Computer Aided Design of Korean Total Artificial Heart

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Introduction

The rolling cylinder type total artificial heart (TAH) with 100ml of pump stroke volume was made and had been implanted in the 100kg calf for 4 days in 1988. The pendulum-type TAH was developed in 1990, which was down-sized to have 70ml of stroke volume for a better anatomical fitting into the small chest animal, such as sheep. In 1993, we improved the pendulum type TAH toward enhancing reliability and better anatomical fitting for human use.

The present version of our TAH has 650ml of total volume, 60~70ml of stroke volume and 1100g of total mass. During series of animal experiments with our TAH, the major problems of the TAH is known to be the anatomic fitting of the 3-dimensional structure of four ports from the implanted TAH to the remnants of the natural heart and the highly negative pressure generated in the left ventricle was one of the most serious problems for the successful implantation. Throughout the durability test of the TAH, fractures of the blood sacs were occurred, then the mean life time of the blood sacs was 15 months. We investigated the main cause of the blood sac fracture is the stress concentration on the polymeric surface due to unsmooth contact between the mechanical parts of the actuator and the blood sac. Therefore, the 3-dimensional geometry of two blood sac and the mechanical parts such as the moving actuator and the rack gear is crucial for improving reliability of the TAH.

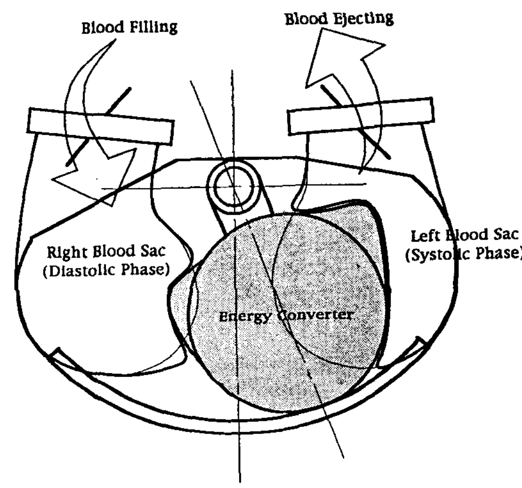
To solving these problems we adopted the techniques of system engineering and system design, and used computer aided design (CAD) and computer aided manufacturing (CAM) program for optimizing our TAH.

In this paper we report on the newly designed moving actuator type TAH (KORTAH v.2.0) based upon the new manufacturing system.

Materials and Methods

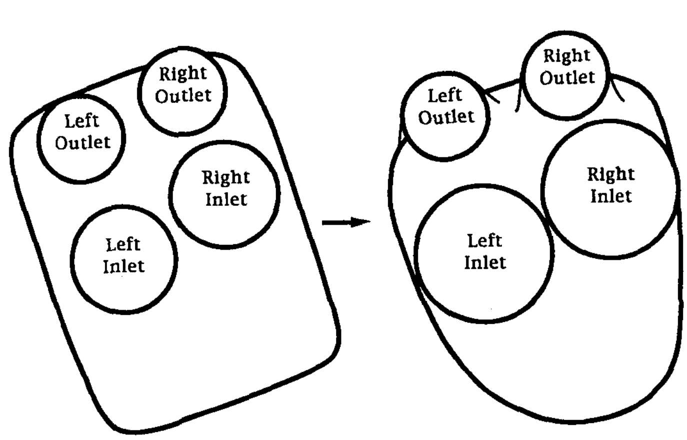
The mechanical parts of our TAH is composed of three major elements ; blood sacs, gear assembly and actuator, as shown in [Fig. 1.].

All of these parts were newly designed using a UniGraphics® CAD/CAM system on the platform of HP 715/600 workstation.



