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Development of Smart Structural Health Monitoring System Study of Bridges Using Internet of Things(Iot)

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ABSTRACT

The field of civil engineering and infrastructures is seeing an increase in structural monitoring applications. However, damage to the structures does not indicate a complete loss of functionality; rather, it indicates that the system is no longer in optimal condition, and the structure may collapse if the damage increases. Structural Health Monitoring (SHM), a process for detecting damage, collects data from appropriate sensors on a regular basis to characterise the damage and determine the structure's health status. As a result, this monitoring will provide information on the structure's condition, particularly its integrity, in a timely manner, and it is necessary to assess performance and health status for infrastructures and civil structures. The purpose of this project is to develop an Internet of Things (IoT)-based structural health tracking system that can detect potential faults and track how the structure functions over time.

Keywords: Internet of things, Data monitoring, Sensors, Structural health monitoring.

INTRODUCTION

SHM is a valuable strategy for enhancing the safety and maintainability of key infrastructure like complex bridges. SHM offers extensive information on the structure in issue, as well as precise and factual statistics concerning its status.Bridge incidents or changes in bridge structure deflection, or the vandalization of concrete piers by the accumulated moisture, or by excessive variation in vibration are now frequently reported annually. To achieve optimal rescue results, different levels of catastrophes and ruined sites necessitate enormous levels of professionals knowledge and emerging techniques to help overcome this situation. However, an absence of facts about the site that has subjected to severe conditions can stymie management of the statistical evidence at the center and operations, ensuing in inefficient rescues or possibly avoidable fatalities.

In continue with this research, data must first be stocked using sensors. SHM frequently employs various types of sensors to spawn signals that travel through unyielding configurations. After that, varied techniques to process the signals were implemented to scrutinize the data stored. Skipping this may lead to, significant changes in the response obtained, masking the potential signal changes due to structural defects.

As a result, in this study, the (IoT) – system based and sensor networks are used to address the aforementioned glitches of ensuring the safety and life of the bridges.This avails us to oversee the environmental veracity of the structure and the data is made to transfer to the respective divides.

By taking a step forward and mending the problems stated previously we need a proper system, that aid the bridge lifecycle management. To meet the various requirements of structures, various notions and techniques have been put forward andenforced into actions. Integration of these various theories has aided in doubling the performance and cut down the cost and hours of reckoning.In order to share data and assure dependability, the systems employ network-based services to cohabit and actually interact with savvy networked devices, widely recognized as the IoT. The Internet of Things opens up new possibilities for our society. The development of internet-based systems,

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which can possibly give a viable solution for quick, accurate, and minimal Systems, has recently been one of the current problems as the IoT advances.Furthermore, integrating the two systems provided pervasive public infrastructure and sophisticated sensing data stream processing that beyond the capabilities of standard SHM systems. In this study, a comprehensive SHM platform with IoT for bridge detection is proposed.

A. Advantages

- Because sensors are a part of the structure, it is constantly monitored.
- The ability to detect damage in real time.
- The use of sensor or actuator networks is an option.
- A conclusive data analysis capable of providing pertinent damage information.
- An automated quality assurance procedure to cut the rate of completely needless maintenance of the tasks and, as a result, improve tax benefits.
- Conditions for evaluating deployable and ecologic stellar performance.

B. IOT

It is a network of tangible entities that have intertwined interface that needs to allow them to interact directly, perceive, and interact with their internal states as well as the outside environment. In 1999, Kevin Ashton of Procter & Gamble, subsequently of MIT's Auto-ID Center, invented the acronym.

C. Components of IOT

Sensors are frequently defined as devices that generate electrical, optical, or digital data in response to an event (IEEE). The data gathered by sensors is then transcribed by digitally into extracted information that intelligent devices or humans may utilise to make decisions.

