Design and Development of a Pressure Measurement Device for Compression Garment (Knee Guard)

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Abstract— **This study is to develop a Pressure Measurement Device, used to measure the compression given by compression garment (knee guard). Flexiforce sensors and microcontroller are the main components used in this project. The sensors are calibrated using 50 gram mass, since the range of pressure is 5332.9072 Pascal or 40 mmHg. A system is designed using an Arduino Uno rev.3 and a Flexiforce sensor. The Arduino programming is compiled and uploaded using Arduino compiler version 1.0.5 r2. The device is programmed to indicate the amount of pressure using LED, where three indicators that were used are yellow, blue and red. The result shows that the pressure exerted by the knee guard is in the range, thus proves that this device is able to measure the compression given by the applicant knee of the knee guard.**

Index Term— **Compression garment, Pressure measurement device**

I. INTRODUCTION

There are various types of injuries that can happen to athletes. To mention, sprained, dislocation, strained, swollen muscles and fractures. The examples of most common injuries are ACL injuries, knee ligament injuries, knee arthritis, sprained ankle, shin splints and etc.

Knee consists of several elements which are bones, cartilage, ligaments and also fluid. In the human body, knee is the most complex systems in human body, the largest joint. The connectors like muscles and tendons enable the knee to moves around.

However, the most common acute injuries that an athlete faced are MCL (Medial Collateral Ligament) and ACL (Anterior Cruciate Ligament) sprains. ACL injuries occur when the athlete lands from a jump, stops suddenly or change direction in a short time, and MCL occurs often in contact sport [1].

55% of the leg injuries are related to knee injuries. The symptom of a knee injuries is depends on the severity and location and thus it may be different from other. Examples of symptoms that often related to knee injuries are swelling and stiffness, limping, redness, unable to straighten the knee or ‘locking’ of the knee [1].

As for prevention measure, the type of treatment offered will be basically based on the severity of the injuries, age, health condition and level of activity. There are two types of treatment, nonsurgical treatment and surgical treatment. For nonsurgical treatment, the knee injuries are treated with immobilization, physical therapy and non-steroidal anti-inflammatory medicine. And for surgical treatment, the injuries needs open surgery that will enable the surgeon clearer view and easy to access to the injure structures [2].

Commonly, different knee guard exerted different pressure due to the material used. Lawrence and Kakkar [3] proposed that to generate the fastest venous flow, the optimal applied pressure is 18 mmHg at the ankle, 14 mmHg at the calf, 8 mmHg at the knee, 10 mmHg at the lower thigh and 8 mmHg at the upper thigh. Pressure generated from branded sport garments ranges from 19.0-30.0 mmHg at the ankle to 17.6-25.0 mmHg at the calf and to 9.1-18.0 mmHg at the thigh, but these claims are not proven by any research [4, 5].

Compression garments’ performance in improving sports performance, minimizing sport injuries as well as maintain muscle function has attracts the attention of many researchers [6] [7].

The compression garments used by the athletes are made using mass production which have several limitations in terms of the pressure level for the compression garment, whether too high or low [8]. When wearing them too tight, it will cause discomfort around the knee as the blood pressure is increasing. Since the wearing of the knee guard is mainly to increase the performance and the rate of healing, if an appropriate pressure is not achieve, then the main function of the wearing will not be achieved. By considering these factors, an accurate range of pressure needs to be determining precisely so that the problem can be overcome.

Therefore, to solve the problem, a solution is identified by choosing a correct pressure sensor is used to detect the pressure exerted by the knee guard. Also, by using appropriate theories and circuits, a measurement system can be developing to produce a device that is measurable and functional.

Based on the problem statement gained, several objectives are identified. The objectives of this project are to identify system that can be implemented in the device, to measure the pressure generated from the knee guard and to design casing of device for measuring pressure generated from knee guard.

