Review of Fiber Pressure Sensor for Using in POLVAD Prosthesis

MSc. Grzegorz Konieczny, *Silesian University of Technology*

Abstract

The following paper introduces review of pressure optical fiber pressure sensor for incorporation in Polish Artificial Heart prosthesis. Paper summarizes research results of noninvasive blood pressure measurement for use in the POLVAD prosthesis as well as method of acquiring noninvasiveness goal. Both initial tests and final solution are being shown.

1. Introduction.

Blood pressure measurement is very important in medical applications. It can give many information about current state of human body. Pressure irregularities may inform of heart and circulatory system. When heart problems occur in patient due to diseases or genetic load [1,2,3]. In these cases heart support prosthesis can be used to fasten healing process. Prosthesis is being put outside human body and connected with the circulatory system through skin. Recently Polish Artificial Project was founded to introduce the polish artificial heart prosthesis for use inside human body. In this case information will be needed for proper driving of prosthesis. Among information about current blood volume inside prosthesis, pressure signals will be needed to adjust prosthesis work to actual state of the patient.

2. Subject of study

Proper pressure measurement is crucial to effective heart support. There were many different approaches to this measurement, many of which used piezoelectric pressure inducers [2-6]. The main problem with blood pressure measurement that would be safe to patient is providing noninvasiveness of the sensor, because any object on the blood path is cause of blood cells damage and can cause thrombosis. Thrombosis occurrence in circulatory system can be fatal to the patient. To avoid this problem new method of pressure sensor with use of fiber and polyurethane separation membrane was proposed. During studies fiber pressure sensor was tested for air pressure measuring properties, fluid pressure measurement and possibility of use in noninvasive blood pressure measurement. Pressure should be measured at few points around prosthesis (Fig.1.)

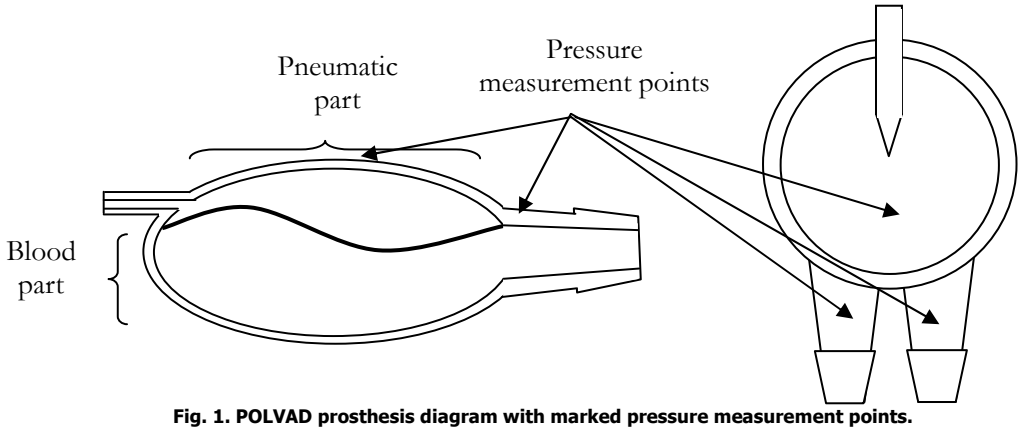

Fig. 1. POLVAD prosthesis diagram with marked pressure measurement points.

3. Proposed FOP-M optical pressure sensor solution.

During research FOP-M pressure sensor was proposed for blood pressure measurement. Its teflon coating makes it intrinsically safe, it is also immune do radio and electromagnetic interference and its measurement range meets project requirements (-100mmHg÷400mmHg) [9]. Measurement is based on Fabry-Perrot sensor situated on tip of the fiber. Pressure related membrane deflection changes reflected light spectrum, which can be translated into required pressure units.

Measurement equipment consisted of FOP-M fiber sensor, conditioner and computer for data presentation and correction(Fig.2).

