Rosenfeld, Moshe; **Avrahami, Idit**

Net flow rate generation by a multi-pincher impedance pump. (English) Zbl 1245.76021

Comput. Fluids 39, No. 9, 1634-1643 (2010).

Summary: The impedance pump is a simple design that offers a promising technique for generating or augmenting net flow of macro or micro-scale devices without employing internal valves or blades. To obtain significant flow, large pinching amplitude or a wide pincher (actuator) is needed, leading to excessive stresses at high frequencies that may pose severe longevity issues. The present study is focused on the feasibility of increasing the net flow rate of an impedance pump using a sequential array of pinchers. This novel design is evaluated using numerical simulations based on a 1-D approximation that allows carrying out an extensive parametric study of the pump. It is shown that several pinchers working in resonance frequency and with the appropriate phase between them may result in a significant flow rate even when small pinching amplitudes or small-size pinchers are used. The net flow is generated by longitudinal standing wave patterns rather than a peristaltic action. The use of multiple pinchers allows controlling both the magnitude and direction of the net flow merely by changing the phase between them.

MSC:

76D05 Navier-Stokes equations for incompressible viscous fluids

Keywords:

impedance pump; 1-D approximation; multiple pinchers; valveless pumping

Full Text: DOI

References:

[1] Liebau, G., Über ein ventilloses pumpprinzip, Naturwiss, 41, 327-328, (1954)

[2] Hickerson AI. An experimental analysis of the characteristic behavior of an impedance pump. PhD thesis, California Institute of Technology; 2005.

[3] Ottesen, J.T., Valveless pumping in a fluid-filled closed elastic tube-system: one-dimensional theory with experimental validation, J math biol, 46, 309-332, (2003) · Zbl 1039.92015

[4] Hickerson, A.I.; Rinderknecht, D.; Gharib, M., Experimental study of the behavior of a valveless impedance pump, Exp fluids, 38, 534-540, (2005)

[5] Rinderknecht, D.; Hickerson, A.I.; Gharib, M., A valveless micro impedance pump driven by electromagnetic actuation, J micromech microeng, 15, 861-866, (2005)

[6] Bringley, T.; Childress, T.S.; Vandenberghe, N.; Zhang, J., An experimental investigation and a simple model of a valveless pump, Phys fluids, 20, 033602, 1-15, (2008) · Zbl 1182.76087

[7] Moser, M.; Huang, J.W.; Schwarz, G.S.; Kenner, T.; Noordergraaf, A., Impedance defined flow: generalization of william harvey's concept of the circulation - 370years later, Int J cardiovasc med sci, 1, 3/4, 205-211, (1998)

[8] Jung, E.; Peskin, C., Two-dimensional simulations of valveless pumping using the immersed boundary method, SIAM J sci comput, 23, 19-45, (2001) · Zbl 1065.76156

[9] Borzi, A.; Propst, G., Numerical investigation of the liebau phenomenon, Zamp, 54, 1050-1072, (2003) · Zbl 1047.76128

[10] Auerbach, D.; Moehring, W.; Moser, M., An analytic approach to the liebau problem of valveless pumping, Cardiovasc eng, 4, 2, 201-207, (2004)

[11] Manopoulos, C.G.; Mathioulakis, D.S.; Tsangaris, S.G., One-dimensional model of valveless pumping in a closed loop and a numerical solution, Phys fluids, 18, 017106, 1-16, (2006)

[12] Avrahami, I.; Loumes, L.; Gharib, M., Numerical investigation of the fluid and structure dynamics in models of impedance pump, J biomech, 39, Suppl. 1, S438, (2006)

[13] Loumes, L.; Avrahami, I.; Gharib, M., Resonant pumping in a multilayer impedance pump, Phys fluids, 20, 023103, 1-11, (2008) · Zbl 1182.76475

[14] Avrahami, I.; Gharib, M., Computational studies of resonance wave pumping in compliant tubes, J fluid mech, 608, 139-160, (2008) · Zbl 1145.76355

[15] Jung, E.; Lim, S.; Lee, W.; Lee, S., Computational models of valveless pumping using the immersed boundary method, Comput methods appl mech eng, 197, 2329-2339, (2008) · Zbl 1158.76454

[16] Hickerson, A.I.; Gharib, M., On the resonance of a pliant tube as a mechanism for valveless pumping, J fluid mech, 555, 141-148, (2006) · Zbl 1156.76320

[17] Jung, E., A mathematical model of valveless pumping: a lumped model with time-dependent compliance, resistance, and inertia, Bull math biol, 69, 2181-2198, (2007) · Zbl 1296.92099

[18] Timmermann, S.; Ottesen, J.T., Novel characteristics of valveless pumping, Phys fluids, 21, 053601, (2009) · Zbl 1183.76520

[19] Lee, C.Y.; Chang, H.T.; Wen, C.Y., A MEMS-based valveless impedance pump utilizing electromagnetic actuation, J micromech microeng, 18, 1-9, (2008)

[20] Chang, H.T.; Lee, C.Y.; Wen, C.Y.; Hong, B.S., Theoretical analysis and optimization of electromagnetic actuation in a valveless microimpedance pump, Microelectr J, 38, 791-799, (2007)

[21] Luo, Z.B.; Xia, Z.X., A novel valve-less synthetic-jet-based micro-pump, Sens actuat A, 122, 131-140, (2005)

[22] Hayamizu, S.; Higashino, K.; Fujii, Y.; Sando, Y.; Yamamoto, K., Development of a bi-directional valve-less silicon micro pump controlled by driving waveform, Sens actuat A, 103, 83-87, (2003)

[23] Olufsen, M.S.; Peskin, C.S.; Kim, Y.; Pedersen, E.M., Numerical simulation and experimental validation of blood flow in arteries with structured-tree outflow conditions, Ann biomed eng, 28, 1281-1299, (2000)

[24] Laney CB. Computational gasdynamics. Cambridge University Press, Cambridge; 1998. p. 319. · Zbl 0947.76001

[25] Sheng, C.; Sarwal, S.N.; Watts, K.C.; Marble, A.E., Computational simulation of blood-flow in human systemic circulation incorporating an external force-field, Med biol eng comput, 33, 8-17, (1995)

[26] Jang, L.S.; Li, Y.J.; Lin, S.J.; Hsu, Y.C.; Yao, W.S.; Tsai, M.S., A stand-alone peristaltic micropump based on piezoelectric actuation, Biomed microdev, 9, 185-194, (2007)