TECHNICAL INSIGHTS

SENSOR

TECHNOLOGY ALERT

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1. DISTRIBUTED WIRELESS SENSOR FOR COAL-FIRED BOILERS

In the process of thermal energy generation, coal is burned in a boiler to generate energy. In the process of coal combustion, the boiler has to maintain a high operating temperate and coal combustion exerts pressure on the boiler. The challenge to generate thermal energy is to achieve high sensitivity to enable damage detection at an early stage without generating false alarms. The device should be able to monitor the strain on the boiler as well as heat transfer and soot accumulation and alert the user when safety risks are posed to the boiler. In addition, the device should be able to maximize the up-time, enabling safe and cost-effective operation.

To address the above challenge, researchers from the University of Texas, Arlington are developing a distributed wireless antenna sensor system to monitor the condition of coal-fired boilers.

The distributed wireless antenna sensor system will employ wireless microstrip patch antennas, strain gauge and temperature sensors. The microstrip patch antenna will be printed on the thick substrate. It is expected that the researchers might use the inkjet printing technique to the print the circuit of the patch antenna. The ground plane and transmission line of the microstrip patch antenna will be made of a highly conducting material, such as copper. This will help researchers to achieve a cost effective and efficient device. These sensors will be useful to monitor in-process control of the boilers. The wireless sensor will perform real-time health assessment of the structural components. The sensor will be used to measure strain distribution and heat transfer in the boiler during combustion of coal.

Once the research project is completed, the sensors will be deployed in pulverized coal-fired boilers which are used to generate thermal energy by burning pulverized coal also called powdered coal or coal dust. In the industrial boiler, the coal dust which is fine powder is blown into the firebox, which further causes combustion. There are three different types of pulverized coal power plants which can be categorized as supercritical pulverized coal plants, subcritical pulverized coal plants, and ultra-supercritical pulverized coal plants. The main difference between these power plants is in the operating temperature and pressure. The distributed wireless antenna sensor system will be deployed in these power plants or boilers to measure strain distribution and soot accumulation in the boiler. The wireless sensor system will help to make boiler units more efficient and safe and produce better design units.

The University of Texas, Arlington has won a grant of $399,311 from the Department of Energy, USA, to study the sensors for monitoring heat transfer as well as the integrity of coal-fired boilers. The project is supported by the researchers from the Department of Nanoengineering at the University of California San Diego. The project is currently in the development stage. Once the project is successfully commercialized, it has opportunities to get a good response from the thermal energy generation industry.

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2. PIEZOELECTRIC DRIVEN SENSORS FOR STRUCTURAL HEALTH MONITORING

Structural health monitoring generates information that can increase confidence in structural integrity and minimize the associated risks as well as downtime. Changes in physical processes, such pressure variation or ambient temperature occur at frequencies that are lower than 1 Hz and are difficult to store and monitor. This poses a challenge for designing self-powered sensors that monitor these quasi-static physical processes and at the same time compute, sense, and store the information. There is a need for a self-powered device that can monitor the changes in quasi-static physical processes below certain frequencies. In addition the device should be cost effective.

To address the above challenge, researchers from Michigan State University have developed self-powered piezoelectricity driven impact ionized hot-electron injection (p-IHEI)-based sensors.

The piezoelectricity driven impact ionized hot-electron injection (p-IHEI) technology is based on the principle of sudden transitions from unstable mode branch switching to generate high-frequency deformations as input to the sensor. The self-powered sensor device based on (p-IHEI) consists of a data logger, processor, rectifier, and a transducer. This setup helps to design self-powered, battery-less micro sensors that monitor quasi-static physical processes, such as ambient temperature or pressure variations that occur at frequencies lower than 1 Hz. In addition the device will search, sense, compute and store operational energy. The self-powered sensor is based on 0.5 micrometer complementary metal oxide semiconductor (CMOS) integrated circuit technology that can count and record the change in structure. This further helps the device to monitor even small changes in the structure.

The sensors can be embedded inside rotating parts, biomedical implants, vehicles, wind turbines, bridges, and rotor blades. They can even be placed inside the human body for knee implants or a heart valves. A network of micro-sized sensors will self-diagnose any catastrophic failure. The network of sensors would become the integral part of mechanical, civil and biomechanical structures, making them smart and intelligent. The network of sensors will be highly cost-effective and compatible with different structures. The researchers are currently working on retrieving diagnostic data from sensors implanted in the body. They are exploring new biomedical applications for this sensor.

Michigan State University has won four grants worth $1,439,209 from National Science Foundation to focus on the fundamental science behind self-powered sensors for structural health and usage monitoring. The project is supported by Piezonix LLC, a start-up company based in Michigan. The company is also responsible for commercializing the sensors. The sensors have potential to get a good response from the civil engineering industry.

