UNIVERSITATEA TEHNICĂ CLUJ-NAPOCA

ASPECTE PRIVIND HEMODINAMICA ASOCIATA VALVELOR MECANICE CARDIACE SI PROTEZELOR VASCULARE

Corina Giurgea, UTCN

HEMODINAMICA ASOCIATA PROTEZELOR VALVULARE SI VASCULARE

ARIA PROBLEMATICA

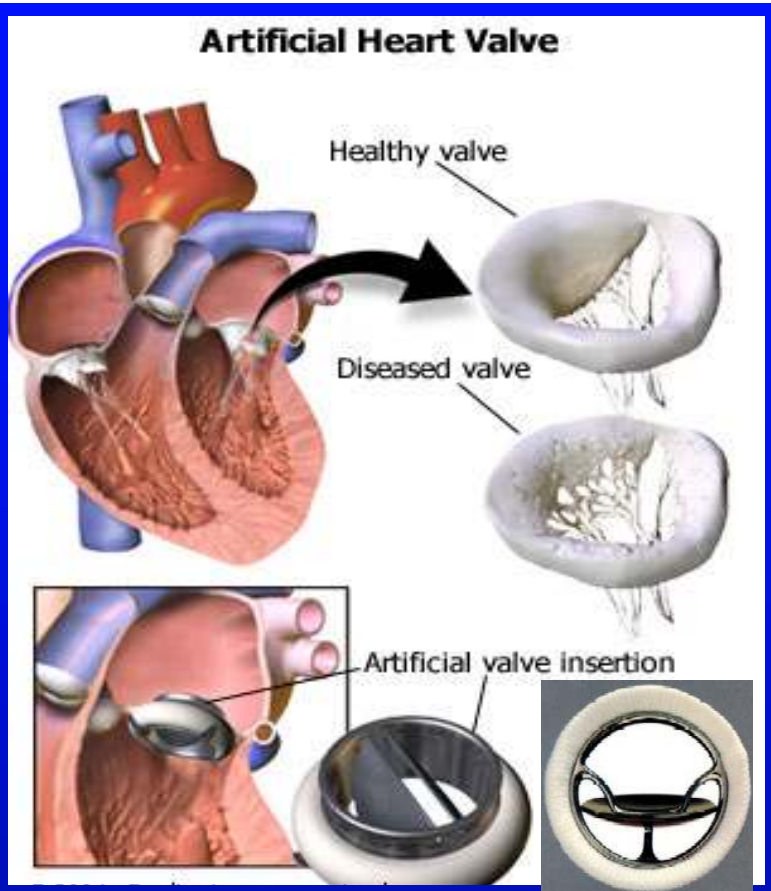
Cercetare de frontiera:

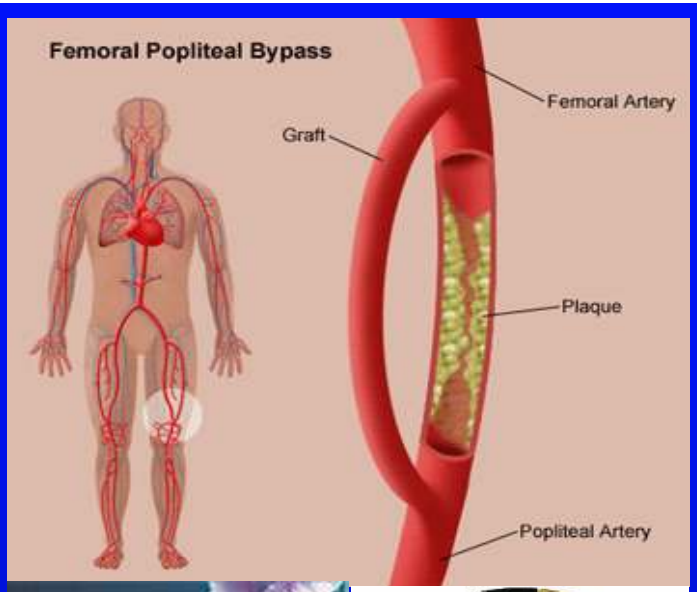
- Investigarea curgerilor prin protezele valvulare si vasculare adoptind aparatul teoretic, metodele si instrumentele mecanicii fluidelor in vederea solutionarii unor probleme specifice cercetarii din domeniul chirurgiei cardiovasculare

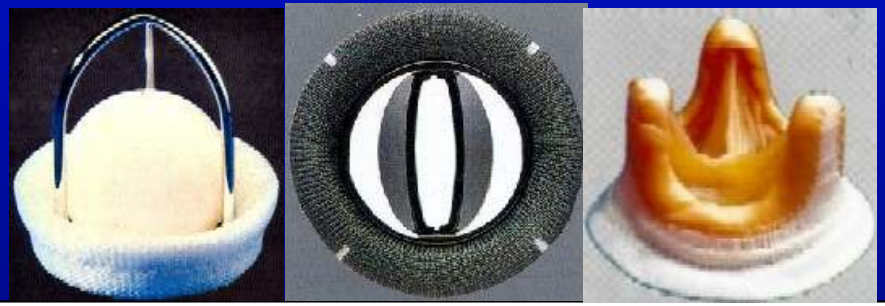
- Implica: activitati de cercetare fundamentale
  activitati de cercetare aplicata

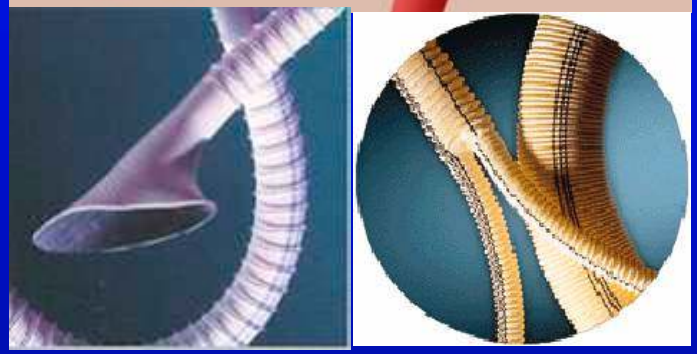
- Motivatia cercetarilor
  - Gasirea unor solutii pentru cresterea performantelor protezelor si a calitatii actului chirurgical

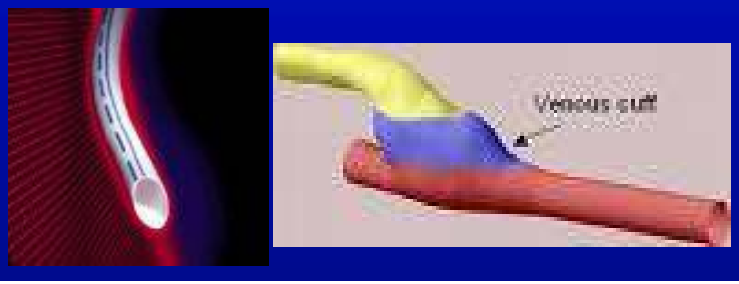
- Cercetari propulsate si sustinute de:
  - producatorii de proteze valvulare si vasculare
  - Agentiile de reglementare a calitatii implanturilor











Anual: 180.000 implanturi
70% valve mecanice
Avantaj: durabilitatea crescuta
<u>Dezavantaj</u>: risc semnificativ pentru complicatii pe termen lung

Anual: 350.000 proteze vasculare
200.000 grefe venoase
<u>Dezavantaj</u>: aparitia restenozarii si obliterarii bypassului intr-un interval de 2 - 24luni la 1/3 din interventii

Scopul fundamental al cercetarii:

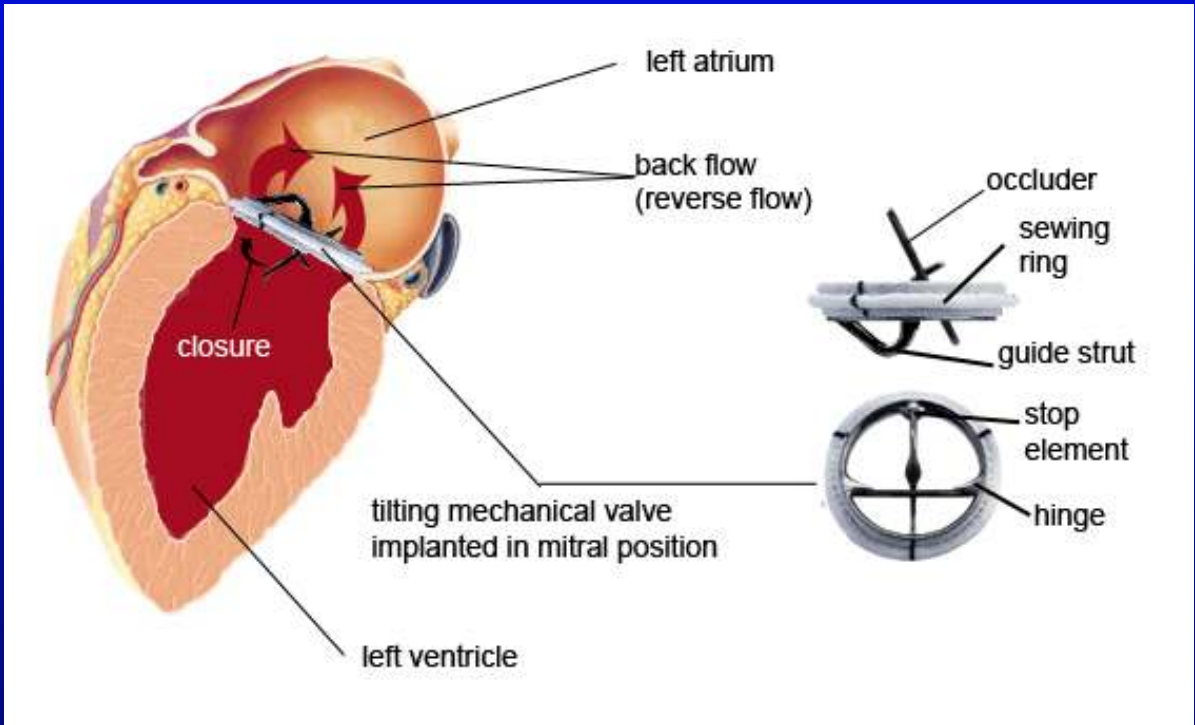
- identificarea acelor solutii pentru cresterea performantelor protezelor si a calitatii actului chirurgical care sa asigure ***minimizarea riscului de aparitie a complicatiilor care insotesc implanturile de valve mecanice cardiace si diminuarea ratei de esec a operatiilor de reconstructie vasculara periferica, de tip bypass***

Complicatiile protezarii ► atribuite curgerii nefiziologice ("perturbate")

Obiective:

- Intelegerea mecanismelor fenomenelor fizice care se produc la curgerea prin proteze
- Identificarea
  - factorilor cu posibil rol in declansarea complicatiilor
  - parametrilor relevanti pentru controlul curgerii
- Identificarea unor solutii de control pasiv necesare:
  - Producatorilor de valve – dezvoltarea de noi proteze
  - Clinicienilor- optimizarea tehnicilor chirurgicale

Hemodinamica asociata valvelor mecanice cardiace

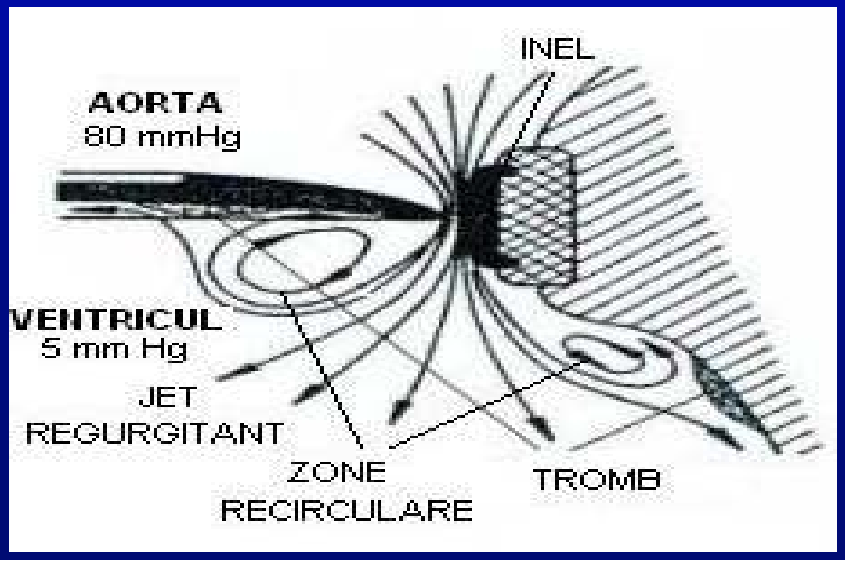


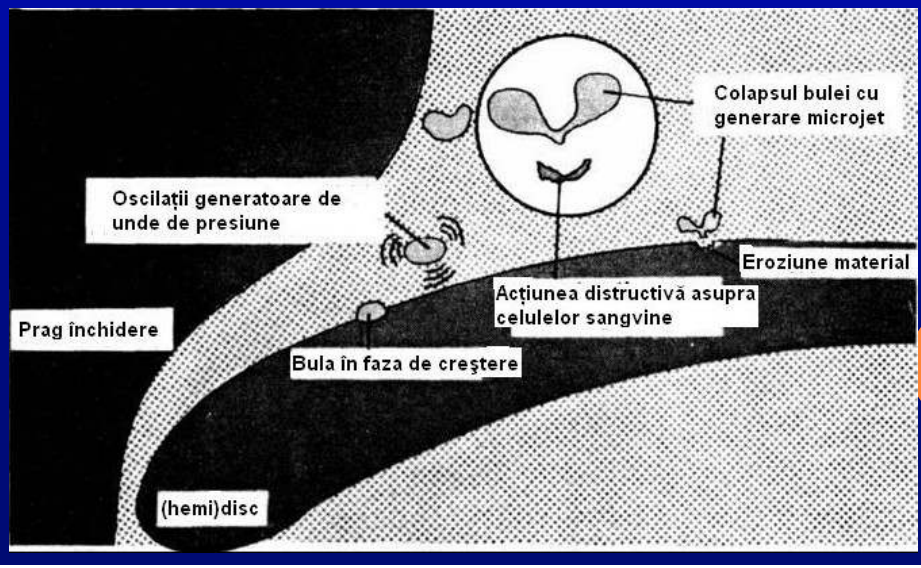
COMPLICATII ALE IMPLANTURILOR CU VALVE MECANICE

- hemoliza
- activarea trombocitelor si declansarea mecanismelor coagularii
- complicatii tromboembolice
- disfunctii de natura mecanica (fisurari, ruperi , dislocari ale elementelor valvei)

