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Modeling of MEMS Pressure Sensor for Cardiovascular Diagnostics using COMSOL Multiphysics

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Abstract

The model is designed forimplantable blood pressure monitoring system through simulations in COMSOL Multiphysics. The model employs an elastic sensing cuff, wrapped around the artery section, made of silicone filled with bio-compatible fluid with an immersed MEMS pressure sensor.With this factor it is possible to adjust the measurement system for different medical applications.

Keywords

Blood Pressure, MEMS (Micro-electromechanical-System), Measurement Cuff, Blood Vessel, Artery.

I. Introduction

Micro-Electro Mechanical System (MEMS) is a process technology used to create tiny integrated devices or systems that combine mechanical and electrical components. On the same silicon chip micro-sensors, micro-actuators and microelectronics, all are integrated. Micro-sensors detect changes in the system's environment by mechanical, thermal, magnetic, chemical or electromagnetic information or phenomena. Microelectronics processes this information and signals the micro-actuators to react and create the changes required. In terms of robustness, low power consumption and accuracy, MEMS sensors have proved its efficiency. MEMS sensors are using in biomedical, optoelectronics, automobile and industrial sectors. For its wide range of application, many researcheshave been done on improving the sensitivity and reliability. One of the implementations that measure blood pressure avoiding the aforementioned problems is the use of an elastic ring placed around the artery. This ring features an inner cavity filled with a fluid able to perceive and transmit the pressured exerted by the blood on the inner walls of the artery. This effect is achieved through the mechanical coupling between the artery and the ring. The pressure is transmitted to the inner fluid of the ring and is measured by a MEMS (Micro-electromechanical System) that uses a built-in pressure sensor.

II. Elastic Ring Pressure Sensors

The Elastic ring model is an invasive model designed to measure human blood pressure. It measures systolic, diastolic and mean arterial pressure. This measurement system need to have a minimal blood contact to reduce the thrombus formation, bleeding and avoid vessel occlusion, which are associated with conventional catheter-tip-based technique.

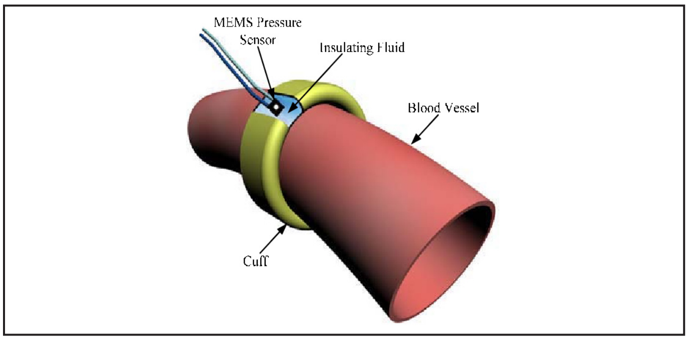

Fig. 1: Implantable Blood Pressure Monitoring System

The model employs an elastic sensing cuff, wrapped around the artery section, made of silicone filled with bio-compatible fluid with an immersed MEMS pressure sensor.

III. Material

To have the mechanical properties of the material selected for the ring, a new material was added to COMSOL's library of materials under the name MDX4-4210(silicone). Silicone exhibit many useful characteristics, including low thermal conductivity, low chemical reactivity, low toxicity, thermal stability (constancy of properties over a wide temperature range of −100 to 250 °C),the ability to repel water and form watertight seals. They are typically heat-resistant and either liquid or rubber-like, and are used in sealants, adhesives, lubricants, medicine, cooking utensils, and thermal and electrical insulation.

IV. Analytical Study

A silicone produced by Dow Corning Company was selected as ring material for this study. The material is known as SILASTIC® MDX4-4210 Biomedical Grade Elastometer with Catalyst [6]. Its characteristics allow it to be used in medical applications. Also, it presents an elastic module (Young Module) in the 0.003−0.03 GPa range, a Poissonrelation between 0.47−0.49, and a density between 1110−1140 Kg/m^3. To build the sensing cuff around the artery, the size parameters are predefined as shown in the Table 1 Here we need the measurements for designing the artery and elastic ring which has to fit around the artery.

Table 1: Sensing Cuff Size Parameter

Dimension	Value[mm]
Outer radius of the artery	0.5
R1, outer radius, inner ring	0.5
R2, inner radius, outer ring	0.07
Re, outer radius of the ring	0.9

Using the above parameters, a tridimensional model of the ring was implemented through COMSOL Multiphysics.

V. Simulation

Considering the parameters in Table 1 the geometry of the model was developed using COMSOL geometric construction tools, Fig. 2.