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3. CONDITION-BASED MAINTENANCE OF AIRCRAFT USING SENSORS

Structural health monitoring provides diagnostic and prognostic information about the integrity of a large structure, thereby minimizing the risks associated with these structures, and maximizing uptime and enabling cost-effective and safe operation. There is a need for structural health monitoring in aircraft that can monitor damages and crack detection without affecting the sensor's properties and physical condition. The sensor should be able to remotely assess an aircraft's structural condition in real time and alert if there is a need for maintenance.

To address the above challenge, researchers from Sandia National Laboratories are working on testing two structural health monitoring programs--Comparative Vacuum Monitoring (CVM) sensors and piezoelectric sensor arrays.

Comparative Vacuum Monitoring sensors will be mounted in aircraft to monitor the weak areas. The sensor will be attached on the surface of a structure with the help of an adhesive which further helps to seal out the atmosphere that is more likely to create a vacuum inside the gallery. When a gallery experiences a tiny crack, there is change in pressure because of the leak. The sensor records the change in pressure and sends an alarm before the crack becomes a major safety issue.

Piezoelectric sensor arrays are well-spread in polyimide films, creating a layer-like structure called smart layers. The layers are attached to the surface of airplanes. Only specific regions are monitored with the help of these layers. The piezoelectric sensor arrays communicate with each other by receiving and transmitting ultrasonic surface waves caused by the vibration. If there is damage to the aircraft, there is a change in the signal pattern waves. The change in the signal pattern is further identified by the software which measures and analyzes changes in the pattern of waves. As soon as the change is detected by the software, it sends an alert alarm before it causes major safety issues.

The sensor would be deployed in aircraft for crack and damage detection. In addition, it will be employed in applications involving harsh conditions such as aircraft mechanics. The scheduled maintenance will be done with the help of real-time sensors. The sensors will perform condition-based maintenance which will help to detect damages in the early stages. Such early damage detection by the sensors will help to reduce cost as it eliminates the need for subsequent major repairs

The program is supported by Structural Monitoring Systems (CVM sensors) and California-based Acellent Technologies Inc. (piezoelectric sensor arrays). The sensors have already rolled out of the lab for testing; and SHM sensors have been flight tested. Sandia National Laboratory has performed realistic crack tests on the sensors. Once the program is successfully completed, it has opportunities to get a good response from aircraft manufacturers.

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4. RECENT PATENTS IN THE FIELD OF STRUCTURAL HEALTH MONITORING

Structural Health Monitoring (SHM) involves autonomous and continuous monitoring of stress, strain, corrosion, cracks, and so on, with the help of embedded sensor systems or permanently attached sensor systems.

A recent patent in structural health monitoring powered by a fiber optic strain sensor (US20140354973) is assigned to SHAN XUEKANG, which pertains to a structural health monitoring method and equipment based on optical fiber bend measurement and includes a fiber optic strain sensor.

Research and development and patent activities in sensor technologies is moving toward detecting multiple types of damages, such as corrosion, cracks, delamination, debonding in both composite and metallic structures. Sensing technologies are becoming more prominent and vital as they are light weight, low profile, reliable, durable, and easily embeddable. Sensing technologies for structural health monitoring that are gaining interest in different industries include fiber Bragg gratings, comparative vacuum monitoring, acoustic ultrasonic, acoustic emission, microwave, electromagnetic, energy harvesting, nano sensor, MEMS (microelectromechanical systems) sensors, piezoelectric, painting material with sensing properties, antenna, temperature, and strain, among others.

Structural health monitoring is seeing growth due to increasing awareness of the risk associated with the extended life of many structures. Structural health monitoring is finding opportunities in numerous application areas, such as geophysics to monitor soil mechanics, volcanoes, earthquakes and in the civil engineering industry to monitor buildings, bridges, dams, tunnels and mining. In the aerospace industry, it can be used to monitor civil and military airplanes, spacecraft, and helicopters. In the transportation sector, it can help monitor cars, trains, and ships, while in the energy sector, it will be used to monitor oil and gas installations and pipelines, wind turbines, nuclear plants, and tidal wave generators among others.

Research and development and patent activities are gaining a lot of traction in the civil engineering and aerospace domains. The energy, space, geophysics, and transportation sectors are witnessing growth in structural health monitoring. These sectors are expected to witness lot of patent activity in the coming years. The highest concentration of patent activities in structural health monitoring can be seen in the US followed by Europe.

