Measurement of Blood Flowrate in Large Blood Vessels Using Magnetic Flowmeter

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Abstract

Magnetic flowmeter works on the principle of EMF (electromotive force) induced in a flowing liquid under the influence of a magnetic field [1]. Magnetic flowmeters are popularly used to measure flow rate of conducting fluids. Measurement of blood flow rate in large blood vessels using magnetic flowmeters is also in practice [2]. The technique is non-invasive since the required magnetic field can be generated by coils external to the patient's body. Also the induced emf can be measured non-invasively (without electrodes puncturing the vessel) [3]. However due to the patient's bodily functions, like respiration, vessels undergo periodic displacement. In this study, performance of the magnetic flowmeter under the influence of vessel movement has been investigated. A multiphysics model integrating electromagnetics, fluid flow and structural dynamics (FSI or Fluid Structure Interaction) was built in COMSOL Multiphysics® software. The induced EMF, was evaluated at deformed condition of the vessel and compared with the EMF in the initial or un-deformed condition.

Model: A Finite element model in COMSOL Multiphysics® software [3] was built (Figure 1). The flow and magnetic field modules were enabled to simulate interaction between the flow and magnetic fields (Lorentz term) to yield the resulting emf within the blood domain:
$J=\sigma(E+v\times B)$ (1)
Where J is internal current, E is induced electric field (gradient of electric potential, Φ) and $v\times B$ is the interaction. The velocity term in equation (1) above was obtained by solving fluid flow equations. Next, structural dynamics equations were solved using the Fluid Structure Interaction module, to simulate vessel deformation and its effect on performance of the flow meter.
$u_{(fluid)} \alpha\, u_{wall}$ (2)
Where ufluid is the velocity of the blood normal to the wall and is directly proportional to wall deformation rate, uwall. The influence of the deformation on flowmeter performance is investigated in this article.

Results: Figures 1 show schematic of the flowmeter, with the electromagnetic coils above and below the blood vessel to generate the magnetic field. The voltage or EMF induced in the tube as a result of interaction of the magnetic field and flow is shown in Figure 2. The induced emf, ΦFE, or Φ1 - Φ2, across the pipe diameter was calculated by the model. Next, the vessel was artificially displaced by 1 cm from the axis to simulate effect of breathing and the induced emf was re-calculated. For the given deformation the induced emf was

found to have increased compared to that in the un-deformed case. This is due to momentary shifting of the blood vessel towards the higher magnetic field zone. Due to the increase in induced EMF at the given flowrate, the proportionality constant between flowrate and induced emf is altered. Hence it is expected to have calibration problems in blood flow measurement a topic that will be explored in our future work.

Reference

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3. Boccalon et al. 1982. Non-Invasive electromagnetic blood flowmeter: Theoretical aspects and technical evaluation. Vol 20.
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Figures used in the abstract

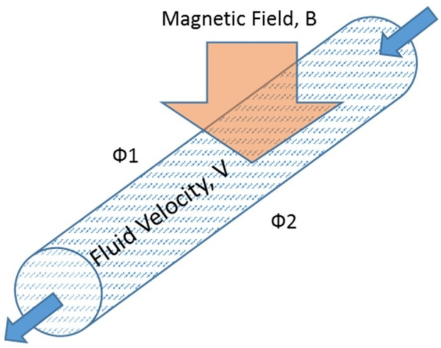

Figure 1: Schematic of the setup.

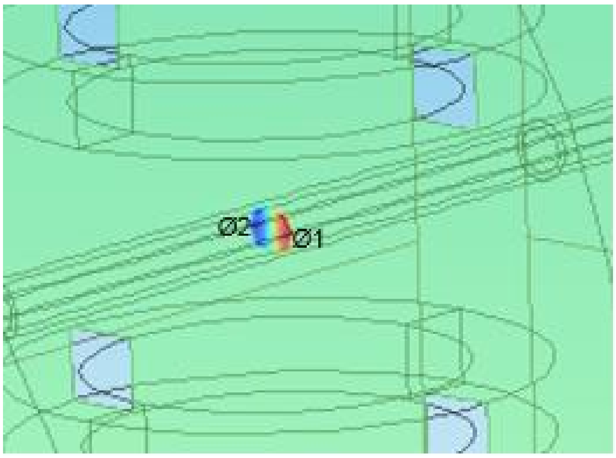

Figure 2: Induced electric potential across pipe cross section,