AN ENHANCED CONDITION MONITORING SYSTEM FOR GAS PIPES USING FIBER OPTIC SENSORS

PROJECT SUMMARY

The project has developed sensor solution for real-time condition monitoring of gas pipelines.

Given that about 95% of Singapore's electricity is generated using natural gas, the safe and reliable operations of gas pipelines have received attention from both the government and public. Existing methods such as pressure monitoring, mass flow monitoring and manual inspections are unable to realise the real-time monitoring and detection of crack and leakage on gas pipelines. Further to this, such methods cannot detect or predict potential failures as early as when the crack and leakage start to develop. To address these challenges, it is crucial to develop a sensor solution for real-time crack and leakage detection.

The objective of the project is to develop an enhanced condition monitoring system for gas pipelines to ensure reliable and early detection of failure of any part of the gas pipelines. Focus areas include:

1. Research, design and development of an advanced architecture of fiber optic sensors to enable early detection of gas leakage, crack and excavation and their locations.
2. Research, design and development of an intelligent data mining and analytics system for real-time condition monitoring of gas pipelines.

In collaboration with **PowerGas Ltd** and **EINST Technology Pte Ltd**, an enhanced condition monitoring system for gas pipelines was developed to ensure continuous real-time monitoring of gas pipelines and early detection of potential failures, and to ensure accurate and cost-effective detection and monitoring of gas pipeline conditions.

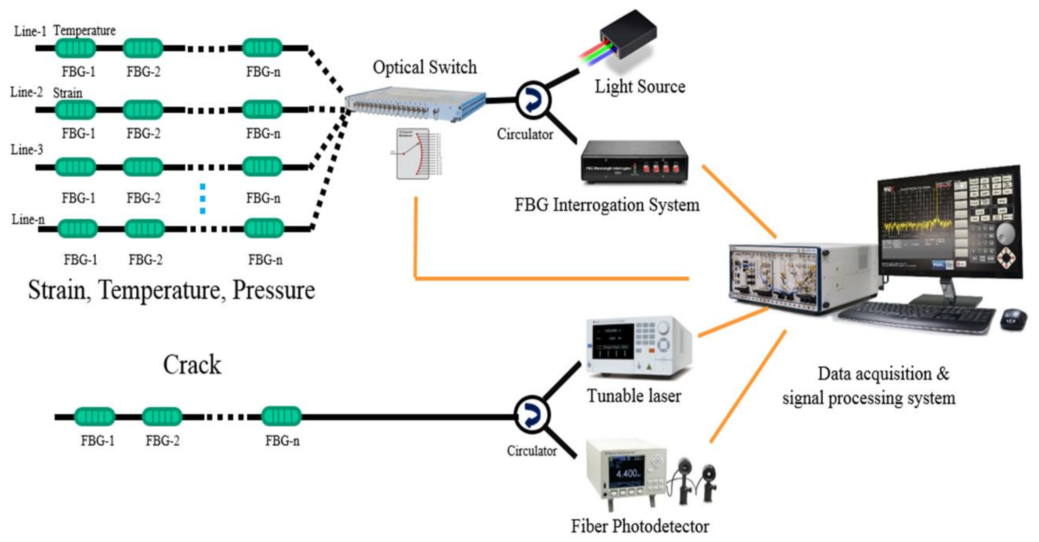

Figure 1: System level Fiber Bragg Grating sensor network of the developed real-time condition monitoring system for gas pipelines.

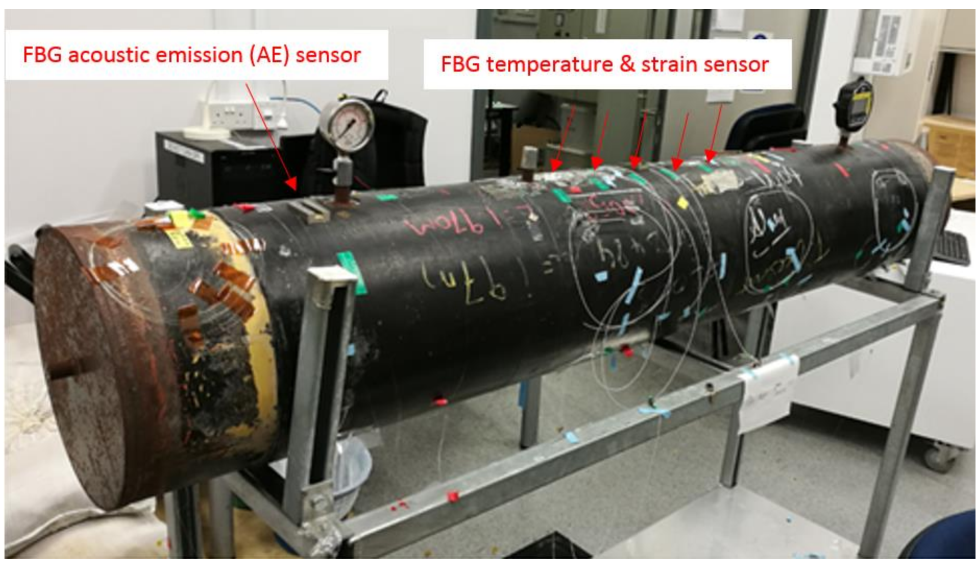

Figure 2: Development and testing of the developed sensors on laboratory-scale prototype.

PROJECT OUTCOMES

The project team has developed two types of sensor subsystems based on Fiber Bragg Grating (FBG) to be deployed on gas pipelines for the monitoring of multiple physical parameters.

