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A Review on Applications of Flex Sensors

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***Abstract*— Flex sensor has multiple applications like most sensors. Even though it is widely used as a goniometer in rehabilitation research, its applications can be seen in different fields like, human machine interfaces, geology and musical instruments. In each application, the sensor identifies the flexure in terms of varying resistance that can be recorded digitally and the data is then used differently depending on application. With the advent of goniometer glove, measuring joint movements in rehabilitation research was simplified, which was earlier measured by mechanical goniometers. Later these gloves were used as human machine interfaces (HMI). Another type of HMI input device called a shape tape has been created to replicate shapes of real objects into CAD environment. In geology, the sensor was used to identify landslides remotely. Also flex sensor is used in creating a musical instrument that can be played by deforming and bending the instrument, to encourage experimentation to create interesting musical effects. Apart from these existing applications, this paper proposes another application to use the sensor to identify the dents on sheet metal panels, by recording flexure in two dimensions across the sheet.**

***Keywords*— Dent detection, Flex sensor, Flexure, Goniometer, Sheet metal**

I. INTRODUCTION

A flex sensor, also called bend sensor, measures the amount of deflection caused by bending the sensor. Developed from late 80's, there are three kinds of flex sensors. Initially optical flex sensors [1] were created and later conductive ink-based flex sensors [2] and capacitive flex sensors [3] were developed as alternates to prior, by different people. Although used for sensing 'deflection', each of the type of flex sensor is different in both construction and working principle.

Optical flex sensor [1] consists of a flexible tube having two ends, a reflective interior wall within the flexible tube and a light source placed within one end and a photosensitive detector placed within the other end of the flexible tube to detect a combination of direct light rays when the flexible tube is bend.

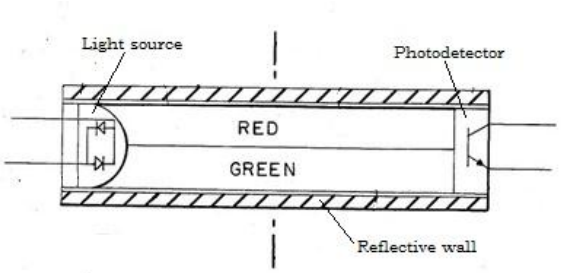

Figure 1 Optical flex sensor [1]

Conductive ink based flex sensor [2] consists of a phenolic resin substrate with conductive ink deposited and thereon a segmented conductor is placed on top to form a flexible potentiometer in which resistance changes upon deflection.

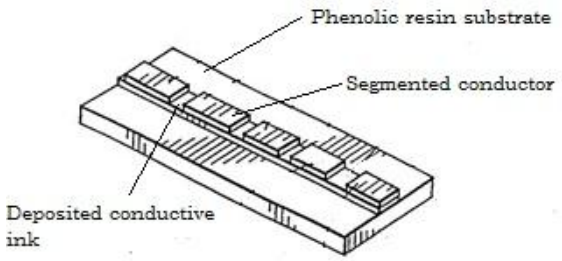

Figure 2 Conductive ink based flex sensor [2]

Capacitive flex sensor [3] has two conductive layers of metals separated by dielectric material in between conductive layers and thereby reducing resistance between them that change in relation with deflection.

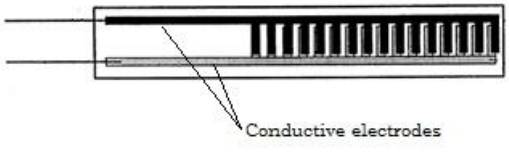

Figure 3 Capacitive flex sensor [3]

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Initially optical flex sensor was invented to be used in goniometer gloves, later with development of sensor; many papers were published that use the sensor in different fields.

II. Current Status Of Knowledge

Some of the papers that provide insight into how wide the applications of flex sensors exist, with various hardware combinations have been briefed below. Also how a flex sensor can be used to identify dents or damage on sheet metal is stated.