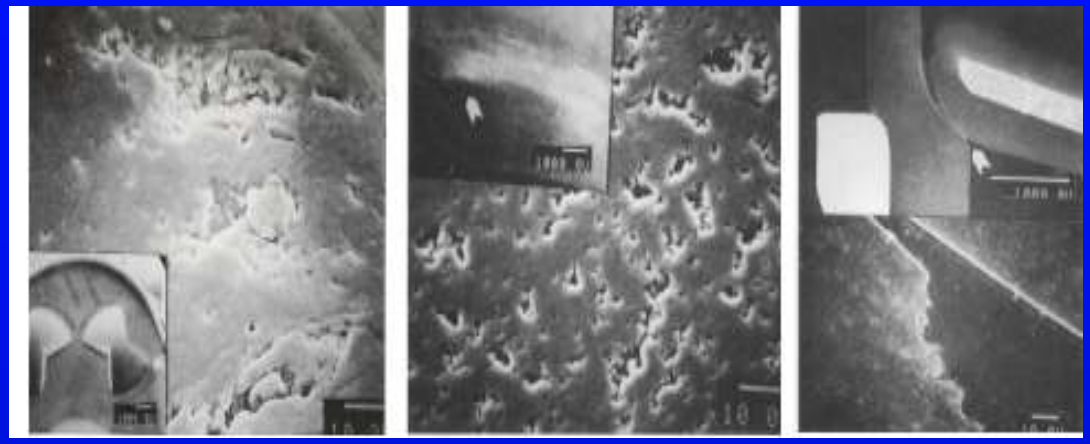
FACTORI care tin de dinamica procesului de curgere prin valva:

- Expunerea RBC si trombocitelor la valori ridicate ale tensiunilor de forfecare:
  - magnitudinea tensiunilor (170 N/m^2 ÷2000 N/m^2)
  - Durata expunerii
- Prezenta zonelor de recirculare si stagnare
- Cavitatia ?

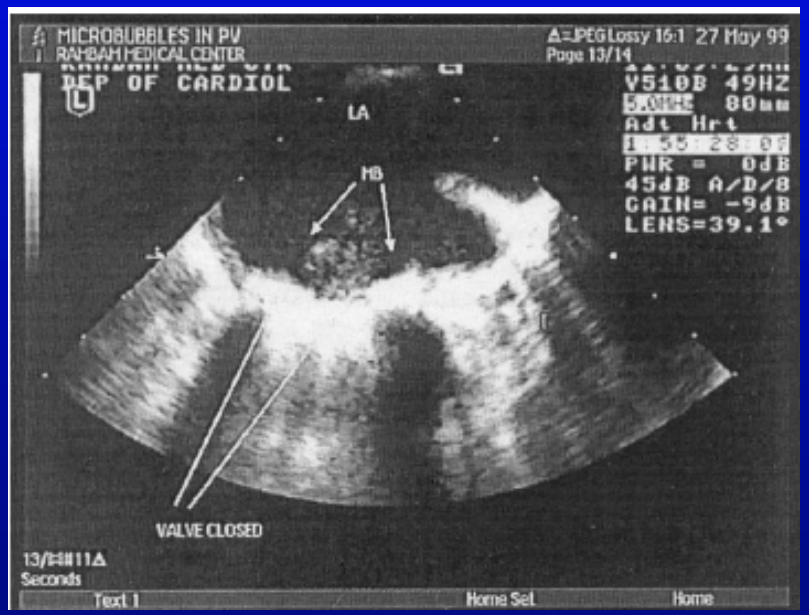


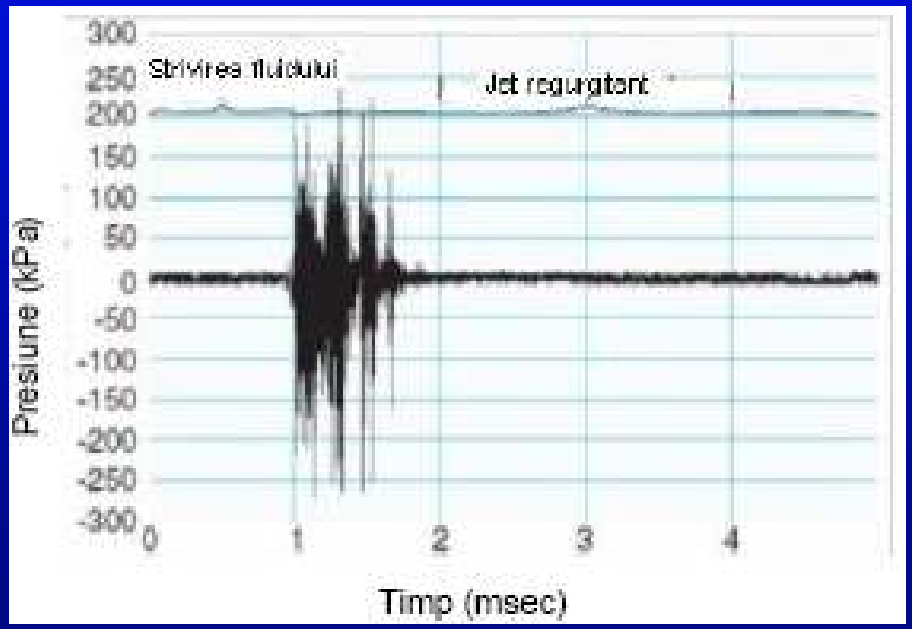


INDICII ALE PREZENȚEI CAVITAȚIEI



1. **Eroziune observată pe explanturi**



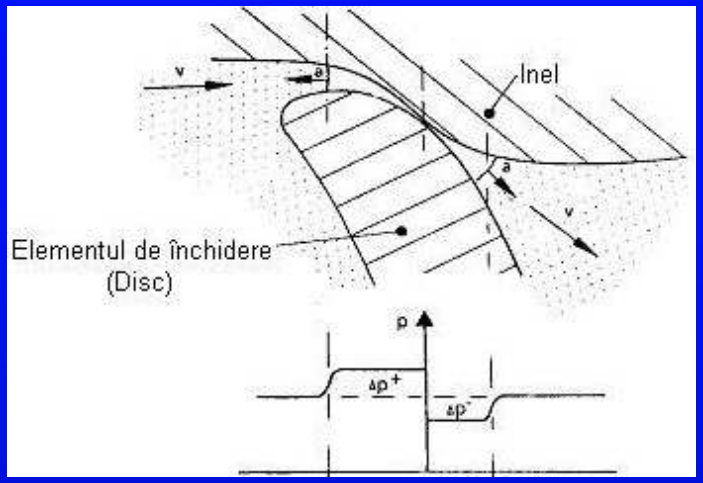


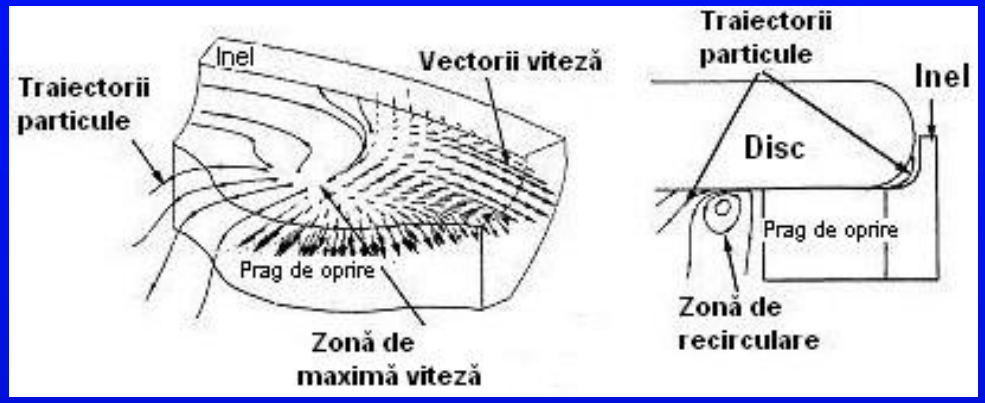
3. **SEC şi HITS**

4. **Conținutul de Hb liber in plasma**

2. **HPPF (in vivo) fluctuații de presiune cu frecvență ridicată (>50 kHz)**

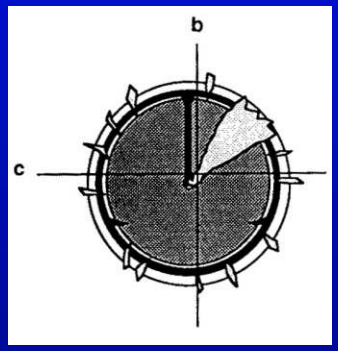
MECANISMELE IMPLICATE ÎN APARIȚIA CAVITAȚIEI



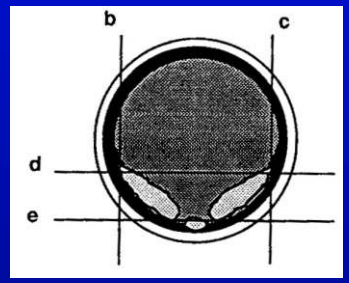


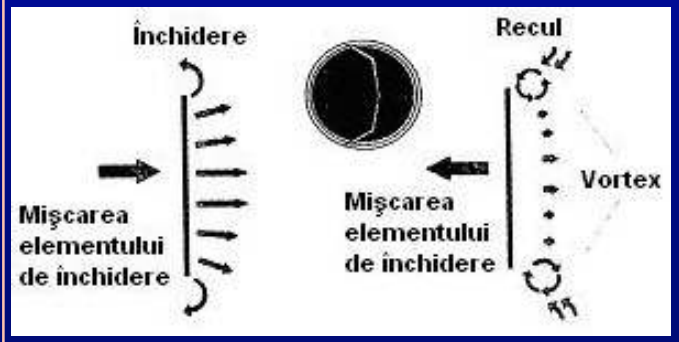
Lovitură de berbec (Graf, Reul)

Strivirea fluidului (Hwang, Homma, Lim)

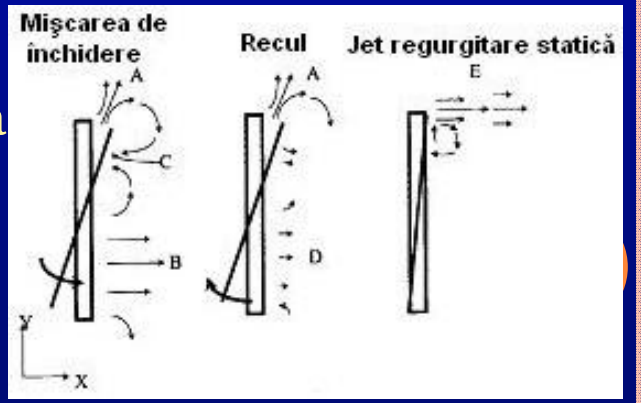


Efect Venturi (Koeheler, Chandran)





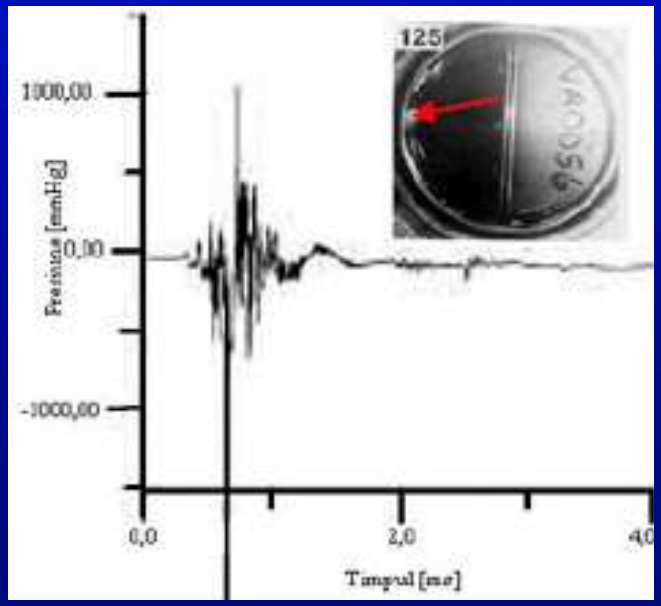
Formarea de vârtejuri la vîrful discului (Tarbell) **intensificate de regurgitarea statică**



