TECHNOLOGY DIGEST

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Technology Scanning Update – Status of 2006 University of Illinois Affiliated Laboratory Projects

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SUMMARY

The Association of American Railroads (AAR) Affiliated Laboratory (Affiliated Lab) Program is one way in which the railroads maintain awareness of, adopt, and assimilate new technologies. The Affiliated Lab Program also provides a pool of engineers and scientists who are familiar with railroads and who are available to solve technological problems. Additionally, Affiliated Lab projects help train the young engineers who will build and maintain the railroads in the future.

There are currently three Affiliated Labs:

- University of Illinois Urbana-Champaign (UIUC)
- Texas Transportation Institute/Texas A&M University
- Virginia Polytechnic Institute and State University

This *Technology Digest* provides a status report of projects at the UIUC funded in 2006. Findings from these projects include:

- Automated Visual Inspection of Railcar Safety Appliances – Machine vision inspection of safety appliances is practical.
- Railroad Applications of Smart Sensors – Prototype systems have been developed for railroad applications. Durability testing is under way.
- Discrete Element Model for Ballast – A new capability has been developed to more accurately model the behavior of granular materials, such as ballast. This model will allow development of better performing track foundations.
- Fiber optic force sensors for Truck Performance Detectors™ – Laboratory testing of fiber optic grating load sensors has been conducted. They offer potential advantages over conventional strain-gage based systems for trackside load measurement devices.
- Rail Cracking under Rolling Contact – Enhanced capability to model the most severe cases of wheel-rail contact. This should assist many industry efforts on running surface profiles and wheel and rail materials development.
- William W. Hay Railroad Engineering Collection – Both the AAR and Federal Railroad Administration have chosen Illinois to be the repository of their railroad engineering collections. The Technology Scanning Program funds the maintenance of the collection and provides access to literature searches that is available to AAR members.

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INTRODUCTION

The Affiliated Lab Program is one way in which the railroads maintain awareness of, adopt, and assimilate new technologies. The Affiliated Lab Program also provides a pool of engineers and scientists who are familiar with railroads and who are available to solve technological problems. Additionally, Affiliated Lab projects help train the young engineers who will build and maintain the railroads in the future.

The program was started in 1981 under the leadership of William J. Harris, then head of the AAR Research and Test Department. There are currently three Affiliated Labs:

- UIUC– Urbana, Illinois. A charter member of the program. Illinois has a long history of affiliation with railroad engineering. Chris Barkan (217-244-6338) is the laboratory director.
- Texas Transportation Institute (TTI)/Texas A&M (TAMU) – College Station, Texas. Joined the program in 1992. Gary Fry is the laboratory director.
- Virginia Polytechnic Institute and State University (VT) – Blacksburg, Virginia. Our newest laboratory, VT joined the program in 2005. Mehdi Ahmadian is the laboratory director.

STATUS OF 2006 PROJECTS

There are 19 projects currently funded by the Affiliated Lab Program. The following paragraphs and tables describe each of the six Illinois projects. Additional *Technology Digests* will cover the TTI/TAMU and VT projects.

AUTOMATED VISUAL INSPECTION OF RAILCAR SAFETY APPLIANCES

The Automated Visual Inspection of Railcar Safety Appliances project has focused on the inspection of safety appliances (e.g., ladders, brake wheels, and sill steps) on freight cars. Machine vision is well suited to this as it can be automated to do repetitive tasks. Automating the monotonous tasks of car inspection allows car inspectors to focus their efforts on fixing rather than finding defects. The end result is a better car inspection and a safer car fleet.

As a demonstration of the potential of machine vision for automated car inspection, the project has focused on identifying defects for a subset of safety appliances on a subset of the car fleet (ladders and brake wheels on coal hoppers and gondolas). A library of defects has been collected and catalogued from revenue service railcars. These have been supplemented with purposely damaged cars at the Transportation Technology Center, Pueblo, Colorado, and simulated defects using image generation software.

