An Approach for Cardiovascular Monitoring Based on Electromagnetic Induction

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A significant issue involving medical implantable devices arises from their battery, because its replacement requires surgical procedure. To increase the functional life of medical implants, several energy harvesting devices have been developed that convert the motions of the cardiovascular system to electrical power. An interesting approach is to relate the output voltage of such an energy harvester with physiological parameters and use it as a sensor. The purpose of this work is to present the potential of a device, originally developed for energy harvesting from arterial motion (Pfenniger, Alois, et al, Medical engineering & physics, 35.9, 1256-1265, 2013), to monitor the cardiovascular system. This device consists of two permanent ring magnets that are placed in parallel and a flexible conductive coil that is placed between them. The artery is inserted through the coil and the holes of the magnets. The coil moves along with the arterial wall inside the magnetic field, and as a result, an alternating voltage proportional to its velocity is induced across its terminals.

An energy harvester based on the above design was fabricated. To evaluate its potential operation as a sensor, an experimental setup was constructed to simulate the blood flow and the arterial motion. An elastic tube was filled with water and a motor-based device was used to compress and decompress a segment of the tube periodically, causing a pressure pulse with controllable frequency and amplitude. The voltage induced in the coil and the pressure inside the tube were synchronously sampled. Moreover, a mechanical analysis was carried out to determine the radius and wall velocity of the deforming tube from the obtained pressure measurements.

Fig. 1(a) presents the peak voltage with respect to the peak velocity of the tube's wall, along with a linear fit. Our experiments demonstrated an excellent linearity between these two quantities (coefficient of determination R^2=0.997) and a sensitivity of 288 mV/(m/s). Fig. 1 (b) shows the peak voltage against the pressure amplitude, and second-order polynomial fit with an $R^2$of 0.996. The voltage-tube's radius diagram had a similar form as the one of voltage-pressure amplitude. Furthermore, a linear relationship between the frequency of the pressure pulse and the peak voltage was realized. Hence, the obtained results showed that the energy harvester under study can be used to determine heart rate, blood pressure, artery's radius and wall velocity.

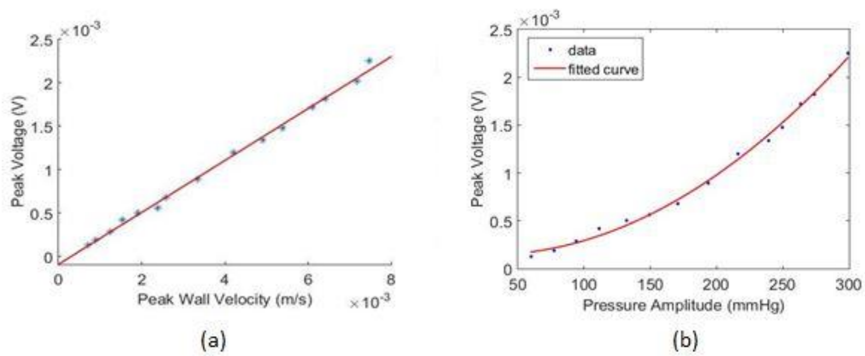

Fig. 1: (a) Peak voltage versus the peak velocity of the tube's wall, (b) Peak voltage versus pressure amplitude.