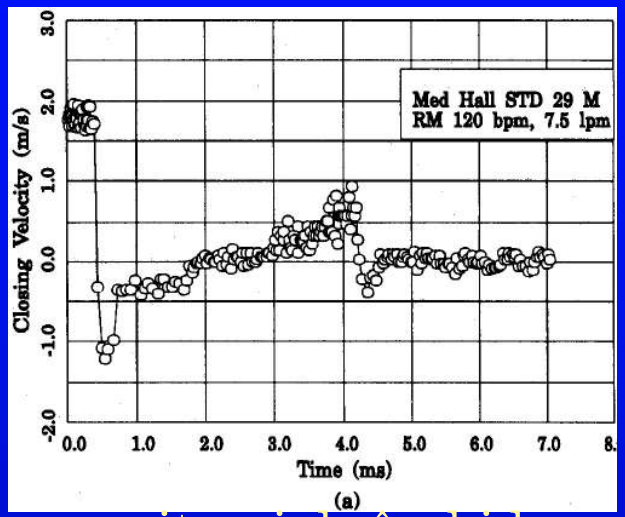
CERCETĂRI PRIVIND ÎNCHIDEREA VALVELOR MECANICE ÎN CONTEXTUL FENOMENULUI CAVITAȚIONAL

A. Cercetări experimentale
B. Simulari numerice

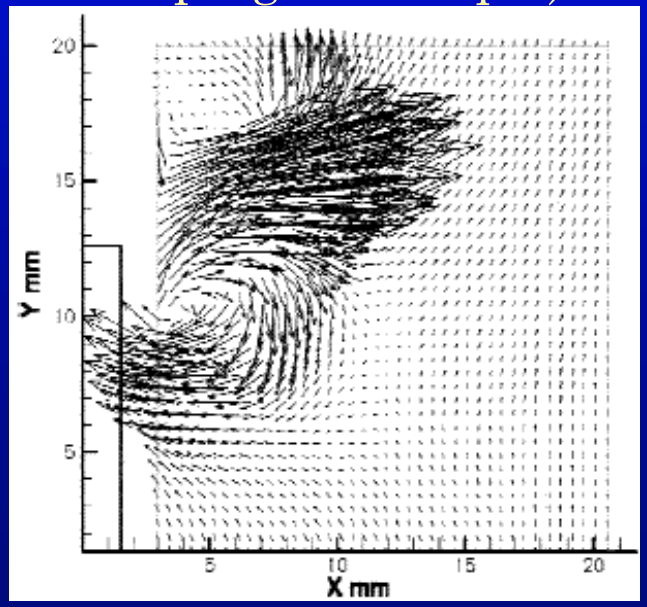
1. Vizualizare bule cavitaţionale



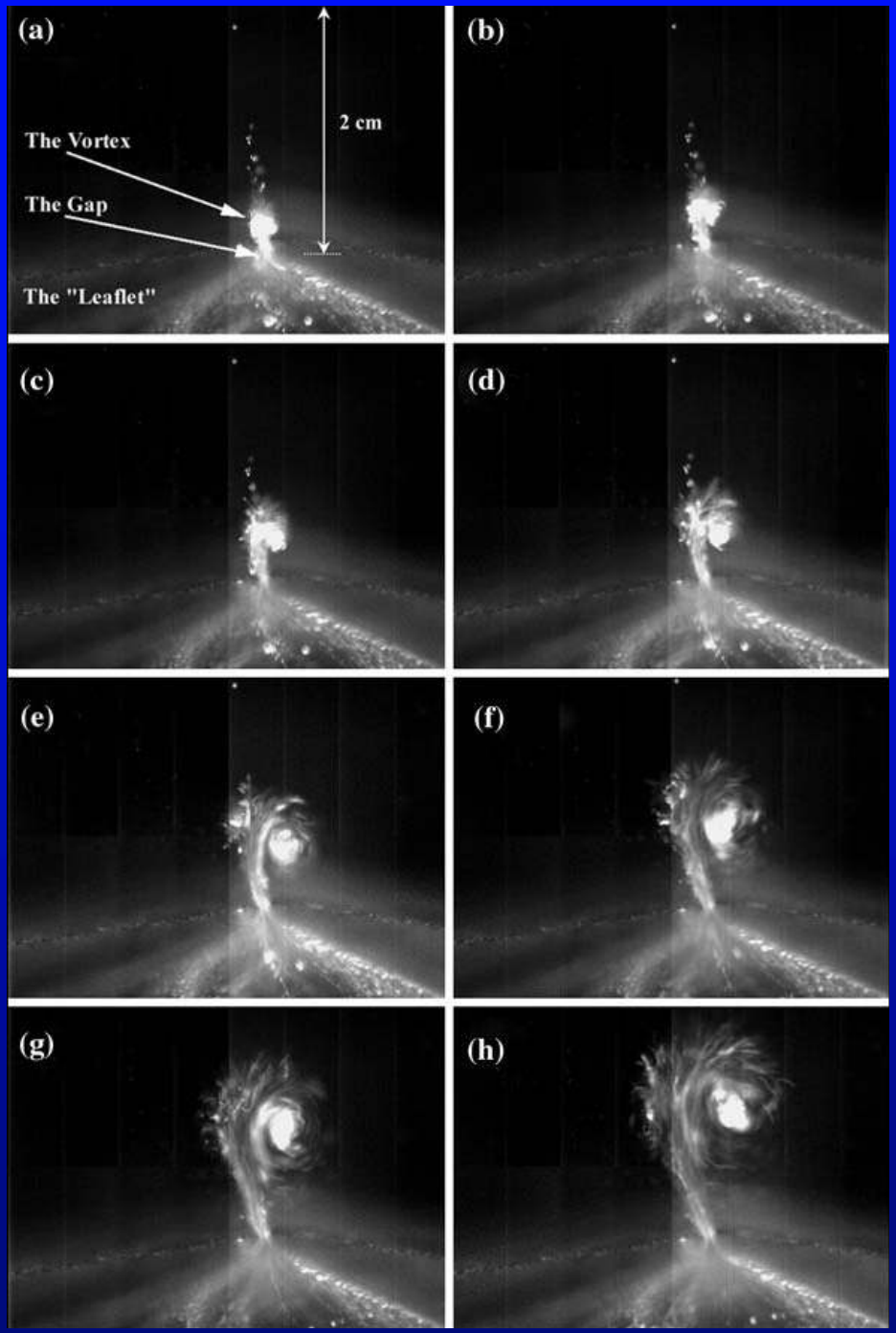
2. Cartografierea câmpului de presiuni

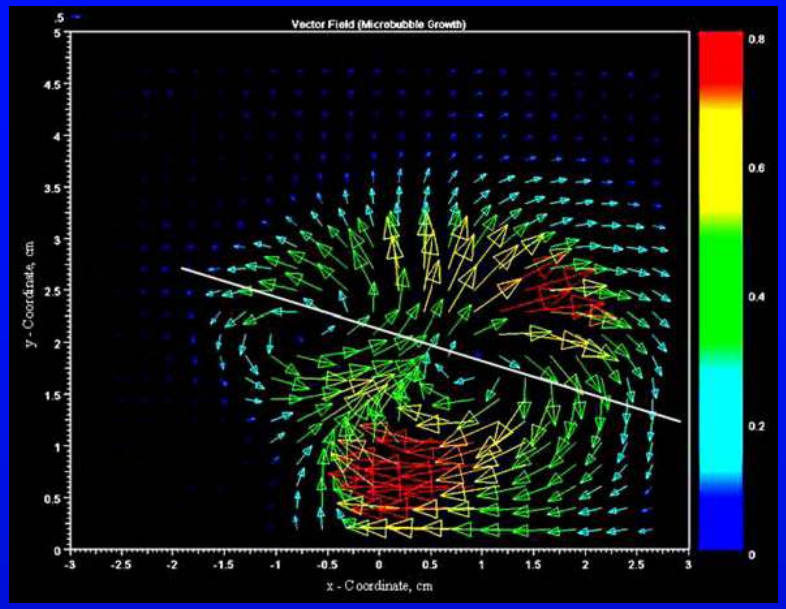


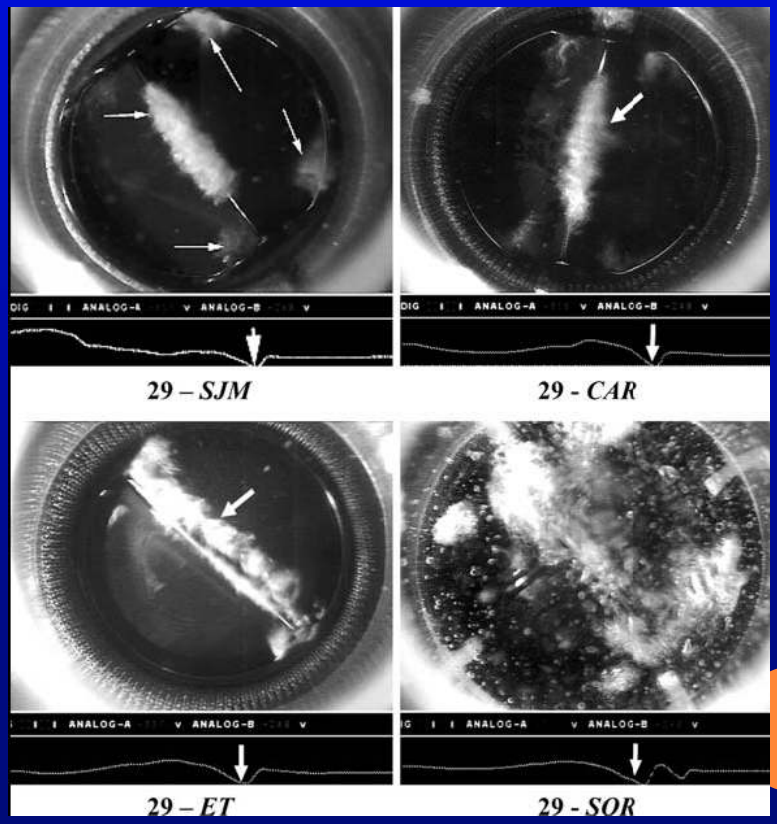
3. Determinarea vitezei de închidere prin LST (Laser Sweeping Technique)



4. Evidentierea formarii vîrtejului de capăt prin LDV (Laser Doppler Velocimetry) şi PIV (Particle Image Velocimetry)







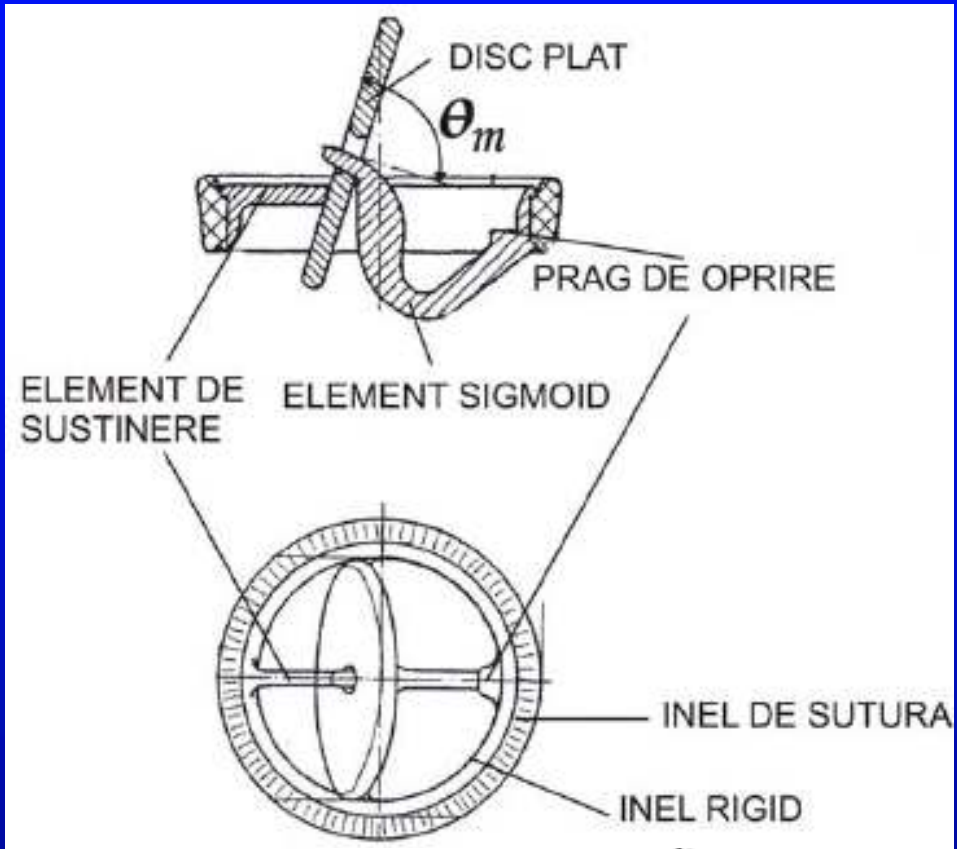
RAMBOD – colectiv CALTECH Institute **Gharib**

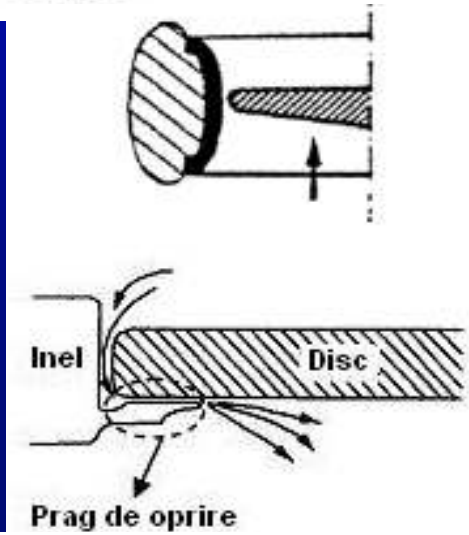
Cercetari si realizari UTCN privitoare la dinamicii inchiderii valvei in contextul fenomenului cavitational