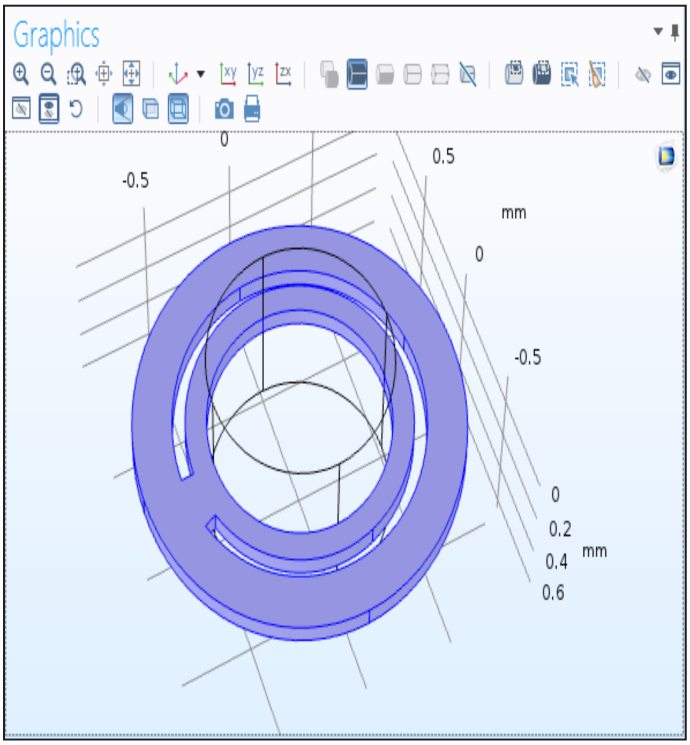

Fig. 2: Sensing Cuff

Then, the ring was fitted together with a section of the artery as shown in the fig. 3.

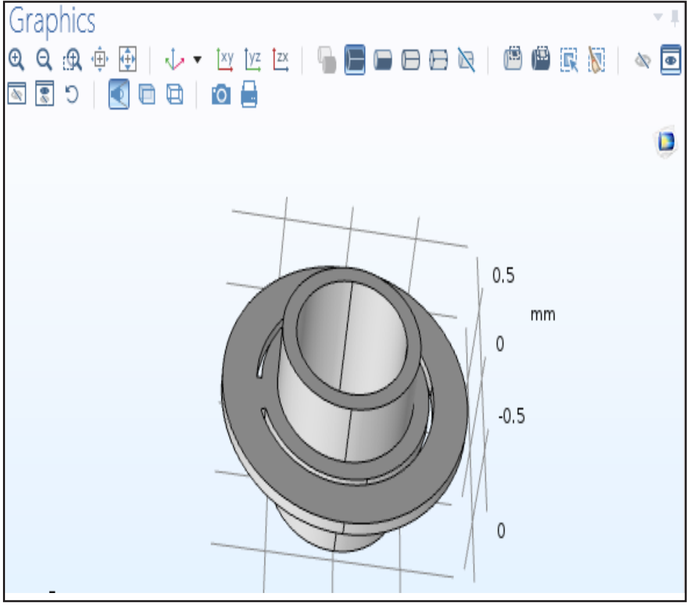

Fig. 3: Sensing Cuff Wrapped Around Blood Vessel

To have the mechanical properties of the material selected for the ring, a new material was added to COMSOL's library of materials under the name MDX4-4210 (silicone).

VI. Results and Discussion

An elastic ring is built with the predefined parameters which are considered by the outcome of literature survey. By computing the results for the elastic ring, the stress distribution of the elastic ring is shown in the below Figure 4. From the figure it is clear that the stress distributed around the ring is minimum wherein the stress in the inner region of the elastic ring where the biocompatible fluid flows that is pressure is applied is the region with the stress. The pressure given to the inner ring is 116.67 Pascal.

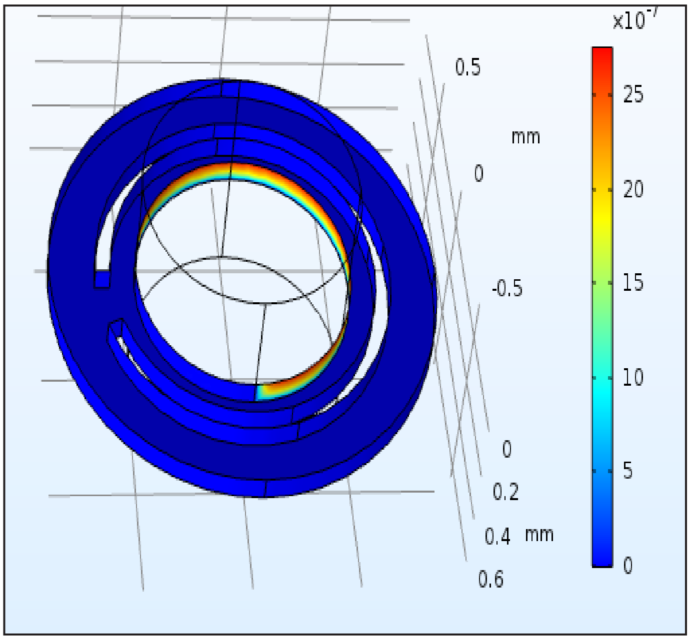

Fig. 4: Stress Distribution of Elastic Ring

To analyze displacement throughout the ring's volume, Fig. 5 shows the stress distribution of elastic ring around the artery.

