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RESEARCH RESULTS
FRA OFFICE OF RAILROAD POLICY & DEVELOPMENT

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DEVELOPMENT OF AN ULTRA-PORTABLE RIDE QUALITY METER

SUMMARY

FRA's Office of Research and Development has funded the development of an ultra-portable ride quality meter (UPRQM) under the Small Business and Innovative Research (SBIR) program. Track inspectors can use the UPRQM to locate segments of track that may have safety defects such as irregular track geometry or poor vertical support. In addition, the UPRQM can be used by researchers studying rail vehicle dynamics and vehicle-track interaction issues.

The UPRQM runs on a standard laptop or tablet and has an intuitive user interface that consists of vertical, lateral, and longitudinal acceleration strip charts (Figure 1), a list of exception locations, and a Geographic Information System (GIS) display (Figure 2).

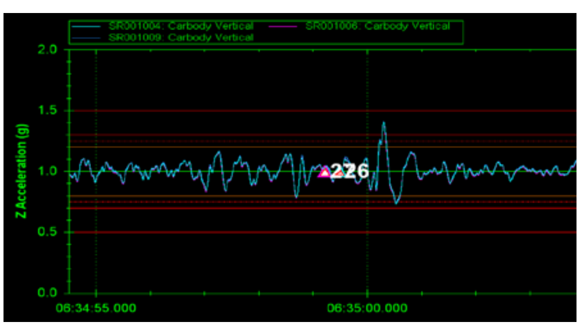

Figure 1. Acceleration Strip Chart

These features allow the user to pinpoint his/her location on the track, as well as the location of nearby grade crossings, bridges, and track distance markers. Additional software features include data analysis tools that can be used by researchers investigating rail vehicle dynamics. Ride comfort and health exposure analyses based on the International Organization for Standardization (ISO) 2631, "Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration," can also be performed.

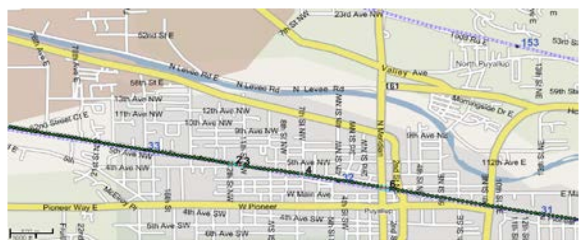

Figure 2. GIS Display

The hardware is ultra-portable and consists of a compact GPS unit, as well as a compact tri-axis accelerometer unit, both of which are connected to the user's laptop via a USB or wireless connection (Figure 3).

Figure 3. Ultra-Portable Ride Quality Meter Hardware

The UPRQM has been beta-tested by FRA inspectors in the field, as well as by researchers at the John A. Volpe National Transportation Systems Center. Feedback from these end users has helped shape the features and functionality of the UPRQM.

BACKGROUND

Timely and effective track inspection methods are required to ensure the safety and efficiency of rail operations. Since railway networks cover wide geographic areas, significant resources are required to perform thorough track inspections at routine intervals. Currently, the railroad industry conducts regularly scheduled visual inspections, which are required under Subpart F of the Track Safety Standards (Title 49 Code of Federal Regulations, Part 213). These visual inspections are either conducted on foot or in a hi-rail vehicle. In addition to visual inspections, the railroad industry also utilizes a number of automated inspection techniques, including rail internal defect detection systems and track geometry measurement systems.

To ensure compliance with Federal Track Safety Standards, FRA's Office of Railroad Safety audits railroad track inspection and maintenance activities. Regional track specialists typically supervise 8 to 12 track inspectors. Due to the relatively low number of track inspectors, FRA is generally limited to conducting "spot-check" visual inspections which serve as a quality check on the railroad's internal track inspection processes and personnel. Presently, FRA track inspectors evaluate the ride quality of a rail vehicle by manually noting "rough ride" locations while riding on in-service vehicles. Such a process is subjective as to what an individual inspector considers a rough ride.

To mitigate this subjectivity, FRA's Office of Research and Development has funded the development of an ultra-portable ride quality meter (UPRQM) that can be used by FRA track inspectors, as well as by industry track inspectors, to make objective measurements with relative ease.

