THE STUDY OF TRAIN INTELLIGENT MONITORING SYSTEM USING ACCELERATION OF ORDINARY TRAINS

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ABSTRACT

Local railways, even though they have a very limited budget, need to keep high safety standards and maintain their railway system. Therefore, we are developing a low-cost railway monitoring system that can be installed in ordinary trains. The field measurements were carried out in a Local Railway with the accelerometer installed on the floor of the train. First, we developed a train position identification method using GPS sensor and train velocity. Second, we confirmed the relation between train acceleration and track irregularity. The acceleration of the train can be calculated from the track irregularity using the equations of motion of a train. Finally, we developed TIMS (Train Intelligent Monitoring System) that is capable of monitoring railway track irregularities.

INTRODUCTION

Maintenance is very important especially in Railway system. Major Private Railways and Japan Railways developed and use new technologies to rationalize maintenance and increase safety. But, local railways can't allocate enough budget for maintenance of their facilities because they have a very limited budget. They need simple and low-cost maintenance system.

Railway tracks are facilities managed by regular maintenance. The maintenance of tracks is most important because any irregularities on the tracks directly lead to accidents. Studies have been conducted to rationalize maintenance system for railway tracks. It was proposed by Furukawa, et.al. [1], that train dynamic phenomena be predicted using system identification approach; and other methods were proposed by some researchers [2]~[4]. But, these methods can't be applied to local railways because these methods need high technical knowledge and renovation of the train. So, a low-cost and simple monitoring system for local railways was studied in this research.

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THE OUTLINE OF TIMS

We developed the Train Intelligent Monitoring System (TIMS) that can be installed in ordinary trains. The features of this system are as follows: First, it needs only a low budget for introduction and operation. Second, it doesn't need technical knowledge for operation. Third, it doesn't need renovation of the train and can easily be installed in ordinary trains. The measurement system of TIMS consists of accelerometers installed on the floor of the train and a GPS sensor for position identification. Figure 1 shows the outline of TIMS. We carried out field measurements in a local railway. The local railway has 26.8 km single track and one train car. Figure 2 shows the arrangement of the system components during field measurement. All equipments were installed at the end of the train.

