CFD Characterization of the Ventricular Assist Device HA5® Through a Sliding Mesh Approach

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Introduction

Cardiovascular diseases are recognized as the main cause of death worldwide, primarily related to heart failure. Owing to insufficient amount of eligible organs for heart transplant annually, various mechanical circulatory support devices as ventricular assist devices (VAD) and total artificial hearts (TAH) have been developed and introduced in the market [1].

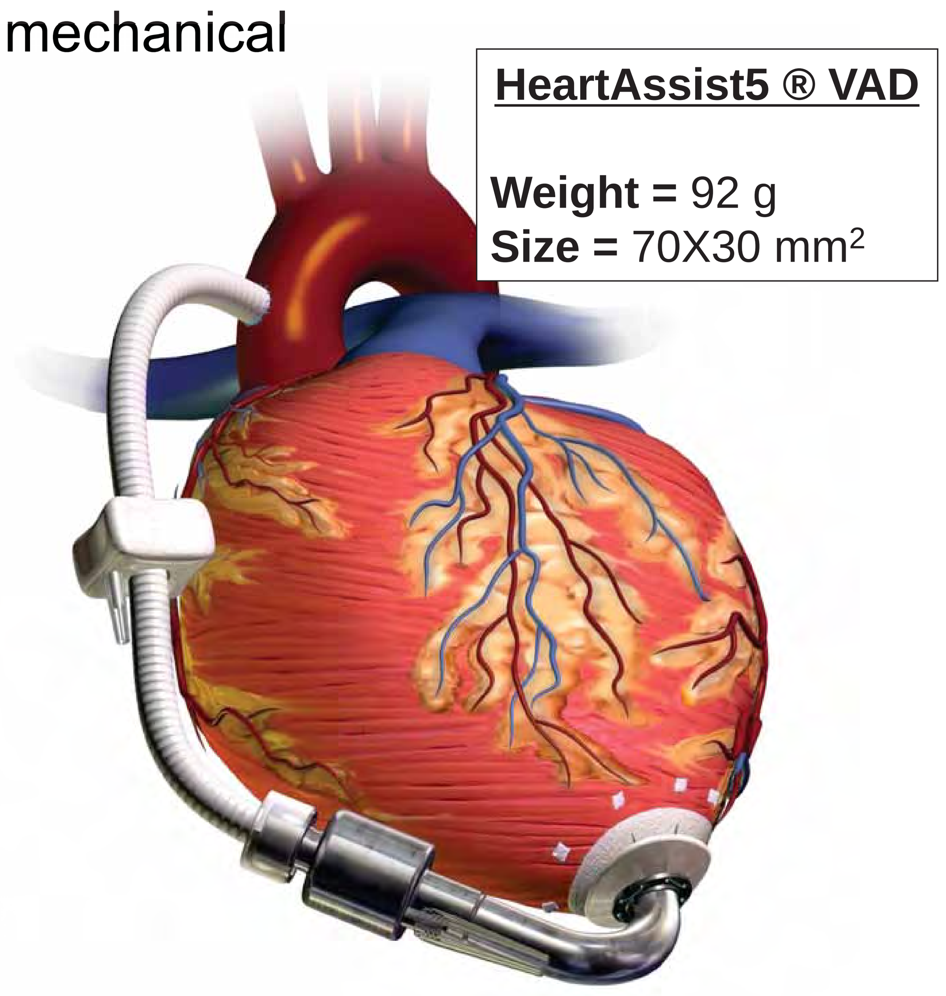

Figure 1 – Heart Assist5 ®, left ventricular assist device (LVAD).

In this work, computational fluid dynamics (CFD) simulations were performed to mimic the realistic operative conditions of the VAD HeartAssist5 ® (HA5, ReliantHeart Inc., USA), shown in Fig. 1.

