Foot Pressure Monitoring Device Based on Optical Fiber

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ABSTRACT: In this paper, a comparison between different types of devices for foot pressure monitoring is presented, including capacitive sensor, inductive sensor, resistive sensor, piezo-based sensor cracked-based sensor and fiber optic. From the comparison, a multipoint pressure sensor using optical fiber sensor based on micro-bending technique is identified as an alternative method proposed for this application. One difficulty in designing foot pressure monitoring sensor is to identify the location to place the sensor on the foot surface for different foot sizes. This sensing method can be implemented to place the sensor according to the foot size for effective foot pressure data collection. The sensor is yet to be applied on a real human's foot for foot pressure distribution data at current stage.

Keywords: *Foot Pressure Monitoring; Optical Fiber Sensor; Embedded in sole or sock*

1. INTRODUCTION

Based on previous studies, the main factors in the occurrence of foot pain is due to overweight and the use of shoes that are not suitable for daily activities [1]. As a result, the pressure due to gait activity cannot be spread evenly on the surface of the foot plantar. Typical example of health problems associated to foot pain are hip pain, knee pain, leg cramps and fatigue, ankle pain, weak ankles, lower back pain, tripping, foot cramps, Achilles pain, arch pain, heel pain, callous (hard skin), pain during or after walking and running and also shin splints (pain in the front and inside of shin) [2].

Foot pain, in particular plantar fasciitis can generally be treated without the need to see a healthcare professional using 'Rest', 'Ice', 'Compression' and 'Elevate' or known as (RICE) therapy. The advantages and limitations of each device are discussed and compared in this paper. A new approach to design foot pressure sensor is also presented to improve current characteristics of the foot pressure monitoring devices.

2. COMPARISON BETWEEN DIFFERENT SENSORS FOR FOOT PRESSURE APPLICATION

The currently available technologies for foot pressure monitoring application is summarized to illustrate the characteristics of each sensing approach.

2.1 Capacitive sensors - composed of two electrically conductive plates separated by an insulating elastic layer and when a force is applied, the distance between the plates changes, resulting in a voltage variation [3, 4].

2.2 Resistive sensors - they are made of a conductive polymer and when a pressure is applied, the resistance of the material declines with the increment of the applied pressing / pressure magnitude. [5]

2.3 Piezoresistive and piezoelectric sensors – based on the piezoelectric effect. When the material is stretched, the variations of an applied pressure are converted into a measurable electrical charge, via the variation of electrical resistance. Another method is, the conductive inks are used for creating a textile material that is thin and sensitive to pressure. [6]

2.4 Inductive sensor – based on eddy-current principle, using a sensing coil and a conductor. As alternating current flow through the coil, a magnetic field surrounds it. When a conductor's surface is brought into contact with the coil (due to pressure detection), eddy currents will be induced. The eddy current, according to Lenz's law, generates its own magnetic field that opposes the original field generated by the coil [7].

2.5 Crack based sensor - In a chamber with a specific radius of curvature, the crack sensor is attached to a stainless steel that can be inserted and fastened. When the crack-based sensor is bent to pressure, the nano- cracks of the sensor disconnect and the resistance rises, allowing pressure to be detected as a change in resistance [8].

2.6 Fiber optic sensor – based on the use of Fiber Bragg grating technique. When light from a broadband source is coupled into an optical fiber that contains the FBG, a narrow spectrum is back-reflected and centered around the Bragg wavelength, which is determined by the FBG's periodic variation and the effective refractive index [9, 10].

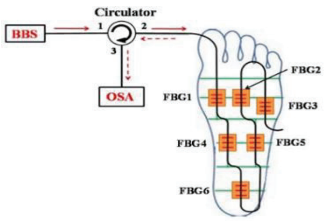


Figure 1 FBG based pressure sensor [9]

3. CLASSIFICATION OF EQUIPMENT IN GAIT MONITORING SYSTEM.

There are three different types of plantar pressure and gait analysis devices on the market right now. Their characteristics, advantages and limitations are as below:

3.1 Platform System

The plantar platform system as shown in Figure 2 is a rigid, embedded platform, built on a flat surface, which enables a dynamic gait and a static posture such as walking, running, and jumping. It contains multiple pressure sensors embedded inside the platform [11,12].

3.2 Wired In-Shoe System

In-shoe system is available at a lower cost as compared to platform system. This system is simpler, portable and can be attached inside the shoes for daily monitoring of the foot pressure data [12].

3.3 Smart Socks using Textile-based Sensor

Smart socks device is based on built-in sensors (i.e. inertial sensor) knitted on the socks' outer surface [12]. This system is more user friendly, lightweight and suitable for continuous foot pressure monitoring.

Table 1: Characteristics of Foot Pressure System

	Type of System	Characteristics	Ref.
1	Platform System	- Static position, not suitable for daily data	11,12
2	Wired in-shoe System	- Low cost, simple design, portable, fix foot sizes	12
3	Smart Socks	- Calibration issue, need frequent change after use	12



Figure 2 The plantar platform [11], Figure 3 Wired insoles system [13], Figure 4 Smart Socks [12]

4. PROPOSED DESIGN FOR FOOT PLANTAR MONITORING

Based on the reviewed existing in-shoe and platform foot plantar systems, it appears that critical locations for foot pressure measurement are dependent on the foot arch type i.e. for a flat arch, normal arch and high arch as shown in Figure 5. It is possible to attach several optical fiber cables into a 3D printed shoe sole which locations can be re-adjusted for different foot arch type or foot size.

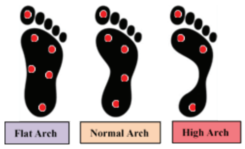
Alternatively, socks can also be used as a medium to attach the fiber with proper knitting process to avoid sensor dislocation during measurement process. Figure 6 shows the proposed optical fiber placement for this application. Flow chart of the proposed optical fiber foot pressure system is as follow:

Foot pressure → Micro-bend fiber sensor → Wireless data transmission → Data storage

Figure 7 Optical foot pressure system flow chart

5. CONCLUSION

Current foot pressure monitoring systems are available using platform-based system, wearable shoes, in-sole system or textile sensor embedded in socks. This paper proposed a wearable optical fiber sensor via micro-bending optical fiber technique. The accuracy, sensitivity and resolution will be discussed in the future publication related to this work.



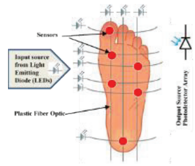


Figure 5. Foot arch type, Figure 6 Proposed Sensor

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