- Cercetari experimentale
  - Vizualizarea aparitiei bulelor cavitationale in cazul a doua valve mecanice (OS si MH), pentru a raspunde la intrebarile unde?, cind?, si sub ce configuratie? apar bulele cavitationale
  - Evaluarea altor parametri relevanti pentru dinamica inchiderii valvelor mecanice
- Simulare numerica
  - Conceperea unui instrument CFD utilizabil in simularea inchiderii unei valve mecanice monodisc
  - Cartografierea precisa a campurilor hidrodinamice si a liniilor de curent asociate stadiului final al inchiderii valvei

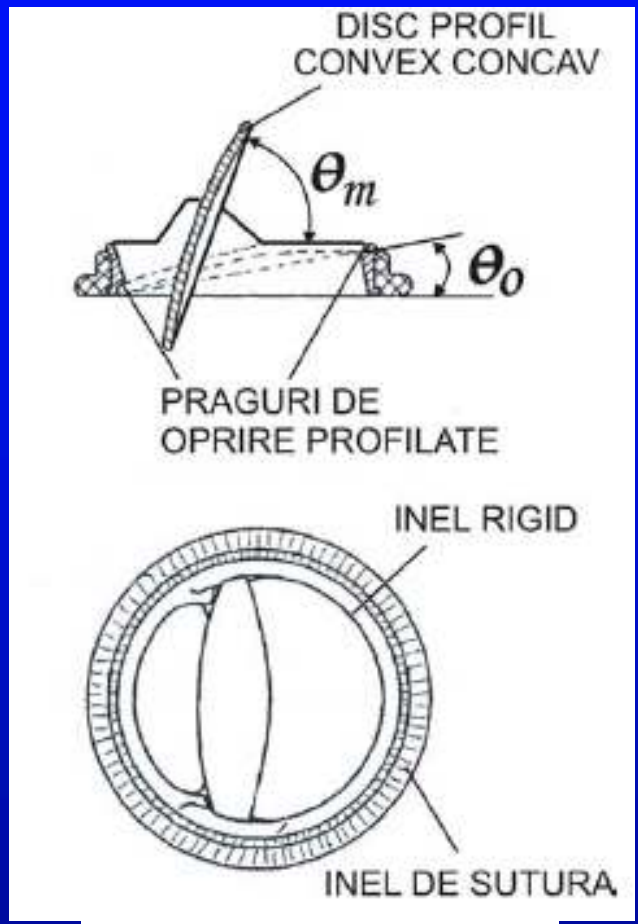
VALVELE STUDIATE

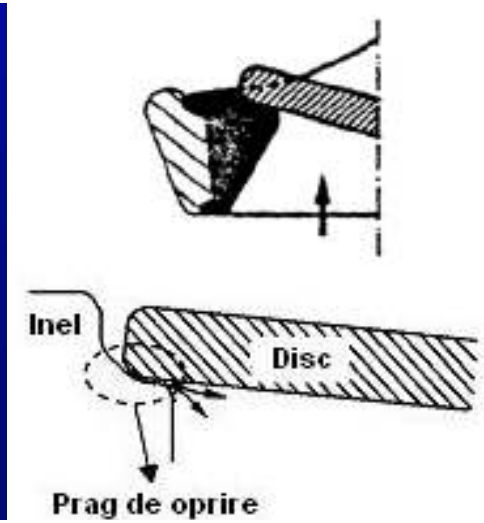
Medtronic Hall (MH)





OmniScience (OS)





Hemodynamics
Typical ventricular (p_V) and aortic (p_A) pressure waves displayed on monitor 1

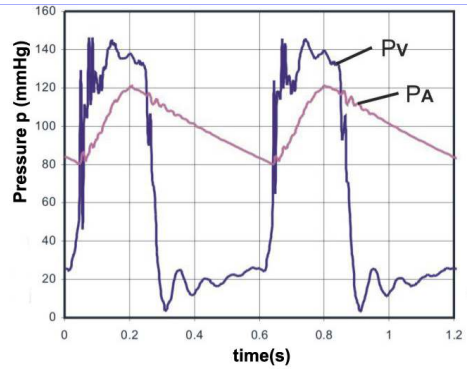
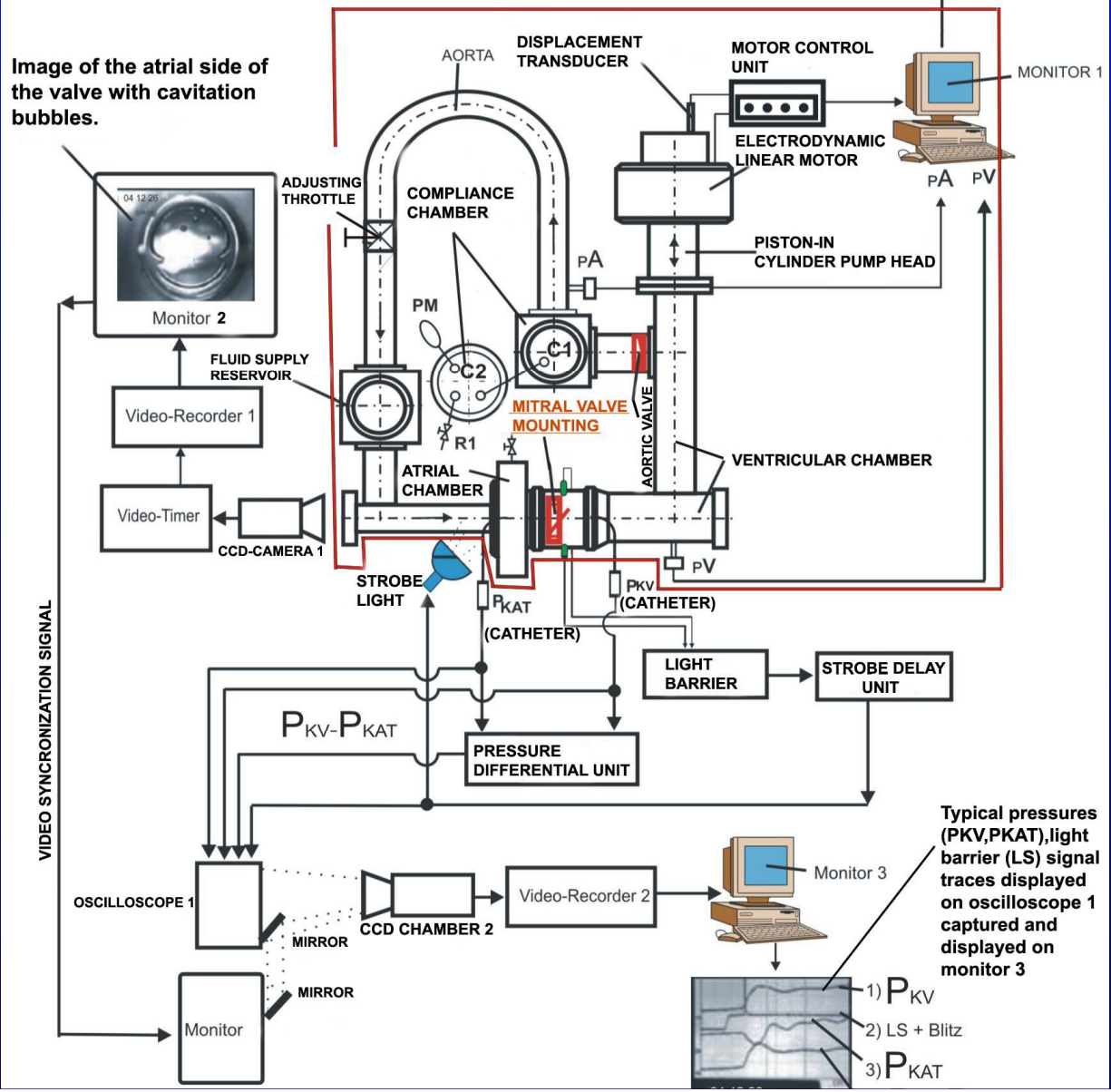
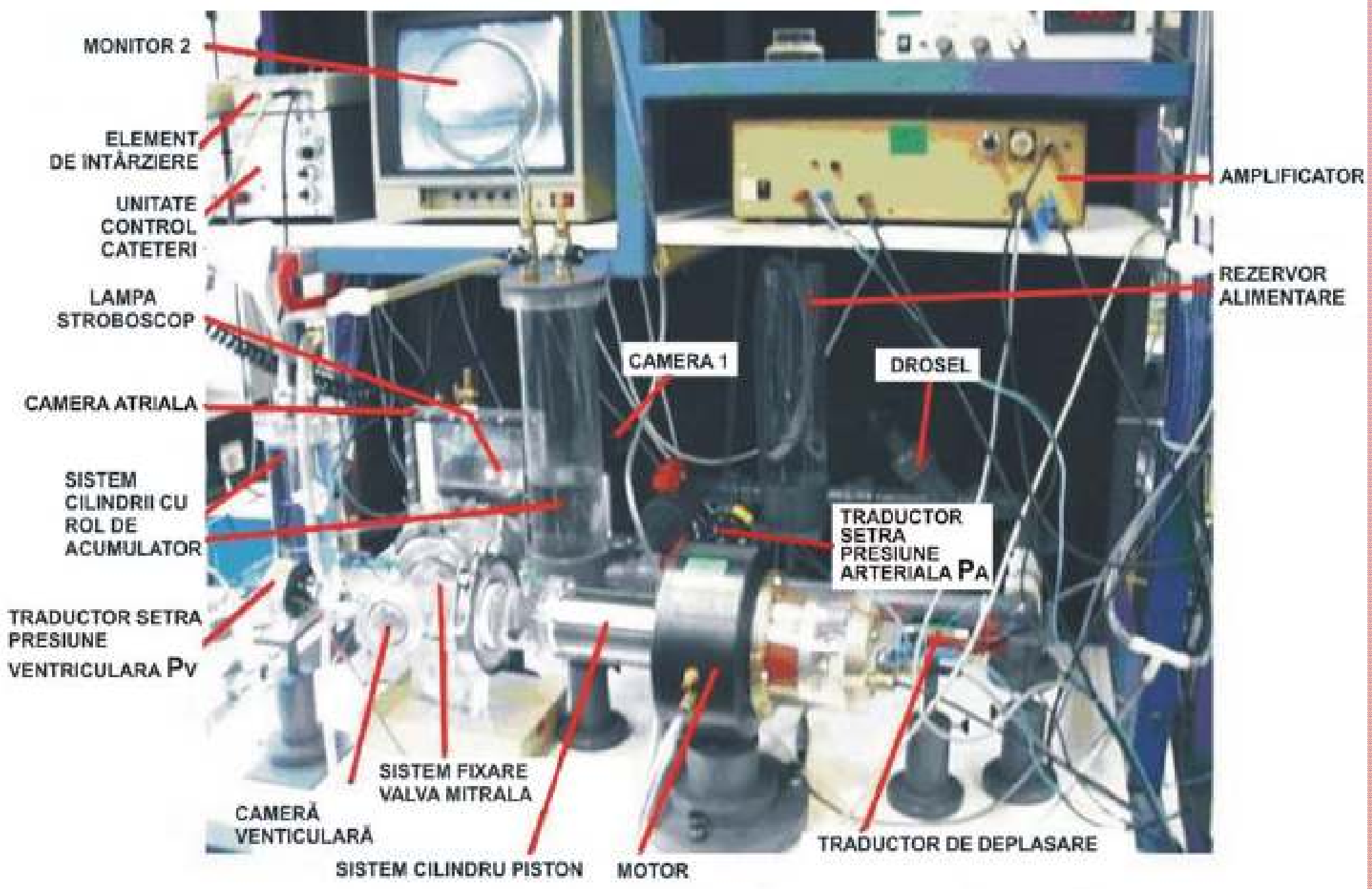


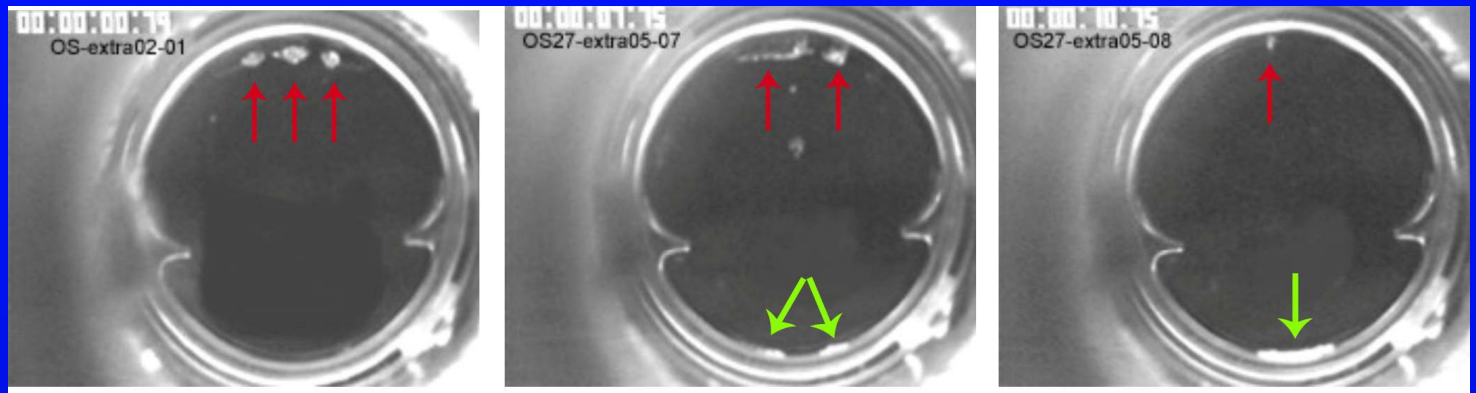
Image of the atrial side of the valve with cavitation bubbles.