Materials and Methods

The CAD model of the device (Fig. 2) was provided by the manufacturer [2] and optimized with **Gambit 2.4.6** (ANSYS Inc., USA). The fluid domain was obtained subtracting the CAD model and a cylindrical conduct. The finite element discretization was performed with the **Meshing** module of ANSYS **Workbench v15.0**.

Numerical approach. Exploiting the capabilities of the ANSYS CFD solver **Fluent**, a **sliding mesh** technique was adopted to simulate the fluid-structure transient rotating behavior of the device (Fig. 2). Specifically, a rotational speed (ω) was set to the rotor part and two mesh interfaces were defined between the moving (rotor) and stationary (straightener, diffuser) domains.

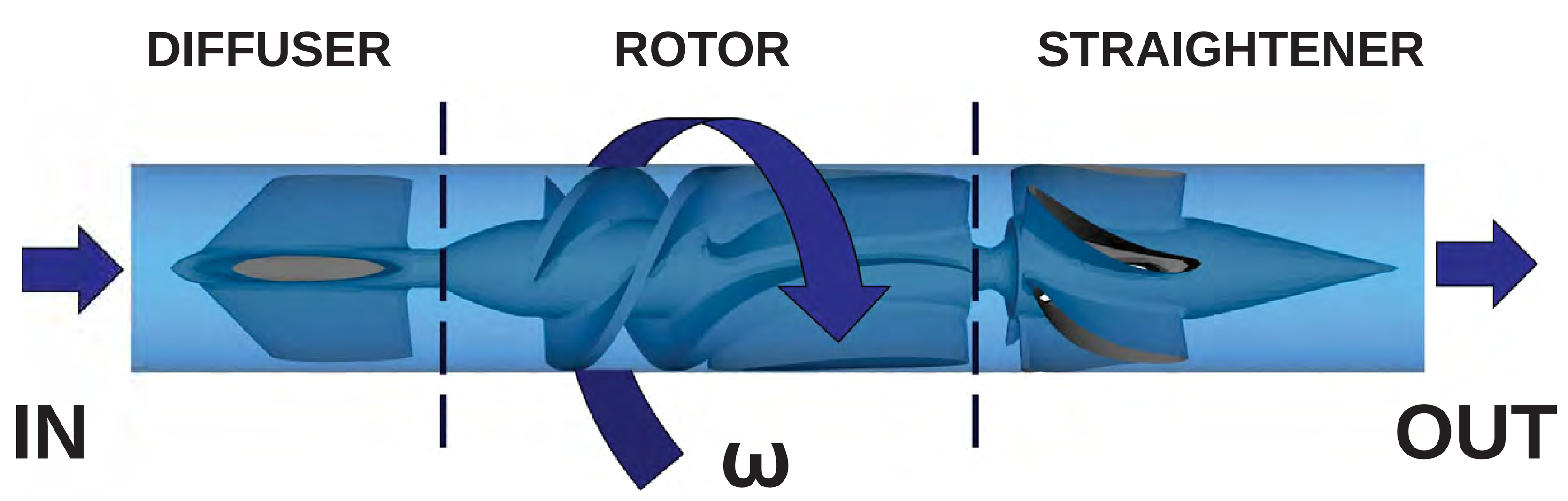

Figure 2 – HeartAssist5 ® CAD model.

Operating conditions.

- The **rotational speed (ω)** of the rotor was set at 9000 RPM clockwise. Six rotations were simulated to stabilize the solution.
- The external wall of the rotor was defined as ***"moving relative to adjacent zone"***, with an opposite rotating direction. The remaining surfaces were defined as stationary walls with no slip condition.
- A **mass flow rate** of 0.07 kg/s (corresponding to a physiological Cardiac Output of 4 L/min) was set at the inlet boundary surface.
- A zero **pressure** was set at the outlet boundary surface.
- **Blood** was considered a **Newtonian incompressible fluid** (ρ=1081 kg/m^3, μ=0.0035 kg/m*s).

