Wireless Crack/Damage Detection in Aircraft Structure Using Wireless System

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***Abstract* — The structural crack/Damage commonly occurs in aircraft structure due to the ageing and repeated variations in stresses. The presence of crack/Damage changes the dynamic characteristics of the material and leads to catastrophic failure. Those are changes in stiffness, mode shape and natural frequency. Due to the crack/Damage in the structure gives uneven vibrations which will be noticed using PZT sensors. PZT sensors are used to detect the vibrations which are produced due to stress and developed a wireless system to read the crack/Damage data from PZT sensors. The wireless system is developed using MSP430G2553 microcontroller and Sub-1GHz transceiver. Selection of the microcontroller & RF transceiver depends on cost, power consumption, speed, memory, frequency and channel bandwidth. The collected data is transmitted wirelessly to the receiver or ground station and then displayed on the Liquid Crystal Display (LCD).**

Keywords— Crack/Damage; Catastrophic Failure; PZT sensor; Wireless system.

I. INTRODUCTION

The ability to monitor a structure and detect crack/damage at the early stage in the civil, mechanical, and aerospace industries. Most currently used damage identification methods are non destructive testing, acoustic or ultrasonic methods, magnetic field methods, radiography, eddy-current method or thermal field method. The quantitative damage detection methods that can be applied to structures to examine changes in the vibration characteristics of the structure. The modal parameters such as frequencies, mode shapes, and modal damping are the functions of the physical properties of the structure those are mass, damping and stiffness. Therefore, changes in physical properties, such as reduction in stiffness resulting from the initiation of cracks will cause detectable changes in the modal properties. Because changes in modal properties are being used as indicators of damage, the process of vibration-based damage detection eventually reduces to some form of a pattern recognition problem.

Crack/Damage may originate during fabrication or may be service-induced, The presence of delamination in a material may significantly reduce its structural integrity as well as its mechanical properties, such as stiffness and strength. These changes in the mechanical properties could result in the variation of natural frequencies and mode shapes. Vibration-based detection methods using dynamic parameters which can be easily and continuously extracted from the vibrations of a structure. The vibration monitoring is that damage in a structure reduces the local stiffness which results in changes in dynamic characteristics of structure such as natural frequencies, mode shapes and damping ratios etc. Therefore, by monitoring changes in these parameters damage can be detected. The monitoring of mode shapes requires measurements at multiple locations and prone to noise.

II. WIRELESS SENSOR NETWORKS TECHNOLOGY

Monitoring of the aircraft structures during the pre-flight testing is a important task of the aerospace industry. The most capable solution,is continuous monitoring of aircraft structures using wireless sensor network technology. WSN consists computational core and communication devices which consists of a processor, memory (Flash and RAM), digital-to-analog and analog-to-digital converters, RF transceiver, power supply. The sensors designed to monitor physical parameters or environmental conditions, such as strain, pressure, vibration etc. The sensor pass their data to a wireless system. The base station transmit data to the ground station via wireless system.

A sensor node typically consists of five main components.One or more sensors gather data from the environment and report the data to the microcontroller. A microcontroller is a central part of a wireless system. It processes all the data that receives from memory, sensor, or transceiver. A transceiver communicates with the environment. It is used radio frequency (RF) as a transmission medium to send data wirelessly. The transceiver can take data from a microcontroller to send it over the air and vice versa. A memory is the main resource for storing programmes and intermediate data coming from the sensors or the transceiver. The size of the memory depends on the application of the sensor.

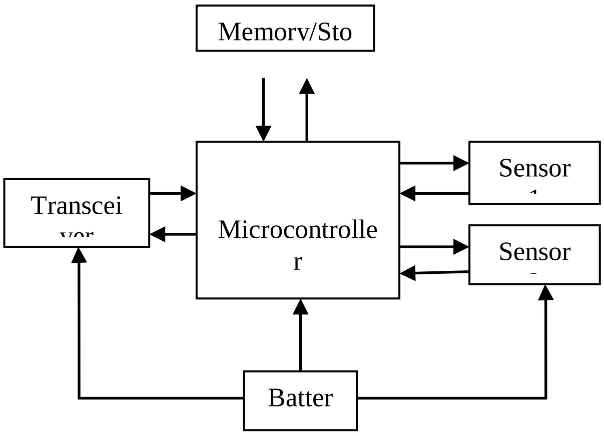


Fig 1: Block diagram of WSN

III. SPECIMEN DESIGN

The schematic diagram of specimen set up showed in Fig 2. The specimen had made dimensions of 180x45x 3mm (height x width x thickness).