The terms "Internet" and "Things" are semantically related, with "Internet" referring to a global system that connects various computer networks via the TCP/IP protocol suite, and "Things" referring to any object or device in the surrounding environment that is capable of sensing and collecting data. As a result, it is frequently defined as a transnational mechanism that employs the IP comprehensive set and includes real objects networked, radio frequency identification (RFID) tags, or barcodes that might have a distinctiveness, continue to function in a cloud platform, and are harmoniously consolidated into the access point through the use of intelligent interfaces. The Internet of Things makes use of materials, network infrastructure, communication protocols, Internet services, and computing technologies. WSN is a critical technology for integrating sensing devices into IoT ecosystems, and it is only one among many technological advances that make up the Internet of Things idea.

Sensory units are strategically placed across a cluster to help gather and send legitimate data to a data center over the internet. End users can afford to operate gadgets remotely via services available through the use of internet.Additionally, they will be able to retrieve, process, and analyse data from the data center at any time and from any location via the hyperspace. Its architecture is a multilayer, open architecture. In recent years, researchers have explored various approaches for implementing IoT systems, including service-oriented architecture. Multiple layers work together to offer facilities often including detecting, automatic transmission, accumulation, archiving, and knowledge acquisition.Constraints on computation and energy are a problem for IoT devices and sensors. As a result, numerous protocols and standards have been developed to enable coexistence across heterogeneous networks and to enable coherent data exchange via the IoT system.

D. Applications of IOT

- We can keep an eye on the various bridges in which our proposed model is embedded using this project.
- The project can be expanded further, and various similar structured models can be installed over bridges for bridge maintenance.
- The presence of moisture can also be detected with the help of this model, and future disasters can be avoided.
- We can get information about the bridge's health or lifespan by sending an email from our phone.
- In addition, we can maintain any structure for purposes such as moisture detection, deflection change, and so on.
- This system can also be used to contribute to aerospace, civil engineering, transportation.

E. Advantages of IOT

- It is a dependable and simple-to-use system.
- There is no requirement for additional training of the user.
- The proposed system will prevent fatalities caused by bridge collapse.
- We can ascertain which bridges require repair before they collapse.
- Traffic can be rerouted prior to the collapse of the bridge, as alerts of extreme levels are monitored continuously on the IoT server.
- It sends an alert if the flow, water level, or load increase.
- Early detection of damage, prompt action and

response.

F. Objective

The Bridge Health Monitoring System's objective is to provide necessary information about the structural condition and potential for damage to the bridge in order to establish a documented basis for making decisions about these matters. The overarching objectives of Bridge Health Monitoring systems are to:

- Ensure structural safety.
- Structural Performance and Applied Loads Monitoring.
- Facilitating Inspection and Maintenance Planning.
- Validating Assumptions and Parameters in the Design.
- Revision and Update of Design Manuals and Standards
- Ensure a secure economic operation.

COMPONENTS DESCRIPTION

A. Microcontroller

A microcontroller is a small computer housed in a single (MOSIC) chip. Several or maybe more processor cores, gathered cache, and customizable I/O workstation peripherals entail a microcontroller.A tiny amount of RAM and program memory in the form of ferroelectric RAM, NOR flash, or OTP ROM are also commonly incorporated on the chip. Microcontrollers, as opposed to microprocessors used in personal computers or other general-purpose applications, are made up of several discrete chips and are designed for embedded applications.

In current terminology, a microcontroller is comparable to, but less technologically intelligent than, a (SoC). A SoC may have a controller, but it is more likely to incorporate specialized accessories such as a GPU, a cordless plugin, or one or more coprocessors.

B. Ultra-sonic sensor

An acoustic device used as a sensor is a voltaic device that measures the position to a designated entity via audible sound pulses and suddenly turns the rebounded sound to an analog voltage. these waves grow more quickly than perceptible acoustic wave. These consist of two major components: the emitting part and the receiving part.