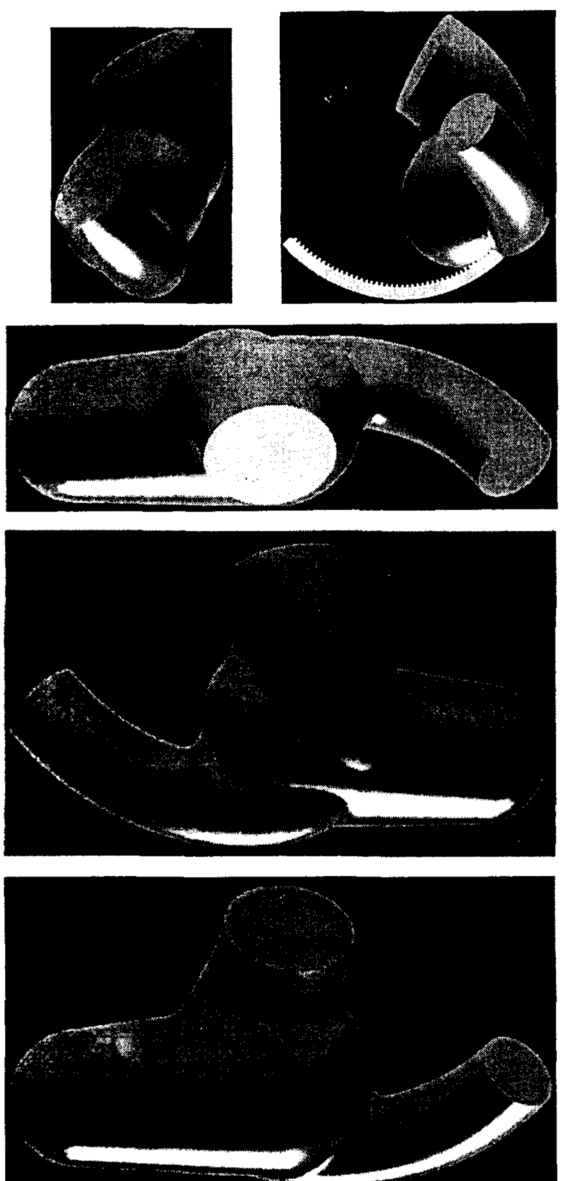
[Figure 1] Schematic Drawing of KORTAH

The outer shape of the new pump was changed to a rounded edge-trapezoid from the rounded edge-rectangle of the present TAH based upon the anatomical analysis of the natural heart. [Fig. 2.]