Results and Discussion

The sliding mesh numerical approach proved able to fully replicate the operating conditions of the HA5 LVAD, within a physiological regime.
We observed a pressure head of the device of approximately 80 mmHg capable of easing the load of the left ventricle (Fig. 3).

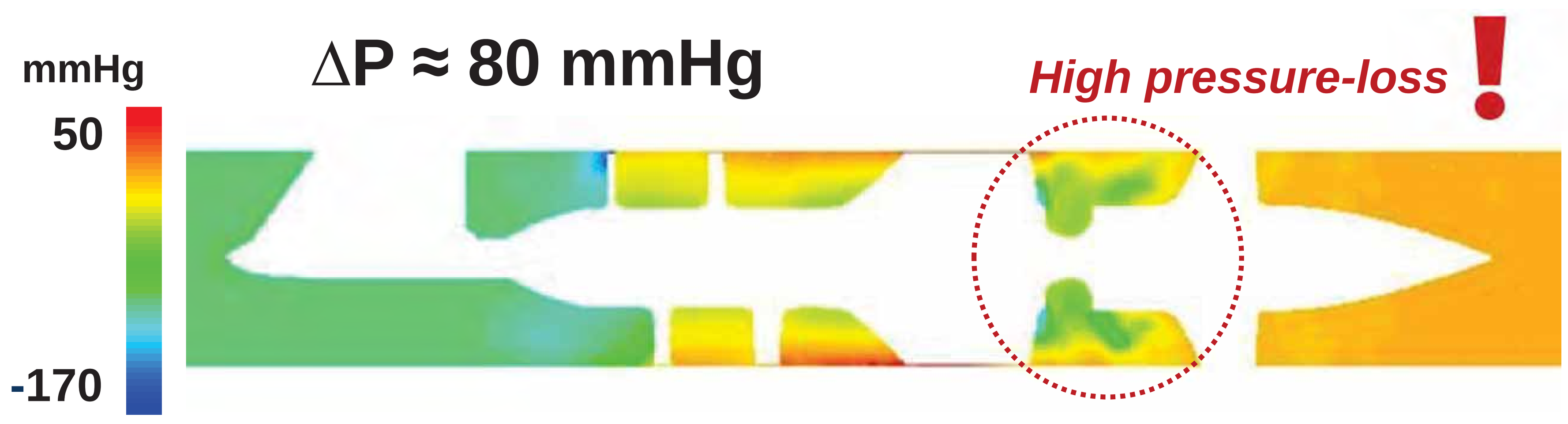

Figure 3 – Static pressure (mmHg) contour on a longitudinal plane to highlight the pressure head of the device.

Moreover, ANSYS **CFD-Post** was used to obtain a qualitative visualization of the velocity field by means of streamlines calculation (Fig. 4, upper panels). Specifically, the interface region between the diffuser and the rotor (I) depicted a laminar rotational flow, whereas the one between the rotor and the straightener (II) highlighted a residual rotational tendency of the flow field.