Typical pressures (PKV,PKAT),light barrier (LS) signal traces displayed on oscilloscope 1 captured and displayed on monitor 3


MONITOR 2
ELEMENT DE INTÂRZIERE
UNITATE CONTROL CATETERI
LAMPA STROBOSCOP
CAMERA ATRIALA
SISTEM CILINDRII CU ROL DE ACUMULATOR
TRADUCTOR SETRA PRESIUNE VENTRICULARA Pv
AMPLIFICATOR
REZERVOR ALIMENTARE
CAMERA 1
DROSEL
TRADUCTOR SETRA PRESIUNE ARTERIALA Pa
SISTEM FIXARE VALVA MITRALA
CAMERĂ VENTICULARĂ
SISTEM CILINDRU PISTON
MOTOR
TRADUCTOR DE DEPLASARE

OS 27

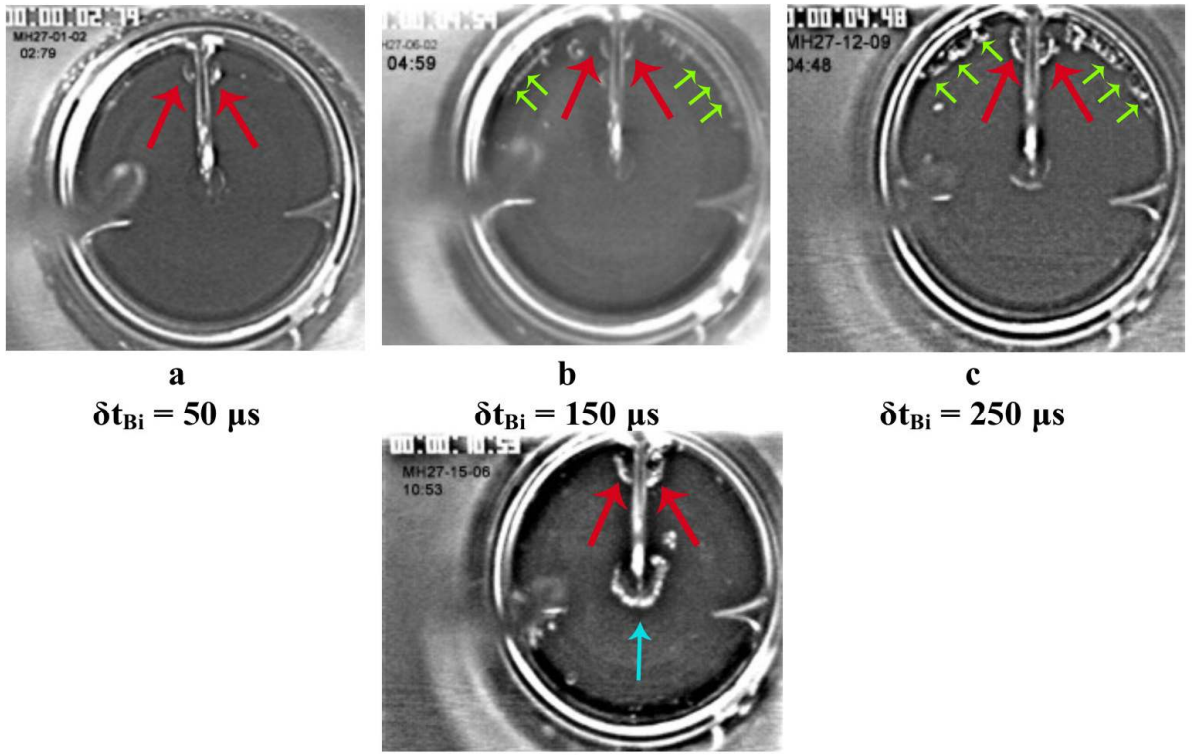


a.
δt_{Bi} = 50 µs

b.
δt_{Bi} = 150 µs

c.
δt_{Bi} = 250 µs

MH 27



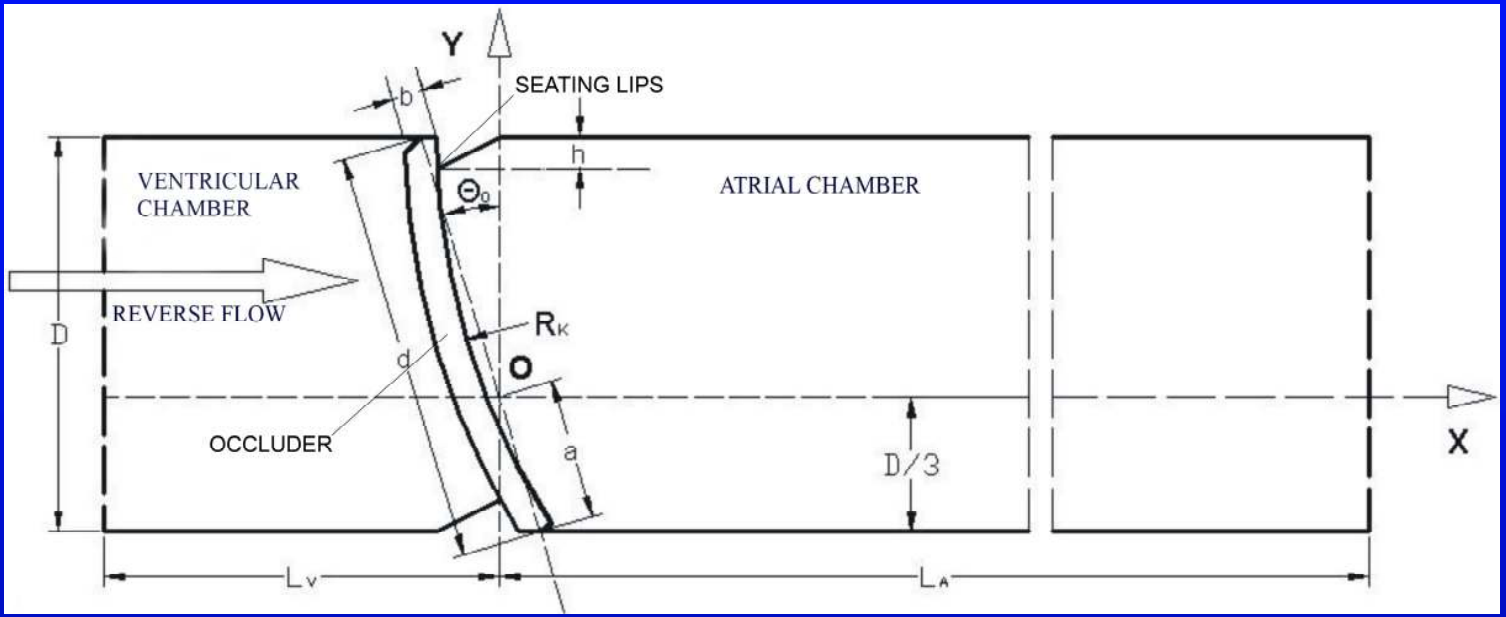
a
δt_{Bi} = 50 µs

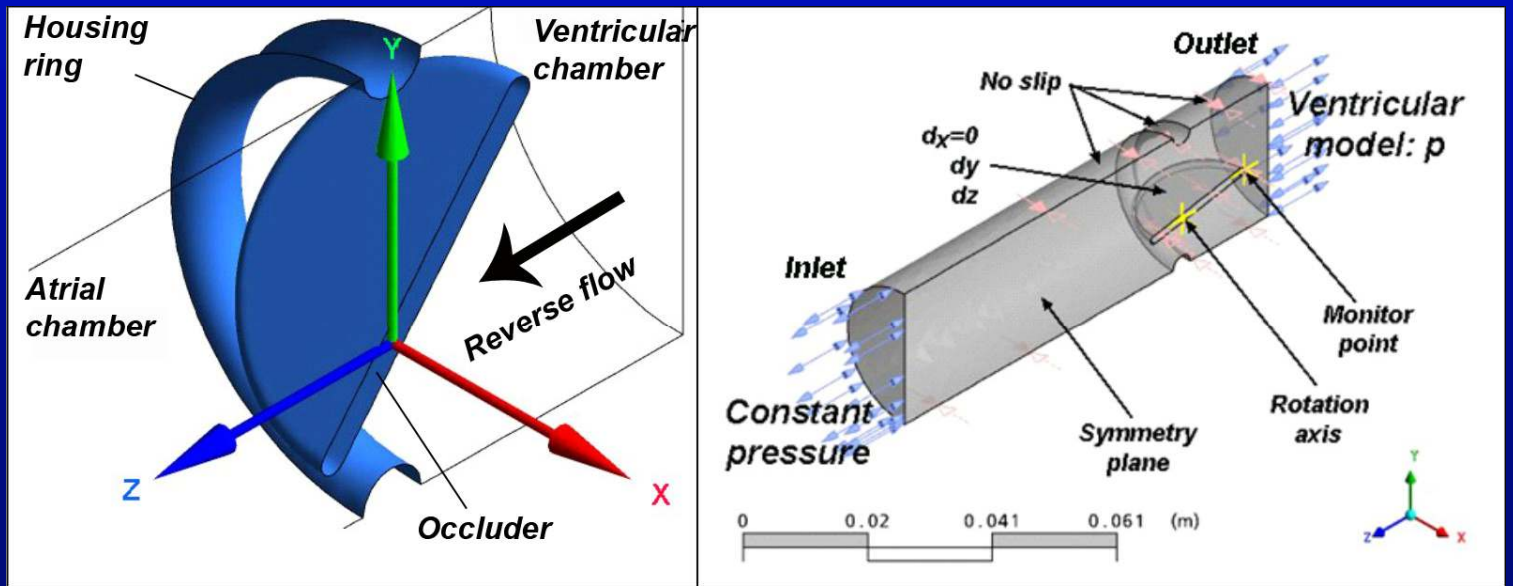
b
δt_{Bi} = 150 µs

c
δt_{Bi} = 250 µs

d
δt_{Bi} = 500 µs

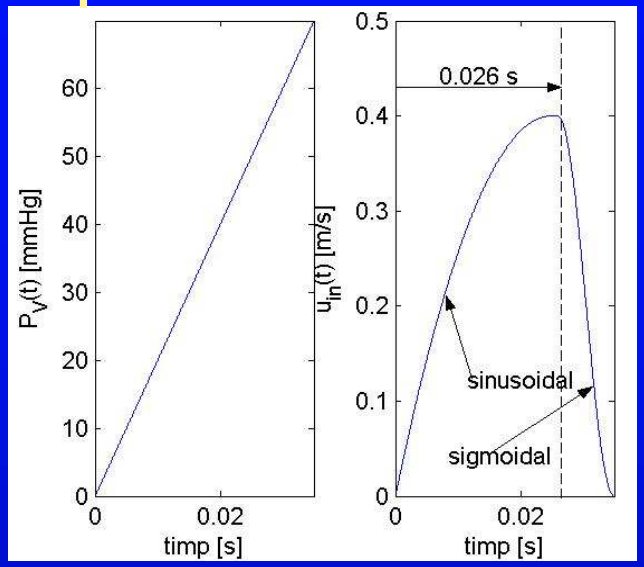
Simulari numerice



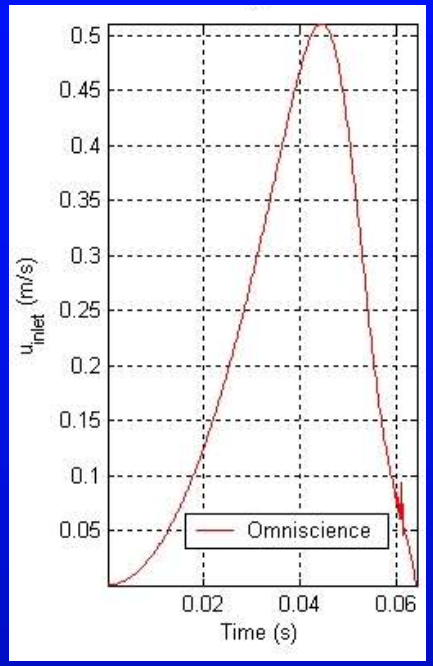


CONDIȚII LA LIMITĂ

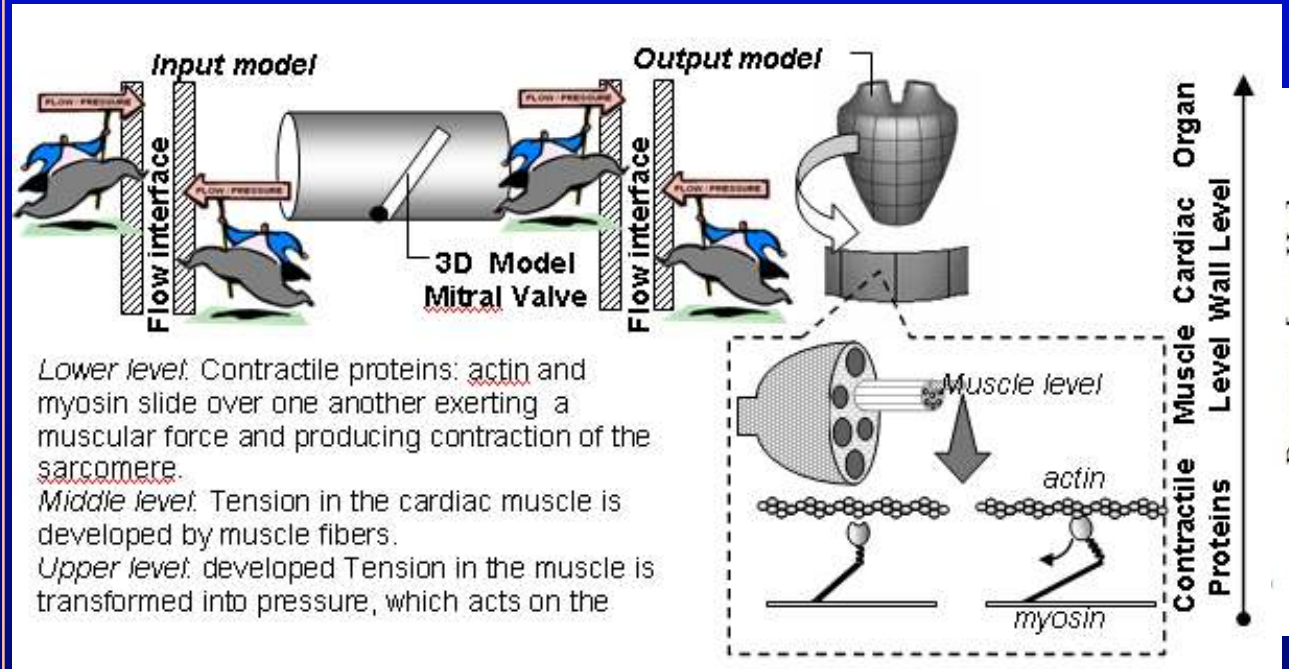
Experiment 1

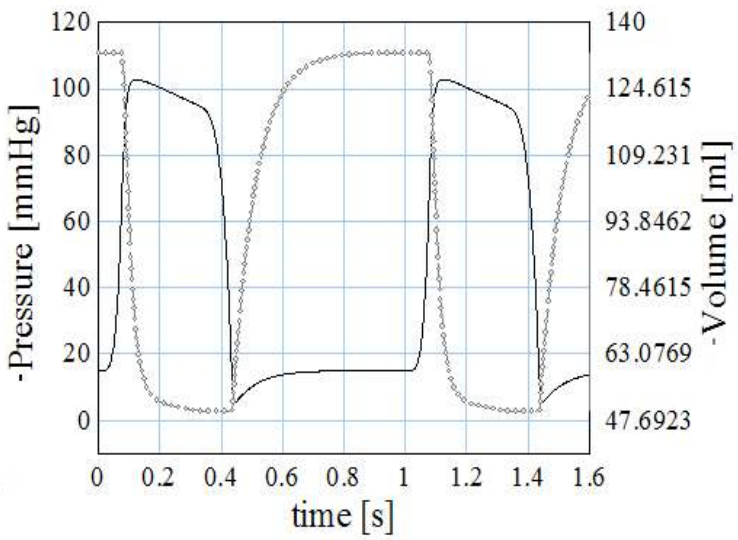


Experiment 2



