

Please send this report to the Secretary of the European Mechanics Council, Professor Bengt Lundberg, Dept of Mechanical Engineering, Luleå University of Technology, S-951 87 Luleå, Sweden, one month after the Colloquium

General

EuroMech Colloquium No: 286

Title: Three-dimensional blood flow in bifurcations

Chairmen: A.A. van Steenhoven, Eindhoven University of Technology

Place and country: Kerkrade, The Netherlands

Dates: October 20-23, 1991

Finance

The conference fee Dfl 200,- included food and lodging expenses

Funding: Netherlands Heart Foundation, Pie Medical, Royal Netherlands Academy of Sciences and Arts.

Accommodation (type and cost): Rolduc Abbey: lodging and meals Dfl 100,-/person, day

Meals: Rolduc Abbey and Castle Vaalsbroek

Participation

Total number of participants: 50

Distribution of participants by country:

Code	Country	Number	Code	Country	Number
A	Austria	<u>1</u>	I	Italy	<u>2</u>
B	Belgium	<u>4</u>	IRL	Ireland	<u>-</u>
BG	Bulgaria	<u>-</u>	N	Norway	<u>-</u>
CH	Switzerland	<u>1</u>	NL	Netherlands	<u>14</u>
CS	Czechoslovakia	<u>-</u>	P	Portugal	<u>-</u>
D	Germany	<u>6</u>	PL	Poland	<u>-</u>
DK	Denmark	<u>-</u>	R	Rumania	<u>-</u>
E	Spain	<u>-</u>	S	Sweden	<u>1</u>
F	France	<u>7</u>	SF	Finland	<u>-</u>
GB	Great Britain	<u>6</u>	YU	Yugoslavia	<u>-</u>
GR	Greece	<u>1</u>	SU	Soviet Union	<u>-</u>
H	Hungary	<u>-</u>	-	Others	<u>7</u>

Is there need of another colloquium on the same subject? Which year? 1993: Blood-wall interaction

Scientific Report

Scope

The analysis of blood flow in bifurcations is a major research topic in Europe. Due to the highly complicated geometry, the unsteadiness of the flow, the deformability of the vessel wall and the non-Newtonian behaviour of blood the subject is a challenge for the technical disciplines. The meeting focused on three-dimensional (3D) flow analyses. The reasons for that are:

- the computational methods and the experimental tools are so advanced now that unsteady 3D flow analyses in complex arterial bifurcations have become common practice;
- the software and hardware in detection apparatus (like ultrasound and MRI) is so improved that non-invasive real-time 3D blood flow analyses can be performed clinically in the near future;
- exchange of ideas and cooperation between the various research groups may enhance the development process of detection equipment and may shed light on the fluid mechanical contribution to atherogenesis.

To that end the program consisted of three sessions:

- **Monday October 21:** The flow field in rigid models of arterial bifurcations. Among others attention was paid to the applicability of flow visualisation techniques (PIV) and detailed results were presented regarding the flow field in various (8) arterial bifurcations as determined by Laser-Doppler anemometry and numerical methods (mainly Finite Element methods).
- **Tuesday October 22:** The influence of wall flexibility and geometrical factors (like stenoses) on the flow field. Among others attention was paid to the properties of the vessel wall, wave propagation phenomena, their influence on the velocity distribution in the branches of the bifurcation and the methods to be used when small stenoses have to be incorporated.
- **Wednesday October 23:** The development of non-invasive measurement methods. Among others attention was paid to the applicability of the ultrasound and MRI-methods to the measurement of blood flow velocity profiles and wall shear rates, and to the flow patterns as detected at various sites in the arterial circulation of men.

The main conclusions of the meeting are:

1. A similar flow behaviour is found in various bifurcations comprising flow separation, secondary flow and skewing of axial velocity profiles. Differences observed are due to different geometries and Reynolds numbers. In all cases laminar flow is observed and it is demonstrated that unsteady flow in a bifurcation completely differs from steady flow.
2. Yet, the influences of wall distensibility, non-Newtonian effects and stenoses are not completely clear. For wave propagation analyses the bifurcation may be regarded as compact. The main effect of wall motion

on the flow field is a reduction of the area of flow reversal. Non-Newtonian effects may induce a different position of this area. For the analysis of the influence of minor stenoses on the flow field spectral element methods and PIV-methods may be favourable as detailed analyses have to be performed of eddy generation.

3. Atherosclerotic plaque formation is found at positions where low wall shear rates occur. Here focal regions of elevated permeability to macromolecules, temporary gaps and a thin endothelial glycocalyx are found. Modelling of the arterial wall is worthwhile, focussing on maximal stress concentration in the intima and the mass transport of atherogenic proteins between plasma and vessel wall.
4. Discussion is needed on the relative merits of a "representative" geometry versus an "individual" geometry. Now the overall flow picture is clear, research has to be focussed on the influence of biological variabilities (bifurcation angle and divider geometry) and on local flow phenomena behind stenoses. A detailed analysis of particle trajectories in bifurcating flows by experimental and numerical flow visualisation techniques is expected to be helpful.
5. Detection methods based on ultrasound and MRI are capable to detect the overall flow picture. For the detection of flow disturbances due to small stenoses, system improvements with regard to accuracy and resolution are necessary.

A general feeling among the contributors of this meeting was that the next Euromech Colloquium in this Biofluid Mechanics Series has to be devoted to the local phenomena close to and in the wall; then probably an improvement can be reached with regard to the understanding of the fluid mechanical contribution to the process of atherogenesis, if any. Prof. Affeld (Berlin) was asked and is willing to prepare a proposal for such a meeting (provisional entitled Blood-Wall Interaction) and the date proposed is 1993.


28/11/91