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UNION OF ENGINEERS AND TECHNICIANS OF SERBIA

BACKGROUND

The roots of Serbian technical civilization date as early as the time of the Nemanjics. Beginnings of engineering activities were associated to the mining and metallurgical undertakings (Novo Brdo) and to building of magnificent medieval sacral structures of the Serbian state.

After the First (1804) and second Serbian Uprising (1815) the technical tradition was renewed and Serbian joined the then current European trends. First educated engineers came in Serbia from Austro-Hungarian Empire in 1830s. At that time, the main preoccupations of engineers were railway construction, town planning, construction of sewage disposal and water supply systems, as well as creating of national defense system. At that time 1834/35 from Austrian Empire arrived first schooled engineers France Janke and Franz Baron Kordon who served as so called “drzavni indzilirin” or state engineers.

In Serbia in the 19th century there were a total number of about 6000 engineers engaged in various activities. In an eighty–year period from 1834-1914 the State Construction Administration (which from 1880 also included railways) employed one third of these engineers. However other ministries were also competent for some engineering affaires like, for example the Ministry of Finance was responsible for mining, or the Ministry of Education and Church Affaires was responsible for education of technical stuff. From 1838 this primarily referred to the Licej: according to “Establishment of public institutions of learning” of 1844, the Department for Philosophy included also subjects such as Pure and Practical Geometry and Higher Mathematics, and Architecture, while in 1853 a separate Natural Sciences and Technical Department was introduced in the Licej and in 1863 the Great School with Technical Faculty started operating. The first classes held at the Technical Faculty of the Great School in 1863 marked turning point in schooling of Serbian engineers.

Out of some 600 engineers, approximately one third were schooled in Serbia and one fifth of them studied abroad as “state grants students”, while about one fourth were foreigners and Serbs from “across the Danube”.

In 1868 one of preconditions which might have contributed to professional associating of engineers was the numerosity of professionals and models from abroad established half a century earlier (engineering associations in Great Britain, Germany and America) had influence on establishing professional associations in Serbia.

The Founding Assembly of the Technicians` Society was held on the 3rd February 1868 in the premises of Great School. Engineer Emilijan Josimovic was elected for the first President of the Society. It is important to mention that this happened only a year after Turkish commander in Belgrade Ali -Riza pasha gave the town and the fortress keys to duke Mihailo Obrenovic. Shortly afterward in 1869 was established Society for Agrarian Economy that is the Serbian Agricultural Society. Association of Serbian Engineers was established in 1890 while in 1896 was established the Association of Serbian Engineers and Architects.

The first scientific magazine published by this Association in 1890 was “Srpski tehnicki list” The “Srpski tehnicki list” besides professional articles also published detailed information related to the work of the Association. The members at that time, who numbered around one hundred of them, initiated a whole series of issues and demand the same to be solved by the competent bodies. During the First World War, two volumes of “Srpski tehnicki list” were published in Thessaloniki. The magazine was initiated by the engineers and architects who were in Thessloniki as members of the Serbian Army. In Thessaloniki was held the General Assembly of the Association in 1918 attended by 463 engineers.

During his short stay in Belgrade, in 1892, famous scientist Nikola Tesla was elected for the first honorary member of the Association of Serbian Engineers.

Providing assets from its own incomes, bank loans, gifts and donations of its organizations-members and its individual members Association built the House of Engineers in Belgrade, Kneza Milosa 7 str in 1932/35. The House of Engineers “Nikola Tesla” in Belgrade Kneza Milosa 9-11 str was built between 1962 and 1969. In the premises of these two Houses of Engineers besides the Union of Engineers and Technicians of Serbia today perform their activities 26 republic`s professional and multidisciplinary engineering-technicians` associations out of 41 collective members of UETS.

Besides **Emilijan Josimovic** who was first President of the Technicians` Society, prominent figure of that time, Rector of Licej and Great School and honorary member of the Serbian Royal Academy, to work of our Union contributed as well: **Kosta Alkovic**, professor at the Great School, Minister of Construction and member of Serbian Learned Society and Serbian Royal Academy, **Dimitrije Stojanovic** professor at the Technical Faculty, first Director of Serbian State Railways, and member of Serbian Learned Society and Serbian Royal Academy, **Milos Savcic**, Minister of Construction and President of Belgrade Municipality, famous businessman who gave the greatest donation for the construction of House of Engineers in 1932, as well as presidents of the Serbian Academy of Sciences and Arts **Josif Pancic, Jovan Zujovic, Simo Lozanic, Kirilo Savic, Aleksandar Despic, Nikola Hajdin** and other famous scientists.