It is most commonly used to detect relative proximity. They are utilised in vehicle pro safety systems and automatic way of parking technologies and theses advancements in sensors are utilised in industrial technologies in addition to robotic obstacle detection systems. In proximity sensing applications, this technology is less vulnerable to interference from defilement than infrared (Infra - red) sensors (even if they are safe from contaminants, still are affected by heat).

C. LCD display

It is a display with a uniform ungraded surface or any other optical appliance that consumes liquidized solid crystals and orchestrated to temper the light. A broody device is used to emit light either in color or in greyscale. These flat monitors are installed to display arbitrary images or images having low content.

A combination of clusters with small broken pixels are viable to create arbitrary images. Both use the similar fundamentals with exceptions discussed in the later. Displays other than these are equipped with larger elements. The normal on / off functions are given in the light of the configurations made.

IDENTIFYING LOADS AND CRACKS

This research discusses various types of bridge loads. It is critical to accurately identify the loads that must be considered during design and construction.

A. Imposed traffic loading

The pressures produced on a bridge by vehicles are referred to as "imposed traffic loads." A bridge's traffic can be automotive, locomotive, pedestrian/cyclist, or a blend of these. The vehicle's kind and potency change depending on the design code.

Trucks weighing substantially greater than the federal point of confinement often dominate the loading of traffic. The traffic load on the bridge is supposed to apply to fictional lanes that are not related to the underlying exact lanes. Normal loading in accordance with Eurocode involves homogeneous loading and the four-wheel tandems in each lane. To account for traffic dynamics, vehicle loads are sometimes skyrocketed by a factor.

B. Crack identification of bridge

Cracking in concrete bridge decks, especially at an early stage, has a significant impact on the bridge's serviceability and performance. Numerous studies are appreciated in an attempt to develop a non-destructive method for crack detection on concrete bridge decks.

Neoteric advances in this technology have facilitated the widespread use of miniature models of sensor in the performance and maintenance of bridges. Kuang established in 2002 that plastic optical fibers could be used to detect hairline cracks, failure cracks, and also to monitor the propagation of cracks in concrete structures.

While the aforementioned techniques were successful in detecting cracks in concrete bridge decks, they did not provide an explanation for how these cracks formed or when they began, which is the first step in treating such a problem. As a result, numerous researchers began instrumenting the bridge deck to monitor its performance in an attempt to ascertain the causes of crack development.

C. Measuring instrumentSensor

The sensors used in this project fall into the following categories:

- Displacement transducers
- Thermocouples.

Displacement Transducer

Displacement transducers are used to determine the expansion or contraction of materials, as well as movement across cracks or joints.There are numerous displacement transducers that can be used to measure displacement. The following transducers were used in this project:

- Crack-meter
- Convergence meter

Crack meter

Geokon's Model 4430 deformation meter (Crack-meter) is primarily intended for the measurement of axial strains or deformations in concrete structures. A series of transducers embedded in concrete can provide the total deformation pattern along that axis. The transducer is composed of a vibrating wire sensing element coupled to a movable shaft by a precision music wire. As the shaft exits the sensor body, both the spring and the vibrating wire lengthen, resulting in a change in their tension, which is quantified in terms of the vibration's frequency.

Accelerometers

Accelerometers are acceleration and vibration sensors. They can have one to three orthogonal measurement axes. Piezoelectric, capacitance, null-balance, resonance, piezoresistive, and magnetic induction are all common types of accelerometers. When an accelerometer is attached to a bridge member, vibration causes it to send electric signals to a computer for conversion to acceleration units.

Thermometers

Thermal sensors provide temperature readings. There are two fundamental methods for temperature measurement: contact and non-contact. Bridge applications necessitate the use of contact devices that require a sensor input or incorporate one. Vibrating wire temperature sensors and resistance temperature sensors are two common types of sensors.

Fibre optic sensors

Fiber-optic sensors can be used in any application that requires a conventional sensor, including bridge applications. Optical fibres have extremely wide bandwidths and are dielectric, which means they are not affected by electromagnetic waves. Fiber-optic sensors can operate in extreme temperatures, pressures, and toxicity.