Accomplishments to date include:

- Camera placement to minimize the number of cameras
- Image selection software to grab the ideal frame from a video movie
- Recommendations for assuring constant lighting conditions
- Visual learning methods that can select defective safety appliances

Figure 1 shows an image of the end of a coal hopper taken from the prototype inspection system. The system has identified the ladder rungs and brake wheel. It has also identified defective (i.e., bent) components. The system has the capability of distinguishing the amount of deformation on a ladder rung to determine which are safety violations. Based on initial work conducted by the UIUC, TTCI began a new project in 2007 to develop a prototype system for automated inspection of safety appliances.

Table 1. 2006 AAR Sponsored Technology Scanning Projects at UIUC

Illinois 2006 Tech Scan Projects	Principal Investigator	Technology	Status
Automated Visual Inspection of Railcar Safety Appliances	Narendra Ahuja	Machine vision inspection	Developed methods of finding defects in ladders and brake wheels of coal cars.
Railroad Applications of Smart Sensors	Darrell Socie	Prototype sensors	Prototypes built for monitoring brake beams.
Discrete Element Model for Ballast	Erol Tutumluer	Model, report	A tool developed to predict the behavior of ballast and tie design parameters.
Fiber Optic Force Sensors for Truck Performance Detectors	S. L. Chuang	Prototype sensors	Developed prototype sensors for rail force measurement.
Rail Cracking under Rolling Contact	Huseyin Sehitoglu	Report	Determines effects of rail materials and wheel rail profiles.
William W. Hay Railroad Engineering Collection	William Mischo	Information retrieval services	Provides the industry with a center for railroad engineering reference materials.

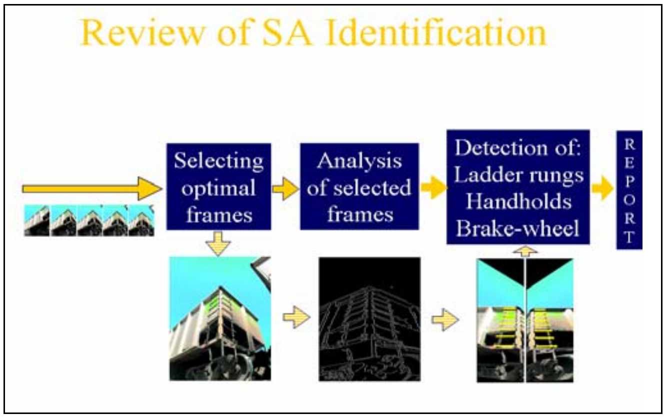

Figure 1. Machine Vision Safety Appliance Inspection Methodology

RAILROAD APPLICATIONS OF SMART SENSORS

The Railroad Applications of Smart Sensors Project is part of a much larger nonrailroad industry project to develop and use self-networking sensors in field applications. The sensor technology will have many railroad applications. It will easily use applied sensors that can communicate with each other. The sensors are smart in that they have the capability to process data, such as component strains, on board. They will also have the ability to summarize the data and make decisions, such as to communicate an alarm about imminent component failure. The sensors ultimately will have the ability to be self powered by using the railroad vibration environment and by minimizing power requirements.

A demonstration project is currently underway with NS to monitor the performance of brake beams on intermodal cars. Brake beam strains are being monitored (with sensors similar to Figure 2) to help the industry improve the reliability and performance of braking. Additionally, the AAR Insulated Joints (IJs) Strategic Research Initiative Program has sponsored development of a prototype smart sensored IJ. The prototype will monitor changes in rail strains that are associated with epoxy bond failures. In this way, the smart sensored prototype should provide warning of an imminent failure, so that the IJ can be replaced before causing train delays.