Commercial systems that record carbody accelerations and ride quality are currently available; however, these systems have hardware or software drawbacks. For example, some systems include bulky hardware components that would place undue burden on a track inspector and might discourage him/her from using the system on a regular basis. Others require fixed, permanent mounting in a dedicated vehicle. Some commercially available systems record the necessary accelerations but do not correlate these accelerations with GPS position, which is critical in a railroad application since inspectors need to know where to perform ground verifications of exceptions detected by a ride meter.

The rail safety inspector affixes the UPRQM USB tri-axial accelerometer to the vehicle floor above the front or rear truck, and the USB GPS receiver is attached to a window in the vehicle. Both devices are connected to the inspectors' laptop computer where time-correlated GIS and acceleration data are recorded using the UPRQM software application. Exceptions are generated at locations where vehicle acceleration levels exceed predetermined thresholds. Data collected from those locations is either transmitted in real-time to a maintenance facility, or reported at the completion of the inspection.

OBJECTIVES

The objective of this technology development effort is to produce a portable system capable of accurately measuring the ride quality of a railcar from an in-service vehicle. The system is designed to use a minimal number of hardware components, all of which will draw their power from a standard computer USB connection. In addition, the ride quality data will be geospatially tagged. The corresponding software is to be user-friendly and will include, at minimum, acceleration strip charts, a list of exceptions, and a GIS display.

UPRQM DEVELOPMENT STRATEGY

Phase I of the development effort focused on demonstrating proof-of-concept. As such, Phase I resulted in a prototype unit with limited software functionality. Despite this, the software interface and associated hardware demonstrated strong potential. Therefore, Phase II development was funded.

The hardware used in Phase II development was largely the same as that used in Phase I, with the exception of the tri-axial USB accelerometer. Phase I utilized an accelerometer which sampled at 200 Hz, while Phase II utilized an anaccelerometer which samples at 400 Hz.

Phase II focused mostly on software functionality enhancements. The incremental lifecycle model, whereby multiple iterative development cycles take place, was the approach adopted for implementing these enhancements. Each development iteration passes through the requirements, design, implementation, and internal testing phases.

User “test and acceptance” was conducted by FRA track inspectors beta testing the most recent version of the UPRQM software. This was accomplished by deploying the ride meter to one FRA track inspector in each FRA region. Improvements subsequently made to each build were based, at least in part, on feedback from these beta testers.

During the beta testing process, several of the inspectors performed ground verifications of some of the locations associated with high acceleration levels (Figure 4).

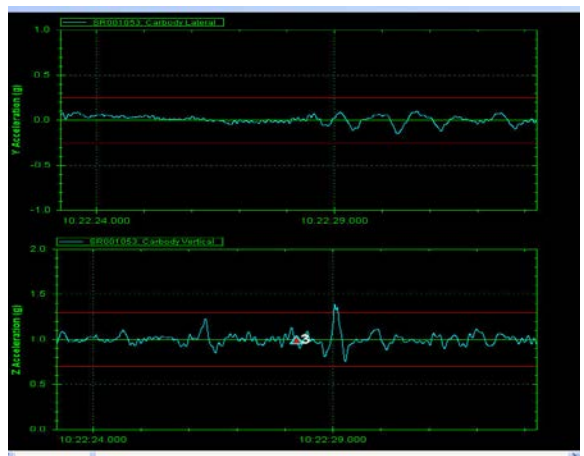

Figure 4. High Acceleration Levels

On several occasions, the inspectors were able to confirm that there was in fact a track deficiency such as irregular track geometry or poor vertical support. Figure 5 shows the mud spot that caused the elevated acceleration levels shown in Figure 4.

Figure 5. Mud Spot That Caused High Acceleration Levels

CONCLUSION AND FUTURE DIRECTION

Refinements to the software are ongoing. Some of these refinements will focus on tailoring exception reports to the end-users' needs, which may vary based, for example, on whether the end-user is an FRA inspector or a railroad inspector. Other refinements will concentrate on providing users with additional analytical tools. Additional hardware options are also being investigated; wireless accelerometers (Figure 6), for example, have been preliminarily tested.

Figure 6. Prototype wireless accelerometer

Future directions include product evolution to autonomous, hand held smart phone applications, inertial sensing capabilities, and an enterprise fleet management portal that would give users the ability to analyze and report on all data recorded by in-service units.

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