Case Study - Trains

Hong Kong, 2007

FBG Sensing System for Health Monitoring of Trains

Aim	To provide real-time and continuous monitoring of the structural condition of commuter trains.
Location	Hong Kong
System Integrator	The Hong Kong Polytechnic University, Hong Kong
End Customer	MTR Corporation, Hong Kong
Date	2007
Instrumentation	(2) Micron Optics sm130, Optical Sensing Interrogator (14) Micron Optics si425, Optical Sensing Interrogator
Sensors	FBG Strain Sensors, HKPU Design FBG Temperature Sensors, HKPU Design
Software	Customer Designed Software, Labview
FBG Technology Benefit	Immunity to EMI, long life-time, and multiplexing capabilities.

FBG Sensing System for Health Monitoring of Trains

- The ever increasing need for improved safety, reliability and efficiency is among the most important aspects of the railway industry world-wide.
- The Department of Electrical Engineering at the Hong Kong Polytechnic University has implemented field projects at MTR Corporation employing FBG sensors measuring temperatures, strains, angle and acceleration measurements on train wagons (cars) and bogies and monitoring these using FBG interrogators developed by Micron Optics.

- Since wear and tear of trains varies due to many non-linear factors, these projects aim to replace the "look-up table" type scheduling of maintenance for trains with "real-time information" based scheduling for train service and maintenance.
- This application is a major effort to provide means for upgrading aspects of the railway industry and update conventional systems into *"Real-time Service and Maintenance"* thereby providing a safer and more reliable train experience to passengers.

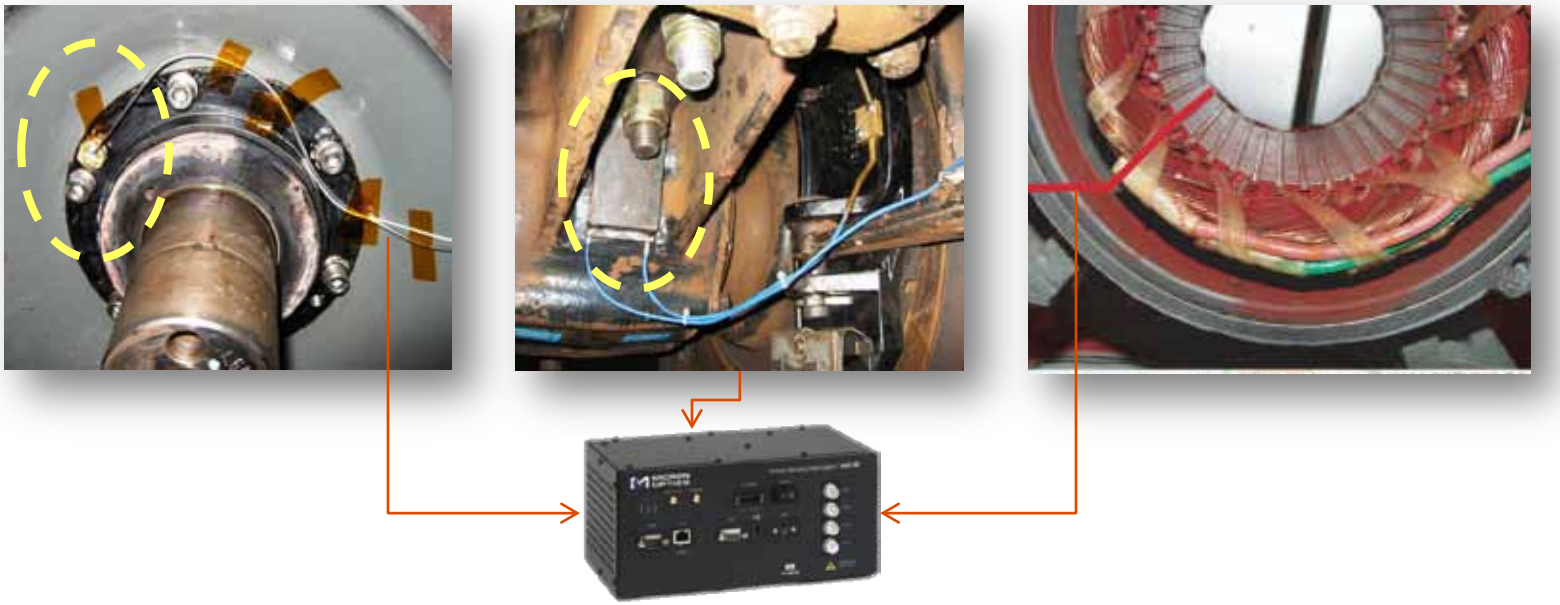
FBG Sensing System for Health Monitoring of Trains

- The application involves the development and implementation of an Optical Fiber Sensor System that incorporates hundreds of Fibre Bragg Gratings (FBGs) in multiple trains.