II. METHODOLOGY

a) System design

The system consist of a Flexiforce sensor, an Arduino board, a breadboard, three light emitting diode (LED), red, yellow and blue, three 10k ohms resistors, one 47k ohms resistor and jumper wires. Flexiforce sensor is build consist of a printed circuit that contains two conductive strips and the active region, and surrounded by two polyester film. The sensor consists of three male pins, where two outer pins are actives and centre pin is inactive. Connect 5V from the Arduino to one pin of the sensor, and ground to the other pin. At the ground pin, connect a 47k ohms resistor. Then, at the place where the Flexiforce sensor and the resistor connect, wired the analog–in pins of the Arduino using a jumper wire. In this project, pin A0 is used. As for the LED, connect the anode pin of the LED to the digital-in pin of the Arduino for 8, 12 and 13 respectively for yellow, blue and red, and the cathode pin to the ground using jumper wire. In the middle between anode pin of the LED and digital-in pin of the Arduino, connect 10k ohms resistor to all LED. The system design and schematic diagram is shown in figure 1 and figure 2.

Arduino is a type of microprocessor that is used in most electronic devices. Arduino requires a programming language, a simple computer programming that can be implemented through universal serial bus (USB) cable, or it can also be stand-alone. The programming needs to be sketches down and uploaded using Arduino compiler or Arduino IDE. In this project, Arduino UNO board rev.3 and Arduino compiler version 1.0.5 r2 are used.

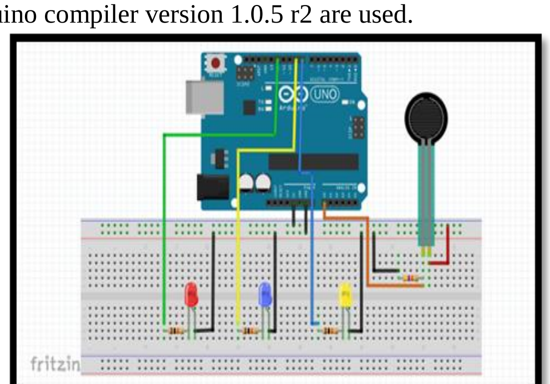

Fig. 1. System design

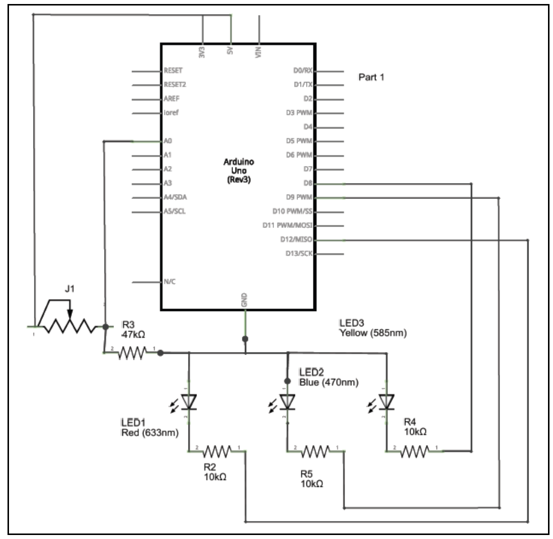

Fig. 2. Schematic diagram

Before using the sensor, calibration process is essential to ensure the accuracy and linearity of a sensor, since the performance is influenced by the surrounding temperature and condition. The calibration of the sensor is depends on the range of pressure, which indicates the amount of masses needed. Since the normal amount of pulse pressure in human is 40 mmHg, the amount of mass needed is 38.78 gram. Therefore, 50 gram of mass is chosen as it is in the range of normal pressure. A total of 60 reading collected in one minute are recorded and tabulated for the calibration process.

Fig. 3. Calibration process

The design is developed based on the dimension of the Arduino microcontroller.