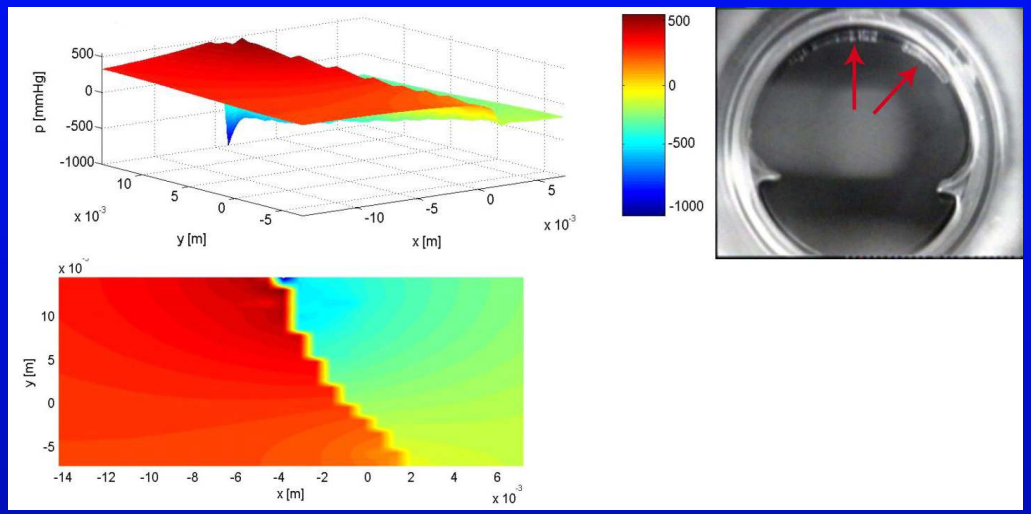
Experiment 3





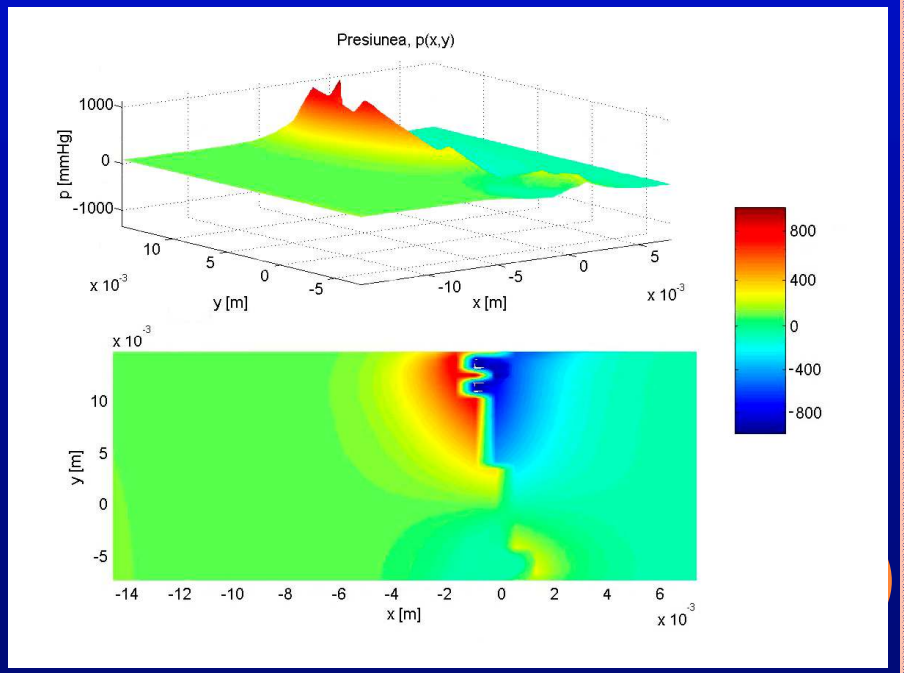
D. Rafiroiu, V. Díaz-Zuccarini, D. R. Hose, P. V. Lawford

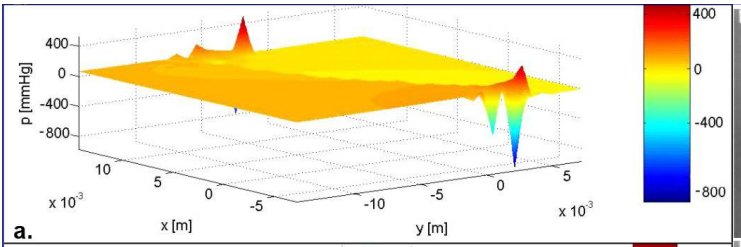
Rezultate simulare numerica
Cimpul presiunilor in imediata vecinatate a virfului valvei

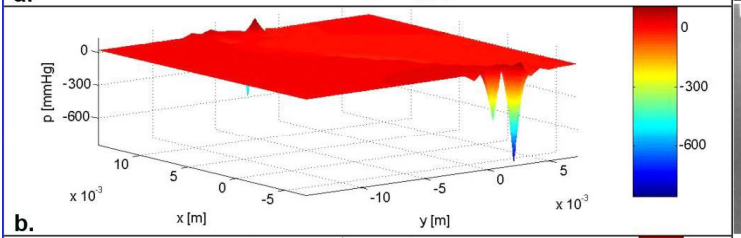


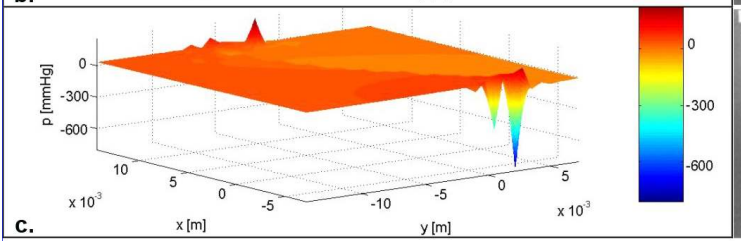
θ=14.2º (dupa impact)

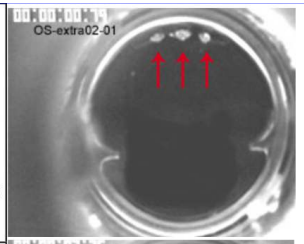
Inainte de impact θ=12.44º (experiment 2)

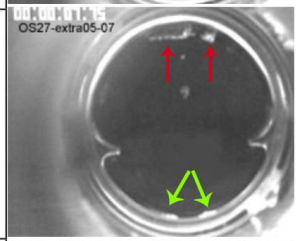


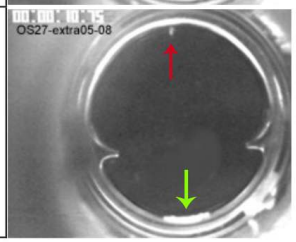

p [mmHg]
400
0
-400
-800
x 10^-3
10
5
0
-5
x [m]
-10
-5
0
5
y [m]
x 10^-3
a.


p [mmHg]
0
-300
-600
x 10^-3
10
5
0
-5
x [m]
-10
-5
0
5
y [m]
x 10^-3
b.

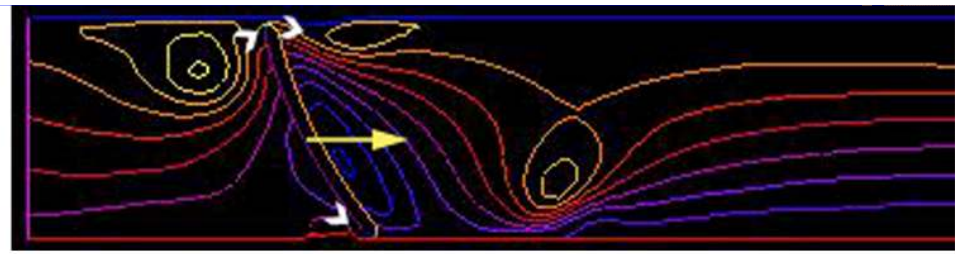

p [mmHg]
0
-300
-600
x 10^-3
10
5
0
-5
x [m]
-10
-5
0
5
y [m]
x 10^-3
c.

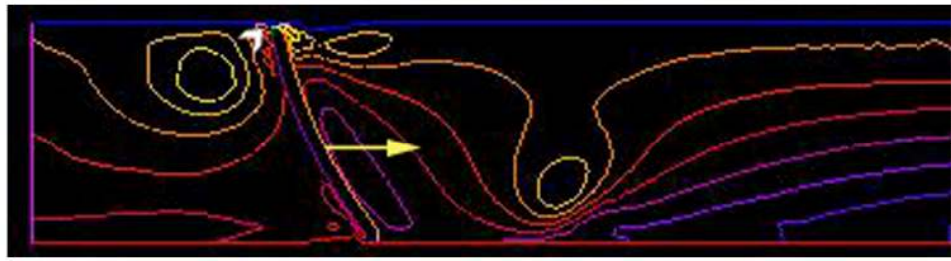

OS-extra02-01

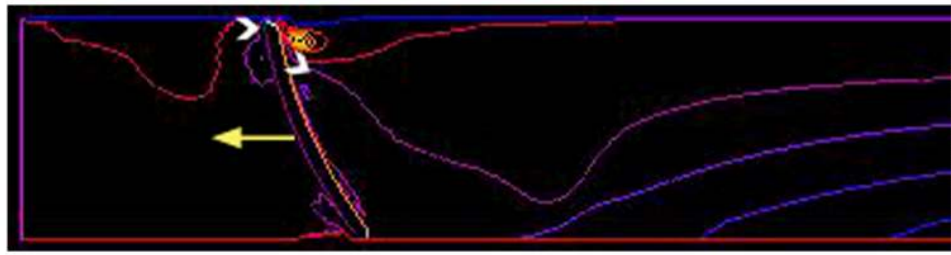

OS27-extra05-07


OS27-extra05-08

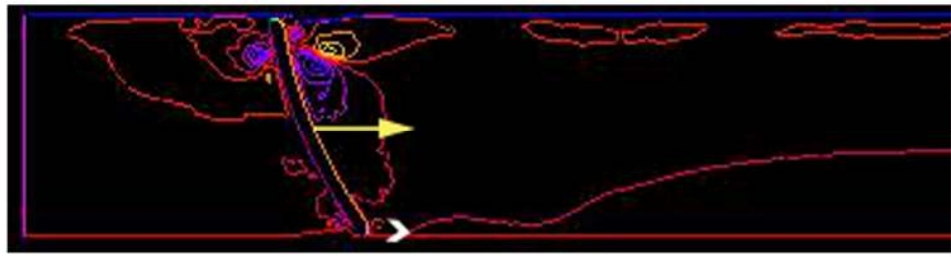
Dupa impact


a


b.

