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EVALUATION OF THE CONCEPT OF AN IN-VITRO TEST CHAMBER SUBMITTED TO PULSATILE HEMODYNAMIC CONDITIONS.

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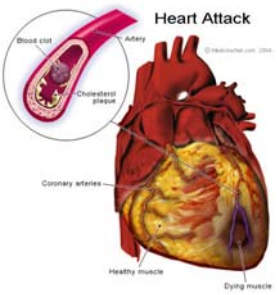
Introduction

Heart and circulatory system diseases are still one of the most serious health problems in the world. Due to the complexity of the problem and the various describers and phenomena involved, worldwide scientists joined in teams having an interdisciplinary character to work together. This collaborative work aims at a better understanding of the activity of the circulatory system and a more efficient fight against the diseases. To avoid delicate in–vivo testing, new breakthroughs have made it possible to create an in–vitro circulatory system. The objective of this work is to create and to control the in–vitro circulatory system which will be used to test new drugs in a vascular tissue submitted to physiological pulsatile flow conditions. For our investigation the tissue is a layer of endothelial cells.

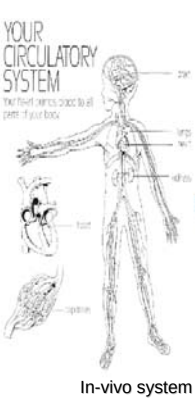
Why a researcher?

- 600 000 people suffering from heart attacks
- Thousands of people have to be hospitalized each year
- In Belgium 40%-60% of deaths are caused by cardiovascular diseases

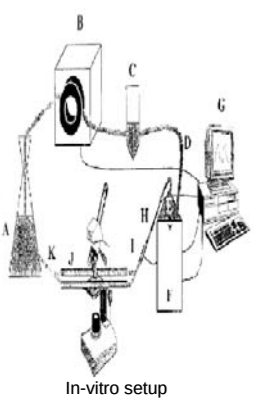


What is an in – vitro test?

It is a test performed with live cells isolated outside their mother organism. These cells are put in an external laboratory system that tries to reproduce in-vivo conditions while keeping the cells alive.



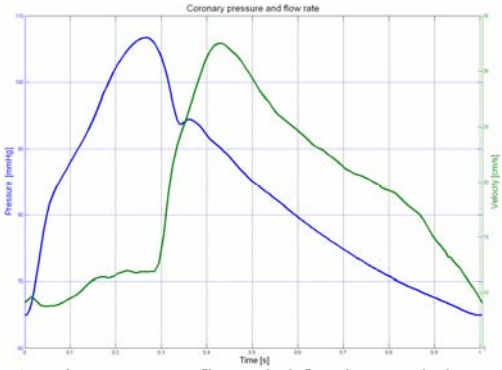
In-vivo system



In-vitro setup

Assumptions

Based on in-vivo data of pressure and velocity measured by the medical team of the CHU of Charleroi, we verify the blood pulsatile flow properties. We show how the flow and the pressure evolve in time into the coronary artery and how the corresponding shear stress evolves on a wall. These in-vivo data will be reproduced in the in – vitro tests.



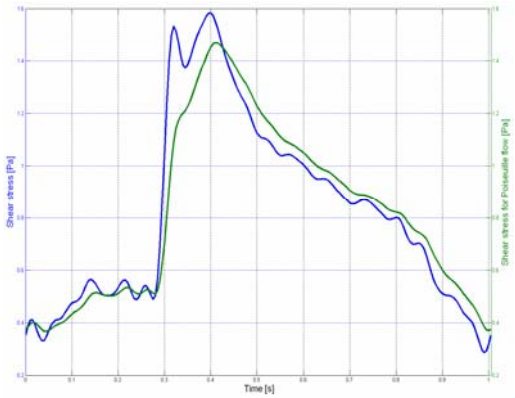
- Pulse: 60 – 120 [beats/min], Time cycle is 1 – 0.5 s
- Range of pressure: Systolic 160 [mmHg], Diastolic 60 [mmHg]
- Incubator: temperature 37°C, Air inside 5% CO2
- Tests will be performed over a period of time from 24 to 48 h.
- Sterilized conditions

A key factor in the development of endothelial cells is the flow shear stress created on the cell surface. The calcolutions of shear stress τ based on the integration of the unsteady Navier-Stokes equation on a circular vessel. The resulting law known as the Womersley law includes Bessel functions :

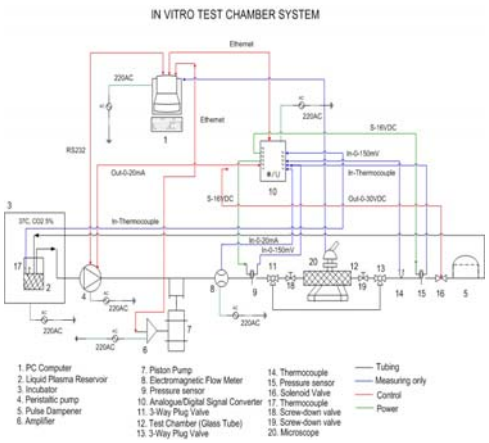
$$U(r,t) = \sum_{-\infty}^{\infty} \frac{G_n i R^2}{\mu \Omega_n^{\,2}} \left(1 - \frac{J_o(\zeta_n)}{J_o(\Lambda_n)}\right) e^{iwnt}$$

$$\tau(t) = -\mu \left(\frac{\partial U(r,t)}{\partial r}\right)_{r=R}$$

G_n = the complex amplitude of the n^{th} harmonic, R = vessel radius, Ω = Womersley parameter, $\Lambda = i^{3/2}\Omega$, $\zeta = \Lambda r/R$, r=radius, J_o, J_1 = Bessel function, ω = $2\pi/T$, t= time, T= pulsatile period

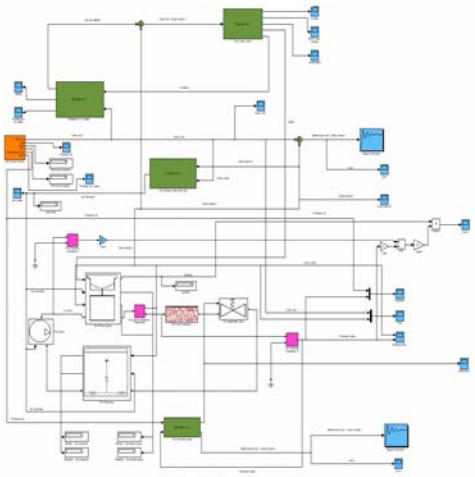


Experimental setup



Cardiovascular system Modeling

We use the analogy between mechanical laws and electrical laws. Within this analogy the flow circuit is modeled as an electrical one using Simulink.



Conclusions

The simulation aimed to validate the concept of the test chamber system and its control system. The task was to show the possibility to obtain pressure levels and flow rates close to realistic pulsatile conditions. For that purpose the flow behavior and the control system of the foreseen experimental setup were validated using the electrical analogies of hydrodynamic laws in flow circuits. We can notice that this pragmatic approach used in the project has provided good tools to choose the pieces of equipment.