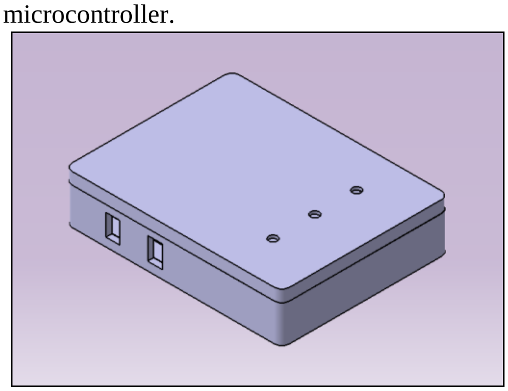

Fig. 4. Cover Design

III. RESULT AND DISCUSSION

a) System calibration

Figure 5 shows the output voltage versus time graph. This graph is plotted to observe the sensor's linearity and accuracy. If the reading is overlap between each other, then the sensor is not considered as linear and thus, the output reading will be incorrect and not consistent.

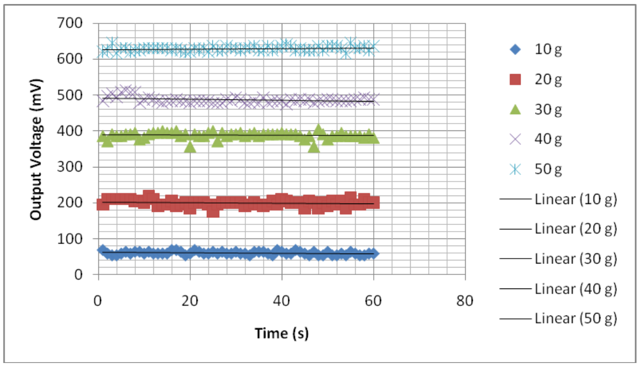

Fig. 5. Output voltage versus time graph

Figure 6 shows the pressure versus average voltage graph. From this graph, it can be seen that as the average voltage is increased, the pressure will also increased.