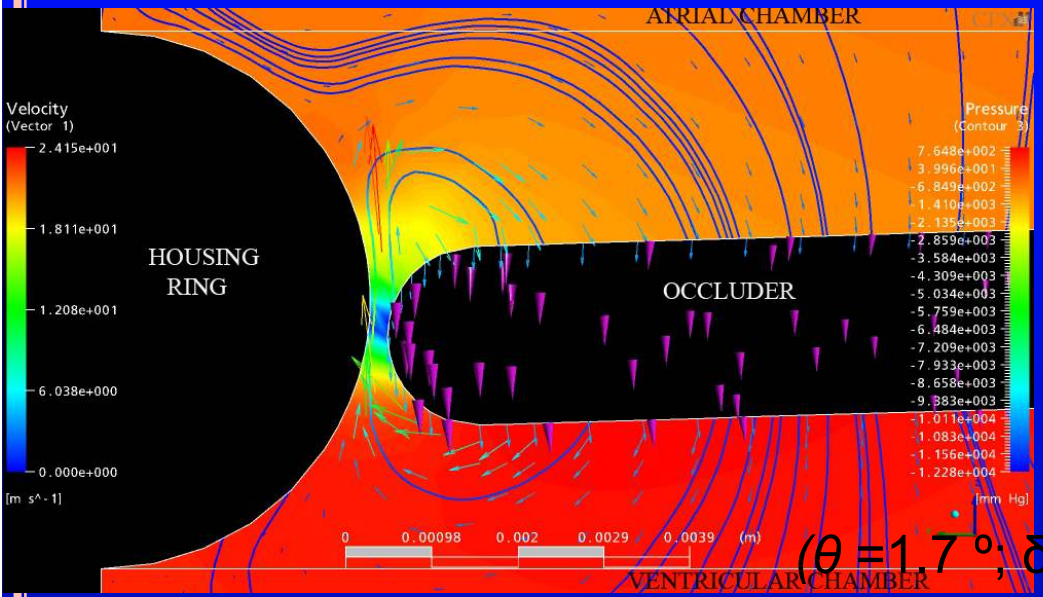

c.


d.

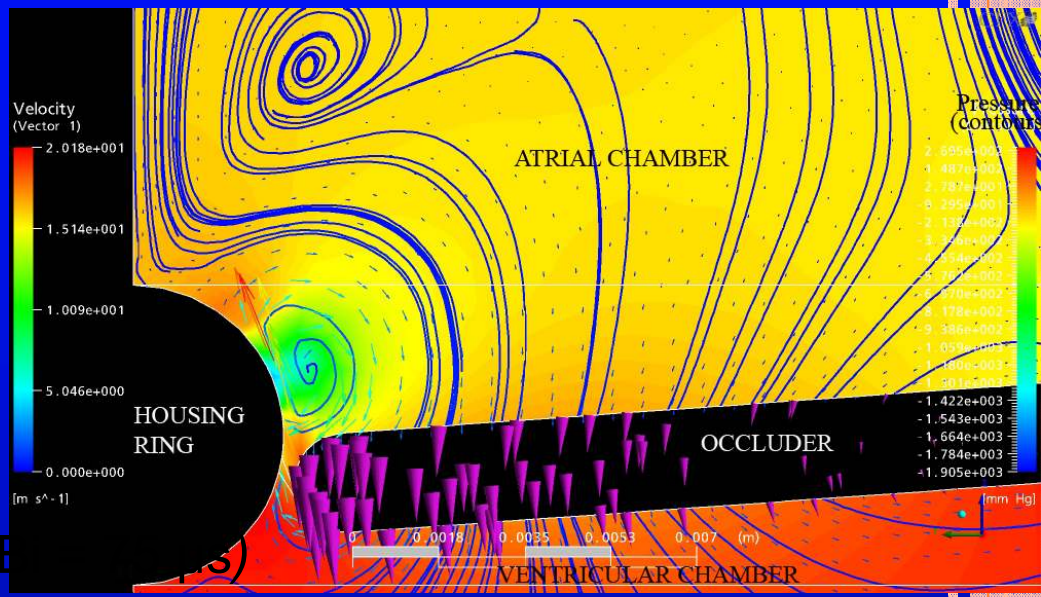

e.


f.

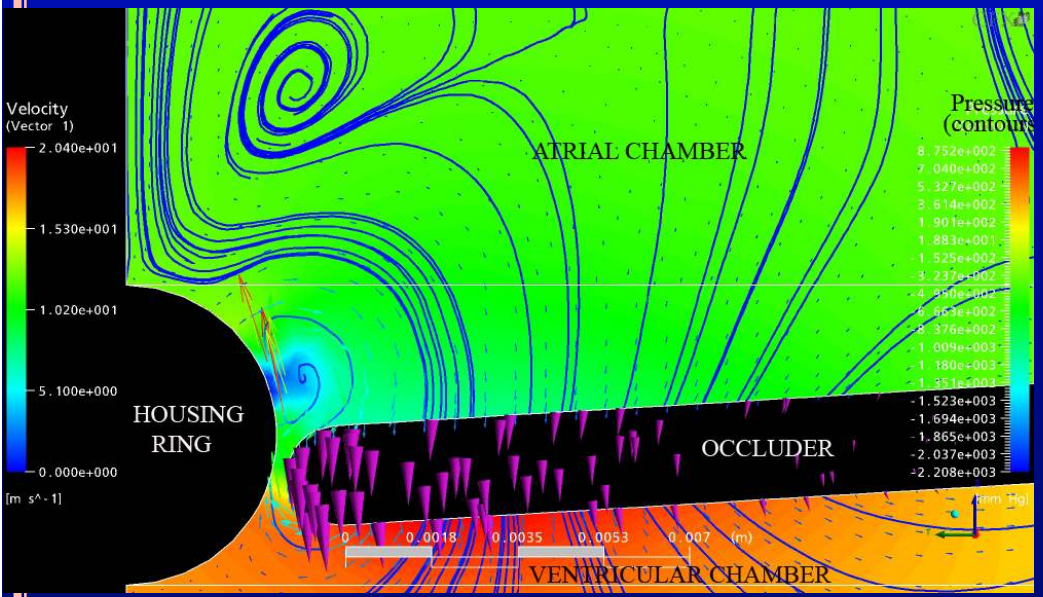
Rezultate simulare model 3 D cimpul vitezelor, presiunilor si liniile de curent



(θ =1.7 °; δtBi = 75 µs)

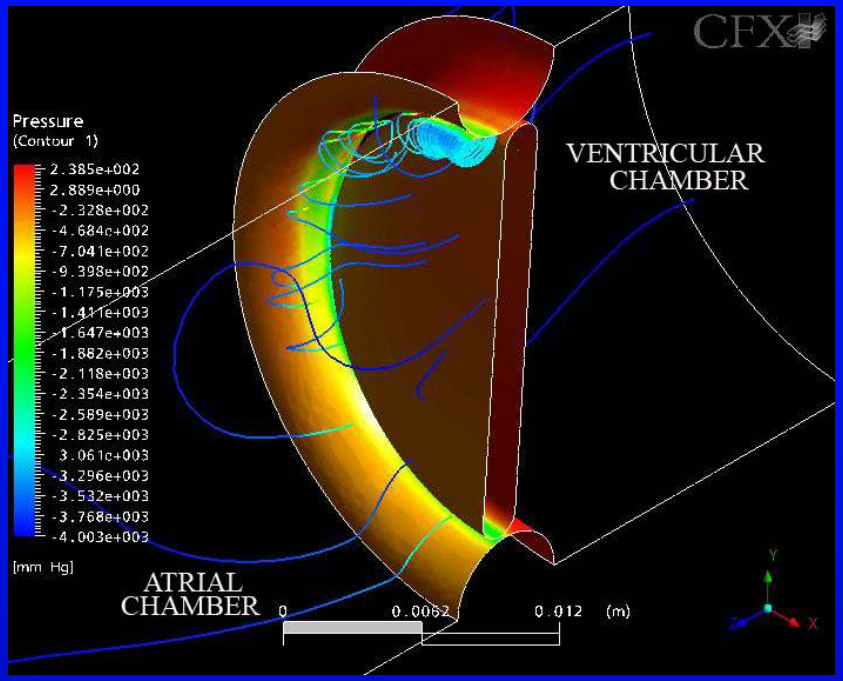


(θ =3.4 °; δtBi = 195 µs)

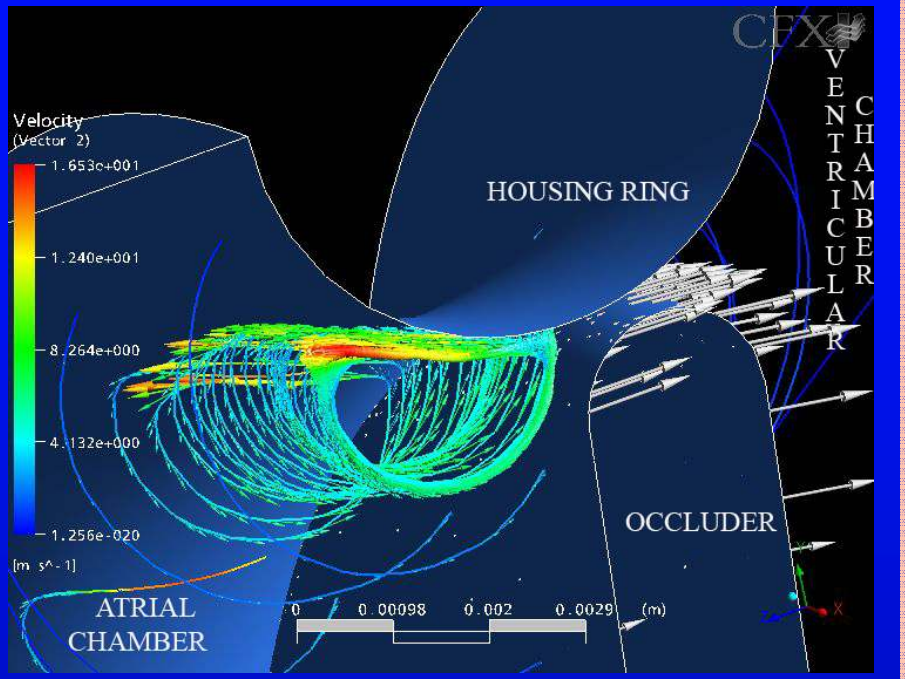


(θ =4°; δtBi = 255 µs)

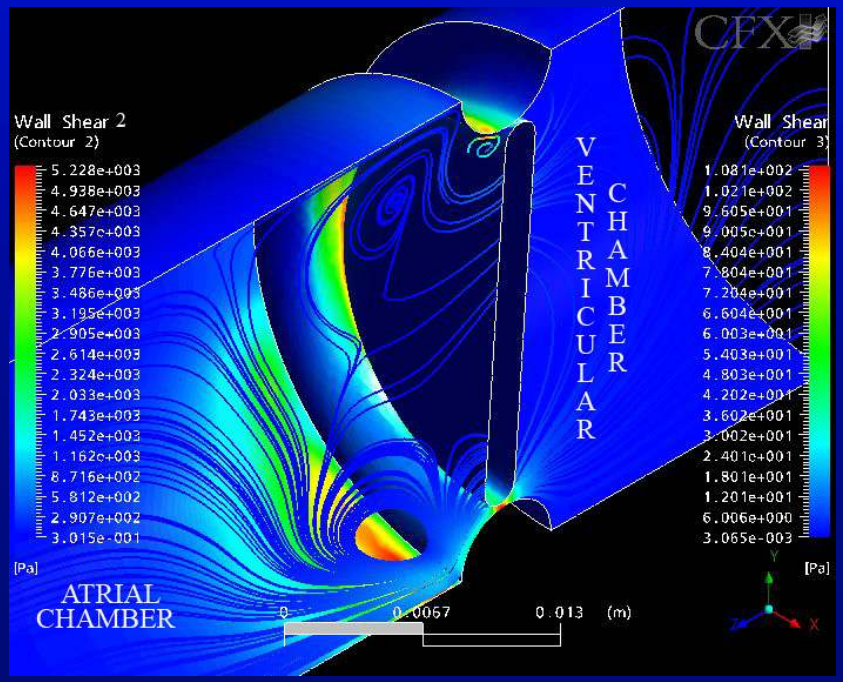
(θ =5.6°; δtBi = 505 µs)



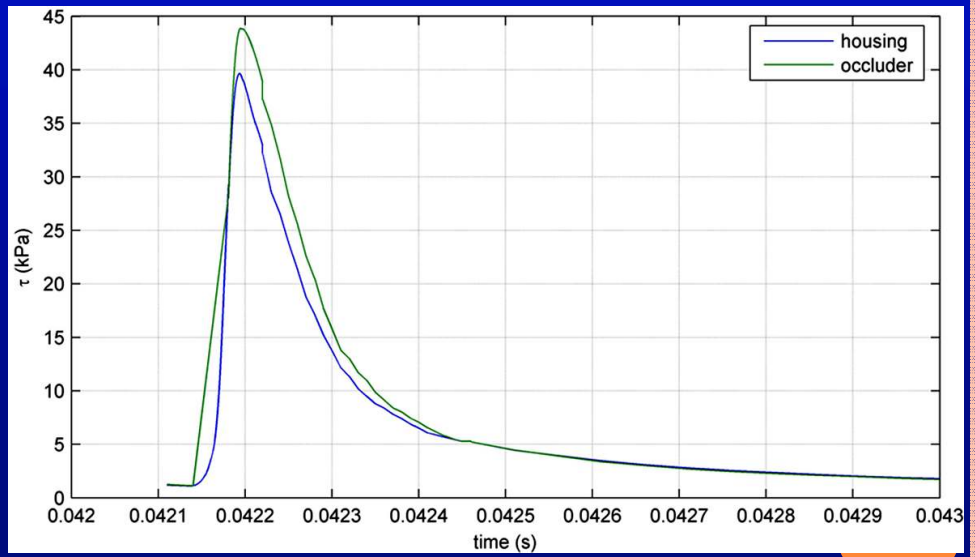
(θ =3.4º; δtBi = 195 µs)