- Health Monitoring of the commuter train's braking components
  - § Prevent and flag brake problems.
  - § Identify operation inconsistencies.
- Undercarriage cable routing and monitoring of weld points for transformers and other train equipment

FBG Sensing System for Health Monitoring of Trains

- The FBG Sensors measure wide strain and temperature ranges well beyond the technical requirements the application demands. Sensors multiplexing allows installation time savings when compared to traditional electrical sensors.



- Installation of FBG sensors at various points of interest (from left to right above):
  - Motor bearing temperature monitoring (to 150 Degrees C)
  - Axle box strain monitoring (to 150 Degrees C and strains of up to +/-2,500 microstrain)
  - Motor winding temperature monitoring (to 300 Degrees C)
  - Several other train hardware elements are also monitored by specialized FBG sensors.

- The FBG Sensors are terminated with rugged fiber-optic cables. The cables are carefully routed to junction boxes and then armoured cables are routed further-on to the Optical Sensing Interrogators located on-board each train.

FBG Sensor on train solebar.

FBG Sensor on train charger, under carriage welding point.

FBG Sensor on train rectifier

- Six FBG sensors installed on trailer car and the same number of sensors were installed on the motor car of train. For the trailer car, three sensors were positioned at the corners of the window frame as shown, with one at the bottom steel bar, while the other two were at the top surface of the car.
- For the motor car, four out of six FBGs were installed at the four corners of a window frame. The other two were located at the top surface and the bottom steel bar, respectively.

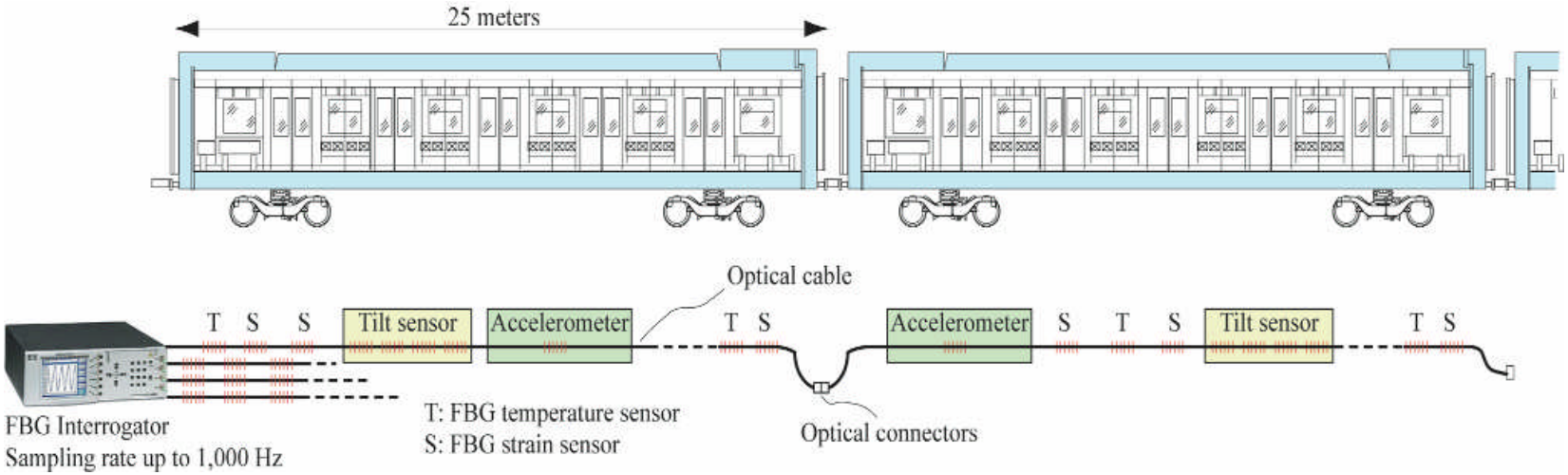
Strain gages instrumented on a train for assessing its structural integrity.

FBG Sensing System for Health Monitoring of Trains

- Micron Optics, si425 Optical Sensing Interrogator placed inside the safety cabinet.
- Fiber leads are properly mounted and protected, and connected to the FBG interrogating and data acquisition system, which are located in the electrical cabinet inside the rail car.