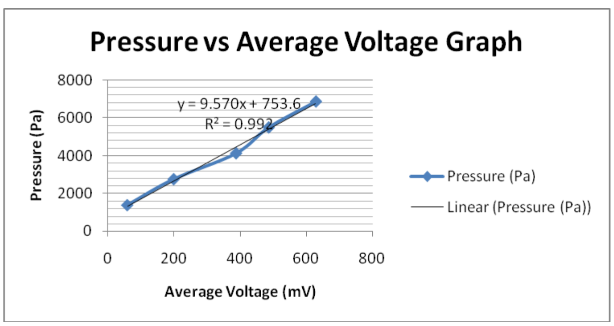

Fig. 6. Pressure versus Average Voltage graph

Fig. 7. Knee guard used in testing

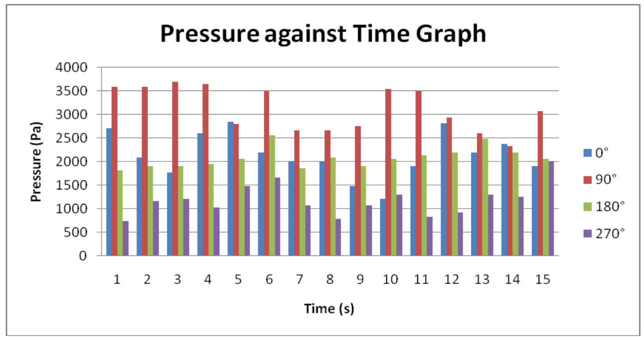

Fig. 8. Pressure versus time graph

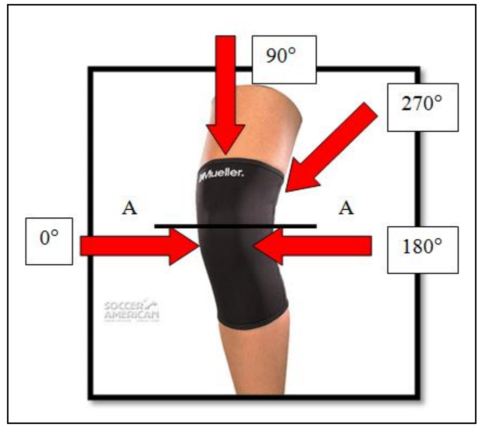

Fig. 9. Position of the sensor

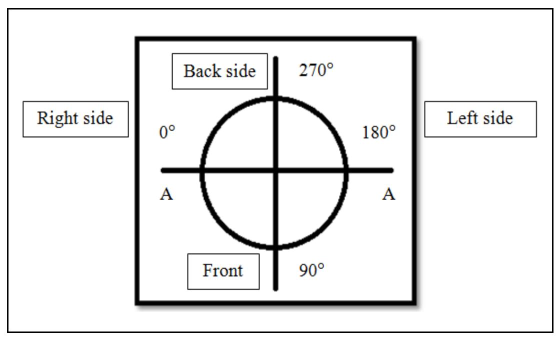

Fig. 10. Cross-sectional area of the knee

The objectives of this project are to identify system that can be used in the device, to measure the pressure generated from the knee guard and to design casing of device for measuring the pressure. To realize these objectives, two main components are identified, which is Arduino Uno rev.3 microcontroller and a Flexiforce sensor. The sensor is used to measure the pressure exerted from the knee guard based on the several characteristics, the sensor have a good flexibility, good linearity and as well as accuracy [9]. Figure 5 shows the results obtained from the calibration process. As can be seen, the reading for each mass is linear and not overlaps each other. Although there is a sudden increase and decrease during a time, the reading is still not overlapping each other. The fluctuations that occur might be due to the external forces like vibrations, temperature changes and etc.

To prove the sensor's accuracy, based on the output voltage that is gained from the calibration, Pressure versus average voltage graph is plotted. From the graph, as in figure 6, the pattern of the line is also linear, as the amount of pressure is increase when the average voltage is increased. There are also some fluctuations that can be spotted at range 200mV to 400mV. Since the sensor is very sensitive to the condition of the surrounding environment and other external forces, therefore, that could be the reasons that cause the fluctuations to occur.

Then, to compare the sensor's validity, a graph of average resistance versus mass and conductance versus mass is plotted. The sensor is typically has a very high resistance when there is no force applied to it. If a force is applied to the sensing area, the resistance will decrease.

To record the variation of pressure generated by the knee guard, the sensor is placed approximately 90° around the athlete's knee, with a total of four different angles. The placement of the sensor is shown in the cross-sectional area of the knee, as in figure 9.

Figure 8 represent the pressure in the bar graph. At 0°, the highest pressure is recorded at fifteen second of time, where for the 90°; the highest reading is recorded at six second of time. As for 180°, the highest pressure is recorded in the six second of time and for 270°, the highest reading of pressure can be seen in the three second of time. The measurement is taken in standing position. The highest average reading recorded are when the sensor is placed at the front of the leg, with 3129.00 Pascal, followed by right side of the knee, with 2144.53 Pascal, left side of the knee, 2081.33 Pascal and at the back of the knee, with 1191.80 Pascal. The decrease in radius will cause the pressure to be higher, as can be seen in the front side reading. It is differ for the back of the knee where the reading is lower compared to other. Since the pressure generated is influenced by the material composition [10], therefore the result could be differ for other types of knee guard.

The LEDs that are used to indicate the pressure have lights up according to the set range of pressure. The range of pressure is set for more than 2666 for yellow LED to light up, more than 5333 for blue and 7999 for red to light up.

IV. CONCLUSION

As a conclusion, in this project, a new system of measuring the pressure generated by the knee guard has been identified and used in carry out this project. The output pressure that is tabulated and recorded is in the pressure acceptance range which is in between 1000 Pascal to 3000 Pascal. The design of the device is finalized using AHP method develop using 3D modeling software, CATIA V5R16 software. This pressure measurement system also can be applied for medical purpose especially on pressure garments.

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