ACTIVITIES

The Union of Engineers and Technicians of Serbia - Savez inženjera i tehnicara Srbije is a voluntary, non-governmental, non-profit, scientific, interest, professional, non-party organization of engineers and technicians, and their organizations in the Republic of Serbia, open for cooperation with other scientific, commercial and other organizations, on the basis of mutual recognition, mutual respect and independence in work.

Union of Engineers and Technicians of Serbia and its collective member finance their own activities from their own assets.

Purposes and tasks of UETS are:

- Assembling and organizing of engineers and technicians of Serbia for the purpose of increase of their expert knowledge, providing appropriate status in the community, on the basis of their contribution to the, scientific-technological and economic and development in general of Republic of Serbia;
- Joining, strengthening and massification of basic engineering-technicians' organizations of Serbia, development of mutual cooperation as well as the cooperation with appropriate international organizations of engineers and technicians;
- Improvement of order-interest, reputation and protection of members of the engineering-technicians' organization of Serbia;
- Providing help to engineers and technicians in scientific, expert improvement and organization of appropriate forms of permanent education;
- Monitoring contemporary development of engineering and technology and pointing out the currents of events and changes in this area and providing opinions on optimality of engineering and technological solutions in investment and other enterprises;
- Caring for and development of ethics of engineering-technician profession, human rights and liberties;
- Stimulating, organization and publishing of scientific and expert papers, magazines and other publications of interest for engineering-technician organization and technical intelligence;
- Work on technical regulations (laws, regulations and standards), providing its modernity, adequacy, actuality and functionality;
- Consideration and providing expert opinions on plans, programs, analysis and other acts, which are important for the development of engineering, technology and production in the Republic of Serbia;
- Stimulating and helping the activities and initiatives, aiming to preserve the human environment and area organization, saving and rationalization of spending of all sorts of energy;
- Preparation and maintenance of the meetings with purpose of permanent education of engineers and technicians;
- Providing help in development of technology and economy whose purposes are similar to the purposes of engineering-technicians` organization;
- Organization of multidisciplinary meetings and meetings of wider social importance;
- Cooperation with appropriate expert, commercial organizations and other organizations and organs at the realization of tasks of mutual interest;

- Management of Houses of Engineers and other property of Union of Engineers and Technicians of Serbia.

Union of Engineers and Technicians of Serbia has developed cooperation with organs of local government, state ministries, Serbian Academy of Sciences and Arts, Serbian, Chamber of Engineers, Engineering Academy of Serbia, Chamber of Commerce and Industry of Serbia, with numerous companies, professional associations, faculties and universities and other institutions. UETS also has developer international cooperation.

In accordance with the Law and Contract with republic ministries in the framework of UETS are organized and performed specialist` exams for several engineering branches.

Union of Engineers and Technicians of Serbia has several thousand individual members and 41 collective members in the Republic of Serbia: 19 republic`s professional associations (associations of architects, town planners, mechanical engineers, electrical engineers, mining and geological engineers, surveyors, agricultural engineers, chemical engineers etc) 7 republic`s multidisciplinary engineering-technicians` associations (ecology, standardization and quality, material protection and corrosion, informatics etc) 1 provincial engineering-technicians` association, 14 municipal and regional engineering-technicians` associations.

Union of Engineers and Technicians of Serbia is founder of the Engineering Academy of Serbia, and collective member of the Chamber of Commerce and Industry of Serbia.

Union of Engineers and Technicians of Serbia, in a cooperation with faculties, universities, enterprises, economic and professional associations organizes various scientific meetings, professional reunions, congresses, seminars, conferences. UETS members publish their expert magazines; “KGH”; “Procesna tehnika”, “Ecologica”, “Tekstilna industrija”, “Forum”, “Sumarska industrija”, “Zastita materijala” and maintain professional reunions, seminars, conferences and congresses in branches of architecture, mechanical engineering, chemistry, electrical engineering, agriculture, forestry etc.

All activities of the Union are performed in accordance with the procedures and standards of **QMS - Quality Management System**.

Union of Engineers and Technicians of Serbia is National member of **FEANI – European Federation of National Engineering Associations** from Serbia. FEANI is a federation of professional engineers that unites national engineering associations from 32 European countries. Thus, FEANI represents the interests of over 3,5 million professional engineers in Europe. FEANI is striving for a single voice for the engineering profession in Europe and wants to affirm and develop the professional identity of engineers. Through its activities and services, especially with the attribution of the EUR ING professional title, FEANI aims to facilitate the mutual recognition of engineering qualifications in Europe and to strengthen the position, role and responsibility of engineers in society.

Union of Engineers and Technicians of Serbia is member of COPISSE – Permanent Conference of the Engineers of Southeast Europe.

Collective members of UETS are members of international professional associations and have developed international cooperation.

With all that has been done and with accomplished results, objectively solid conditions have been provided for further and more successful work, business operation and development of the Union of Engineers and Technicians of Serbia.

