DESIGN AND SIMULATION OF MEMS BASED SENSOR FOR ARTIFICIAL HAND

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Abstract: An artificial hand is the one that replaces the hand lost through trauma, disease, or congenital conditions. The proposed design is to simulate a sensor used in prosthetic hand so as to measure the pressure required to hold the object. The physical parameters such as size, shape and mass of the object were optimized so as to hold an object. The weight of the object is taken as the input (in terms of load on finger) and its corresponding output is taken as stress. Size of the object is measured by capacitance found. For a distance of 4 inches capacitance value obtained is $5.8166*10^{-13}$. Values obtained state that simulated using COMSOL MULTIPHYSICS 4.3b capacitance value is linear.

I. Introduction

In today's scenario, designing of the device before actual fabrication is very necessary to save economy and time both. So the designing and simulation of prosthetic hand before fabrication will give us the precise model and design for hand. The principle involved for sensing the object is based on calculating, load experienced initially by sensors present at edges of each fingers. Another way to calculate size of the object is by measuring capacitance values for generation of best fit polynomials and evaluation of capacitance by closed form integral expressions, with the dielectric and distance between fingers. Exact force for holding the object can be calculated with known values of size, stress and mass. Force for holding the object can be calculated and controlled through external hardware device. Finding the medium of dielectric is also necessary while applying the force to hold the object.

II. Comsol Multiphysics

For the prosthetic hand, modeling physics involved are structural mechanics and AC/DC module. Structural mechanics involves for finding the force experienced by the finger when the hand comes in contact to the object to carry or move as shown in the figure 5. Force experienced initially is to sense the object. Figure 3 shows the capacitance value is measured for the dielectric medium (object) present in between the figures. With the capacitance value, distance between the fingers is sensed. During the time of carrying or moving the object forced to be applied for holding the object is been designed for different materials and mass for different object with respect to capacitance value.

III. Design parameters

Designing of a device depends on various parameters like material, structure and shape etc. Material between the fingers is considered to be the dielectric and finger surfaces to be the electrodes of opposite polarities. All the parameters are needed to be optimized to obtain the desired specification of the device.

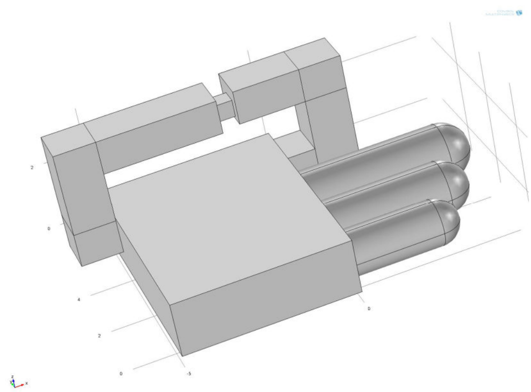

Fig 1: Schematic of thumb and index finger holding a box.

Figure 1 show the design starts with the hand structure with two different sensors for analyzing the stress and capacitance value. Shape of the capacitance plate on the finger was optimized according to the outer surface area for the fingers.

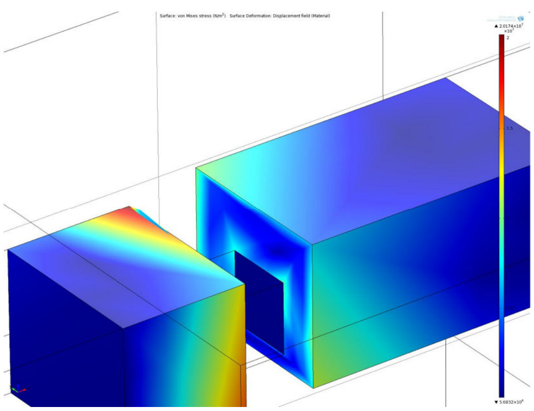

Fig 2: Schematic of thumb and index finger holding a Square box of 0.5".

Figure.2 shows the initial pressure experienced by the fingure when gets in contact to the object for the first time. The weight of the material is converted to its corresponding pressure of arround 2.6 KPa and deflection is sensed. Once it is sensed the distance between the object is calculated as shown in the figure 3.

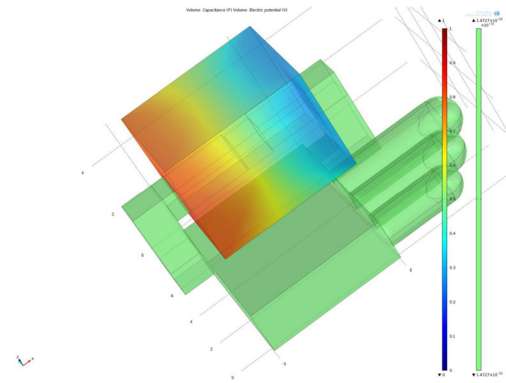

Fig 3: Schematic of thumb and index finger holding a ball of 0.5" radius.

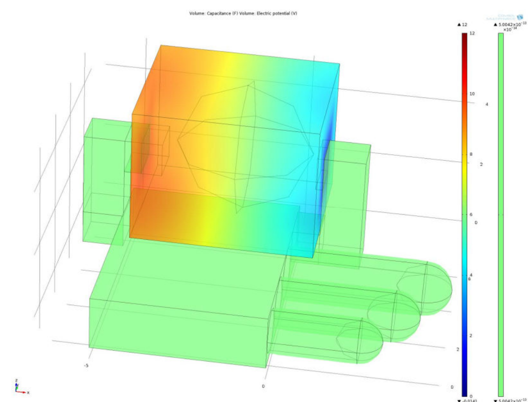

Fig 4: Schematic of thumb and index finger holding a ball of 2" radius.