Fiber-optic sensors monitor the structural health of buildings by periodically sending light beams down optical fibres and measuring the change in time-of-flight. There are several types of fiber-optic sensors being used in bridge applications at the moment. Fabry-Perot and Fiber Bragg Grading sensors are two types that measure interference fringes and frequency, respectively. A third type is based on Brillouin Time-Domain Reflectometry (BOTDR)

D. Internet of Things (IOT)

Personnel in charge of infrastructures built for transportation with assistance of the technologies discussed earlier effectively monitor and manage ageing structures.

Another prospective use of IoT technology might be growing beneath the wheels of industry vehicles as new applications of IoT technology arise in the mobility and logistic support sector, ranging from predicting driver fleet analysis and management of cargo transportation to self-driving engines.

All the other modes of the boundless structures that is involved in haulage should be superintended and supervised. This is to continue the adoptability and safety. This requirement becomes even more critical as these infrastructure components age.

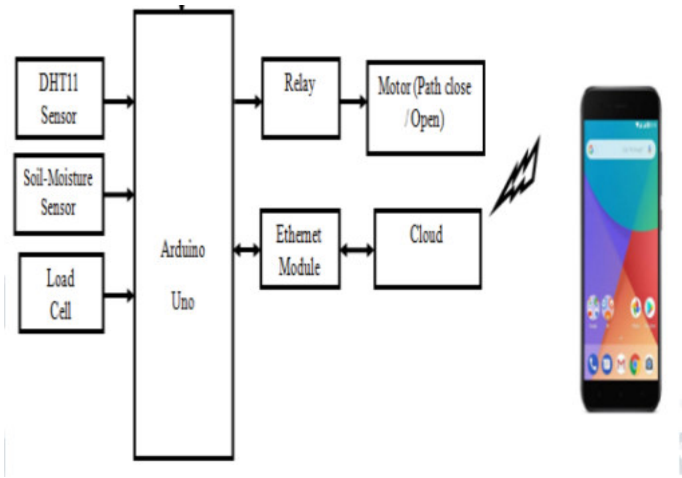

Fig – 1: Process Layout

E. Data monitoringSensor

A device that employs ultrasonic sound waves to measure the distance to an object is known as an ultrasonic sensor. A transducer is used in this device to broadcast and receive significant pulses that relay information about an object's vicinity. The echoes produced by the waves reflecting off physical limits are unique in pattern.

Ultrasonic sensor work

Ultrasonic sensors work by sending out a sound wave that is higher in frequency than the human hearing range. The transducer on the sensor works as a functional microphone, receiving and transmitting high supersonic sound. Our u/s sensors, like many others, use a single actuator to emit a pulse burst and end up receiving the resounding effect. By monitoring the time delay between delivering and receiving the u/s pulse, the sensor determines the distance from the source to a target.

This module operates on a straightforward principle.When it hits an obstruction or item, it releases a 40kHz u/s pulse that travels through the air and snaps back to the sensing unit. By multiplying the transit time by the sound speed, the distance may be determined.

U/S sensors are a great way to identify fully transparent things. Because of the target's glimmer, applications that rely on infrared sensors, for example, struggle with this use case for liquid level measuring.

The existence of items is detected by u/s sensors indifferent of their pigmentation of the surface, outer film texture, or texture (unless the whole material found is exceptionally soft, such as those of as wool, which therefore absorbs sound.)

U/S sensors are a trustworthy option for distinguishing translucent and other things happening where optical automation may fail.

Ultrasonic sensors used

Our u/s proximity, threshold, and noticeable distance sensors are commonly used in conjunction with microcontroller platforms such as the Raspberry Pi, ARM, PIC, Arduino, and Beagle Board.

U/S sensors direct sound waves at an intended target and the length of time it takes for the rebounded waves to finally return to the intended receiver to conceivably calculate its critical distance.