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Fluid Structure Interaction on the Example of Real Artery Bifurcation of Random Selected Patient

MILAN BLAGOJEVIĆ, University of Kragujevac,
Faculty of Engineering, Kragujevac
ALEKSANDAR NIKOLIĆ, University of Kragujevac,
Faculty of Engineering, Kragujevac
MIROSLAV ŽIVKOVIĆ, University of Kragujevac,
Faculty of Engineering, Kragujevac
SLOBODAN SAVIĆ, University of Kragujevac,
Faculty of Engineering, Kragujevac

Original scientific paper
UDC: 616.154:532.54

This paper presents the procedures and tools developed for simulating the fluid and structure interaction on the example of a patient-specific carotid artery bifurcation. Volumetric model of the carotid artery bifurcation is obtained through the processing of images from CT scanner. Finite-element model, generated using multiblock approach, accurately reflect the arbitrarily shaped domain. Presented numerical results show that developed methodology is very flexible and efficient for the applied research in biomedical engineering. Thanks to the detailed image about the phenomenon that occurs when blood flows through the carotid artery bifurcation, cardiologists make a decision on the necessity of intervention.

Key words: *fluid-structure interaction, blood flow,FEM, wall shear stress, artery bifurcation*

1. INTRODUCTION

Fluid-structure interaction problems are too complex to be solved analytically [1, 2]. Therefore, these problems are analyzed experimentally and by numerical simulations [3, 4]. Over the years, mathematical modeling, such as the finite element method (FEM), has become a complementary to experimental approaches in the study of clinical problems, as well as predicting the biomechanical behavior [5-7]. The finite element method allows the reiteration of numerical experiments by changing certain parameters. In this way researchers are able to analyze the impact of specific variables on the observed phenomenon [3].

The finite element method requires the existence of the physical domain in which the problem is observed and discretization of the domain. Accurate capturing of the geometry of the blood vessel does not guarantee accurate modeling. The generation of high-quality mesh of eight-noded 3D finite elements for complex structures is still a significant problem [8]. The existing methods are also very slow. It is well known that the quality of the mesh plays a significant role in the simulation using the finite element method [9]. The accuracy of the numerical solution depends on the type of finite elements used in modeling of the physical domain. Numerical errors are dependent on the quality of the mesh, which is especially important in computational fluid dynamics, where the numerical errors become visible in the resulting solution.

Research in computational fluid dynamics and solid mechanics are still in focus of many scientists and research institutions. The computational fluid dynamics is used in biomedicine in order to achieve better understanding of how fluid flows in arteries and veins. Blood flow is governed by the Navier-Stokes eq-

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Author's address: Milan Blagojević, University of Kragujevac, Faculty of Engineering, Kragujevac, Sestre Janić 6

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uations and the continuity equation. Computational solid mechanics is used to calculate the corresponding stress and strain of arterial walls, using specially developed material models [10].

Numerical simulation of interaction between solids and fluids belongs to the group of coupled multiphysics problems, which in this decade has been the subject of intense research and development of simulation codes [10]. Starting from models that describe each domain individually, defined system of equations is describing the coupled behavior of these two domains [10-12]. During the calculation of coupled problems fields of pressure, velocity and shear stress on the arterial wall are determined for fluid domain, while the stresses and displacements at the nodes are determined for solid domain.

This paper presents a methodology developed for the rapid modeling of the blood and blood vessels interaction on the example of the complex geometry of real arterial bifurcation.

2. PAK-FS – COMPUTER CODE FOR SIMULATION OF FLUID STRUCTURE INTERACTION

Two basic approaches for numerical solution of the fluid-structure interaction are strong coupling and weak coupling [10, 12]. The basic idea of the strong coupling is to solve complete system of equations in one step. In this way, all variables, related to solid and fluid, are determined simultaneously. This methodology becomes enormously expensive to solve 3D problems, which dramatically increases system of equations to be solved. In order to solve the coupled problems using this methodology, it is necessary to make a specific solver for solving solids and fluids. An alternative method to strong coupling is the weak coupling, which has a number of advantages. The main advantage is the use of an already existing program to solve solids and fluids with very small modification. Calculating the unknown values for the solid and fluid are independent, in separate programs, where the variables at the interface are exchanged at each time step.

For the numerical simulation of the fluid-structure interaction problem software PAK-FS [13] is used, developed by coupling existing software for computational fluid dynamics PAK-F and software for computational solid dynamics PAK-S, using the weak coupling. The calculation results are written to the file FEMAP Neutral, IDEAS UNV and the VTK. The global algorithm of developed code is shown in Figure 1.

Fluid and structure occupies different subdomains, and the corresponding system of equations is set independently for each subdomain, providing that the subdomains discretizations are compatible on the interface.