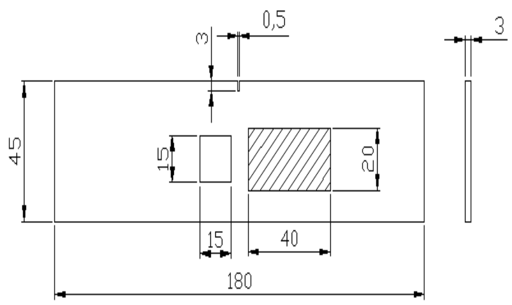


Fig 2: Specimen design

A 3mm small notch was made on middle of the test specimen. This has two PZT sensors of dimension 40x20x1mm and 15x15x1mm are used. PZT sensor with dimension 40x20x1mm bonded one side of specimen and opposite side dimension of 10x10x1mm PZT sensor are bonded with commercial adhesive Araldit

IV. EXPERIMENTAL SETUP

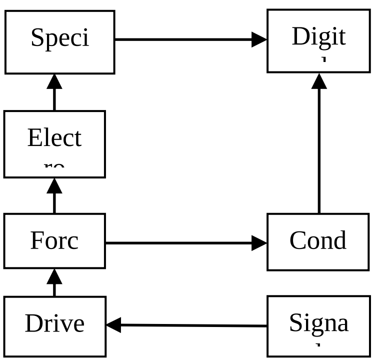


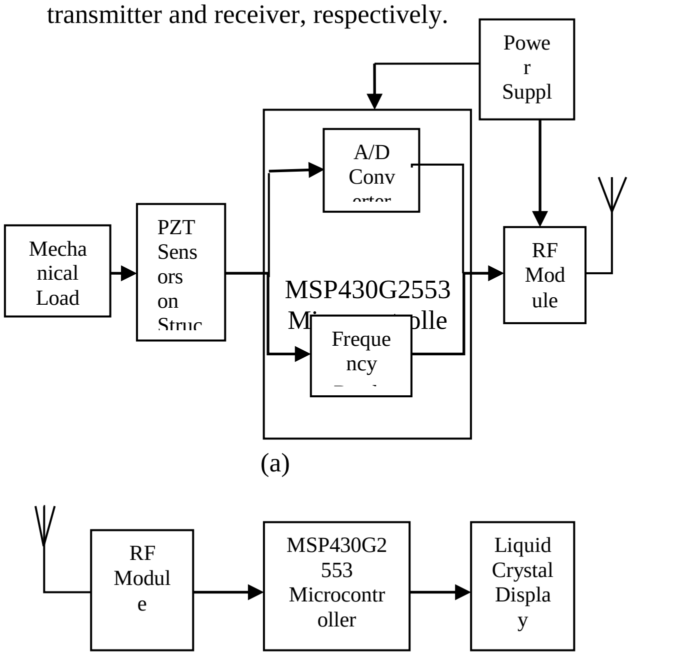
Fig 3: Block diagram of the experiment

The fig 3 shows the connection set up of the experiment which consists of electronic equipments namely, signal generator, driver amplifier, force transducer, conditioner amplifier,, electro dynamic shaker, specimen-Al plate with two PZT sensor, and two digital oscilloscope

Frequency generated from function generator is given as input signals to the driver amplifier. The amplified signal is applied to the electro dynamic shaker to vibrate the specimen. Force transducer converts this electrical energy to mechanical energy. The specimen consists of two sensors which produce voltages due to vibration and then these voltages are measured in oscilloscope. Accelerometer sensor is fixed at the tip of the specimen to detect vibrations from the specimen. The accelerometer and force transducer outputs are given as input to the conditioner amplifier. Output from conditioner amplifier is given to oscilloscope. Since PZT sensor generates AC voltage so two bridge rectifiers (BAT89 diodes) are used to convert AC to DC voltage. The sensor output DC voltage is connected to the laptop to store the output voltages.

V. HARDWARE IMPLEMENTATION

Fig 4 (a) and (b) shows the block diagram of transmitter and receiver, respectively.



