Design of a Pressure Sensor to Monitor Teeth Grinding

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Abstract

Studying teeth grinding behavior and other oral diseases requires the ability to accurately measure the pressure on the teeth. Placing a sensor in the mouth requires small size devices with powering and measurement techniques that do not hinder the normal life of the patient. To meet these requirements, we designed, using COMSOL, a small, easy to read MEMS capacitive force sensor, with adjustable dynamic range and high sensitivity. The sensor is a capacitive sensor and can be read using commercial Radio Frequency Identification Device (RFID) tag reader. A small RFID tag, with 3 mm antenna coil, is integrated with the sensor. The sensor is then implanted on the top of a tooth. If a force is applied on the tooth (the sensor), a related change in the sensor's capacitance takes place. Since the sensor's capacitor is added in parallel to the tag's original capacitor, the change in the tag's capacitor results in changing the resonance capacitance of the tag. This can be related to the applied force. Using digital signal processing techniques, the tag's readings can be measured with high accuracy. Figure 1 shows the schematic diagram of a group of four force sensors: two are shown and the other two are behind. The crown ends with cones to apply the force on the diaphragm. Under the crown, there is elastic material to allow for the free movement of the cones. Since the crown is free to move only in the Z direction, only Z-direction forces applied on the crown are transferred to the sensor's diaphragm through the cones. This results in the corresponding movement of the capacitor plate in the same direction. The circumference of the diaphragm is connected to a fixed frame, with high young's modulus, to allow only the center point of the diaphragm to move, as shown in Figure 2. COMSOL simulation, shown in Figure 2 (b), shows the diaphragm displacement under the forces, which is equal to the moving plate displacement. Hence, a relation between the applied force and the capacitance can be obtained. The sensor operation was simulated using COMSOL. The sensor is designed to measure 200 N of force on the tooth. The relationship between the applied force and the sensor capacitance is shown in Figure 3. The relation is nonlinear and would work if only one sensor is used per tooth. However, using more sensors per tooth requires the operation in the linear region. Otherwise, each sensor will need a separate RFID tag. COMSOL results show that the Capacitance-Force relationship is linear for the range 0 to 10 N, see Figure 4. To be able to measure the full range of 200 N, 20 sensors need to be used for each tooth. Since the sensor size is about 200 um, such a cluster of sensors can be built for a tooth. In conclusion, we designed and simulated a capacitive pressure sensor to measure the force on the teeth.

Figures used in the abstract

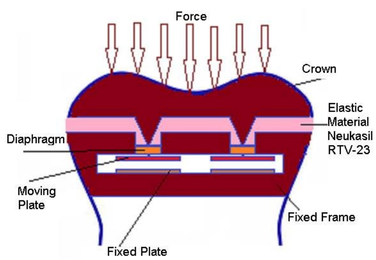

Figure 1: Sensors inside the crown of a lower jaw tooth, shown in the XZ plane. In XY plane, there can be four sensors or more working in parallel to provide a more accurate mapping of the forces applied. The elastic material is used to facilitate the force transfer through cones to sensor diaphragms.

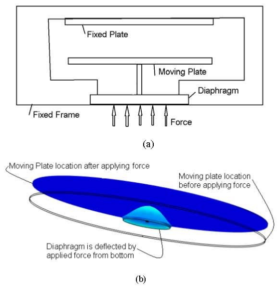

Figure 2: (a) A detailed schematic of the sensor showing the diaphragm and its coupling with the moving plate. The force is applied through the tip of a cone. (b) Simulation result using COMSOL showing diaphragm deformation caused by the applied pressure on a sensor attached to the a tooth of the upper jaw.

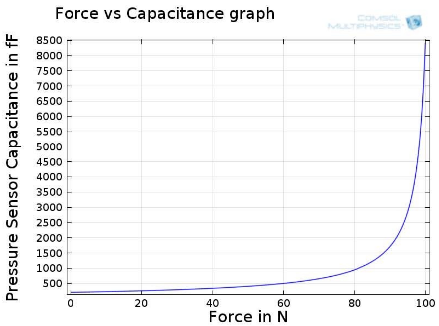

Figure 3: The relationship between force and capacitance change in sensor. Graph is generated by COMSOL.

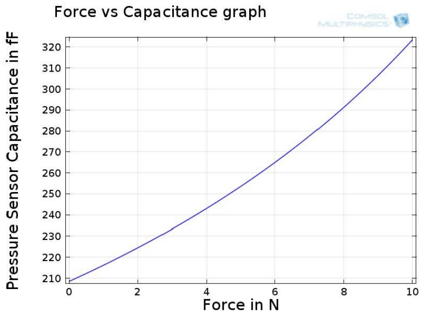

Figure 4: The relationship between force and capacitance change in sensor when the force is limited to 10N. Graph is generated by COMSOL.