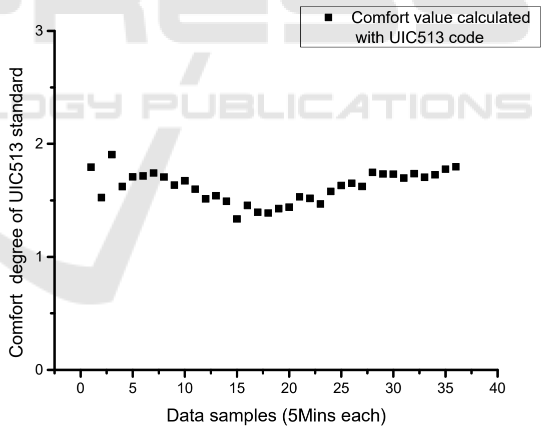

Figure 4: Comfort values calculated with method of UIC513 Standard.

Table 2 shows the comfort calculated by the vibration acceleration of 4 test points with adjusted method. It shows that the comfort values of all test points are within the interval 2-3, which are rated as moderate comfort. Notablely, the comfort of TP2 and TP3 test points, which are in the middle of carriage are superior to that of TP1 and TP4 in two ends. It is speculated that this could be caused by the relatively large vibration in TP1 and TP4 which are located above bogies.

Table 2: Comfort values calculated with adjusted method.

Section name \ Test point	TP1	TP2	TP3	TP4	Average
Sihe-Guangdu	2.443	2.248	2.256	2.627	2.3935
Huafu Avenue-Sihe	2.899	2.727	2.593	2.999	2.8045
5th Tianfu Street-Huafu Avenue	2.573	2.203	2.265	2.714	2.4388
3rd Tianfu Street-5th Tianfu Street	2.482	2.166	1.986	2.465	2.2748
Century City-3rd Tianfu Street	2.987	2.795	2.470	2.890	2.7855
Average value of a fixed TP during whole trip	2.677	2.428	2.314	2.739	2.5395

The comparison between data in figure 4 and the average comfort values of 4 test points in the same interval in Table 2 indicates that their variation tendency conforms to each other. However, the average comfort values acquired by directly adopting the UIC513 standard are greater than the values acquired by the adjusted method. Analyzing the acceleration data of samples, this situation caused by exclusion of the data during train stopping from calculation with the adjusted method, this is shown in figure 5. As the UIC513 standard stipulated, the trains shall be in operation state during the process of gathering acceleration. On this premise, when the interurban train stops at station, the acceleration values are approaching to 0 emerged in three directions simultaneously. The train will be regarded as in the state of uniform linear motion, in another word, the train runs stably. Therefore, the comfort value acquired by calculation is much lower while the comfort evaluation is higher.

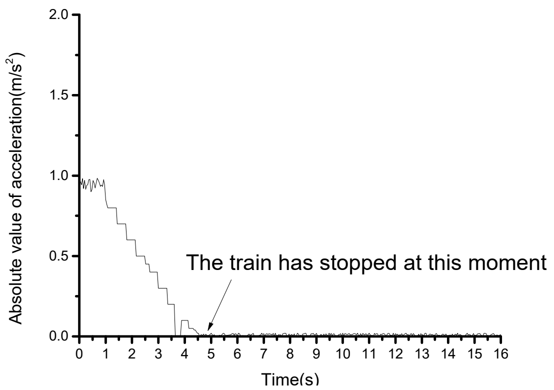

Figure 5: Acceleration data from x-axis of train parking period.

4 CONCLUSIONS

Based on above analysis, this paper believes that by stetting test points according to passenger flow density and removing the acceleration data acquired during train stopping from the calculation unit, comfort value obtained by the adjusted model, is more practical and representative than the that obtained directly applying the UIC513 standard. The model of adjusted method can provide reference for the comfort optimization of the ATO system in urban rail transit.

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