This sensor is used to detect accurately, that measures the path length to an objective using u/s sound waves and then alchemize the sound that has been emulated to anvoltaic signal.

Additionally, u/s sensors are preffered in systems to avoid the existing obstacles and manufacturing.

Our short-range sensors enable detection at closer ranges, where a sensor capable of detecting objects as close as 2cm may be required. Furthermore, these are built with extremely low power concerns in thought, as well as noise outright rejection settings in mind.

LCD display

The LCD display is used in conjunction with the I2C communication module to facilitate data transmission and reception in real time. The LCD display module is equipped with four pins. The VCC pin on the LCD is connected to the Arduino's ICSP VCC pin. The LCD's GND pin is connected to the Arduino's ICSP GND pin. Then, connect the SCL pin to the Arduino's A5 analogue pin and the SDA pin to the Arduino's A4 analogue pin. When required, Arduino's pins A4 and A5 are also used as SCL and SDA.

F. Data acquisition

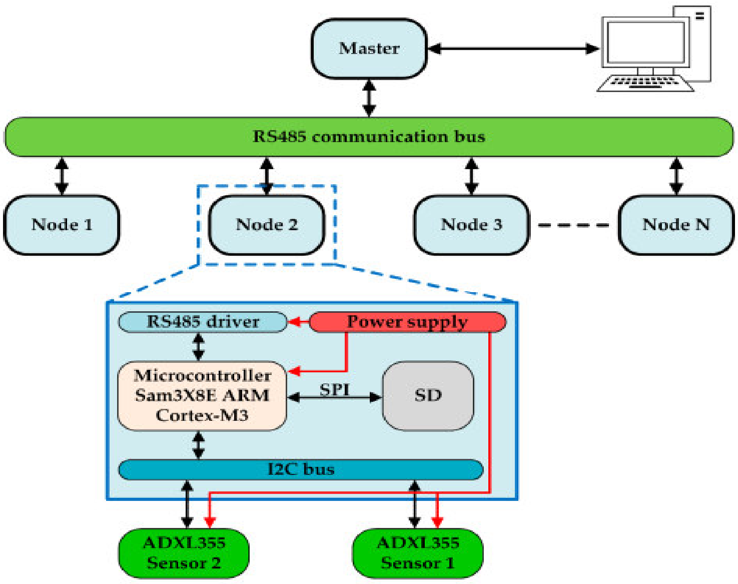

Fig – 2: Layout of the monitoring system

The data acquisition phase of the WINS Process entails determining the quantity, type, and location of sensors to be used, as well as the data acquisition hardware to be used. Additional considerations include how frequently data should be collected and how data should be normalized. This system is composed of several critical components:

- Microsensors with integrated a-to-d converters,
- Wireless data transmission,
- Power source, and
- Local excitation sources.

G. Experimental setup

The proposed monitoring system was evaluated using the experimental setup depicted in, which employed the harm indicator recognition technique. The test temperature was set to 25 °C, and the sensor's sensitivity was determined at this temperature.

One of the primary factors affecting the health of operational bridges is the deterioration or failure of transverse connections between beams, which results in decreased transverse collaborative work capabilities and highly unfavorable stress states in the bridge's upper structure. As a result, it is critical to monitor the decline in capabilities for lateral collaborative work. Acceleration data could be used to assess bridge structural deterioration via the use of smart sensors in an IoT network. Such exercises can also be used to determine the efficacy and viability of the IoT framework developed for the bridge. Trial, based on the site was conducted aseparate span of the Bridge. Acceleration in the lengthwise vibration of 10 plate beams was measured at the middle span's transverse cross section.

H. Implementation of the technique

A set of nodes, or piezoelectric sensors, are implanted on various parts of a structure under the direction of a civil engineer. This assists in identifying the building's most vulnerable areas, which may develop cracks or losses. Until it is used in a house, laboratory tests are conducted on concrete block and brick, which are listed in the following section.