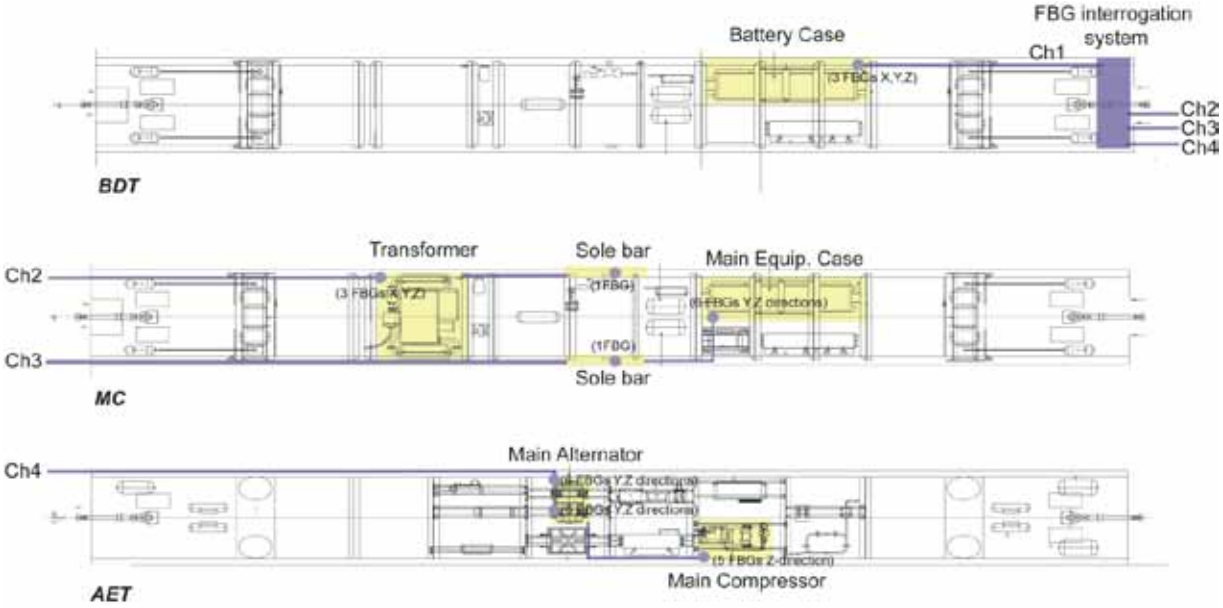
FBG Sensing System for Health Monitoring of Trains

- FBG measurements are wavelength-encoded and immune to intensity fluctuations and can be interrogated at very high-speed of up to 500 kHz.
- Multiplexing large number of FBGs over long distance is particularly important for condition monitoring applications in railways.
  - § FBG arrays for the measurement of temperature, strain, tilt angle, and acceleration of train wagons using a Micron Optics si425 and sm130 FBG interrogator.



FBG Sensing System for Health Monitoring of Trains

- FBG sensors installed in the under frame of trains, monitor the vibrations in critical locations including welding joints, cross beams and sole bars.
- The level of self-generated vibrations - due to local compressor or motor alternator - could also be checked. Measured strains on train-borne equipment allow the operators to determine whether any rail sections have excessive vibrations and whether it is necessary to carry out any rail tamping or polishing.



Locations of weld joints where FBG sensors are installed for monitoring the dynamic strain of the joints where heavy critical under-frame equipment are mounted. BDT=Battery Trailer, MC = Motor Car, AET = Auxiliary Equipment Trailer.

FBG Sensing System for Health Monitoring of Trains

- The FBG Monitoring System is fully operational and currently in service.
- It provides information on multiple train parameters including:
  - Stresses experienced during service, both static and dynamic, under different operational and environmental conditions.
  - The loading and traffic status of the passenger cars.
  - Temperature-induced stresses and deformations on rails and carriages.
  - Temperatures in and around axles and wheel brakes.
  - Dynamic axle vibrations due to corrosion and bearing wear .
  - Also, other parameters relevant to railroad health monitoring.
- On-board industrial grade computers, train condition optical monitoring systems configured to allow wireless data transmission were some of the important application specific requirements defined by the customer.

- Results
  - The field measurement results together with the experiences gained from these projects demonstrated that distributed sensing based on Fiber Bragg Gratings (FBGs) is an excellent method for the realization of smart condition monitoring systems for the railway industry.
  - Train monitoring systems are now used by the railway industry.
  - The Hong Kong Polytechnic University is sharing local experiences within Hong Kong as a reference to promote the Optical Monitoring Systems for broad deployment by railway operators/consultants in other parts of the world.
- Acknowledgements
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