Some of the participants investing in the R&D of structural health monitoring are Smart Fibers Ltd., Micron Optics Inc., MEMSIC, SENSR, Acellent Technologies Inc., Microstrain Inc., MicroGen Systems Inc., Metis Design Corporation, Roctest Ltd., Advitam SA, Analatom Inc., and Electrawatch Inc.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Structural health monitoring method and apparatus based on optical fiber bend loss measurement	04.12.2014; US20140354973	SHAN XUEKANG	SHAN XUEKANG	A fiber optic strain sensor, an optical pulse generator generates an initial optical pulse, and launches it into an optical fiber-optical strain probe chain through an optical circulator. The scattered optical power in the optical fiber and optical strain probe chain is sent to an optical receiver, also via the optical circulator. The optical strain probes are attached to a structure whose strain is to be measured. Strain in the structure causes the fiber bend loss to change in the strain probe, and causes the scattered optical power received by the optical receiver to change accordingly. From the change of the output of the optical receiver and the time required for the scattered optical power to travel from the probe, the strain at each of the probes is calculated.
EFFECTIVE STRUCTURAL HEALTH MONITORING	13.11.2014; WO/2014/180870	VRIJE UNIVERSITEIT BRUSSEL	DE BAERE, Dieter	A system is described for performing structural health monitoring of an object (102) under study. The system comprises a hollow cavity structure (101) comprising one or more cavities obtained using additive manufacturing. The cavity structure (101) is sealable from its environment and forms an integral part of the object (102) under study. The cavity structure furthermore is connectable to a pressure sensor (103) for sensing a pressure in the cavity structure (101).

Structural health monitoring using hollow cavity structure	12.11.2014; EP2801809	UNIV BRUXELLES	DE BAERE DIETER	A system is described for performing structural health monitoring of an object (102) under study. The system comprises a hollow cavity structure (101) comprising one or more cavities obtained using additive manufacturing. The cavity structure (101) is sealable from its environment and forms an integral part of the object (102) under study. The cavity structure furthermore is connectable to a pressure sensor (103) for sensing a pressure in the cavity structure (101).
MOBILIZED SENSOR NETWORK FOR STRUCTURAL HEALTH MONITORING	21.05.2014; EP2732281	BOEING CO	JANG JUNG SOON	A method and apparatus for inspecting an object is provided. Movement of inspection vehicles relative to a surface of the object is controlled using a controller. Generation of data about the object by sensor systems configured to generate the data when the sensor systems are in a configuration with respect to a location on the object for inspection and receiving power from the inspection vehicles is controlled using the controller. The data generated by the sensor systems is stored.
Wireless intelligent aggregate health monitoring device and method for concrete structure	14.05.2014; CN103792263	SHENYANG JIANZHU UNIVERSITY	YAN SHI	The invention provides wireless intelligent aggregate health monitoring device and method for a concrete structure, and belongs to the technical field of health monitoring of concrete structures. Compared with the other same type of sensors, the wireless intelligent aggregate health monitoring device has the characteristics of good durability, low manufacture low, small volume and the like, and is embedded inside the concrete structure. The wireless intelligent aggregate health monitoring device can be equivalent to an ordinary aggregate and has no effect on the mechanical property of the structure. Compared with a conventional intelligent aggregate, the wireless intelligent aggregate health monitoring device transmits signals through a wireless network, so that not only can a great quantity of materials and a great amount of labor cost be saved, but also the maintenance of a health monitoring system can be reduced due to easiness of installation and maintenance of knots of the wireless intelligent aggregate and the like. The problem that cables cannot be arranged at multiple positions of certain large-size structures can be effectively solved by using a wireless signal transmission technology.
SYSTEM AND METHOD FOR MONITORING THE STRUCTURAL HEALTH OF ROTATING ELEMENTS	01.05.2014; US20140116145	ACELLENT TECHNOLOGIES, INC.	POLLOCK Patrick Joseph	A structural health monitoring system capable of maintaining electrical contact with sensors affixed to a rotating structure. One such structural health monitoring system comprises a rotatable structure, a plurality of sensors each affixed to the rotatable structure, and an interface. The interface has an inner housing and an outer housing, and maintains a plurality of individual electrical connections, each of the individual electrical connections being an electrical connection between one of the sensors and an electrical contact maintained on the outer housing, the electrical connections configured to be maintained during rotation of the structure. The inner housing is affixed to the structure and the outer housing is rotationally coupled to the inner housing, so that the inner housing

				is free to rotate with respect to the outer housing during rotation of the structure and the sensors, while maintaining the electrical connections.
SYSTEM AND METHOD FOR MONITORING THE STRUCTURAL HEALTH OF COUPLED BEARINGS	01.05.2014; US20140116142	Acellent Technologies, Inc.	POLLOCK Patrick Joseph	Placement of structural health monitoring sensors within a coupled bearing assembly. An exemplary structural health monitoring system comprises first and second bearings configured for rotatable positioning along a structure, and a spacer positioned between the first and second bearings. The first and second bearings are placed against opposing sides of the spacer, and have a preload force engaging the respective first and second bearings against the opposing sides of the spacer. A plurality of sensors are coupled to the spacer so as to be positioned between the spacer and at least one of the first and second bearings, the sensors further coupled to at least one of the first and second bearings so as to be configured to monitor a structural health of the at least one of the first and second bearings.

Exhibit 1 lists some of the patents related to structural health monitoring.

Picture Credit: Frost & Sullivan

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