Modeling of Elastic Ring for Artery using COMSOL Multiphysics

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Abstract— Microelectromechanical System (MEMS) is a technology defined as miniaturized mechanical and electromechanical elements in micro meter scale that are made using the techniques of micro fabrication. MEMS devices are generally in the range of 100mm to 10 nm. It is the combination of mechanical and electrical functions on the same chip. This MEMS model explains the use of a model to design an implanted blood pressure monitoring system through simulations in COMSOL Multiphysics. This measurement system needs 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. The model employs an elastic sensing cuff, wrapped around the artery section, made of silicone filed with bio-compatible fluid with an immersed MEMS pressure sensor.

Keywords: MEMS, COMSOL Multiphysics, HARM

I. INTRODUCTION

MEMS is a process technology used to create tiny integrated devices or systems that combine mechanical and electrical components. They are fabricated using integrated circuit (IC) batch processing techniques and can range in size from a few micrometers to millimeters. These devices (or systems) can sense, control and actuate on the micro scale, and generate effects on the macro scale. The interdisciplinary nature of MEMS utilizes design, engineering and manufacturing expertise from a wide and diverse range of technical areas including integrated circuit fabrication technology, mechanical engineering, optics, instrumentation and packaging. The complexity of MEMS is also shown in the extensive range of markets and applications that incorporate MEMS devices.

MEMS can be found in systems ranging across automotive, medical, electronic, communication and defense applications. Current MEMS devices include accelerometers for airbag sensors, inkjet printer heads, computer disk drive read/write heads, projection display chips, blood pressure sensors, optical switches, microvalves, biosensors and many other products that are all manufactured and shipped in high commercial volumes. MEMS has been identified as one of the most promising technologies for the 21st Century and has the potential to revolutionize both industrial and consumer products by combining silicon-based Micro-electromechanical systems (MEMS) is a process technology used to create tiny integrated devices or systems that combine mechanical and electrical components. They are fabricated using integrated circuit (IC) batch processing techniques and can range in size from a few micrometers to millimeters. These devices (or systems) can sense, control and actuate on the micro scale, and generate effects on the macro scale while the device electronics are fabricated using 'computer chip' IC technology, the micromechanical components are fabricated by sophisticated manipulations of silicon and other substrates using micromachining processes. Processes such as bulk and surface micromachining, as well as high-aspect-ratio micromachining (HARM) selectively remove parts of the silicon or add additional structural layers to form the mechanical and electromechanical components. While integrated circuits are designed to exploit the electrical properties of silicon, MEMS takes advantage of either silicon's mechanical properties or both its electrical and mechanical properties.

II. METHODOLOGY

A. *Construction of an Elastic Ring:*

To carry out the study of the mechanical system, a cross-sectional scheme of the ring around the artery was prepared.

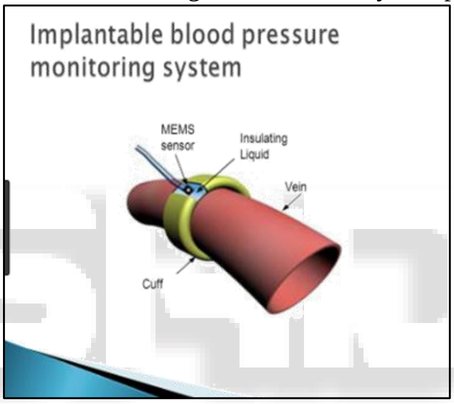

Fig. 2.1: Implantable blood pressure monitoring system

The Figure 4.8 explains the implantable blood pressure monitoring system. A sensing cuff is designed and built with the predefined size parameters. A MEMS sensor is immersed in an insulating liquid. This ring(sensing cuff) features an inner cavity filled with a fluid able to perceive and transmit the pressured exerted by the blood is transmitted to the inner fluid of the ring and is measured by a MEMS (Microelectromechanical System) that uses a built-in pressure sensor.