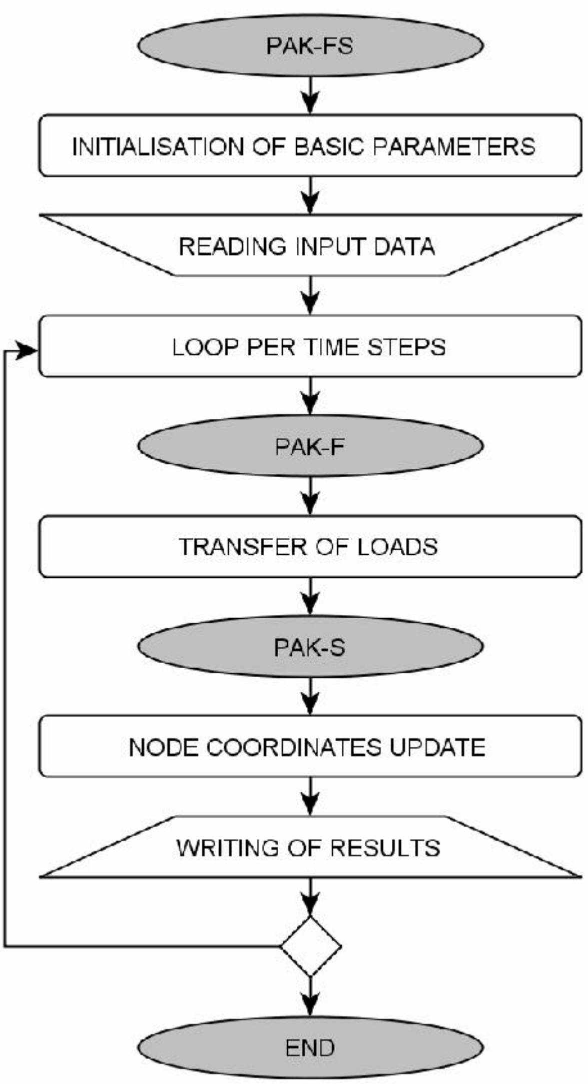


Figure 1 - The global algorithm of PAK-FS

Program for Computational Fluid Dynamics (CFD) as a boundary conditions uses the current geometry (surface) and the velocities of the nodes corresponding to these surfaces. This information was obtained by computational solid dynamics program that solves problems in the domain of solids (arterial wall). On the other hand, the load of the domain of the fluid is transferred into a solid domain.

3. METHODOLOGY FOR RAPID FINITE ELEMENT MODEL GENERATION OF ARTERIAL BIFURCATION

Bifurcation sites of human arteries are among the most frequent locations affected by atherosclerosis, being involved in up to 20% of percutaneous interventions. Several studies on the distribution of plaque in the cardiovascular system have shown that atherosclerosis occurs mainly on the branches of the vascular tree, where the arteries have relatively complex geometry [14-16]. The complex geometry conditions affect the flow, which is unique for each individual patient [14]. Most flow simulations reported in literature were conducted over the so-called average or idealized geometries. The solutions thus obtained may significantly deviate from the solutions to obtain some accurate modeling of blood vessels [17]. Nowadays, the trend and the need are to generate models that accurately describe the actual geometry of arterial bifurcations due to improvements made in the fields of equipment for radiological diagnostics and computer performance [18-19].

Contribution of authors to improve the methodology of generating high-quality finite element mesh is described in detail in this section. To speed up the process of generating models, software STL2BLOCK is developed. Based on volumetric models obtained by radiological imaging it generates a topology of the blocks for generating finite elements by multiblock method. The first step in generating a finite element mesh is the determination of the geometry of the wall of carotid artery. It is now possible to do this in many ways, such as computed tomography (CT), magnetic resonance imaging (MRI)... The original CT images, which contain information about the tissues in the vicinity of the branch of the carotid artery using DICOM format are loaded into the software MIMICS. In this software, for each of the images, based on adjustable thresholds contrasts, regions representing different tissues and organs of the observed image are identified. By merging the boundaries of these regions, along with the information about the spatial position of each image, and then by polygonization of models, the 3D model of all organs whose contrast corresponding to the selected range is generated. Figure 2 shows the volumetric models of tissue, mainly the bone and blood vessels, which are obtained by treating the images generated by computer tomography (CT scanner).

From this set we should exclude all but blood flow organs (Figure 3). Imperfections of software for the volumetric model reconstruction cause that this model include plaque built of calcium, creating the illusion that the flow cross-section is increased. The reason for this is that calcium has the same contrast ratio as the blood, and the software does not distinguish these two materials. These places need to be fixed by deleting the local irregularities in poligonized mesh and reconstructing the resulting discontinuities. If necessary, decimation of model can be performed to the level of the retention of the necessary quality of details, which affects the performance of the next steps in the FEM model generation process. Finite elements mesh generation starts from the point that the exact geometry of the models is contained in the STL file, the interface to the next stage in the model's creation.

