Numerical computation can save life: FEM simulations for the development of artificial hearts

André Pohlmann, Marc Lessmann[1], Thomas Finocchiaro[2], Thomas Schmitz-Rode[2] and Kay Hameyer[1]

[1]Institute of Electrical Machines, RWTH Aachen University, D-52056 Aachen, Germany

[2]Applied Medical Engineering, Helmholtz Institute, RWTH Aachen University, D-52074 Aachen, Germany

andre.pohlmann@iem.rwth-aachen.de

Abstract— Worldwide cardiovascular diseases are the major cause of death. Together with the limited heart transplants due to the limited number of donor hearts, artificial hearts (AH) are the only therapy available for terminal heart diseases. Starting from the first design of an AH to its operation inside a human body, the AH has to pass several clinical trials, which result in redesigns and optimizations. During this process the dimensions, the weight and the required electromagnetic forces of the AH as well as blood damage, caused e.g. by shear forces or overheating are important parameters. In the design of electrical machines, FEM is a standard tool to calculate forces and losses causing heating in the machine. For this reason numerical computation is adopted for the design of AHs to shorten the described design process.

This contribution provides an overview of the historical development of AHs in general and exemplify the adoption of FEM simulations for the design of artificial hearts developed at the RWTH Aachen University. The heart prototype was already in operation during clinical animal test.

I. Introduction

Due to the limited number of donor hearts, Total Artificial Heart (TAH) systems are required for the therapy of terminal heart diseases. An idea of such a system is illustrated in Fig. 1. The patients wear a battery pack, which is connected to a transcutaneous energy transfer system, supplying an implanted battery in the human thorax. This replaces extra corporal connections through the abdominal wall. This results in lower infections risks for better quality of life for the patient. Besides the battery of a TAH is implanted into the thorax. Due to the limited space the volume and the weight of the TAH is restricted. However, the TAH must be able to pump 6-7 l. of blood per minute and to avoid blood damage by shear forces or high electrical losses, which result in overheating. There are various concepts, which can nowadays be distinguished into three generations of blood pumps.

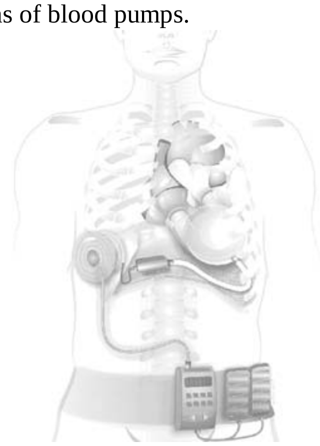

Fig. 1: Total Artificial Heart System [1].

In the first generation the blood is pumped pulsatile, while the two other generations have a continuous blood flow. Third generation blood pumps [3], [4] have contactless bearings to avoid wear effects.

II. Technical Information

In Fig. 2 the TAH ACcor, a first generation blood pump developed at the RWTH Aachen University, is shown. Its design did not meet the requirements for implantation. FEM was applied for the optimization of the ACcor heart. In [2] a linear motor concept with a high power density is determined by evaluating numerous designs by FEM (Fig. 3).

Fig. 2: Total Artificial Heart ACcor.

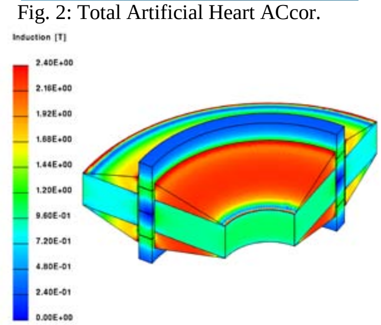

Fig. 3: Distribution of the magnetic induction in the drive of a TAH.

III. References

[1] M. Lessmann, T. Finocchiaro, U. Steinseifer, T. Schmitz-Rode and K. Hameyer, "Concepts and designs of life support systems." IET Science, Measurement & Technology 2008, 2(6): 499-505.

[2] T. Finocchiaro, T. Butschen, P. Kwant, U. Steinseifer, T. Schmitz-Rode, K. Hameyer and M. Lessmann, "New linear motor concepts for artificial hearts." *IEEE Transactions on Magnetics 2008*, 44(6): 678-681.

[3] E. Tuzun, K. Roberts, W. E. Cohn et al., "In vivo evaluation of the HeartWare centrifugal ventricular assist device." Texas Heart Institute Journal, Cardiovascular Surgical Research Laboratories, Texas Heart Institute at St. Luke's Episcopal Hospital, Houston, Texas 77030, USA 2007, 34(1): 406-411.

[4] J.P. Mueller, A. Kuenzli, O. Reuthebuch et al., "The CentriMag: a new optimized centrifugal blood pump with levitating impeller." Heart Surgery Forum, Clinic for Cardiovascular Surgery, University Hospital Zurich, Switzerland 2004, 7(1): E477-E480.

978-1-4244-7061-7/10/$26.00 ©2010 IEEE