Piezoelectric transducers were used to construct the sensing device. These sensors are ready to use once the electrical contacts are completed. The transducers transmit the lamb waves, which are received by another piezo transducer acting as the receiver. The difference between the sending and receiving times is used to calculate the wave velocity across the corresponding portion of the building using a timing unit.

This Lamb wave is critical for injury detection. The lamb wave velocity varies according to the dimension of the crack. If there is any disruption or crack in the wave, this indicates a fault. This ensures that the pulse velocity is used to determine the consistency of the concrete and the damage indicators indicate the distance between the cracks.The injury-related values are processed in the IoT system that is connected to the sensors.

RESULTS AND DISCUSSION

The sensors were installed in ten different locations along the bridge structure, and the depth of the damage was recorded and displayed on the screen. The positions of the sensors were labelled with numbers to facilitate identification.

The graph below illustrates the values collected by the IOT monitoring system. The damaged areas are highlighted in red, whereas the safe portions of the structure are highlighted in green.

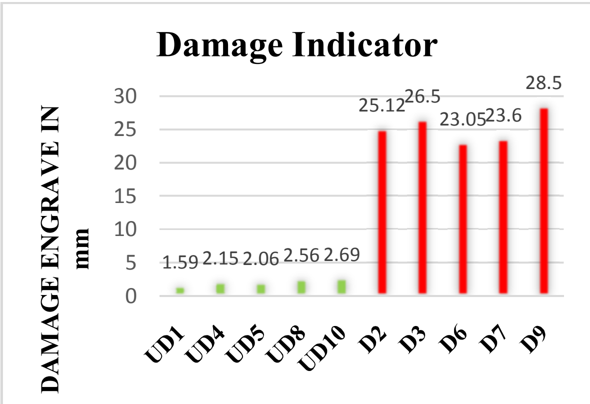

Fig – 3: Damage Indicator

These values are obtained when signals are passed into and received by the structure. When a structure has a crack, the time required increases while the velocity of the signals received decreases.

CONCLUSION

This paper developed an IoT framework for bridge vibration tracking by combining wireless sensors, gateways, and a cloud network, enabling real-time remote cluster monitoring of the bridge. A bridge was used to demonstrate the validity of the IoT-based method for monitoring bridge health. The following summarizes the article's findings:

Because the wireless sensor is based on microelectronics technology, it is more compact, resulting in lower installation and maintenance costs. It can be recharged via solar panels or a piezoelectric cantilever beam to ensure long-term tracking.

The gateway is capable of managing multiple data collections from various built-in sensors, such as temperature and humidity sensors, which can be used to continuously monitor environmental conditions. Both tracked and untracked data can be stored and accessed via the cloud platform's archive.

The IoT system will eliminate traditional supervision's drawbacks, such as wiring and power supply, as well as the disruption of routine bridge inspections. Meanwhile, sensor and gateway implementation is straightforward, saving both time and money. Due to the device's convenient wireless networking platform, it can also be used to control bridge clusters.

REFERENCES

[1] X. Hu, H. Ji et al, “A wireless sensor net.-based struct. health monitoring system for NH bridges,” Computer-Aided Civil and Infrastructure engg., vol. 28, no. 3, pp. 193–209, 2013.

[2] D. Culler, S. Kimet al., Health Monitoring of Civil Infrastructures Using Wireless Sensor net., EECS dept., University of California, 2006.