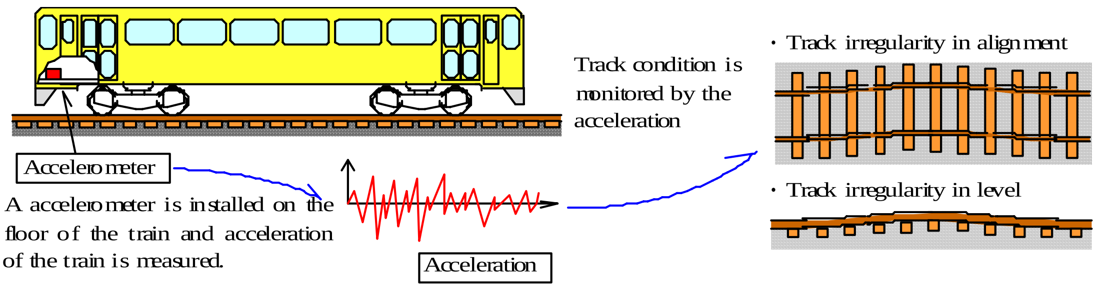


Figure 1: The outline of Train Intelligent Monitoring System

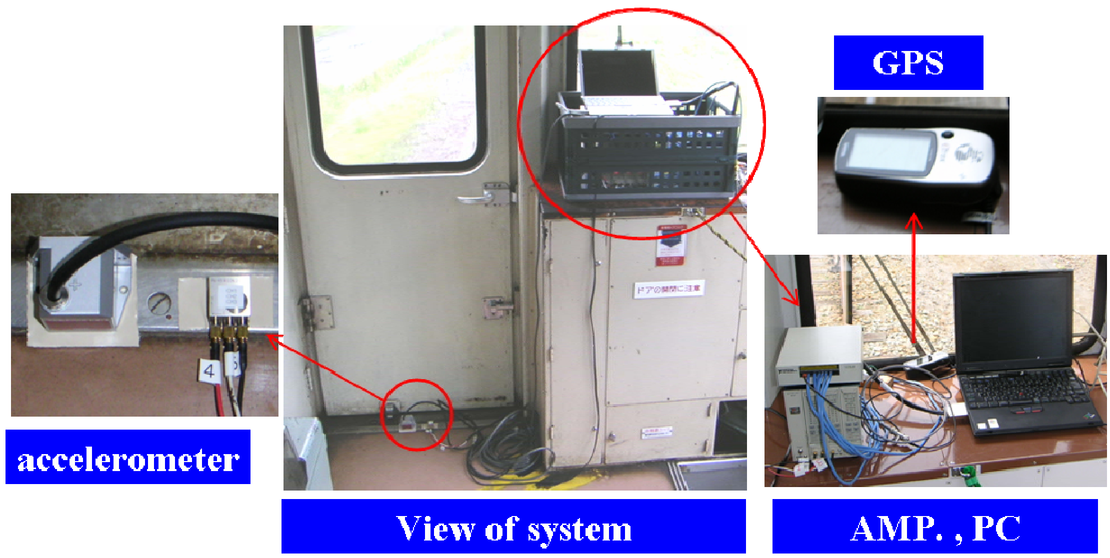
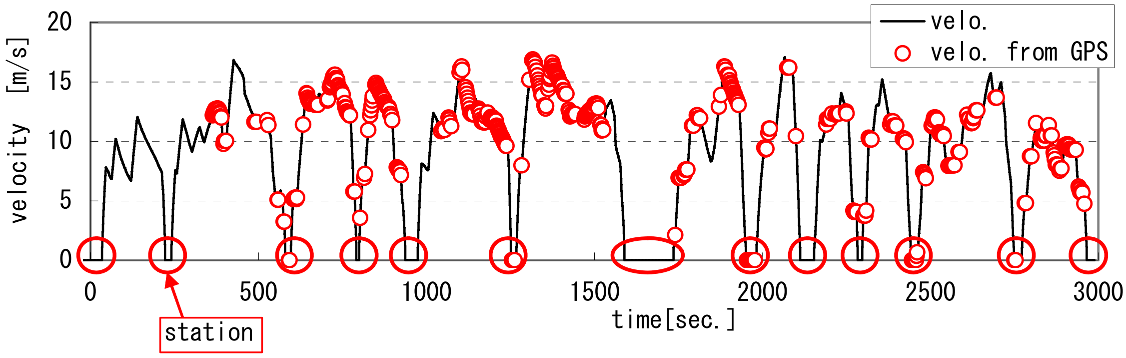


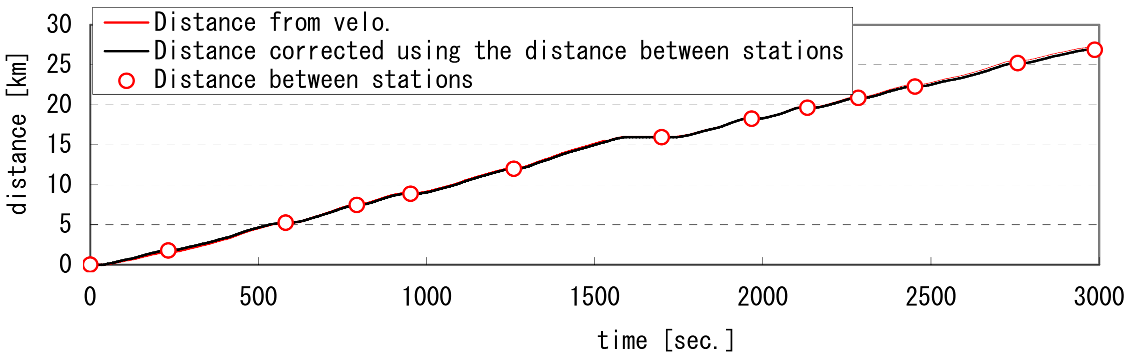
Figure 2: Measurement System Components during field measurement

THE POSITION IDENTIFICATION METHOD

Initially, the velocity of the train taken from the GPS sensor was used for train position identification. But, we couldn't get the GPS data continuously because the signal reception of the GPS wasn't good at mountain sides and stations which had roof. Therefore, we needed a new position identification method. In this new method, the distance between stations, the train velocity taken from the GPS sensor and the train velocity calculated by integrating the longitudinal acceleration were used. First, the times when the train stopped at the stations were identified from the lateral and vertical accelerations of the train. Second, the velocity of the train was calculated by integrating the longitudinal acceleration. The velocity data was corrected by the GPS data and the velocity when the train stopped at the station. Fig.3(a) shows the identification results of the train velocity. Third, the distance the train traveled was calculated by integrating the velocity data. The distance data was corrected by the distance between stations which is usually known. Fig.3(b) shows the identification results of the distance the train ran. The merits of this method are, it is low-cost and there is no need to renovate the train car. The demerit of this method is, it is not accurate. The amount of error is around several ten meters. For comparing two records, the Dynamic Planning Matching method was used.