To build the sensing cuff around the artery, the size parameters are predefined as shown in the Table on the inner walls of the artery. This effect is achieved through the mechanical coupling between the artery and the ring.

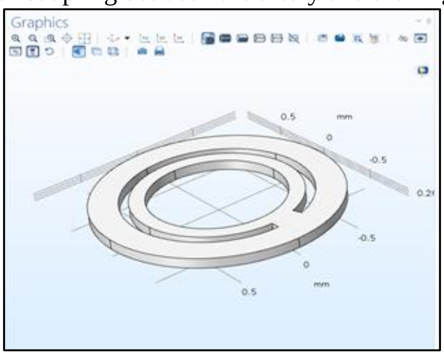

Fig. 2.2: Sensing cuff

A tridimensional model of the ring was implemented through COMSOL Multiphysics®. Considering the parameters in Table the geometry of the model was developed using COMSOL geometric construction tools, Figure 2.2

Then, the ring was fitted together with a section of the artery as shown in the Figure 2.3.

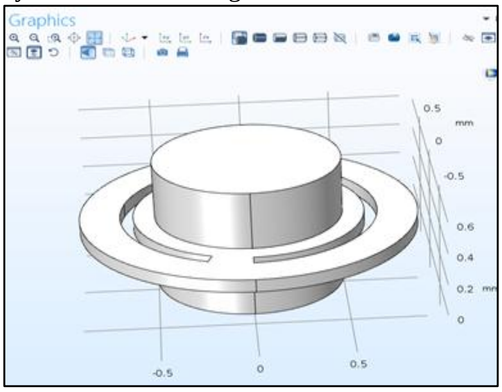

Fig. 2.3: Sensing cuff wrapped around blood vessel

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). 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.

Regarding the ring's inner chamber, water was used as fluid from the library of materials.

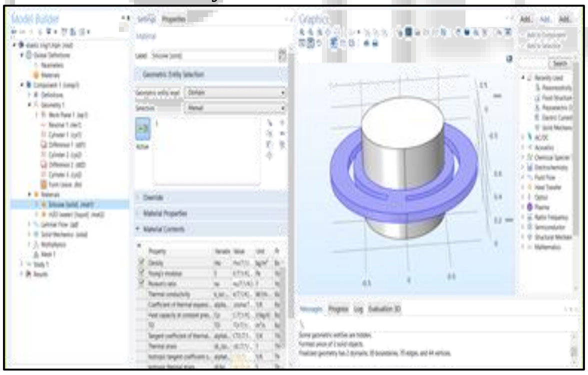

Fig. 2.4: Adding Silicone material

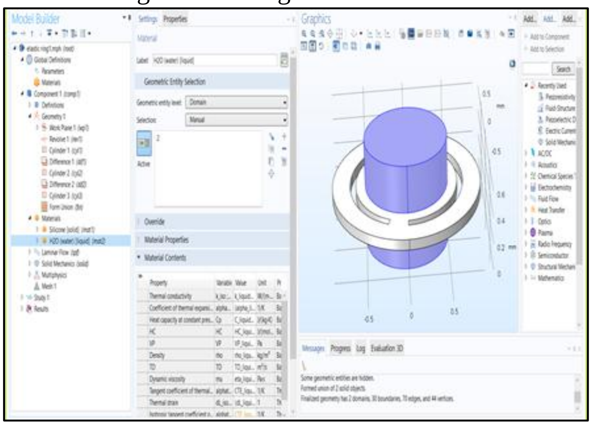

Fig. 2.5: Adding Water material

B. Meshing

Meshing is a task carried out by software to divide the entire problem domain into subdomains called elements. Each element is described by a set of nodes whose connectivity completely describes the element in FE space. There are two types of meshing, Physics controlled mesh and User controlled mesh. In Physics controlled mesh, the element size is decided by the software according to the needs.