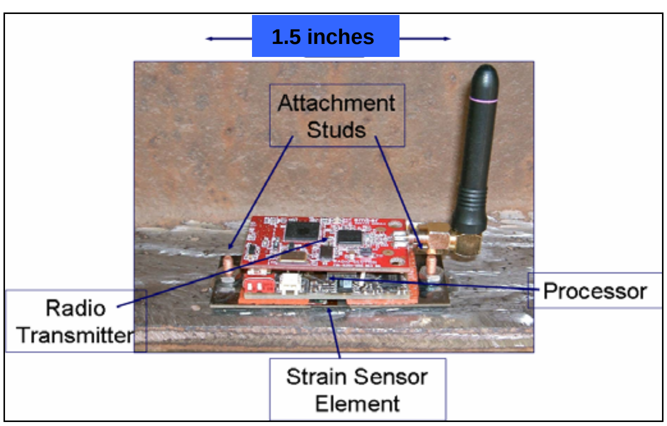

Figure 2. Prototype Smart Sensor for Monitoring Strain

DISCRETE ELEMENT MODEL FOR BALLAST

Use of a discrete element model will allow the railroads to accurately model the behavior of ballast. Until today, ballast has been modeled as a continuous layer. This approximation does not allow for evaluation of the effects of ballast particle size and shape, tie surface texture, or maintenance procedures.

Figure 3 shows a schematic of the discrete element ballast model that has been developed; advantages of the model are shown. Ballast may be modeled as individual particles, with its behavior more closely representing actual in-track behavior.

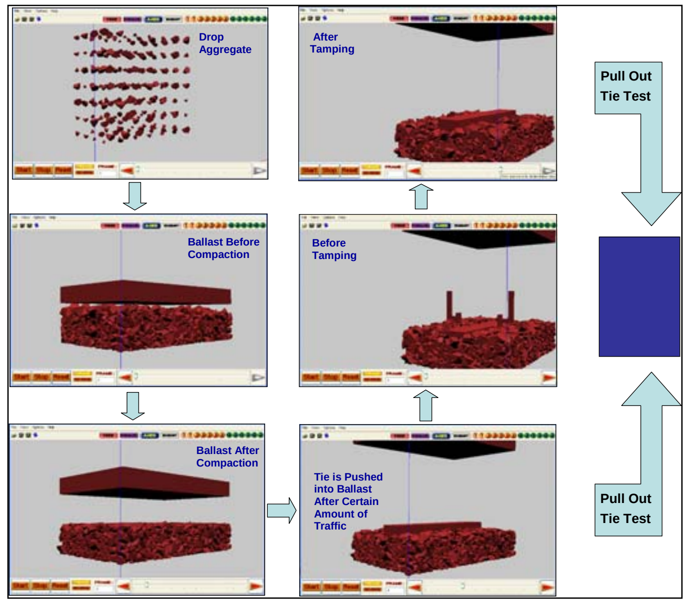

Figure 3. Model Schematic of Ballast Performance with Tamping

Exercise of the model has shown the following:

- Ballast settlement follows a power law relationship (as expected)
- Loading frequency affects ballast settlement. Low frequency loading rates (i.e., 1 to 5 Hz) result in the largest settlement per load cycle
- Particle shape (particularly, angularity) affects settlement

The second and third findings would not be possible with a continuous layer model.

This technology will enable track engineers to better design ways to improve the performance of track in terms of vertical and lateral stability. It may also allow the reduction of spending on track surface maintenance actions.

FIBER OPTIC FORCE SENSORS FOR TRUCK PERFORMANCE DETECTORS

Fiber optical grating sensors are being used in the oil exploration, aerospace, and highway industries as alternatives to traditional strain gages. The sensors have several advantages over conventional gages in that they are immune to electromagnetic noise (e.g., due to lightning and locomotive traction motors) and can have many sensors on one cable.

Envisioned railroad applications include trackside load stations, such as wheel impact load detectors and truck performance detectors. Fiber optic sensors may allow enhanced capabilities on these detectors, as well as the potential to lower life cycle costs.

Prototype sensors have been constructed and are undergoing laboratory evaluations. Results to date show that the sensors have the potential to be used for measuring the vertical and lateral performance of rail vehicles. Figure 4 demonstrates the sensitivity of the fiber optic sensor to periodic lateral wheel forces, such as one may have when a truck is hunting. Fiber optic sensors, deployed over a few hundred feet of track, would be able to detect these events.