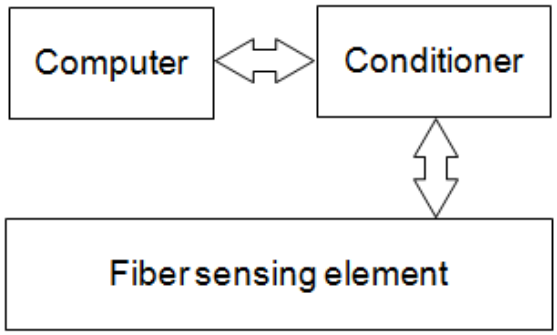

Fig.2. Fiber measurement system.

Pressure sensor was chosen in preliminary tests and both air and water pressure measurements were conducted. Testing chamber construction and data acquisition site were described in previous article [7].

FOP-M fiber sensor can`t be used directly in blood environment, so during research possibilities of meeting noninvasiveness requirements of the project were tested.

Membrane for pressure transmission testing were provided by Foundation for Cardiac Surgery Development. During testing different thickness polyurethane membranes properties were tested. The thickest one (0.35mm) had good transmission properties and its thickness could guarantee reliable separation between blood environment and the sensor chamber. Exemplary results of water pressure transmission are shown in Fig.3.

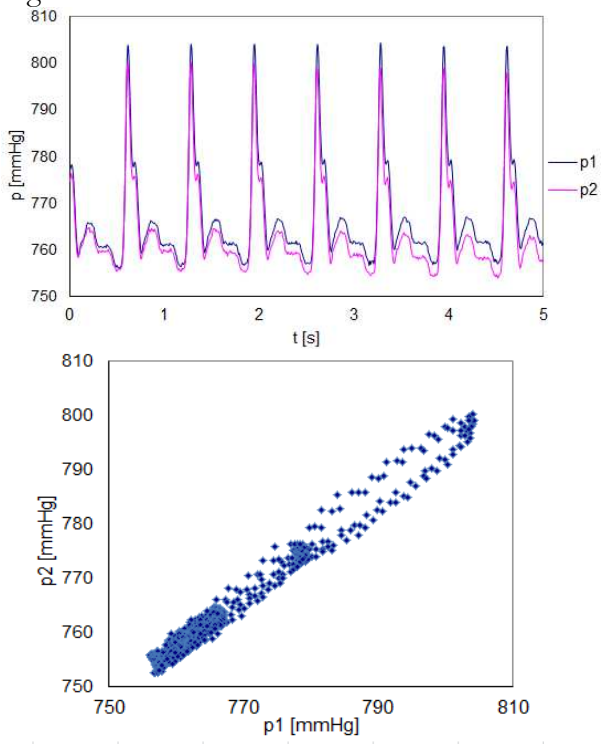

Fig.3. Water pressure transmission results (a – time and b – direct comparison of sensors pressure data).

Pressure loses due to membrane transmission properties were within acceptable range and future study of membrane material should provide better pressure transmission results.

Successful membrane pressure transmission properties testing was followed by measurement points construction on polyurethane tube. Construction of sensing point had to be universal to enable incorporation of pressure sensor in different parts of POLVAD prosthesis casing.

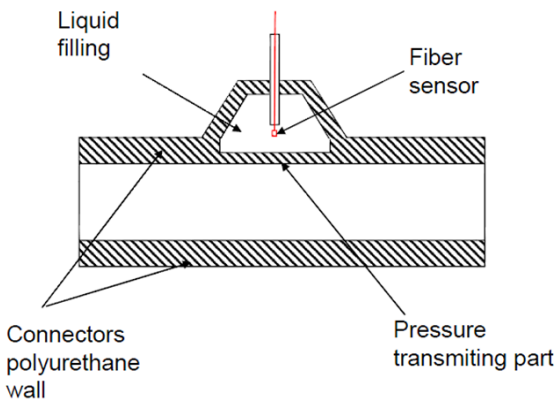

Fig.4. Proposed prototype blood pressure measurement point diagram.