(θ =3.4º; δtBi = 195 µs)



(θ =3.4º; δtBi = 195 µs)



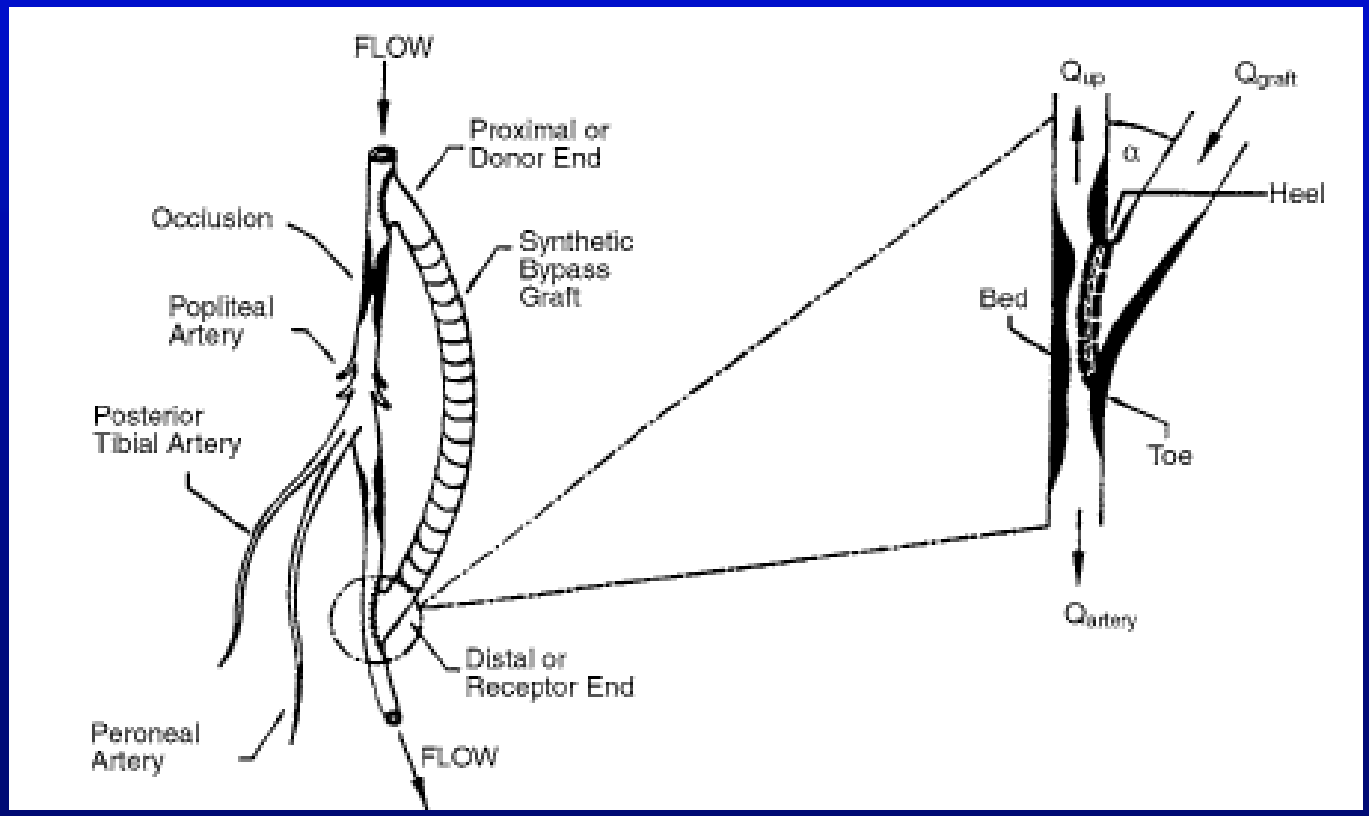
Directii viitoare de cercetare

- Integrarea investigatiilor experimentale cu cele numerice
  - Experimental:
    - evaluarea cimpurilor, vitezelor, si a vorticitatii, asociate inchiderii ambelor valve, utilizind PIV
    - pe baza acestor masuratori, se va incerca o analiza cantitativa a contributiei vartejurilor la aparitia cavitatiei
  - Numeric:
    - imbunatatirea modelului 3D existent, prin includerea geometriei reale a valvei MH, si ulterior a valvei OS
    - Luarea in considerare a miscarii compuse, rotatie + translatie de alunecare, a discului valvei MH

MAACH - Metode Avansate de Analiza si Control in Hemodinamica cu aplicatii in chirurgia vasculara periferica

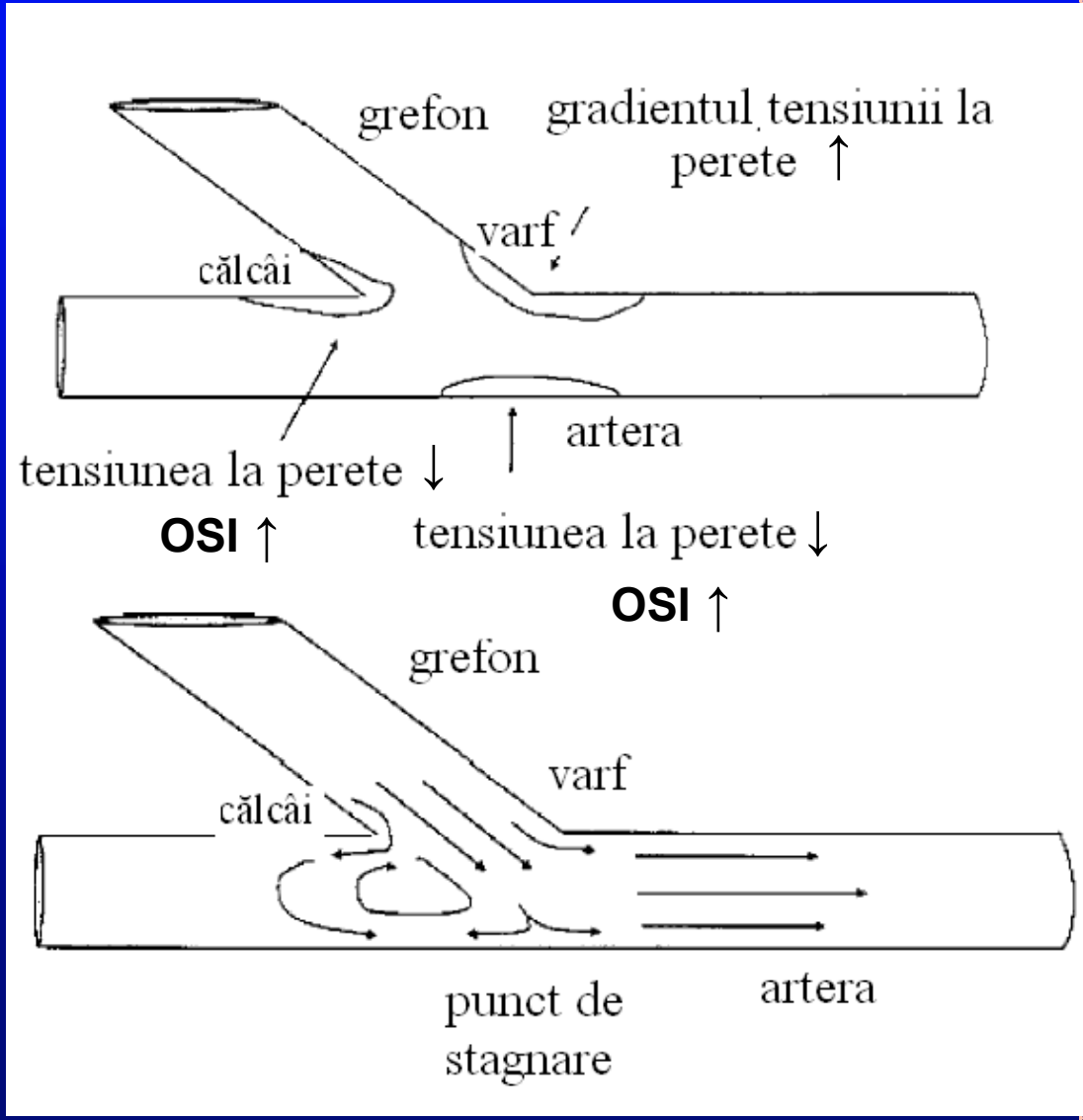
Scopul fundamental al proiectului:

diminuarea ratei de esec a operatiilor de reconstructie vasculara periferica prin identificarea unor solutii de control pasiv al curgerii in configuratii complexe de tip by-pass



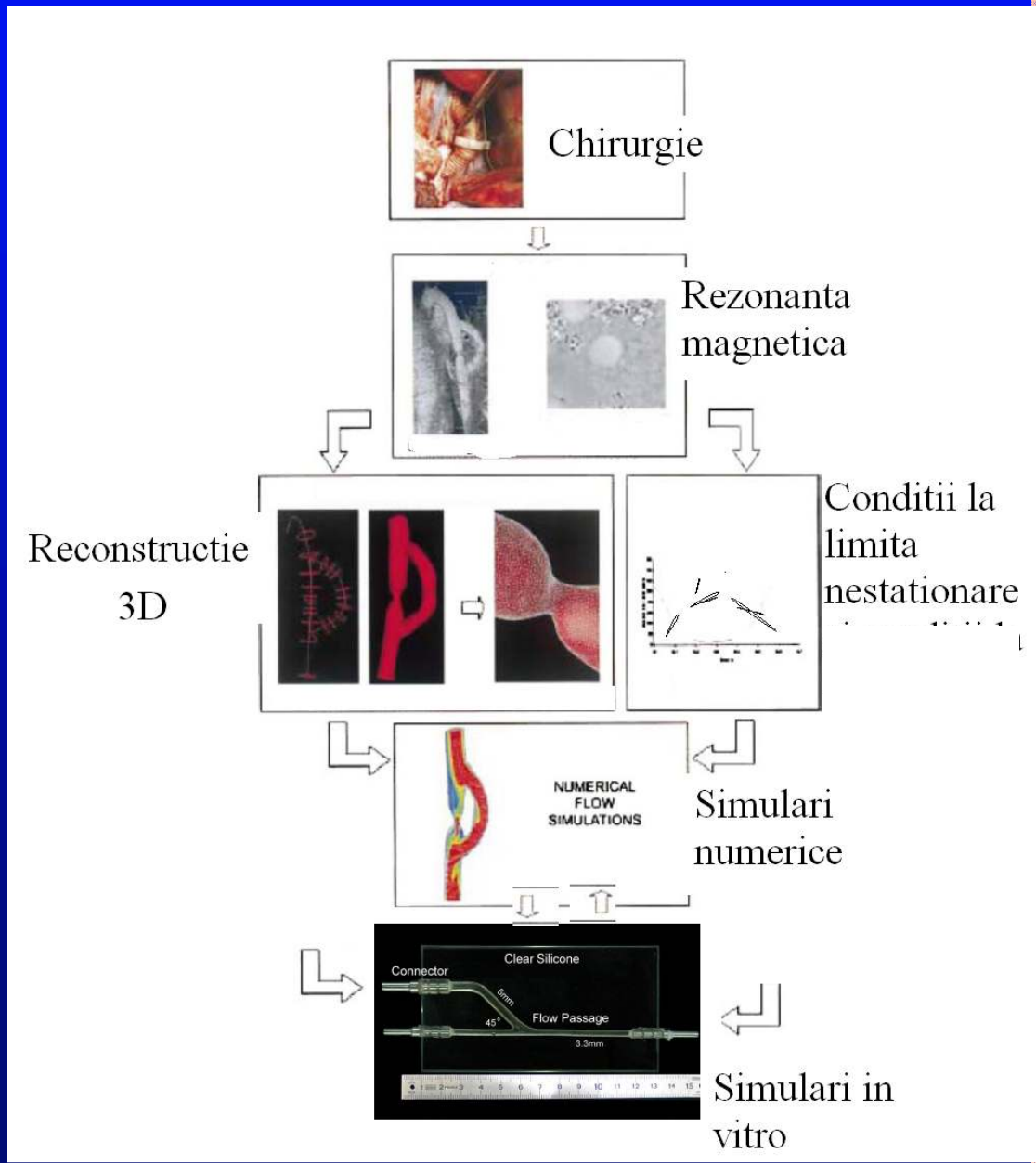
Cauza majora de esec: hiperplazia miointimala, declansata de traiecte modificate de curgere (“curgeri perturbate, nefiziologice”):

- **zone de recirculare si stagnare**
- **valori scazute ale tensiunilor de frecare la perete**
- **oscilatii temporale si valori ridicate ale gradientilor temporali si spatiali ai tensiunilor de forfecare**



Abordarea studiului by-passului de artera femurala

- investigatii clinice si paraclinice (EcoDoppler si angioCT/ RMN) → furnizare de date primare pentru simulari
- reconstructia 3D din informatii CT → modele virtuale 3D de vase de singe si by-pass → fabricare prototip fizic (RPT)
- simulare numerica a curgerilor pulsatorii prin stenoze si by-passuri
- investigare in vitro a curgerilor pulsatorii (PIV)
- monitorizare postoperatorie → validare in vivo a predictiilor modelelor numerice si experimentale



Rezultate asteptate

- Realizarea unui sistem integrat format din modele matematice ale curgerilor nestationare ale fluidelor ne-newtoniene in incinta cu pereti elastici, pachete de programe , pachete d e programe software, modele fizice si standuri experimentale .

VA MULTUMESC PENTRU ATENTIE!!