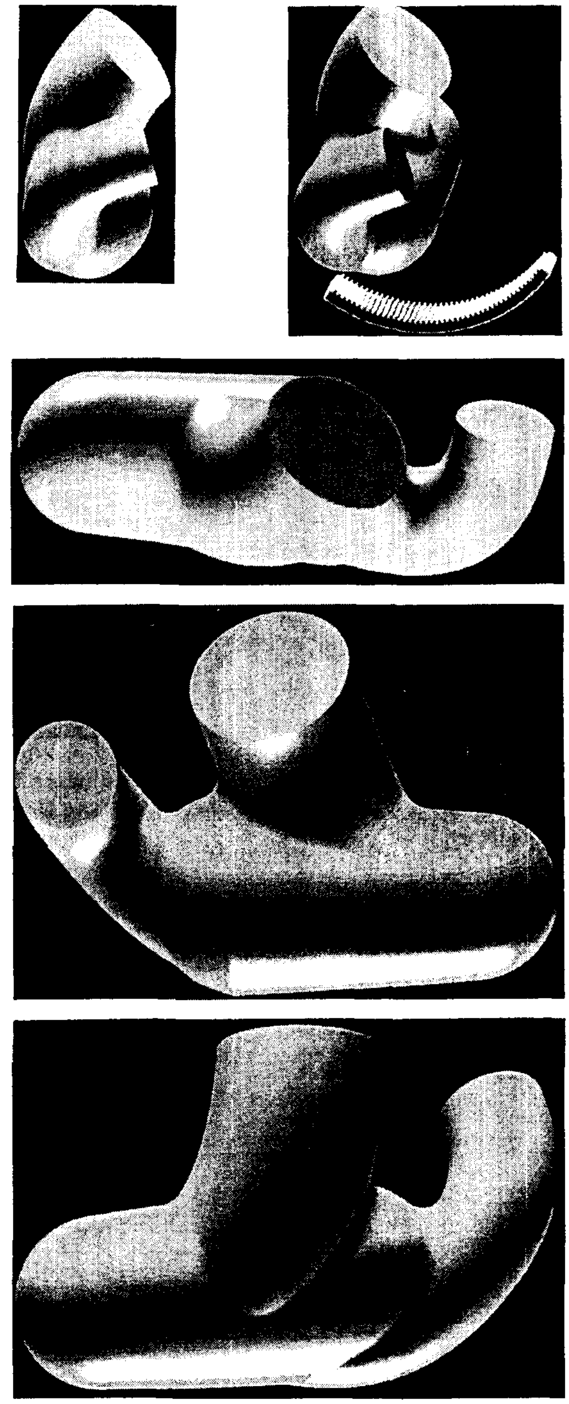


[Figure 2] Shape Change of KORTAH

The blood sacs were also designed as rounded edge-truncated cones for smooth assembly with the outer shape of the new pump. Static stroke volumes of left and right blood sac are 92ml and 80ml respectively. The diameter of both inlet ports is 33mm which was 24mm in the present version to provide the less pressure drops across the inlet valve. While the diameter of outlet port is 22mm same as the present version. With the CT image analysis of more than 20 patients, the ports are carefully positioned to eliminate the risk of compression of cardiovascular remnants and the improper contact with other mechanical parts, and to connect smoothly with the great vessels surrounding the TAH. [Fig. 3 .,4.]

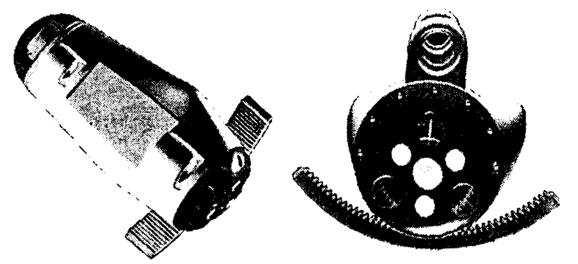


[Figure 3] Left Blood Sac ; Front view, Front view with rack gear, Top view, Left view, Right view (from upper-left clockwise direction)



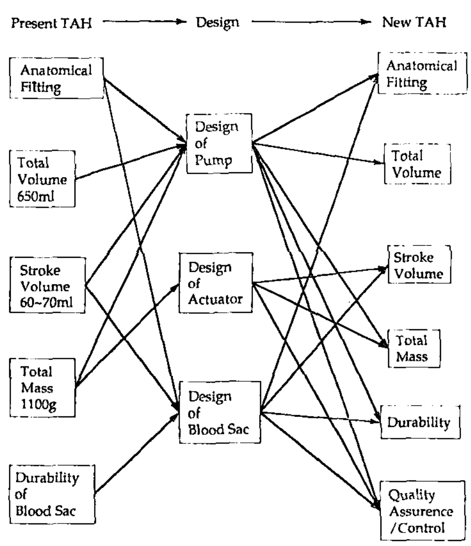
[Figure 4] Right Blood Sac ; Front view, Front view with rack gear, Top view, Left view, Right view (from upper-left clockwise direction)

The cross-sectional plane of the actuator is a truncated-triangle same as those of the blood sac and the outer pump housing. Therefore, TAH has the similar shape to natural heart like truncated cone with apex. The lateral sides of the actuator was modified by attaching free-form features to make better folding patterns of blood sacs and to increase the dynamic stroke volume. [Fig. 5.]



[Figure 5] Actuator ; Isometric view (left) Front view (right)

The materials of the actuator is changed to the duralumin-aluminum alloy from duralumin and the pump housing to duralumin from aluminum, to reduce the total weight of TAH. [Fig. 6.]



[Figure 6] The new TAH vs. the present TAH

Results and Discussion

The rendered images of the designed TAH elements are shown in Figure 3, Figure 4, and Figure 5. The geometrical structure of the blood sac and the rack gear is shown in Figure 3 and Figure 4. This structure will facilitate smooth contact between the actuator and the blood sac without stress concentration.

By using a CAD system, we could achieve design-improvement of our TAH in the point of view of reliability and fitting compatibility. These designed elements will be manufactured using a CAM system for the precise realization of our designing phylosophy.

Acknowledgment

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