In User controlled mesh, the element size is specified by the user. The elastic ring is uniquely meshed. For better calibration, the divided element size is chosen to be "normal" or "fine". As the number of elements increases, the accuracy of computation increases and vice-versa. This is shown in the Figure 4.13.

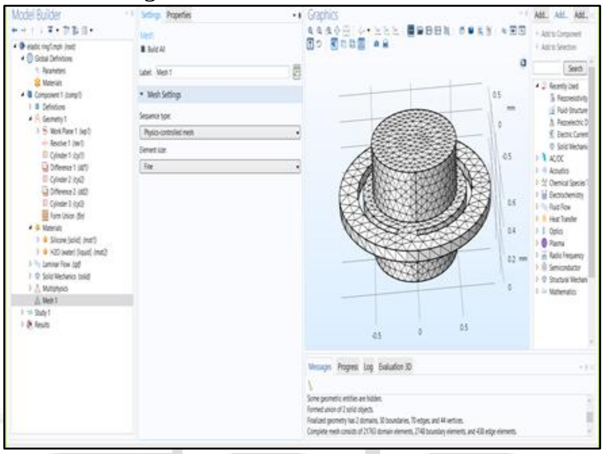

Fig. 2.6: Meshing of elastic ring

The response of each element is expressed by unknown functions and the response of the whole model is then considered to be approximated by assembling the collection of all elements. Therefore, Finite-element requires discretization of the domain. It is done by meshing it, so that, nodal representation of the geometry and functional representation of the domain are obtained. And, FEM is heavily mesh dependent. Refining is needed for two main reasons. One geometrical and other is mathematical.

To study the mechanical interaction between the blood flow, the arterial wall, and the ring the Fluid-Structure Interaction (FSI) module was used. Thus, pressure changes produce a normal net force on the surface that can be translated into a possible deformity in elastic materials. This way, the ring being mechanically fitted to the arterial wall and the deformities (expansions and contractions) of the artery produce a transmission towards the inner fluid pressure in the ring. Therefore, it is possible to measure the pressure variations of the ring's inner fluid caused by the variations from the blood flow pressure. Pressure losses caused by mechanical couplings in charge of transmission generate a lower measured value, hence this model allows to obtain a measurement scale value according to ring dimensions and material properties.

III. RESULT AND CONCLUSION

An elastic ring is built. By computing the results for the elastic ring, the stress distribution of the elastic ring is shown in the below Figure 3.1.

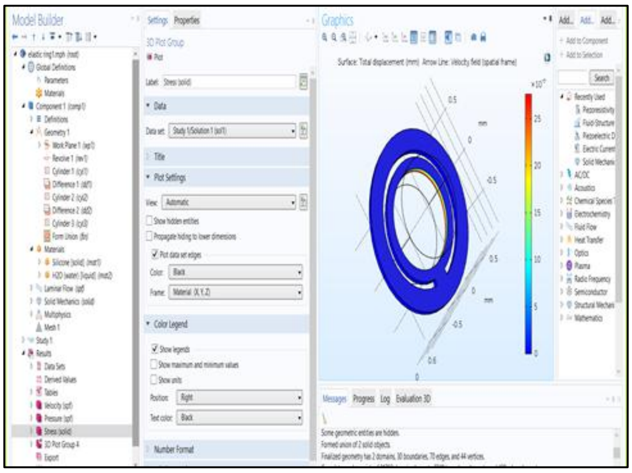

Fig. 3.1: Stress distribution of elastic ring

To analyze displacement throughout the ring's volume, Fig. 3.1 shows the total displacement of the ring along with the stress for the time of the systolic peak pressure. The previous result was expected since the outer ring is thicker and works as a mechanical resistance to inner ring deformation; an effect that allows the transmission of pressure to the ring's cavity fluid.

IV. CONCLUSION

This model allows us to estimate the scale value of the blood pressure measuring system under study 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

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