As mentioned before the noninvasiveness requirement forbids pressure sensor having direct contact with blood environment. In proposed construction special small chamber for sensing fiber was made in the tube wall. Cavity was supposed to be filled with fluid, and fiber sensor placed in chamber. Chamber and blood track should be separated by thin polyurethane wall. According to proposed theoretical model (Fig.4.) physical model was constructed (Fig.5.) and connected to physical human circulatory system model in Foundation for Cardiac Surgery Development in Zabrze [8].

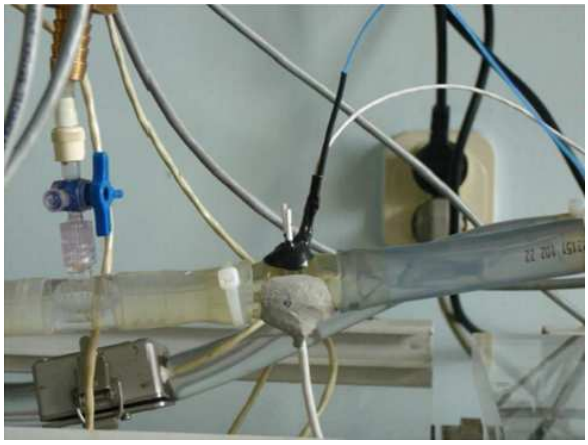

Fig.5. Physical human circulatory system model.

Test were conducted using water in Foundation for Cardiac Surgery Development in Zabrze. Prosthesis that was used for water circulation, was driven by POLPDU unit. Different heart supporting speeds and driving pressures were used during examination of sensors pressure transmission properties.

Example results are shown in Fig.6. Data from both pressure sensors: first inside polyurethane tube (induced pressure) and second fiber probe inside oil filled chamber in sensing point construction (transmitted pressure).

Pressure drop due to polyurethane wall properties was present as expected during membrane transmission properties testing (Fig.3.).

Relation between pressure signals from both FOP-M sensors is fairly linear [9]. Few points don't follow this relation, which may be caused by membrane inertia, elastic properties or turbulent water flow.