(a) Train velocity



(b) Travel distance

Figure 3: Train velocity and distance traveled identified by the new method

THE VERIFICATION OF REPEATABILITY OF TRAIN ACCELERATION

Fig.4 shows the time and frequency domain accelerations measured in the field. To reduce noise and remove the effect of high frequency vibration, a low-pass-filter (20Hz) was applied. Fig.4 shows that the dominant frequencies of lateral and vertical accelerations are smaller than 3Hz. These dominant frequencies are free vibration components of the train. Fig.5 shows an example of two acceleration records measured at a straight track. Fig.6 shows an example of two acceleration records measured at a curved track. These figures show that repeatability of acceleration measurements is very good. It was confirmed that the train acceleration depends on track irregularity in the vertical and lateral direction.

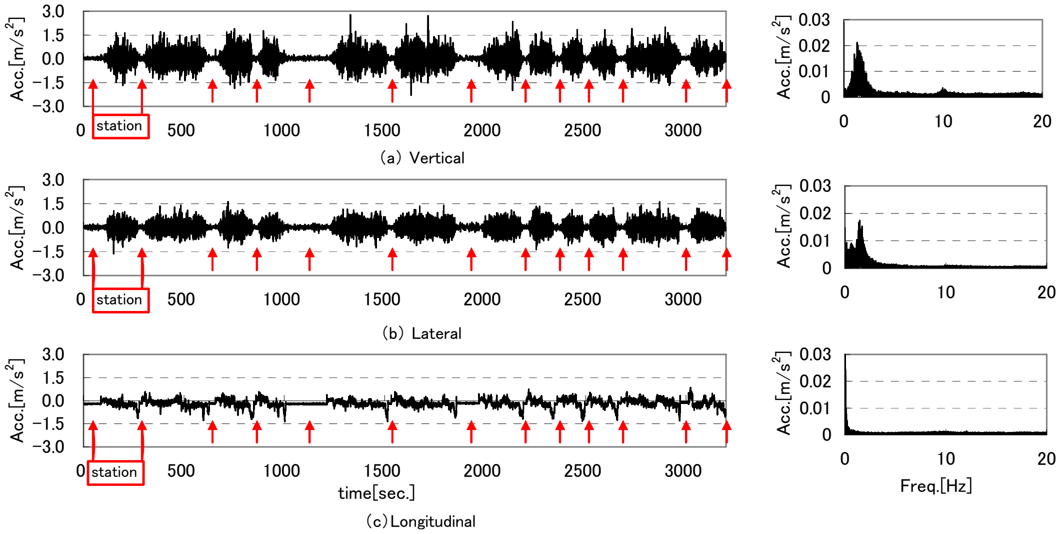


Figure 4: Train acceleration measured by TIMS

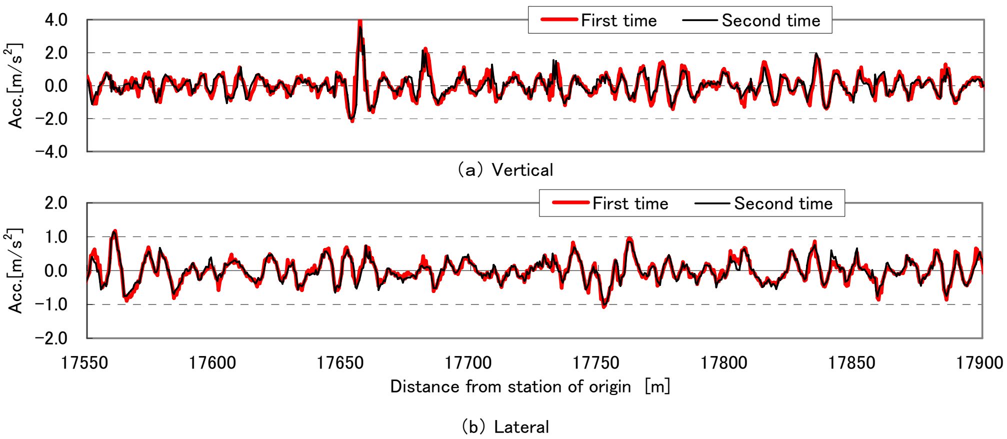


Figure 5: Two acceleration records measured at a straight track

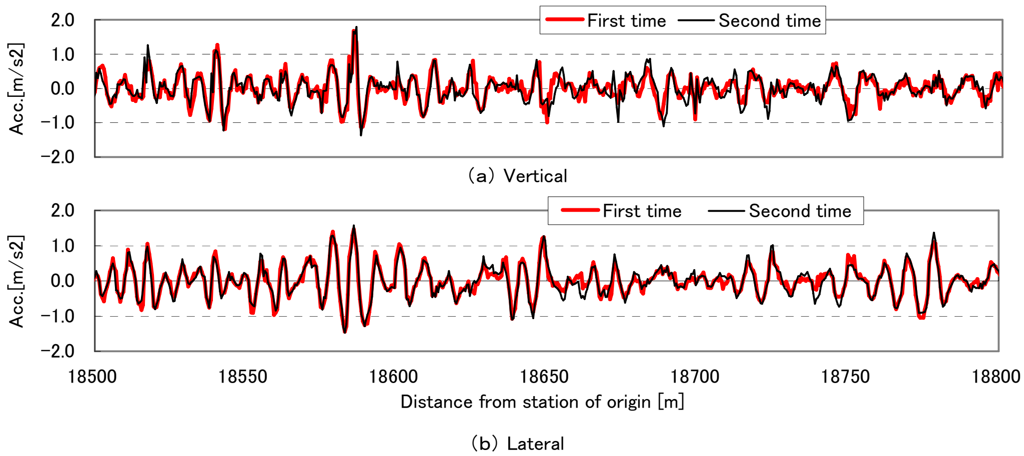


Figure 6: Two acceleration records measured at a curved track

ANALYSIS USING EQUATIONS OF MOTION OF A TRAIN MODEL

To confirm the relation between train acceleration and track irregularity, the analysis using the equations of motion of the train model was conducted. Fig.7 shows the train model for the vertical and lateral directions. The model for the vertical direction has 3 masses and 6 degrees of freedom. The model for the lateral direction has 3 masses and 8 degrees of freedom. The track irregularity taken by conventional method was used in the train model. Fig.8(a) shows the vertical acceleration measured during field measurement. Fig.8(b) shows the vertical acceleration calculated using the train model. Fig.8 shows that there is good agreement between the measurement and analysis results. To compare the measurement with the analysis result quantitatively, the RMS values were calculated. Fig.9 shows the RMS value of the measurement and analysis results. This figure shows that there is overall good agreement between the RMS values calculated from the measurement and analysis results. The coefficient of correlation between the two values is 0.78. Thus, it was confirmed that the acceleration of a train can be calculated using the equations of motion and track irregularity.