(b)

Fig 4: Block diagram of (a) Transmitter and (b) Receiver, respectively

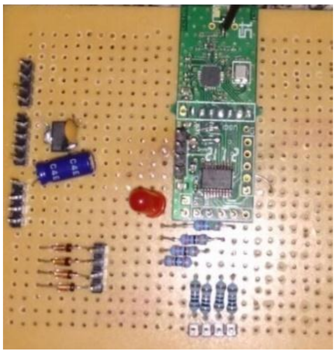
A Texas Instruments based mixed signal microcontroller MSP430G2553, is used in the transmitter and receiver. MSP430G2553 has a 16bit CPU and a built-in 10bit ADC and is used for low power applications. The architecture used in the CPU is 16 bit Reduced Instruction Set Computer (RISC) [9]. In idle mode the current drawn is less than 1 μA.

RF communication between Transmitter and receiver using ISM band is employed. The hardware CC110l is a sub-1 GHz type of RF transceiver. It operates in the frequency bands of 300 MHz to 348 MHz, 387 MHz to 464 MHz, 779 MHz to 928 MHz. The integration of the RF transceiver is done with baseband modem. Different types of modulating formats are supported by this modem and data rate is 600kbps.

Burst transmissions, data buffering and packet handling is supported by this CC110l. Serial Peripheral Interface (SPI) is used to control transmitting and receiving of data packets of 64-byte First In First Out (FIFO) configuration. This CC110l is used in both transmitter and receiver sides.

In the transmitter side four channel ADC has been configured to receive the four PZT sensor signals. Similarly, at the receiver side the demodulated signals are displayed on the 4 lined LCD.

An adjustable and fixed low dropout Voltage Regulator TLV1117 is used for providing an output current of 800mA and is shown in Figure 3. The Regulator operates in differential voltage with 1V input and the maximum dropout voltage is 1.3V at 800mA.


(a)


(b)

Fig 5: Hardware design of (a) Transmitter and (b) Receiver, respectively

Microcontroller is used to read the data which is obtained from the sensors. This data is transmitted wirelessly through antenna to the receiver where again the data is read from the microcontroller. Then the damages found are displayed on the LCD. The logical code for working of the transmitter and receiver are developed using Code Composer Studio (CCS) and flashed in to the microcontroller for working as independent modules. The receiver module is interfaced with LCD to work with battery.

VI. FLOW CHART

The flow chart for crack/damage detection in aircraft structure using CCS software. The CCS software interfaces with MSP430 microcontroller.

At the Transmitter side of the microcontroller

1. Power on the microcontroller by giving 3.3V power supply.
2. Run the microcontroller @1MHz frequency
3. Enable the ADC pins to capture the amplitude
4. Enable the capture compare input pins to capture the frequency
5. Feed the clock to the ADC and enable the ADC to measure the voltage
6. Enable the timer to continuous mode and enable the counter to count
7. Configure capture input pin as rising edge so when there is a rising edge on a pin will get an interrupt
8. When we get an interrupts will take the counter value and find the difference between two rising edge to get the frequency
9. Transmit ADC and frequency values via RF transmission
10. Enable SPI port and load the RF port configuration parameter to configure RF communication to be in transmitter mode with 868MHz
11. Transmit the data via SPI port to receiver

At the Receiver side of the microcontroller

1. Enable SPI port and load RF port configuration parameters to configure RF communication to be in receiver mode with 868MHz
2. Once the data is received from transmitter Sort out the data into individual sensors data
3. Enable the LCD and display the data.

VII. RESULTS AND DISCUSSION

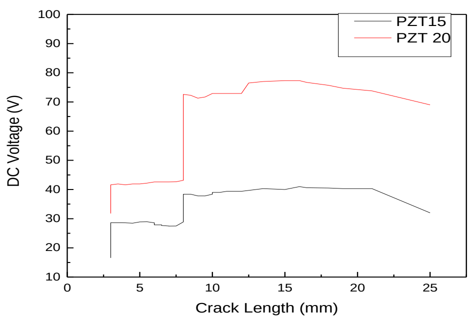


Fig 6: Crack Vs DC Voltage

The experiment of the crack detection specimens was carried out. It is observed that the energy from the PZT sensor increases as the crack propogates. And also observes that voltages increases depending on crack length increases. Once it reaches critical crack length the energy from the sensor reduces step by step. By this catostrophic failure of the structure can be identify using pzt sensor.

VIII. CONCLUSION

The aircraft industry benefit from the use of WSNs. Those benefits are weight savings, reduction in design complexity, lower operational and maintenance costs. In this paper we have discussed about wireless based crack/damage detection. From the experimental result concluded that without damaged specimen gives constant voltage and with damaged specimen varies the output voltage that should be displayed on the LCD using WSN.

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