RAIL CRACKING UNDER ROLLING CONTACT

This project is intended to enhance the railroad industry's ability to model wheel/rail contact in the critical flange throat/gage corner region. This contact condition can occur during curving and can result in rolling contact and sub-surface fatigue of both components.

Currently, most wheel/rail contact models use an elastic material model. This simplification is effective when wheel rail contact is like the tangent track case of contact on the wheel tread and railhead center. However, the simulation breaks down when modeling wheel/rail flanging as in a sharper radius curve. Use of improved materials, contact condition, and ratcheting models will allow for improved wheel/rail performance predictions. This is relevant to current AAR projects on wheel and rail profile design, rail lubrication, rail steels, and wheel defect prevention.

WILLIAM W. HAY RAILROAD ENGINEERING COLLECTION

UIUC has the third largest public library in the world. Being the university that has granted the most doctorates in engineering in the United States, its holdings are extensive in many areas of Engineering. Both AAR and Federal Railroad Administration have chosen UIUC to be the repository of their railroad engineering collections.

The Technology Scanning Program funds the maintenance of the collection and a literature search capability that is available to AAR members. The William W. Hay Railroad Engineering site is at: http://g118.grainger.uiuc.edu/whay/.

ACKNOWLEDGEMENTS

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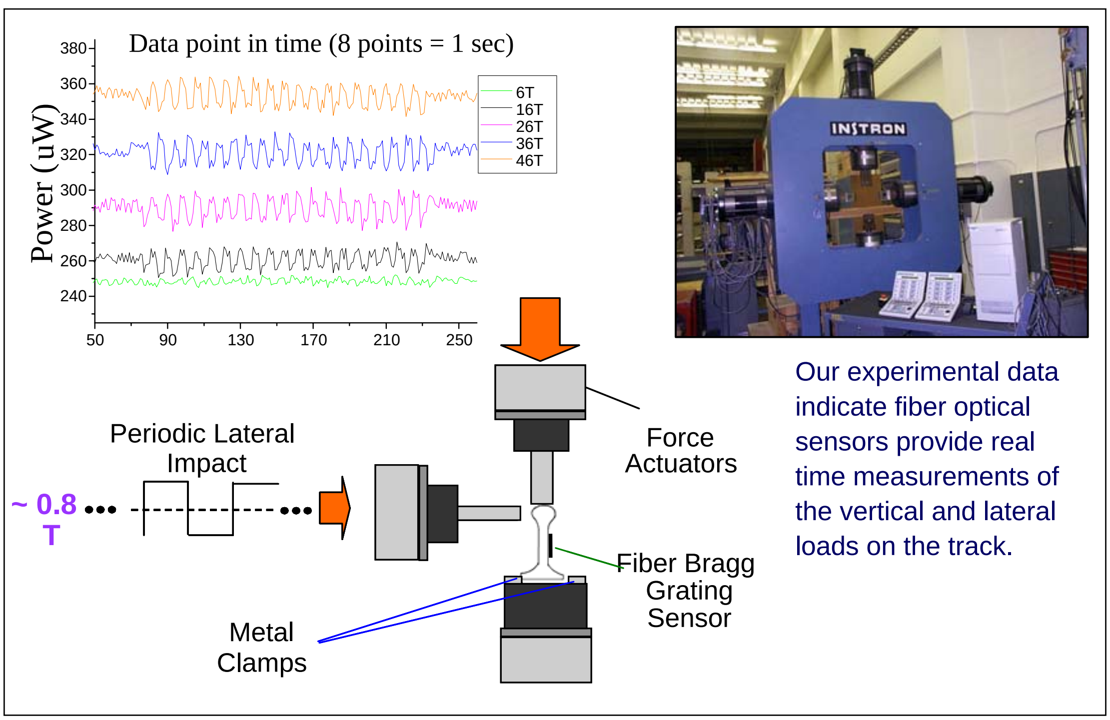

Figure 4. Fiber Optic Sensor Laboratory Tests