Study on a Two-Dimensional Valveless Impedance Pump

Hien, Doan Duc、葉俊良 ; 溫志湧

E-mail: 9700691@mail.dyu.edu.tw

ABSTRACT

We constructed a two-dimensional valveless impedance pump consisting of a rectangular rigid tube, covered by an elastic patch at one end to form asymmetric acoustic impedance. Two acrylic reservoirs were glued to the ends of rigid tube to make an open loop and filled with water. By periodically squeezing along the elastic patch at asymmetric position using a vertical electric-mechanical compression mechanism, a pressure across the pump is generated to drive the 2D persistent flow through cumulative effects of wave propagation and reflection. This effect, called the Liebau phenomenon or valveless pumping, has been known for some time. Along with constructing a model of circular pump with the same hydraulic diameter, we studied the flow rates for various squeezing locations, frequencies, and compression amplitudes. The results between two models were compared. In the theoretical work, we have tried to model such a system as a flat tube with unsteady flow, Euler ' s equation with appropriate boundary conditions. Analytic solutions calculated to compare with experimental flow rates.

Keywords : Two-dimensional valveless impedance pump, elastic tube, wave propagation. Two-dimensional valveless impedance pump, elastic tube, wave propagation.

Table of Contents

REFERENCES

[1] Mackay, R.C., " The practical pumping handbook " , Mc Graw-Hill, New York, 2001.

[2] Rinderknecht, D., Hickerson, A.I., and Gharib, M., " A valveless micro impedance pump driven by electromagnetic actuation, " Journal of Micromechanics and Microengineering, vol. 15, pp. 861-866, 2005.

[3] Hickerson, A. I., " An experimental analysis of the characteristic behaviors of an impedance pump, " Ph.D. Dissertation, California Institute of Technology, California, 2005.

[4] Moser, M., Huang, J. W., Schwarz, G. S., Kenner, T., and Noordergraaf, A., " Impedance defined flow: Generalization of William Harvey ' s concept of the circulation - 370 years later " International Journal of Cardiovascular Medicine and Science, vol. 1, no. 3/4, pp. 205 – 211, 1998.

[5] Liebau, G., " Uber ein ventilloses Pumpprinzip " Naturwissenschaften vol. 41, p.327, 1954.

[6] Liebau, G., " Die stromungsprinzipien des herzens " , Z. Kreislaufforsch vol.44, p.677, 1955.

[7] Von Bredow, H. J., " Untersuchung eines ventillosen Pumpprinzips " Fortscher Reihe 7, Nr. 9, 1968.

[8] Rath, H. and Teipel, I., " Der Fordereffekt in ventillosen, elastischen Leitungen " Zeitschrift frangewandte Mathematik und Physik, vol. 29, pp. 123 – 133, 1978.

[9] Takagi, S., and Enbody, R. J., " Study of a piston pump without Valves, " Bulletin of JSME 28, pp. 831-836, 1985.

[10] Thomman, H., “ A simple pumping mechanism in a valveless tube, ” Zeitschrift fur angewandte Mathematik und Physik, vol. 29, pp. 169 – 177, 1978.
[11] Borzi, A., Propst, G., “ Numerical investigation of the Liebau phenomenon, ” Zeitschrift fur angewandte mathematic und physik, vol. 54, no.6, pp. 1050-1072, 2003.
[12] Ottensen, J., “ Valveless pumping in a fluid-filled closed elastic tube system: one dimensional theory with experimental validation, ” Journal of Mathematical Biological, vol. 46, no. 4, pp. 309-332, 2003.
[13] Auerbach, D., Moehring, W., and Moser, M., “ An analytic approach to the Liebau problem of valveless pumping, ” Cardiovascular Engineering: An International Journal, Vol.4, no.2, pp.201-207, 2004.
[14] Hickerson, A. I., Rinderknecht, D., and Ghrib, M., “ Experimental study of the behaviors of a valveless impedance pump, ” Experiments in Fluids, vol. 38, no. 4, pp. 535-540, 2005.
[15] Christos G.M., Demetri S.M., and Sokrates G.T., “ One-dimensional model of valveless pumping in a closed loop and a numerical solution ”, Laboratory of Biofluidmechanics & Biomedical Engineering, Fluids Section, School of Mechanical Engineering, National Technical University of Athens, Athens 157 73, Greece, 2006.
[16] Jung, E., and Peskin, C., “ 2-D simulations of valveless pumping using immersed boundary methods (ii), ” Ph.D. Dissertation, 20 [17] Wen, C.Y., Cheng, C. H., Jian, C. N., Nguyen, T. A., and Hsu, C. Y., “ A Valveless Micro Impedance Pump Driven by PZT Actuation, ” Proceedings of ICAM2005, 2005.
[18] Thomas, T., Vandenberghe, N., Zhang, J., “ An experimental investigation and a simple model of a valveless ” , New York, United State, 2006 [19] Hickerson, A.I., Gharib, M., “ On the resonance of a pliant tube as a mechanism for valveless pumping ” , J. Fluid Mech. Vol. 555, pp. 141-148, 2006.
[20] Andersson, H., Der Wijngaart, W., Nilsson, P., Enoksson, P., and Stemme, G., “ A valveless diffuser micropump for microfluidic analytical systems, ” The microTAS syposium, Enschede, 1999.
[21] Jensen, O., “ Instabilities of flow in a collapsed tube, ” Journal of Fluid Mechanics, vol. 220, pp. 623 – 659, 1990.
[22] Jensen, O., and Pedley, T., “ The existence of steady flow in a collapsed tube, ” Journal of Fluid Mechanics, vol. 206, pp. 339 – 374, 1989.
[23] Olsen, J. H., and Shapiro, A. H., “ Large-amplitude unsteady flow in liquid-filled elastic tubes, ” Journal of Fluid Mechanics, vol. 29, no. 3, pp. 513 – 538, 1967.
[24] Pontrelli, G., “ A mathematical model of flow in a liquid-filled visco-elastic tube, ” Medical and Biological Engineering and Computing, vol. 40, no. 5, pp. 550 – 556, 2002.
[25] Wang, D., and Tarbell, J., “ Nonlinear analysis of flow in an elastic tube (artery): Steady streaming effects, ” Journal of Fluid Mechanics, vol. 239, pp. 341 – 358, 1992.
[26] Okamura, S., Suzuki, A., Johkura, K., Ogiwara, N., Yokouchi, T., and Sasaki, K., “ Formation of the biopulsatile vascular pump by cardiomyocyte transplants circumvallating the abdominal aorta, ” Tissue Engineering, vol. 8, pp. 201 – 211, 2002.
[27] Toro, E., Enbody, R.J., “ Science and application of nanotubes, ” Kluwer Academic/ Plenum Publishers, New York, 2000.
[28] Sanks, R.L., George, T. L., “ Pumping station design, ” 2nd edition, Mc Graw-Hill, New York, 1998.