Figure 2 – Volumetric model of tissue (blood and bones) generated by processing of CT images

Structured mesh is most appropriate method for domain discretisation. Method is founded on direct mapping from physical to computational model (Figure 4a). Points at domain border are used for interpolation of points inside computational domain. Structured mesh provide finite element mesh that accurately describe the boundaries of the domain, so the boundary conditions are accurately and correctly set for the given domain. The application of structural mesh is limited to domain with simple geometry. Modeling of complex domains is difficult or impossible to the procedure described above.

Instead, the authors propose a composite or multiblock approach in which the computational domain is divided into a finite number of smaller domains called blocks [20-21]. The entire mesh is formed by connecting these blocks. Each block in the physical domain is mapped to a poligon block in the data domain (Figure 4b). Structural mesh techniques are now applied to the individual blocks, which can then be joined together by building a complex mesh that accurately describe the complex geometry of diseased and/or normal blood vessels.

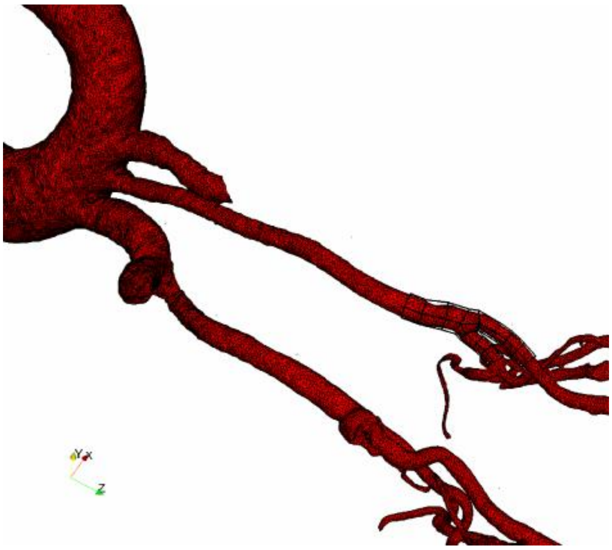


Figure 3 – Volumetric model of carotid arteries tissue

Blocks are represented using hexahedron, defined by vertices and edges. Local nodes labeling of blocks is shown in Figure 4a. The distribution of points within a block is determined by solving a set of three Poisson equations, one for each local direction of the block.

The software Geomagic Studio is used for setting the planes that define sections in which the vertices of blocks will be placed. Planes are placed so that they are aligned perpendicularly to the centerline of the blood vessel in the chosen field. The three planes are required to define a set of observed domain boundaries. Other planes are placed in areas where there is a change of direction, or bending of the vessel. The software reads the data on the cross sections from the file, and then specifies the center of gravity for section. To determine the center of gravity for section it is necessary first to set up a central intersection point whose coordinates are the average of the coordinates of all points of intersection. Further procedure is reduced to the determination of center of gravity for complex surface, consisting of triangles with vertices at the center point and the intersection point along the line of intersection. For each cross-section is determined the maximum dimension of intersection and normal vector to the intersection.

External vertices of blocks are placed so that they are aligned in cross section and are in the middle of the maximum dimension of intersection of the center of gravity of section in the directions of the local coordinate axes x1 and y1 (Figure 4b). Internal vertices of blocks are placed by the same criteria as outside, except that half of the maximum dimensions section is multiplied by a user-defined positive factor of proportionality. This factor is in the interval [0, 1] and is defined in a configuration file. Vertices of the blocks are numbered with 1-8, where number 1 carries the lower left vertices on the inside, and the number 5 carries lower left vertices on the outer ring. The vertex following the numbering of the sections has a larger to 8 in relation to the vertex of which precede them.

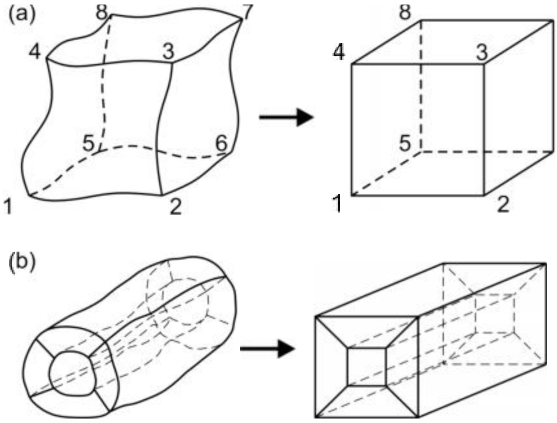


Figure 4 - Block – Basic tool in miltiblock concept of finite element mesh generation

Different topologies of blocks can be applied to the vertices set. The blocks are labeled in such a way that the central block is a 1, the blocks 2, 3, 4 and 5 below, to the right, above and to the left of the central unit, respectively. This layout of blocks is seen from the top of the local z axis. Adding a new section the total number of blocks increases by 5. Applied block structure is favorable for all sections, because all of the observed branches have the same arrangement of the blocks, as can be achieved with any other configuration. Figure 5 shows the blocks generated by software STL2BLOCK.

