Fluid-Solid Interaction in the Aortic Heart Valve

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Introduction
More than 170.000 substitute heart valves are implanted worldwide each year. These substitutes show either hemodynamical or mechanical complications. Synthetic and tissue engineered prostheses could circumvent these complications. Development of improved prostheses is enhanced by FEM models as laborious experiments can be avoided [1].

Objective
Develop a fluid-solid interaction model. Apply model
☐ to optimize synthetic prototypes
☐ to design scaffolds for tissue engineered valves

Methods
Fluid-solid interaction is described by a Lagrange multiplier based Fictitious Domain (FD) method [2]:

☐ Eulerian fluid/ Lagrangian solid description
☐ fully coupled approach
☐ interaction at interface $\Gamma$ (Fig. 2) through:

$$\int_{\Gamma} \lambda \cdot (\vec{u}_s - \vec{u}_f) \, d\Gamma$$

Results

2-D FD validation
Experimental validation (Fig. 3) is done on a two-dimensional representation of the aortic valve using:

☐ Laser-Doppler anemometry
☐ digitized high speed video recordings

Fig. 3 Leaflet motion: – exp., – model; axial velocity: – exp., – model. Applied flow pulse is given on the right.

3-D FD/ ALE
A three-leaflet valve with compliant aortic root is analyzed for flow characteristics $Re = 1000$ and $Sr = 0.06$. Solid motion and fluid flow are shown in Fig. 4.

Discussion
The FD/ ALE method has proven to give satisfactory results. The method in general is applicable as:

☐ numerical design tool for prostheses
☐ analysis tool for blood-tissue interaction
☐ diagnostic tool for clinical purposes

References: