TECHNICAL NOTE

Fabrication and Validation of Respiratory Control Belt Using Load Cell Sensor

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Abstract

Purpose: In this work, we have focused on fabrication and validation of a respiratory belt that produces respiratory signals from the patient's abdominal and thorax.

Materials and Methods: A load cell transducer was attached to the belt to create an electrical signal from respiratory movement. It converts a force or load into an equivalent electrical signal or digitized load value. The accuracy of the signals from our respiratory control belt was evaluated according to a comparison with the signals from commercial SOMNO medical device.

Results: The pattern of the signals from our respiratory belt is in good agreement (4%/3mm) with the pattern of commercial SOMNO medical device.

Conclusion: The manufactured respiratory control belt can be used during imaging and radiotherapy procedures for breath control in a patient's abdominal and thorax region.

Keywords: Respiratory Getting Belt; Load Cell Sensor; Breath Control.

1. Introduction

Obtaining a respiratory signal using load cell sensors has attracted attention among electronic community due to its versatility and growing availability, as well as the potential availability of different geometries useful for quality assurance. In contrast, conventional respiratory signal receiving devices in the market are mainly expensive. Therefore this respiratory signal device can provide a potent tool providing the electronic and medical etc. communities with their specific needs [1–3].

There are several types of strain gauge load cells available to researchers and manufacturers. Strain gauge load cells offer accuracies within the range of 0.03% to 0.25% full scale and are suitable for almost all industrial applications. They are also recommended for medical applications and in general anywhere more accuracy is required [4,5].

Strain gauges are resistors that change their resistance proportional to the load that deforms them. They consist of a pattern of resistive foil mounted on a backing material. The strain gauge can usually convert pressure (force) into an electrical signal [5–9].

There are a number of publications related to load cell sensors in the field of electronic, medical physics, etc. [2,9]. Mizuno *et al.* in 2019 used one of the load cell sensors model for commissioning a respiratory gating system in radiotherapy [10]. Muller *et al.* in 2010 used load cell sensor entitled Load Cells in Force Sensing Analysis – Theory and a Novel Application, which examined the types of load cells [2].

In this work, we have focused on fabrication of a device that produces a respiratory signal and evaluates this signal by using a commercial SOMNO medical device.

2. Materials and Methods

A load cell is a transducer used to create an electrical signal (usually a voltage) whose magnitude is directly proportional to the measured force. When a load is applied to an object, the object is deformed a certain amount. The amount of deformation of the object experiences is affected by the size and material of the object as well as the size of the load applied to it. The ratio of the deformation of the object to its original size is known as strain (Equation 1). The Strain of the load cells is

introduced as a conversion of a force or load into an equivalent electrical signal or digitized load value.

$$Strain = \frac{l(deformation)}{L(original\ size)} \qquad (1)$$

The gauges themselves were bonded onto a beam or

Figure 1. The definition of strain

structural member that is deformed when weight is applied. In this study, four strain gauges were used to obtain maximum sensitivity. Two of the gauges were usually in tension, represented as T1 and T2, and the other two in compression, represented as C1 and C2 in Figure 2. All wires have compensation adjustments. Gauges were mounted in areas that exhibit strain in compression or tension. When weight is applied to the load cell, gauges C1 and C2 compress decreasing their resistances. Simultaneously, gauges T1 and T2 are stretched increasing their resistances. The change in resistance causes more current to flow through C1 and C2 and less current to flow through T1 and T2. Thus, a potential difference is between the outputs so it leads to the signal of the load cell. The gauges were mounted in a differential bridge to enhance measurement accuracy. When weight is applied, the strain changes the electrical resistance of the gauges in proportion to the load.
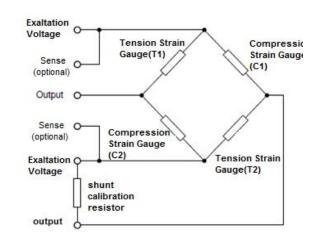

Figure 2. Principle of a Wheatstone bridge

A load cell usually is in the form of a properly shaped and sized piece of material, often a type of metal, to which the force is applied. The distortions applied to this material caused by the force may be measured by attached strain gauges, piezoelectric elements, or other methods. The material's shape and elasticity determine the output response, which may be balanced or adjusted to counteract effects (Figure 3) [11].
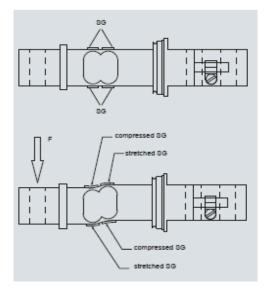

Figure 3. Principle of a bending load cell, unloaded and loaded

Herein, each straight bar load cell is made of an aluminum-alloy and is capable of reading a capacity of 5 kg. These load cells have four strain gauges that are hooked up in a Wheatstone bridge formation. The color code on the wiring is as follows: red = E+, green = O+, black = E-, and white = O- (Figure 4).
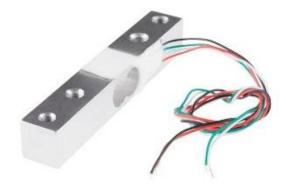

Figure 4. Load Cell–5 kg, Straight Bar

The fabricated respiratory control belt in this study has utilized a main board and a load cell sensor (pressure sensor). The strain gauge load cell, which is connected to the main board through a port, is enclosed by a belt around the patient's body. When the patient is breathing, pressure is applied to the sensor.