A. Flex sensor as Goniometer

Goniometer glove is widely used in rehabilitation research, to measure movements in fingers. Giovanni Saggio [4] stated "mechanical goniometer takes lot of time to measure and poor repeatability, while goniometer glove has high repeatability"; evidently the sensor has high repeatability. He used a coating of carbon resistive element on a plastic substrate to use as flex sensor. An electronic circuit was designed to acquire resistance values cycling among sensors, to realize an A/D conversion, and send data to a computer. A similar setup of goniometer glove to measure hand function in individuals with hand dysfunction was evaluated for feasibility, measurement repeatability and reliability, fidelity of wireless transmission and user acceptance, was done by Lisa K. Simone et al. [5]. The sensor signals were sampled using the 12 bit A/D. The wireless protocol selected by them was IEEE standard for low-rate wireless personal area networks.

Figure 4 Goniometer glove [4]

B. As HMI device's sensing element

HMI devices help interact with machines by hand gestures.

A glove was developed by Giovanni Saggio et al. [6], to interact with virtual 3D objects. The measured movements of user hand furnish electrical signals that are converted into action/movement of a virtual 3D avatar. An operating range of -90^o to 180^o is achieved by programming. ZigBee protocol, a low cost, low power networking standard has been used to wirelessly record data via Wireless Personal Area Network (WPAN).

C. As obstacle contact sensor

R. Ponticelli et al. [7] have developed a low cost obstacle contact sensor. On a mobile system like autonomous mobile robot; the sensor is used to detect both the contact state and the direction of contact parallel to the movement plane. Other obstacle sensors like infrared, ultrasonic etc. may employ a higher cost. A set of four flex sensors is connected mechanically to the contact detecting ring, and wired to a low-cost electronic module to sense obstacles. Moreover a fuzzy inference system is used that represents the contact zone of the sensor's platform, instead of a binary data classification, neural networks or support vector machines.

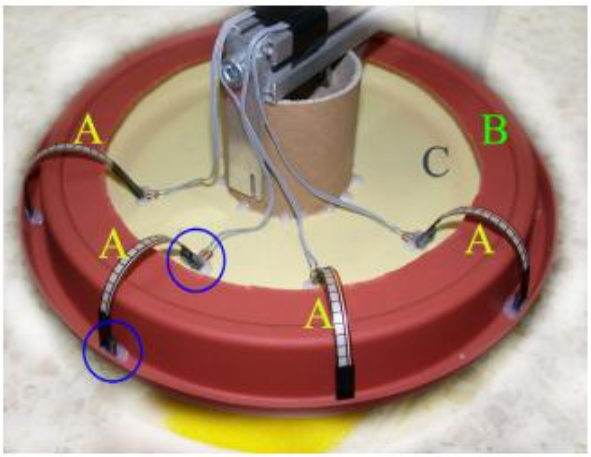

Figure 5 Obstacle contact sensor [7]

D. As a sensor in identifying landslides

Amrutha Joshy and S. Senthil Kumar [8] have made a sensor system that can identify landslides. The system consists of receiver station and transmitter poles or sensor columns which communicate through internet. Each sensor includes a stick with flex sensors and Micro Electro-Mechanical Systems (MEMS) accelerometer. User Data-gram protocol (UDP) was used for sending and receiving data.

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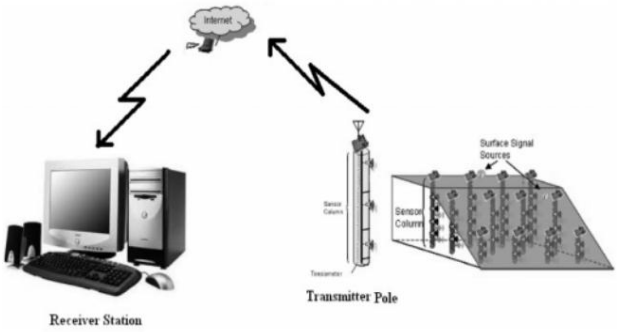

Figure 6 Sensor system for identifying landslides [8]

E. As a sensor for intrusion detection system

Flex sensor was also used to detect status of door for an intrusion alert system. In a project done by Chabbila Prasad Suna [9] at NIT Rourkela, status of a door was detected using this flex sensor. A circuit has been made using Arduino board, and flex sensor attached to its analog terminals. The status of door can be detected by indicator LED on Arduino board.

F. As sensing element of pliable interface

Mark Zadel et al. [10] have created a physically manipulable musical instrument interface using the sensor as an element of it. Flex sensors were embedded to foam pad, and were concealed by another foam sheet. Two pairs of sensors were placed perpendicular, to measure deformation of foam pad in two directions.