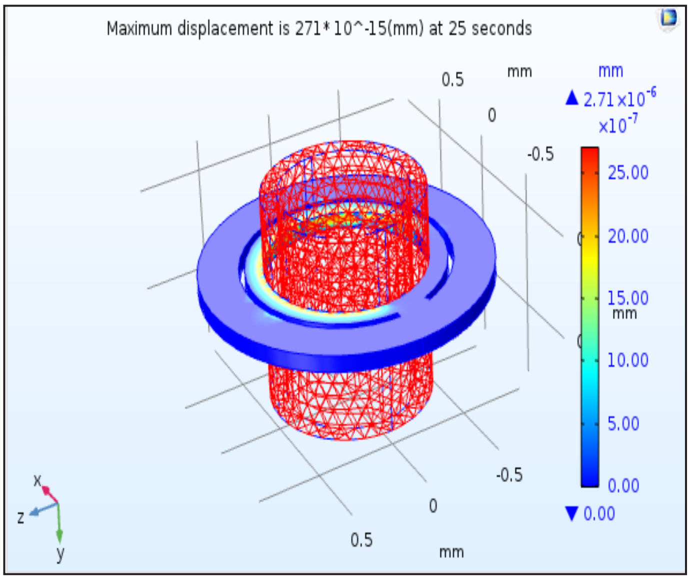

Fig. 5: Stress Distribution of Elastic Ring Around the Artery

The maximum displacement of the ring around the artery is 271 femto (mm) at time 25 seconds, this displacement undergone by the ring due to the contraction and expansion of the artery caused by blood pressure change.

VII. Conclusion

This model allows to estimate the scale value of the blood pressure measuring system understudy so that it is possible to make geometrical redesigns, material changes, changes in operating conditions, among other necessary modifications. It is thus possible to perform an optimization process in the design of the ring according to the medical application for which it was intended or the type of patient who requires it, according to age and health condition.

As, for instance, an older adult exhibits a higher degree of stiffness in the arterial walls than a young person, and a child has smaller diameter arteries. In order to avoid to need for a multitude of wires, such sensors must be self-sustaining and should be able to communicate wirelessly. As a result, not only more sensors are needed, but also small energy generating modules and wireless transmission components. Clearly, the increased number of devices will drive size reduction which intern will enable higher levels of integration. This prediction combined with the foregoing discussion on the advantages of MEMS over macro devices lead us to predict that MEMS will soon be integrated into are everyday life just as the computers have been.

VIII. Future Work

The next works consists in giving the connection to the ring and the sensor, compute and check the results, testing and to design a specific process to fabricated a scaled version of the model with the specific materials and techniques required. Is important to record that the objective is to have a biocompatible system, and the materials, shapes and stiffness are another important design requirement. Another related work is the monitoring system,include the design of the pressure sensor and the electronic data acquisition system with the next post-processing data.

References

[1] J. A. Potkay,“Long term, implantable blood pressure monitoring systems,” Vol. 1943, No. 2007, pp. 379–392, 2008.

[2] P. Cong, D. J. Young, B. Hoit, W. H. Ko,“Novel Long-Term Implantable Blood Pressure Monitoring System with Reduced Baseline Drift,” pp. 1854–1857, 2006.

[3] N. Chaimanonart, M. D. Zimmerman, D. J. Young, “Adaptive RF Power Control For Wireless Implantable Bio-Sensing Network To Monitor Untethered Laboratory Animal Real-Time Biological Signals,” pp. 1241–1244, 2008.

[4] P. Cong, W. H. Ko, and D. J. Young, “Wireless Batteryless Implantable Blood Pressure Monitoring Microsystem for Small Laboratory Animals,” Vol. 10, No. 2, pp. 243–254, 2010.

[5] [Online] Available: http://www.ijeset.com/media/0002/4N13-IJESET0603132-v6-iss3-308-315.pdf

[6] [Online] Available: https://www.ijser.org/paper/MEMS-based-capacitive-sensor-simulation.html

[7] [Online] Available: https://en.wikipedia.org/wiki/Blood_pressure

[8] [Online] Available: http://coureses.lumenlearning.com/suny-ap2/chapter/blood-flow-blood-pressure-andresistance-no-content/

[9] [Online] Available: http://www.urmc.rochester.edu/encyclopedia/content.aspx

[10] [Online] Available: https://www.cdc.gov/bloodpressure/measure.htm

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