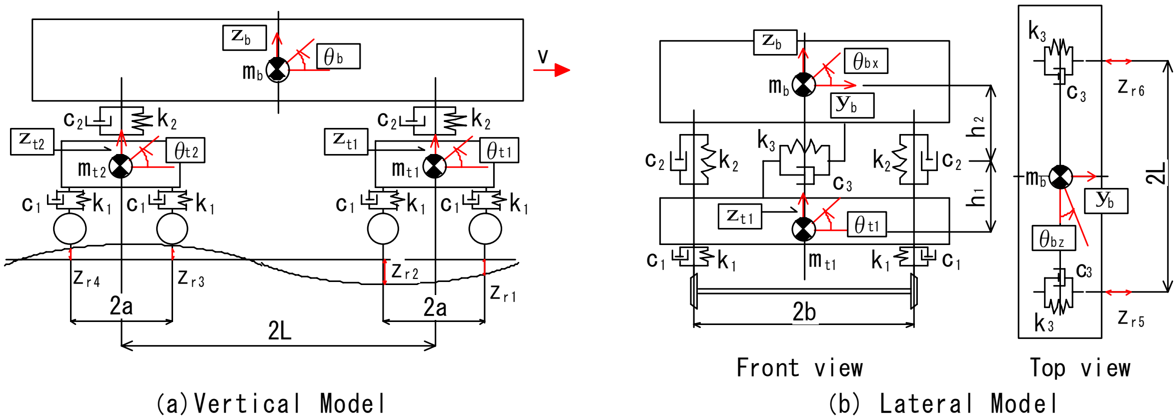


Figure 7: Train Model

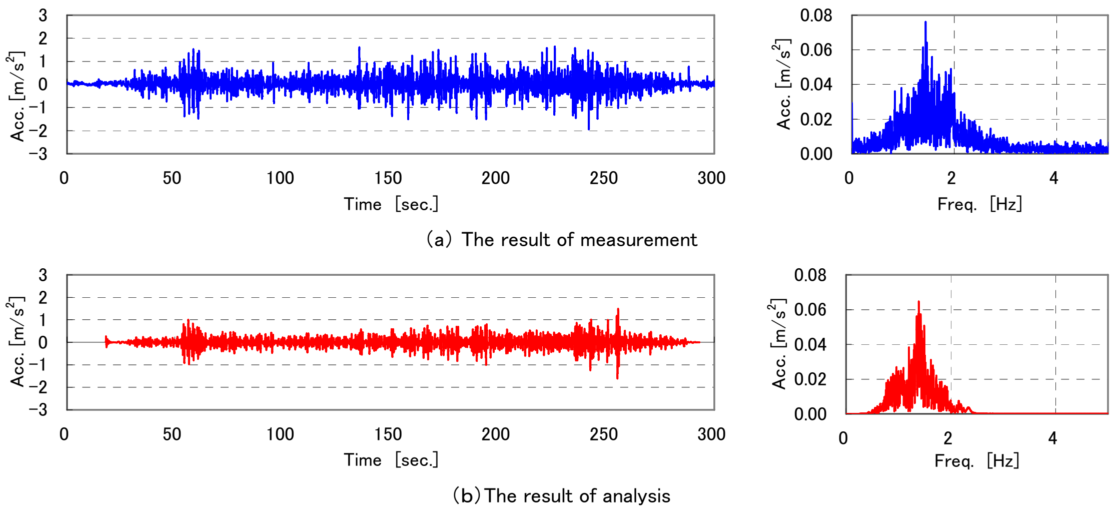


Figure 8: The Vertical acceleration measured by TIMS and calculated using train model

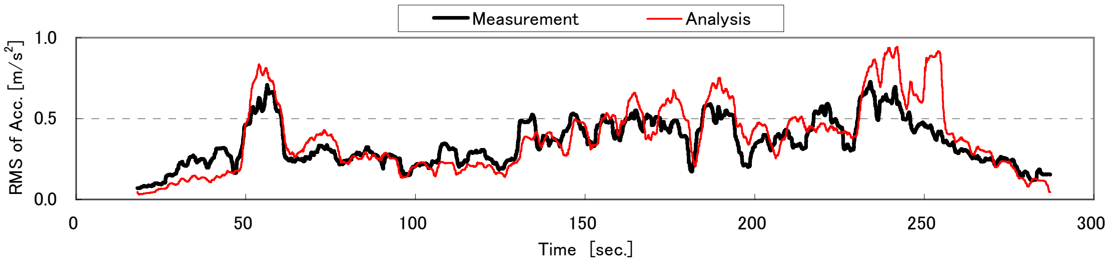


Figure 9: The RMS value of train acceleration

THE MONITORING SYSTEM USING TIMS

For monitoring the track condition, the acceleration measured by TIMS is compared with a control limit. Therefore, for monitoring changes in the track condition, the variation with time of the acceleration, measured daily by TIMS, is monitored.

The control limits for acceleration were calculated by setting control limits for track irregularity using the train model. Fig.10(a) shows an example of the control limit for track irregularity. Fig.10(b) and (c) show the train acceleration when the train speed is 60 kph. Fig.10(d) shows the relation between the train velocity and acceleration. The acceleration of the train depends on the train speed. The control limit for acceleration can be decided using Fig.10(d).