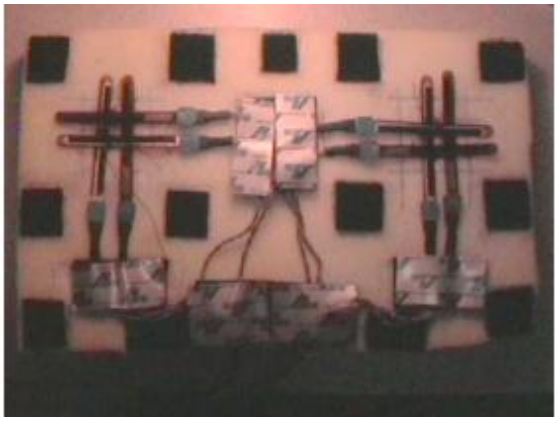

Figure 7 Two pairs of flex sensors arranged perpendicularly [10]

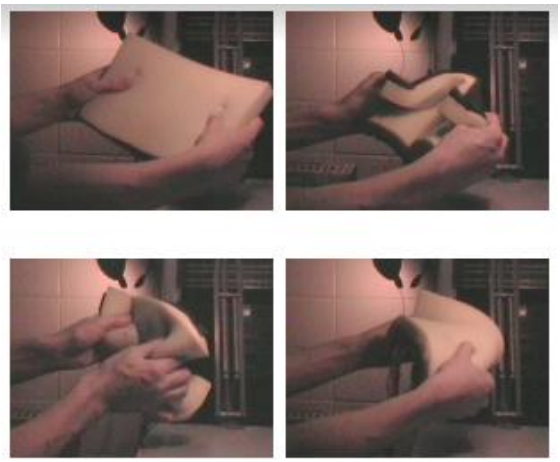

Figure 8 Deformation gestures [10]

G. Dent or Damage detection

Dent or damage detection earlier was done in German research project KESS (Konfigurierbares Elektronisches Schandensidentifikationssystem) [11], by using sound emission analysis. Sound emission analysis was earlier used for aircrafts [12]. In project KESS, a test car has been equipped with eleven structure-borne sound sensors. Every sensor is mounted to a single vehicle body part. The digital signal is then forwarded to internal microcontroller to be analyzed, and a notification message is sent to electronic controller unit if and only if a minor damage occurs. The vibrations of vehicle in various test drives have been recorded on different road surfaces like blacktop, cobblestone, dirt road, field road and concrete highway. But such a system may not give accurate results in case of a vehicle crash, since natural frequency of metal panels change vigorously after large deformations, and damage detection may be inappropriate.

Hence a damage detection system should be able to record the shape of the metal sheets at all times to detect a dent or damage. A shape tape has been created by Ravin Balakrishnan et al. [13], a new input device in 3D computer graphics modeling. Bend and twist are measured at 6 cm intervals by two fiber optic flex sensors. By summing the bends and twists of the 16 sensors along shape tape, the shape of the tape relative to first sensor can was recorded. A flex sensor can be thus used to detect the shape of objects effectively.

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A grid is to be made out of these flex sensors to detect the changes in shape on sheet metal in two dimensions similar to the work of Mark Zadel [10]. To detect dents or damage, a layer of flex sensor grid is to be made and a way of attaching the grid beneath sheet metal has to be established. Once this is done, the grid of these flex sensors has to be connected to a microprocessor to record the data digitally. Such a setup should be able to record a dent or damage in terms of deflection of a sensor below it.

III. Applications

Since sheet metal is used in applications such as automobile body panels, lockers or vaults, damage can be recorded digitally and alert can be generated remotely. Unlike damage detection by sound emission analysis, this method can be used not just in automobiles but in other sheet metal applications, where the sheet metal structure has no natural vibration.

IV. Conclusion

A large number of applications already exist for a flex sensor. The already existing applications show that the flex sensor has good repeatability. The sensor data can be wirelessly transmitted in different ways, and it can be effectively used in identifying the shape of objects. These applications mentioned, aided for using the sensor in a new application, i.e. to use a grid of flex sensors as an instrument to identify dents on sheet metal is proposed.

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