Capacitance value for different size of object is been calculated and tabulated as in table 1 and table 2 for ball and box respectively. Final pressure experienced by the finger is around 29 KPa for which the deflection is found to be maximum of 2.978 x 10^{12} and minimum of 5.6115 x 10^{6}. Because of the system with a parallel plate capacitor, it can be modeled using COMSOL Multiphysics under DC Electrostatic physics. Capacitive sensor consists of two plates, which is placed on both the finger while both the plates are movable.

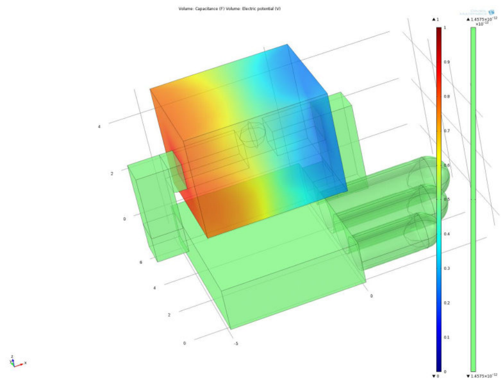

Fig 5: Downward force of box in Z-axis.

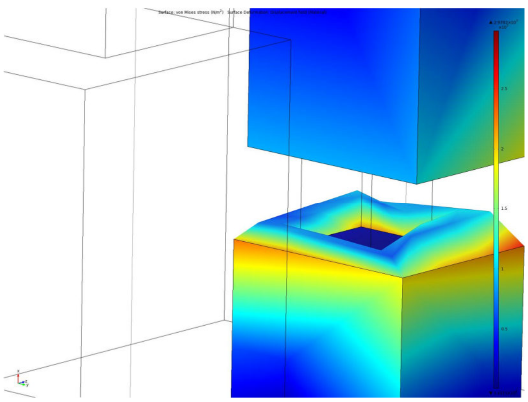

Fig 6: Force of box in X-axis.

When distance between the plates increases the capacitance value varies propositionally. The change in capacitance is then observed. The concept of parallel plate capacitor is expressed as follows

$$C = \varepsilon_o \varepsilon_r \text{ --------------------(1)}$$

Where, 'ε_o' is the permittivity of free space and 'ε_r' is the dielectric constant of the material between the plates of the capacitance.

IV. Result

Capacitance variation

Using COMSOL Multiphysics, the capacitance between the electrodes is found by modelling the system. COMSOL solve for the surface charge densities on the surfaces of the electrodes, then integrating over the surface area of the electrodes to determine the over all charge. Now, to investigate the variation of capacitance value with fingers position model is simulated by changing the fingers position on either sides of the object.

Table 1: Capacitance value for different ball size.

S.no	Radius of the ball	Capacitance
1	2"	$5.8166*10^{-13}$
2	1.5"	$7.5145*10^{-13}$
3	1"	$1.0089*10^{-12}$
4	0.5"	$1.4512*10^{-12}$

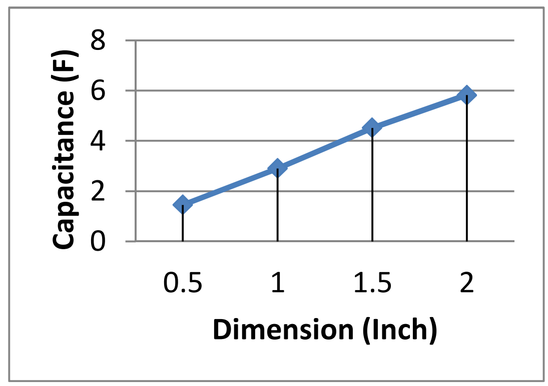

Fig 7: Capacitance variation for different ball size.

Table 2: Capacitance value for different Squarebox.

S.no	Length of Sq. box	Capacitance
1	2"	$1.0400*10^{-12}$
2	1.5"	$1.1855*10^{-12}$
3	1"	$1.4727*10^{-12}$
4	0.5"	$1.7988*10^{-12}$

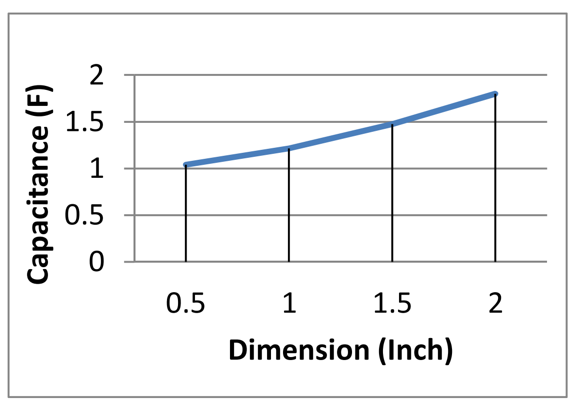

Fig 8: Capacitance variation for different box size.

Capacitance measurement also allows for the ability to identify the size of the object, as the capacitance value differs between object.

V. Conclusions

The change is capacitance varies linearly with the increase in the dimensions of the object. As the size of the object increase the change in capacitance decreases, since the dielectric area is varied for box and square. In the same way, objects of different size and shapes can be chosen to study the change in the behavior of the prosthetic hand. Dimension

References

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