Simulation of individual movement of human cells in a cell suspension

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Introduction

CFD simulations of the individual moment of human fat cells are to perform to support the development of a new WAL device for autologous adipose tissue transplantation. A fan-shaped water jet loosens fat cells in the human body to improve the subsequent aspiration (Fig. 1). The capabilities of the ANSYS Fluent Six-Degree-of-Freedom (6DOF) model, which is used to simulate the individual movement of the adipocytes, are investigated in this study.
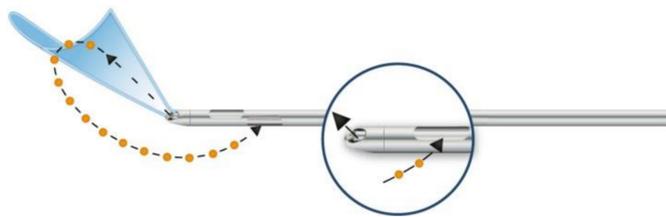

Fig. 1. WAL-dissector with illustration of basic principle

Methods

To perform CFD (Computational Fluid Dynamics) simulations the Navier-Stokes equations are solved numerically on a grid that represents the volume filled with the fluid. At the inner wall of the WAL-dissector the velocity is set as zero (no slip condition). On certain problems with moving geometry (like pumps, valves, engines) it is also necessary to move these walls and deform the mesh over the simulation to represent the real physical process.

The idea of this approach is to also treat the human cells as such walls, move them and deform the mesh according to the forces and moments of the surrounding flow.

Fig. 2. Channel with marked inflow and outflow region and start positions of the two moving ellipsoids

To investigate the capabilities of the 6DOF model a test simulation with two ellipsoids moving within the shear flow of a channel has been performed (Fig. 2). This simulation is a good start to develop and improve the model step by step and to observe the motion of the two ellipsoids relative to another as simply as possible.

Since the velocity is zero at the ellipsoid walls large velocity gradients occur in this region. To resolve these gradients and keep the simulation physical it is necessary to create a finer mesh there. Because the CFD solver needs to deform the mesh over the simulation time to account for the individual cell movement it is necessary to preserve the mesh refinement and prevent its deformation. A separate zone for this static mesh refinement, which surrounds the human cell, has been declared (brown zone in Fig. 3) while the outer mesh stays dynamic.
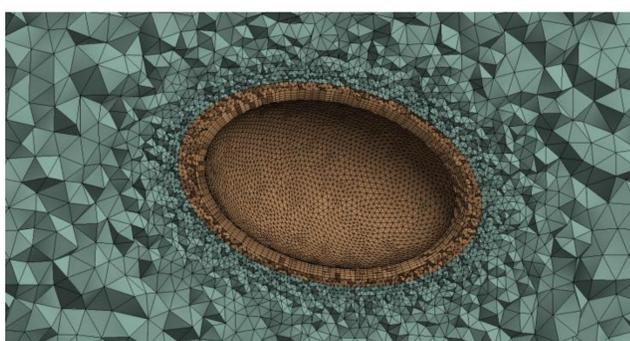

Fig. 3. Mesh refinement near ellipsoid

Results

Both ellipsoids translate and rotate independently from each other through the channel according to the forces and moments of the surrounding fluid (Fig. 4). Contact of an ellipsoid with the surrounding geometry or even the other ellipsoid is treated using a contact detection. Once the distance between the two ellipsoids or an ellipsoid and a wall falls below a pre-defined threshold the contact detection reflects the ellipsoid over this wall or the other ellipsoid by calculating a new velocity and direction based on arriving angle and velocity.
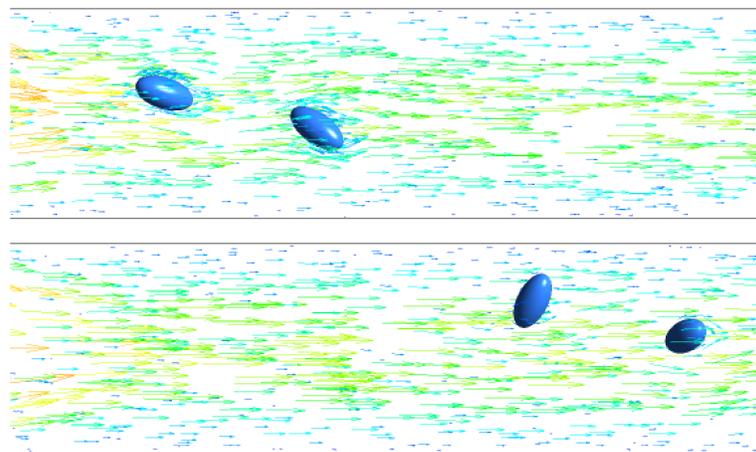

Fig. 4. Translational and rotational movement of the two ellipsoids

Because the model shows to be capable of simulating rigid body movement in a fluid it is possible to advance to the real problem and simulate the WAL-dissector. The WAL dissector sprays water (Fig. 5 left) to a rigid body 8x8x8 cell package (Fig. 5 right) to move the cells individually and push them apart. Then the next step is to simulate a complete cycle of injection and aspiration of the loosened fat cells to also investigate the shear rates in the aspirate.
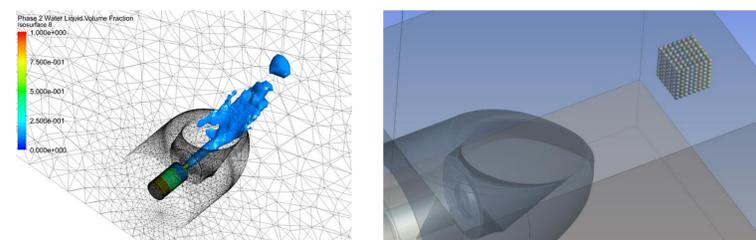

Fig. 5. WAL dissector spraying water (left), 8x8x8 cell package (right)

Conclusion

The capability of the ANSYS FLUENT 6DOF model to simulate the individual movement of human cells in a fluid has been shown by simulating the rigid body movement of two ellipsoids in a channel. Mesh refinement in a separate cell zone and rigid body reflection after collision have been implemented. With this knowledge it is possible to simulate the real application of the WAL dissector and an 8x8x8 cell package.

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