The left and right carotid bifurcations for a particular patient are not geometrically identical. On the basis of practical examples, it is well known that the geometry of the bifurcation is very different for different patients. In rare cases manual intervention is required to fine-tune the vertices of the blocks to cover the bifurcation itself as accurately as possible.

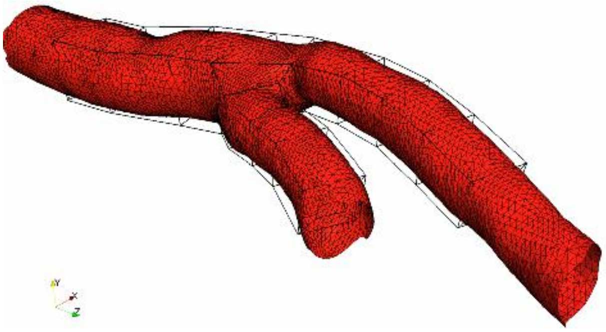
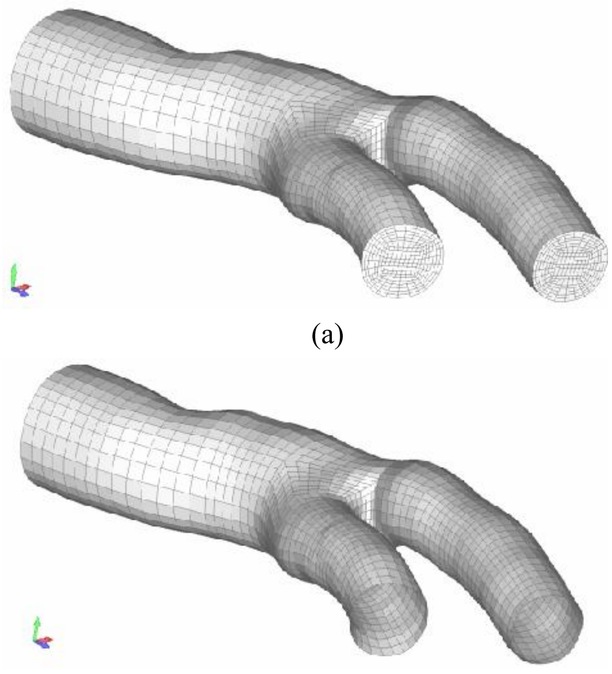


Figure 5 – Blocks generated using software STL2-BLOCK



(a)

(b)

Figure 6 – Finite element models of carotid artery bifurcation: (a) fluid domain i (b) solid domain

Topology of blocks is recorded in the VTK file, and can be used in other software for generating 3D finite element mesh. An example of such software is IA-FEMesh [22], open source software that relies on VTK library. The software uses the multiblock method for generating finite elements, wherein the nodes are generated using the transfinite interpolation without relaxation of the mesh [23]. You can create two types of finite elements: eight-noded 3D elements (Figure 6a) and four-noded shell elements (Figure 6b). The resulting finite element models accurately reflect the observed physical domain.

4. NUMERICAL SIMULATION OF FLUID-STRUCTURE INTERACTION

Simulation of blood flow through an elastic blood vessel was carried out on the example of real artery bifurcation of random selected patient whose model is shown above. The calculation was performed using the software PAK-FS.

The calculation was performed in 30 time steps in the interval of 0.8s. The first 10 steps are at intervals of 0.02s, and other 20 steps are at intervals of 0.03s. We used the following input data for the fluid domain: the average flow velocity at the inlet section $v_{SR} = 16.9\,\mathrm{cm/s}$, density of blood $\rho = 1050\,\mathrm{kg/m^3}$ and coefficient of dynamic viscosity $\mu = 0.003675\,\mathrm{Pa \cdot s}$ [24-25]. The input data for the elastic artery wall are: modulus of elasticity $E = 0.361\,\mathrm{MPa}$, Poisson's coefficient $\nu = 0.49$ and density of the arterial wall tissue $\rho = 1100\,\mathrm{kg/m^3}$. In the simulation standard systole and diastole phase of an adult human cardiac cycle is used (Figure 7) [25].