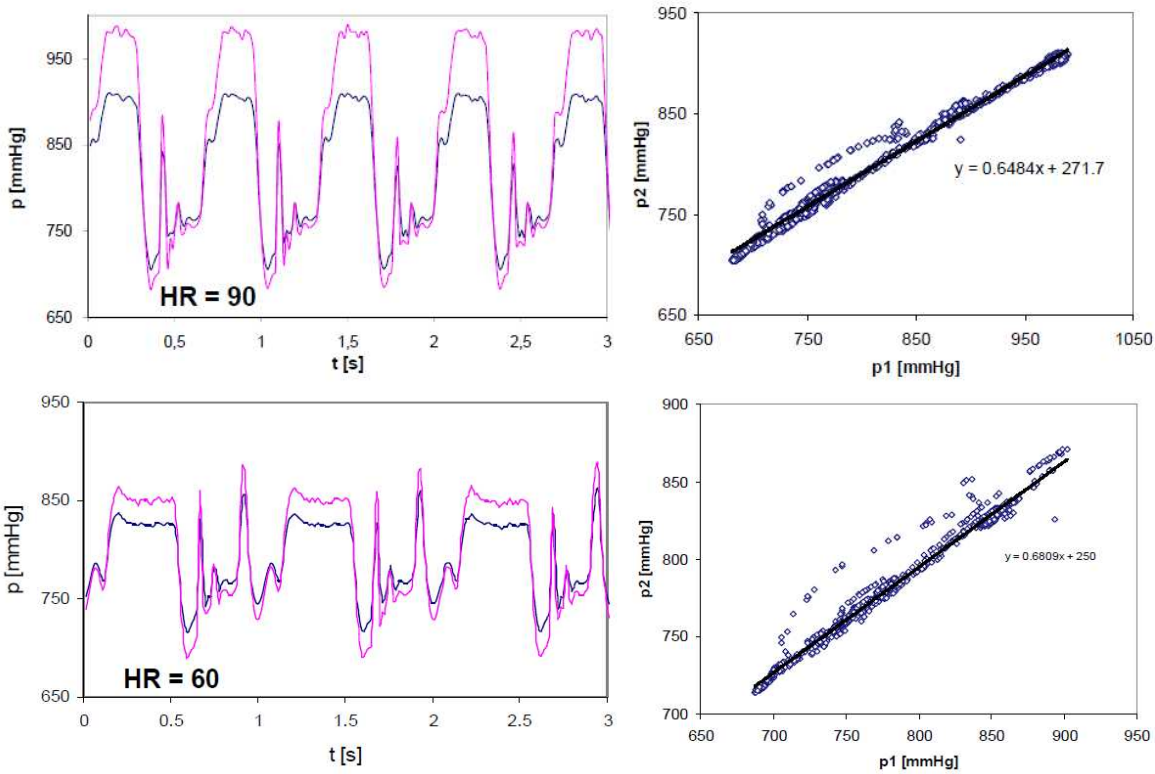

Fig.5. Results of pressure transmission measurements acquired in prototype testing.

Despite this most of pressure changes are being transmitted correctly. Conducted research shows that proposed pressure transmission method is valid. Results show that pressure transmission through polyurethane membrane is possible, and worth future investigating. It can be seen that pressure wave shape is being reproduced on sensor point side with expected pressure drop due to transmission process.

4. Conclusion

The goal of the research was to prove and test possibility of optical pressure sensor use incorporating in POLVAD prosthesis. Sensor should enable pressure measurement without contact with blood environment. The conducted research provides efficient data to concern this type of pressure method for incorporation future prosthesis status measurement system.

Future tests require construction of measurement points with pressure transmission in POLVAD prosthesis casing, more crucial polyurethane membrane properties testing and tests in blood environment on live animal.

Presented work was realized within the framework of the "Polish Artificial Heart" project: 06/WK/PO1/0001/SPB-PSS/2008.

Bibliography

1. Religa Z., Kustosz R., *Mechanical heart supporting. Coronary vessels surgery*. PZWL, Warsaw 2002, 158-166 (in Polish).
2. Darlak M., Opilski Z., Gawlikowski M., Kustosz R., Pustelny T., *Acoustic method of noninvasive blood volume monitoring in POLVAD pump*, Artificial Organs, vol. 31, No 10, (A50) (2007).
3. Pustelny T., Struk P., Nawrat Z., Gawlikowski M., *Design and numerical analyses of the human greater circulatory system*, European Physical Journal- Special Topics, vol. 154, 165-170 (2008).
4. Gawlikowski M., Pustelny T., Przywara-Chowaniec B., Struk P., *The anatomic structure of pulmonary arterie as a source of unreliability in thermodilution cardiac output measurement*, Acta Physica Polonica, vol.114, No.6-A, 79-88 (2008).
5. Darlak M., Pustelny T., Gawlikowski M., Kustosz R., *Preliminary Investigations Regarding the Possibility of Acoustic Resonant Application for Blood Volume Measurement in Pneumatic Ventricular Assist Device,* Molecular and Quantum Acoustics, vol. 27, 89-96, (2006).
6. Pustelny T., Struk P., Nawrót Z., Gawlikowski M., *Numerical and experimental researches of mechanical heart prosthesis*, European Physical Journal- Special Topics, vol. 154, 161-164 (2008).
7. Konieczny G., Opilski Z., Pustelny T., Maciak E., *Research into pressure measurement methods for using in POL-VAD,* Conference Archives PTETiS Vol. 26, 2009.
8. *http://www.frk.pl/frk/*
9. FISO – Fiber Optical Pressure Sensors – http://www.fiso.com/modules/

Author:
MSc. Grzegorz Konieczny

Silesian University
of Technology
ul. Akademicka 10
44-100 Gliwice
tel. (032) 2371208
email: *Grzegorz.Konieczny@polsl.pl*