- One subsystem is used to monitor static or slow changing parameters, including temperature and strain profiles of the gas pipeline. After signal processing, this subsystem provides gas leakage information in real-time as shown in Figure 3(a).
- The other subsystem is used to monitor high-frequency signals (i.e. acoustic and vibration signals in real-time) as shown in Figure 3(b). This subsystem captures the signals from crack and leakage events on the gas pipeline. The developed Artificial Intelligence (AI)-algorithm is also able to locate nearby events (i.e. cracks, leakages and construction works), accurately identify and distinguish the event and predict the potential failure as shown in Figure 4.

As the acoustic signals from crack and leakage events are weak signals that are difficult to detect especially when they are propagated and attenuated on long gas pipelines, the project team has developed a novel fiber-optic acoustic sensor with high resolution and sensitivity that is suitable for detecting such events on the gas pipeline. Further to this, the project team has developed an amplified structure based on resonant principle as shown in Figure 5, to ensure accurate detection of these weak signals. A Singapore patent (Application No. 10201809670W) was filed for the developed acoustic sensor.

The developed real-time condition monitoring system was tested on the actual gas pipelines of 2kPa pressure provided by PowerGas Ltd. Results showed that the developed condition monitoring system was able to detect crack and leakage signals in real-time with an accuracy of ±1m.

The project team has published 7 international top journal papers and 7 international conference papers over the four years.

Deploying the sensor solution can realise the real-time condition monitoring of gas pipelines in Singapore, which enhances the energy reliability for Singapore's power supply system.

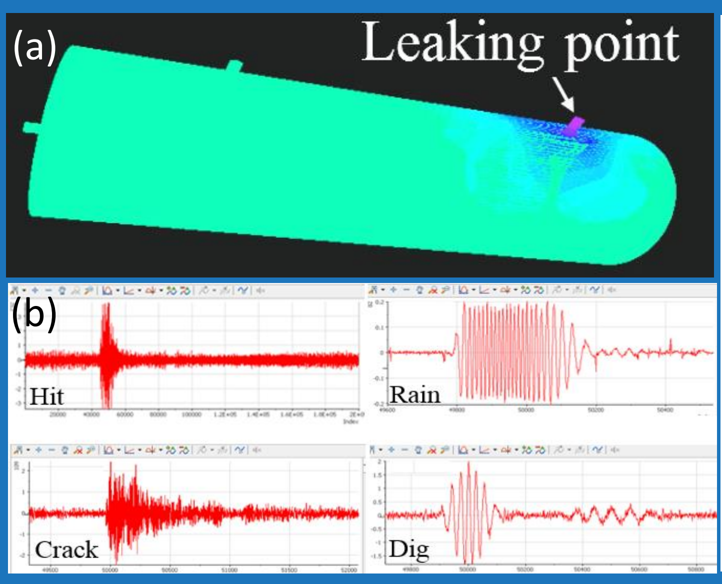

Figure 3: (a) Real-time temperature profile acquired from FBG sensor network implemented on the gas pipeline; (b) Real-time acoustic and vibration signals of different events from on-site tests.

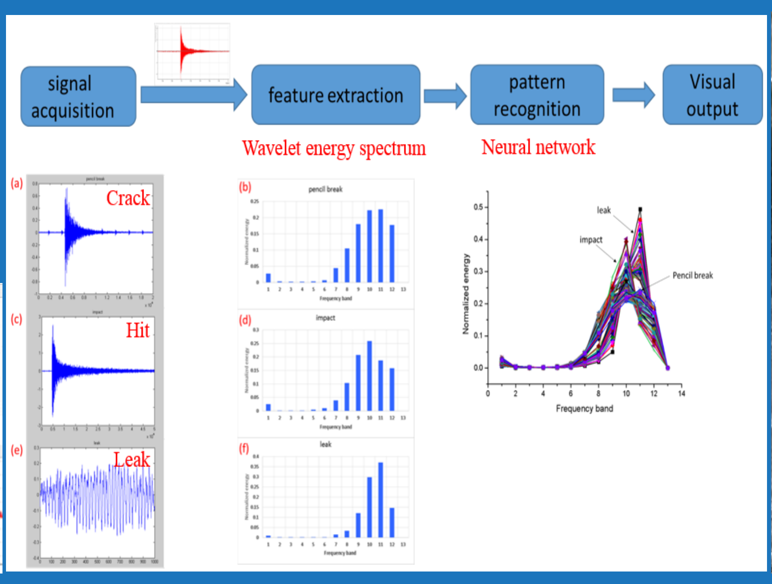

Figure 4: Flowchart and signal analysis of AI algorithm to distinguish different events.

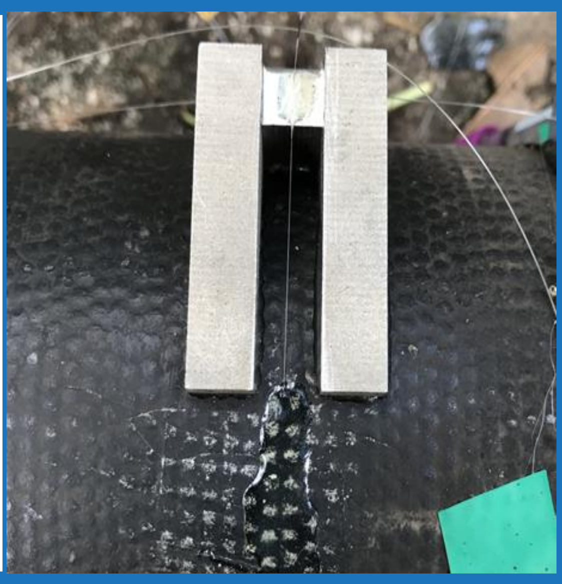

Figure 5: Developed fiber optic acoustic sensor being tested on-site at PowerGas' gas pipeline.

PRINCIPAL INVESTIGATOR

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