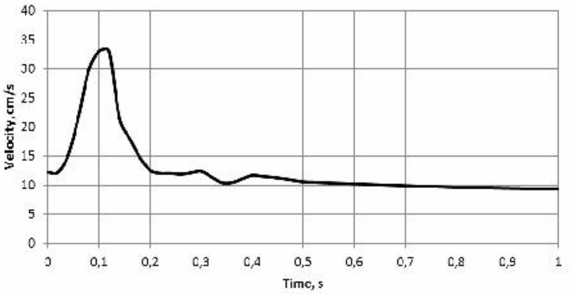


Figure 7 – Velocity field in the centroid of the input section for one cardiac cycle

For the fluid domain the following boundary conditions are applied:

- parabolic velocity profile corresponding to the developed laminar flow through a straight circular pipe is set on inlet section,
- the deformability of the arterial walls, and the speed of the interface equal to the velocity obtained from the calculation of strength are taken into account, and
- at the outlet sections of the model there is resistance that occurs because the flow of blood continues through the other blood organs.

For solid domain nodes at the inlet section have constrained movement in the flow direction. Also, movement of the section centroid is limited to the plane of the input section.

In the following figures the results of interaction of fluid and solid simulation are shown. Velocity field in the third step of the cardiac cycle is shown in Figure 8a.

When pressures on the model outlet surfaces are not given as boundary conditions, the result is the field of pressure drop in the modeled domain. Field of the pressure drop in the third step of the cardiac cycle is shown in Figure 8b. Field of endothelial shear stress on the blood vessel walls in the third step of the cardiac cycle is shown in Figure 9a. Places with lower stress value are more prone to plaque occurence, so this result is of great importance in the diagnosis and treatment of atherosclerosis. Field of the equivalent stress of the arterial walls in the third step is given in Figure 9b.

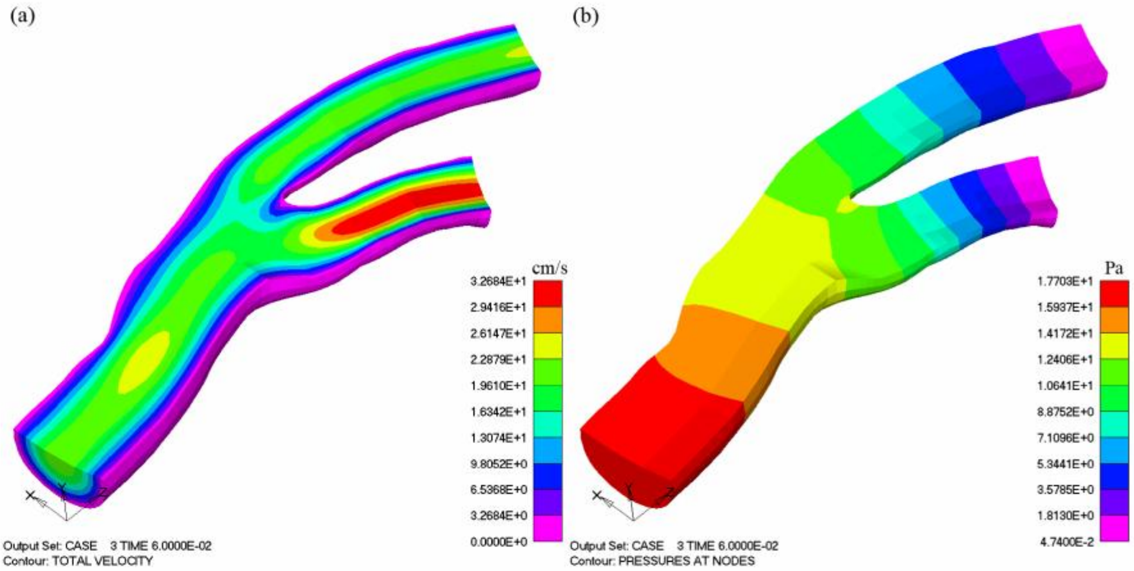


Figure 8 – Velocity field (a) and Field of pressure drop (b) in 3rd step of cardiac cycle

