NUMERICAL SIMULATIONS OF FLOWS IN AN ELASTIC CYLINDER WITH TWO CHAMBERS

Sunmi LEE [1] , Eunok JUNG [2]

1) *National Institute for Mathematical Sciences, Daejeon, KOREA*

2) *Department of Mathematics, Konkuk University, Seoul, KOREA*

Corresponding Author : Sunmi LEE, sunlee@nims.re.kr

ABSTRACT

In this work, we construct a new model of a fluid inside an elastic cylinder with two chambers. Mathematical modeling and numerical simulations of flows driven by pumping are presented. A periodic compression of the asymmetric part of the elastic tube generates a unidirectional flow. Both size and the direction of the generated net flow highly depend on the pumping frequency.

INTRODUCTION

Valveless pumping is closely related to the cardiovascular system and Liebau suggested that asymmetric periodic compression of the heart causes the blood circulation. He did a physical experiment using elastic tubes with different length and materials and observed the net flow of those systems. Liebau made two models: first, a closed loop with different length or materials and secondly, two open tanks are connected with an elastic tube (see figure1). There has been more work of computational, analytical and experimental research on the valveless pumping phenomenon in the first model [3],[4] than the second model [1], [2].

In [3], the 2-D Navier-Stokes equation coupled with the elastic boundaries was solved using Immersed Boundary (IB) method for the first model. However any work has not been computed by the 2-D Navier-Stokes equation for the second model. In this work we construct a new model which corresponds to the second model, which are modified so that IB method can be used to simulation (see figure2). We are able to observe the occurrence of net flow in this new model and also this net flow and the direction highly depend on the pumping frequency. Our main result of the averaged net flow for 30 seconds versus frequency is given in figure 3.

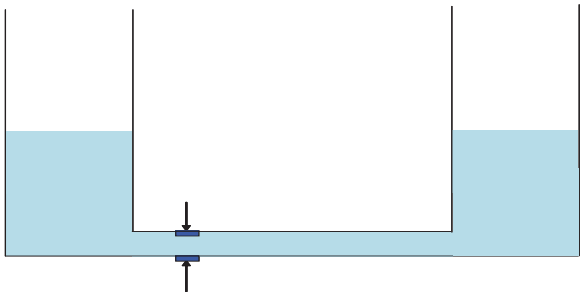

Figure 1. Liebau model, two rigid open tanks are connected with an elastic tube and periodic pumping is given at the location of arrow marked.

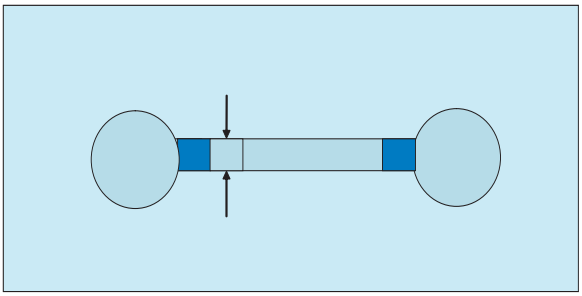

Figure 2. Modified model of figure 1 so that IB method can be applied: a fluid filled in the entire box and an elastic cylinder with two chambers are immersed in the fluid (dark blue part is almost rigid material) and periodic pumping is given at the location of arrow marked (the second sixth of the elastic tube).

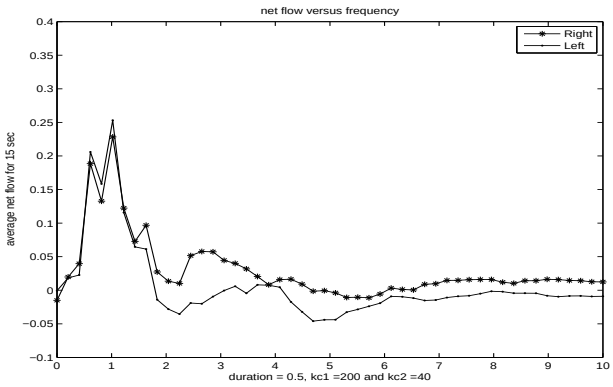

Figure 3. Average net flow versus frequency: average net flow is computed at cross section of two dark blue parts (right and left) for 30 seconds and frequency is varied from 0.1 to 10. Positive net flow represents the flow from left to right and negative net flow represents the flow from right to left.

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