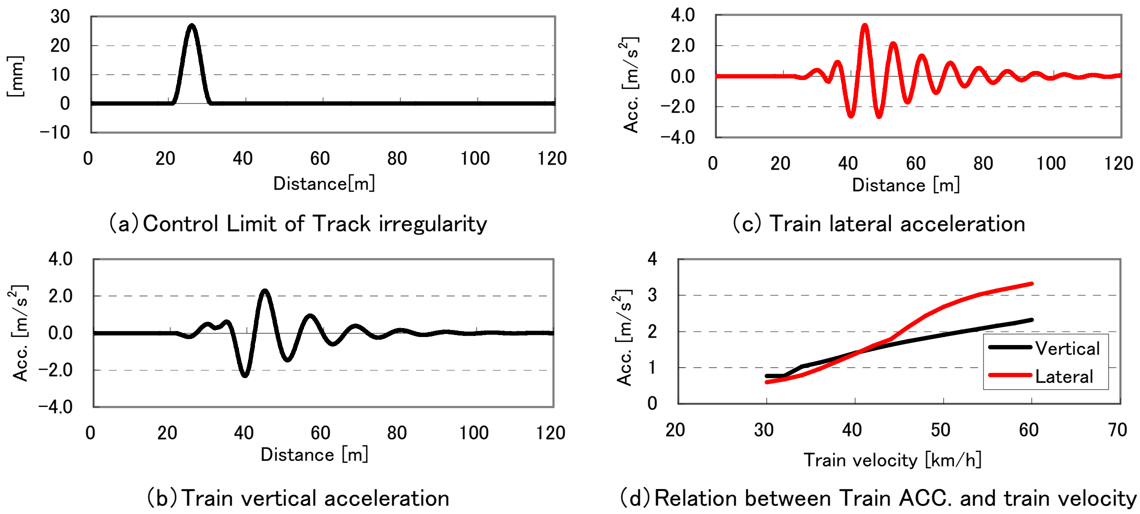


Figure 10: The control limit for train acceleration

The change in the track condition is monitored by checking the variation of the RMS value of acceleration measured by TIMS. Fig.11 shows the RMS value of the train acceleration measured on Feb.2005 and Dec.2005. This figure shows that the track condition around 14.5km on december was worse than the track condition on february.

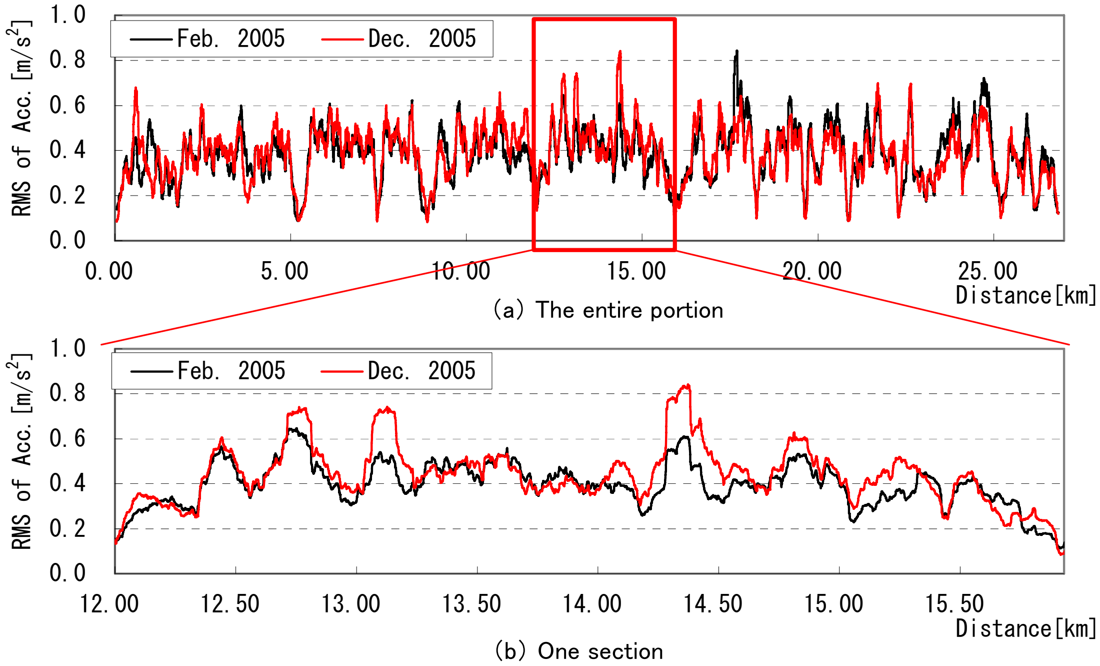


Figure 11: Changes in train acceleration

CONCLUSIONS

In this research, we conducted a study of the Train Intelligent Monitoring System (TIMS) for local railways that can be installed in ordinary trains. First, the train position identification method using accelerometer and GPS sensor was developed. Second, the repeatability of acceleration was confirmed by comparing two measured data. This shows that the train acceleration depends on the track condition. Third, the relation between train acceleration and track condition was confirmed using the equations of motion of the train model. It was confirmed that the train acceleration can be calculated by the equations of motion of the train model and track irregularity. Finally, we developed TIMS, which can easily monitor the condition of the railway tracks.

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