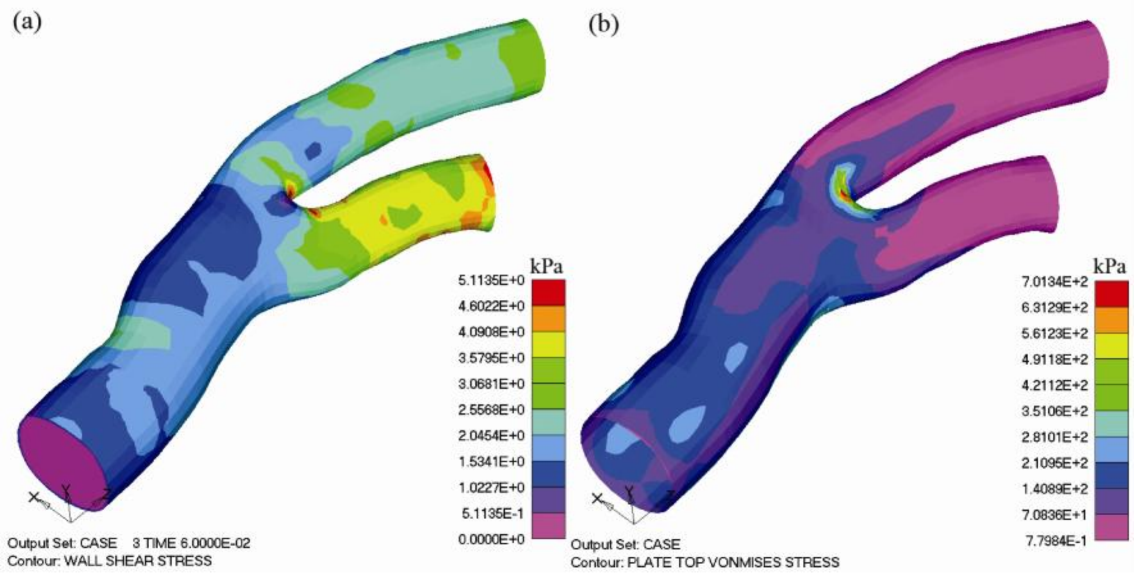


Figure 9 – Endothelial shear stress (a) and Equivalent stress (b) in 3rd step of cardiac cycle

5. CONCLUSION

Developing of new software for solving problems of interaction between solids and fluids is a difficult and time-consuming task.

When the softwares to solve fluid and solid dynamics separately already exist, cost-effective solution is to write drivers to use these solvers with minor modifications. To this end, as better solution is implemenation of the weak coupling of these solvers, because in that case each solver solves part of the problem in the domain for which is designed. However, this coupling is due to its specificity, which normally does not occur in the strong coupling, prone to many problems. The primary problem is the time integration. Because of the diversity of the physical characteristics of solids and fluids, it is generally not possible to use the same time step. Another difficulty arises in solvers communication. Different (incompatible) discretization is additional problem because it is necessary to transfer data from one mesh to another.

The proposed solution covers the entire process of analysis by software developed at the Faculty of Engineering, University of Kragujevac (STL2BLOCK - software for generating blocks for the discretization of the domain and the PAK FS - software for solving the coupled problem of fluid dynamics and the dynamics of solids) and open source software (IA-FEMesh - software for generating finite element meshes, and PARAVIEW - software for post-processing of the results). The methodology has been applied to the real model of arterial vascular bifurcation of the patient, taking into account the elastic wall of the blood vessel. The presented methodology is applicable to modeling other branches of the flow-organs of the human body (coronary artery branching, branching in the lungs, ...).

When generating finite element mesh multiblock approach was used, which speeds up the process of generating multiple models while minimizing errors in the numerical solution. The developed tool is very effective in creating computaional meshes for the complex geometry in biomechanics and engineering in general. In this way, hardware demanding and time-consuming procedures of NURBS surface reconstruction, and then the CAD modeling are skipped, because the finite element model is created directly on the volumetric model.

The presented results show that the deformation which occurs at the interaction between the blood and the arterial wall significantly affects the values of the hemodynamic forces acting on the arterial wall, as compared to the case when rigid wall is observed. Compared to previous studies [17] it was observed that simulations carried out with negligence of the arterial wall elasticity overestimate the maximum value of shear stress, and its field distribution on the arterial wall.

Based on the obtained results it can be concluded that this methodology is a useful tool that can provide important baseline information to cardiologists. Thanks to the detailed image of a phenomenon which occurs when blood flows through the carotid artery bifurcation, they decide whether and at what time point some intervention is required.

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REZIME

INTERAKCIJA SOLIDA I FLUIDA NA PRIMERU REALNE GEOMETRIJE ARTERIJSKE BIFURKACIJE SLUČAJNO IZABRANOG PACIJENTA

U radu su prezentovane razvijene procedure i alati za simulaciju interakcije fluida i strukture na primeru realne geometrije karotidne arterijske bifurkacije slučajno odabranog pacijenta. Geometrija karotidne arterijske bifurkacije dobijena je obradom snimaka sa CT skenera. Model konačnih elemenata verno opisuje složenu geometriju domena. Prikazani numerički rezultati pokazuju da je razvijena metodologija veoma fleksibilna i efikasna za primenjena istraživanja u biomedicinskom inženjeringu. Zahvaljujući jasnoj predstavi o fenomenima koji se javljaju pri strujanju krvi kroz bifurkacije karotidne arterije, kardiolozi donose odluku o neophodnosti intervencije.

Ključne reči: *interakcija fluida i strukture, proticanje krvi, metoda konačnih elemenata, napon smicanja na zidu, arterijska bifurkacija*