INTEGRATED ENGINEERING SOFTWARE

University of Nottingham designs artificial heart at 5% of the current cost

There are 11.2 million sufferers of Congestive Heart Failure (CHF) worldwide, which is steadily increasing by 10% annually. Each year, 3000 people receive a heart transplant as the only current long-term treatment for CHF. Blood pumps offer a solution either as a bridge to transplantation or to recovery. The market potential is valued at $5.4 billion annually.

However, since the current cost of manufacturing the complex parts that are needed in modern artificial hearts is around $30,000, the availability of the device is severely limited.

In a recent study conducted by Andrew Hilton at the University of Nottingham, it was found that a few changes to the current design of centrifugal blood pumps reduced the total cost to 5% of the original cost by designing around standard stock parts that are currently available from engineering suppliers.

Under the current design of blood pumps, the pump must operate continuously pumping at 6 litres/minute, cycling at a rate between 2,000 -20,000 revolutions/minute. The pump must have an operating temperature under 37° Celsius and provide energy sufficient energy on a beat-by-beat basis to replicate the pressures seen within the heart.

The system must be nontoxic to the human body, damage to cellular components, and element s such as platelets must be prevented. The system must not produce blood clots (thrombi) that can lead to a malfunction of the pump and ultimately a stroke.

For the new design of pump, Hilton optimized his model by using AMPERES (from INTEGRATED Engineering Software), a CAE software package designed to perform full three-dimensional simulations of magnetic physical systems. The geometry was designed for a pump operating at 2000 rpm. Full specifications included inlet and outlet diameters, blade heights at each inlet and outlet and the appropriate casing size that enabled the   designer to maintain a constant velocity of the fluid. The new drive system employed the use of electromagnetic coils to drive the pump. There was only one moving part in the whole system, no mechanical seals around rotating components, and a full non-contact bearing that minimizes heat generation and maximizes the reliability of the design.

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In the design of the drive system various arrangements of magnets were considered. Primarily, the magnets had to be small enough to fit inside the impeller. This has direct consequence on the attractive force seen between the two components. Secondly, the angular orientation of the magnets produces a significant radial force maintaining the central axis of rotation of the impeller. By using off-the-shelf components, such as pre-sized permanent magnets and stock electromagnets, it is possible to construct a drive system similar to that seen in the VentrAssist device.

The drive system was designed by evaluating the forces that occur within a blood pump, such as shock forces due to the patient falling over. The appropriate magnet configuration was selected, and has been modeled using computational analysis. It was necessary to measure how the force of attraction between the parts varied at angles of misalignment; this was modeled using finite element method/boundary element method (BEM) using AMPERES. The program provides users with a wide variety of analysis options, including the ability to create contour plots and graphs of field quantities. To perform a simulation in AMPERES, a geometric model of the physical system was constructed, by using the built-in geometric modeler.

Once the geometric model was built, physical properties such as material and magnet flux density vector orientation were assigned. The BEM analysis yielded results for the axial force and the torque between the components at angles of misalignment, and showed how the coupling may be used as a radial bearing by examining how the radial forces vary with an increasing cone angle.

The research found that the total cost of the pump is reduced by implementing a drive system that acts as a magnetic bearing; it consists of two components: permanent magnets with the impeller of the pump and the electromagnets within the pump casing. Using stock components available from standard engineering suppliers, the cost of manufacturing may be reduced up to 95%. An upcoming prototype incorporates a hybrid electromagnetic drive/bearing system, together with a hydrodynamic bearing.

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