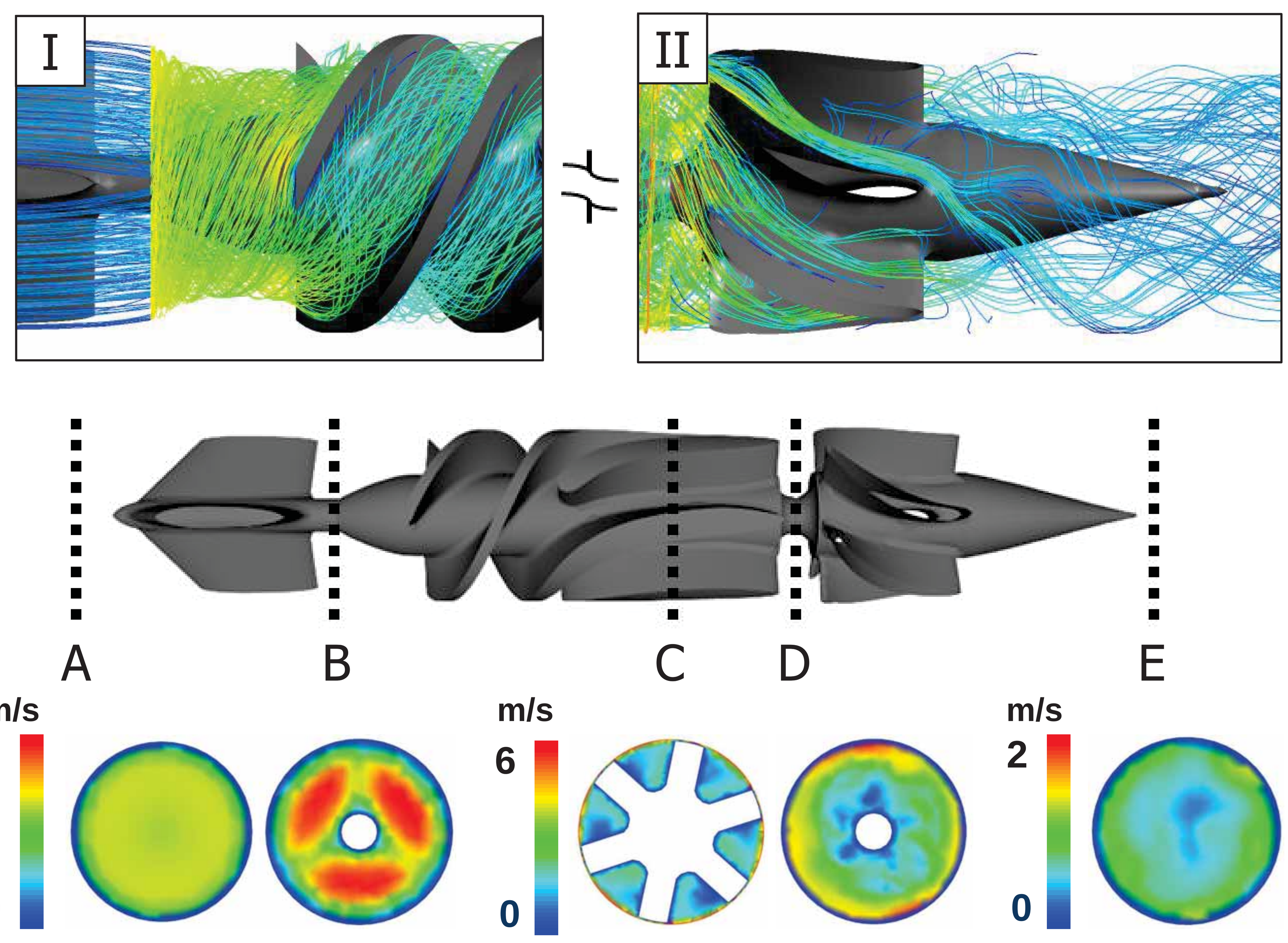

Figure 4 – Upper panels: streamlines calculation to highlight the velocity field before (I) and after (II) the rotor. Lower panels: velocity magnitude (m/s) contours on different cross-sectional planes (A – E).

Velocity magnitude contour maps (Fig. 4, lower panels) were extracted at different locations of the fluid domain. The rotor part was characterized by the highest values, close to 6 m/s, whereas, mostly due to the reduction of helical flows, the outflow tract was closer to physiological values of 1 m/s.

Conclusions

In the present study, high-end numerical CFD simulations allowed to evaluate the HA5 LVAD hemo dynamics under realistic working conditions: the proposed approach may be further used to focus on specific locations of the device in order to optimize its geometry and to estimate its hemolytic potential [2].

References

[1] D.N. Helman, E.A. Rose, *Progress in Cardiovascular Diseases*, 43, 2000
[2] W. Chiu, G. Girdhar, D. Bluestein at al., *Journal of Biomechanical Engineering, 136*, 2014