The respiratory signal from the pressure sensor is transmitted to the main board and after analyzing is transferred to the computer via Bluetooth. The main board consists of several modules. Pre Amp, where the signal information is first transmitted to, does the initial amplification of the signals coming out of the sensor and eliminates the impact of loading on the sensor. After Pre Amp, the information enters A/D (A to D) where the digital data from the previous module is read in it. MSU packs the data and then introduces it to a new module which might be Bluetooth, Wi-Fi or USB. A Bluetooth was used in this study for data transfer. A\D has 24bit resolution and 10Hz sampling rate. Bluetooth is in the form of waves that has an antenna, so information is transmitted to the computer in the form of waves. The battery in the main board is connected to all parts (Figure 5).
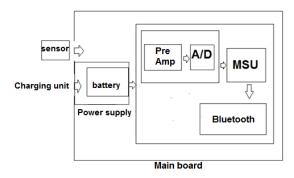

Figure 5. The graph of main board

When the data is received by the computer, through MATLAB Program we can observe and evaluate the patient's respiratory signal. The horizontal and the vertical axis depict the sampling rate and the range, respectively (Figure 6).
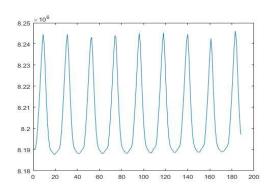

Figure 6. The respiratory signal obtained from the device

The respiratory signal acquired from the pressure sensor was then compared to the signal from SOMNO medics for the evaluation of the respiratory control belt to compare the overall amplitude and phase shape.

SOMNO medics device is a commercial device that can record respiratory signals during ambulatory/home sleep test.

SOMNO medics Technical Features:

- Miniaturized, portable unit, worn by the patient

- Up to 58 channels-8 channels integrated in base unit

- Modular design upgradeable at any time

- Adjustable sampling rates up to 512/s (4096/s optional)

- Continuous display and recording of electrode impedances

- Display with control keys allows PC independent set-up and operation

- View and check signals on the display, including system status and signal quality

- Li-Ion battery for up to 33 hours of continuous recording and rechargeable without memory effect. The battery can be replaced quickly and easily

- Data is stored on industry standard High-Speed Compact Flash Cards with up to 2 GB capacity or up to 100 hours of PSG recording time (Figure 7)

To perform the validation of our proposed device, a SOMNO device called the effort sensor (thoracic and/or abdominal effort) was used that includes Respiratory Inductive Plethysmography Belts or Strain Gauge Sensor. Both devices were used simultaneously on the patient's body and the respiratory signal was obtained from it (Figure 8).

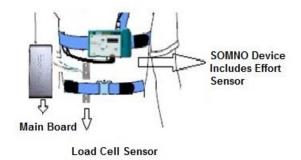**Figure 7.** SOMNO device

Figure 8. Effort sensor

Figure 9. How to place two devices on the patient's body

3. Results

The diagram shows the accuracy of our device in comparison with the SOMNO device. The red signal is obtained from the sensor and the blue signal from the SOMNO device. The chart is in terms of amplitude and sampling rate. The amplitude results were in good agreement (4%/3mm) (Figure 10).

4. Discussion

Load cells are highly accurate transducers which provide the users with information not generally obtainable by other technologies due to their commercial factors. Considering the shape and size of the sensor due to its placement on the surface of the human body and the high accuracy required due to the small displacement of the body, the strain gauge load cell was the best option. They do not contain fluids, therefore, there is no possibility of contamination during the process even if they break. The load cells of the voltage meter can be used for both expansion and compression. Strain gauge load cells are less costly so mostly used in the industry [12–14] .In order to get the most benefit from the load cell, the user must have a thorough understanding of the technology,
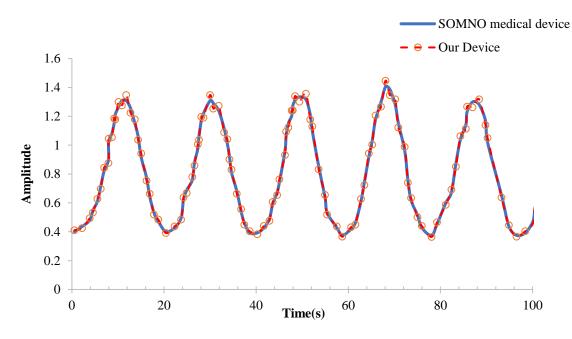
Figure 10. Comparison of respiratory signal device with SOMNO device

construction and operation of this unique device. The respiratory signal device is very light and easily portable, which is one of its potential advantages and it is also reasonably priced compared to other devices.

5. Conclusion

In this study, a manufactured respiratory control belt introduced for imaging and radiotherapy procedures for breath control in a patient's abdominal and thorax region.

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