[3] DuY.-L, Z.-F. Gao,., M.-B. Su, and B. Chen, "Network sensor and its app. in struct. health monitoring system," in Proceedings of the 1st Int.Conf. on Innovative Computing, Information and Control (ICICIC '06), pp. 68–71, August-September 2006.
[4] B. C. Lee, W. J. Staszewski and R. Traynor, "Fatigue crack detection in metallic struct. with Lamb waves and 3D laser vibrometry," Measurement Sci. and Tech., vol. 18, no. 3, pp. 727–739, 2007.
[5] D. Dutta, H. Sohn, J. Y. Yang et al., "Delamination detection in composites through guided wave field image processing," Composites Sci. and Tech., vol. 71, no. 9, pp. 1250–1256, 2011.
[6] G. Park, C. R. Farrar and J. R. Wait, "Integrated struct. health assessment using piezoelectric active sensors," Shock and Vibration, vol. 12, no. 6, pp. 389–405, 2005.
[7] Barke, D.; Chiu, W. Struct. health monitoring in the railway industry: A review. Struct. Health Monit. 2005, 4, 81–93.
[8] E.P.; Brownjohn, Carden, , J.M. Fuzzy clustering of stability diagrams for vibration-based Struct. health monitoring. Comput.-Aided Civ. Infrastruct. Eng. 2008, 23, 360–372.
[9] K. Chintalapudi, J. Paek, N. Kothari, et al., The Performance of a Wireless Sensor Network for Struct. Health Monitoring, Center for Embedded Net. Sensing, 2004.
[10] Pradhan, H.S.; Sahu et al. A survey on the perf. of dist.FO sensors. In Proceedings of the 2015 Int.Conf. on Microwave, Optical and Comm.Engg. (ICMOCE), Bhubaneswar, IN, 18–20 December 2015; IEEE: Piscataway, NJ, USA, 2015; pp. 243–246.
[11] Sikarwar, S, et al Review on pressure sensors for struct. health monitoring. Photonic Sens. 2017, 7, 294–304.
[12] Sofge, D.A. In Proceedings of the ANZIIS'94-Australian New Zealnd Intelligent Information Systems Conf., Brisbane, Australia, 29 Nov.–2 Dec. 1994; IEEE: Piscataway, NJ, USA, 1994; pp. 91–94.
[13] C.Imregun, Zang, and M. Struct. damage detection using artificial neural net. and measured FRF data reduced via prin. component projt. J. Sound Vib. 2001, 242, 813–827.
[14] Anaya, M. Design and Validation of a Struct. Health montr. System Based on Bio-Inspired Algorithms. Ph.D. Thesis, Uni.Politècnica de Catalunya, Barcelona, Spain, 2016.
[15] Le, M.Q.; Capsal, J.F.; Lallart, M.; Hebrard, Y.; Van Der Ham, A.; Reffe, N.; Geynet, L.; Cottinet, P.J. Rev. on energy harvesting for struct. health montr. in aeronautical app. Prog. Aerosp. Sci. 2015, 79, 147–157.
[16] Mitra, M.; Gopalakrishnan, S. Guided wave based struct. health monitoring: A review. Smart Mater. Struct. 2016, 25, 053001.
[17] Das, S.; Saha, P. A review of some adv. sensors used for health diagnosis of civil engg. structures. Measurement 2018, 129, 68–90.
[18] Vendittozzi, C.; Sindoni, G.; Paris, C.; del Marmo, P.P. Application of an FBG sensors system for struct. health montr. and high perf. trimming on racing yacht. In Proceedings of the 2011 Fifth Int.Conf. on Sensing Tech., Palmerston North, New Zealnd, 28 November–1 December 2011; IEEE: Piscataway, NJ, USA, 2011; pp. 617–622.
[19] Catbas, F.N.; Susoy, M.; Frangopol, D.M. Struct. health monitoring and reliability est.: Long span truss bridge app. with env. monitoring data. Eng. Struct. 2008, 30, 2347–2359.
[20] Tibaduiza, D.A.; Torres-Arredondo, M.A.; Mujica, L.; Rodellar, J.; Fritzen, C.P. A study of two unsupervised data driven stat. methodologies for detecting and classifying damages in struct. health montr. Mech. Syst. Signal Process. 2013, 41, 467–484.
[21] Padmavathy, T.; Bhargava, D.; Venkatesh, P.; Sivakumar, N. Design and dev. of microstrip patch antenna with circular and rectangular slot for struct. health monitoring. Pers. Ubiquitous Comput. 2018, 22, 883–893.