The Torque and Damping Characteristics Analysis of the Non-contact Permanent Magnet Driving Device for Artificial Heart

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Abstract —In this paper, we analyze and calculate the magnetic field and eddy current distribution and electromagnetic torque characteristics of the non-contact permanent magnet driving device with the damping system and without the damping system for the power supply of the blood pump of artificial heart using finite element method. The research results show that the damping system can produce larger damping torque in the speed fluctuations of the passive magnet and greatly increase the stability of the transmission speed. This research on the driving mechanism and driving characteristics of the non-contact permanent magnet power transmission system has laid a theoretical foundation for the optimal design of an artificial heart with the permanent magnet driving device.

I. INTRODUCTION

After several decades of research on artificial heart, several related products have been produced and are gradually put into use [1]-[3]. From a clinical view, however, it is very difficult to replace the human heart with the existing artificial heart thoroughly, for many essential problems have not been solved. Apart from the problems of thrombus and hematolysis, there are many problems such as the power source and the heat generated by the motor. Some of the devices have complex structures and big sizes, so they will take up large space and oppress the internal organs when transplanted into the body and the possibilities of infection will largely be increased. Some devices require a skin channel to import the necessary energy for the equipment to run that will bring about serious infection at the same time. After implanting such kinds of artificial heart, although the life of the patients will continue, the patients cannot leave the hospital and freely move[4].

Because of the problems stated above, the existing artificial heart is far from satisfying. Much effort has to be paid in order to implant the artificial heart and replace the damaged human heart. The research and development of a simple, lightweight, economic and reliable artificial heart are very urgent in order to save more patients with heart disease.

II. NON-CONTACT DRIVING DEVICE

In order to reduce the amount of foreign matter and avoid using the channel through the body to provide energy, we adopt permanent magnets to transfer the energy required by the artificial heart.

The key components of an artificial heart - the blood pump and its drive unit work according to this principle: The active magnet driving unit located outside the body and the passive magnet which is installed in blood pump located inside the body form a pair of permanent magnet. When the active magnet rotates, its magnet field changes and passive magnet will follow the rotation of the active magnet [5].

In this way, we can overcome the fatal shortcomings of the fundamental need of electric drive energy access through the body and the existence of a heat generator for energy conversion inside the body. Compared with the existing artificial heart, it has the following advantages: The total amount of foreign matter implanted into the body is significantly reduced, the size of implanted devices is significantly reduced, the total energy imported into the body for driving the blood pump is reduced, the trauma caused by implanting is greatly reduced, the reliability of the overall structure is improved, it is completely avoided that wires penetrate the body, the blood contact surface of artificial heart is greatly reduced, the removal of natural heart is avoided.

The basic structure of the non-contact driving device for the power supply of the blood pump of artificial heart is two cylindrical magnets which are separated by a certain distance. The magnetic force between the two permanent magnets is the foundation of energy transfer. Fig. 1 shows the active and the passive permanent magnet of the non-contact driving device. As the active magnet is located outside the human body, it is less restricted by space, so it may have a larger geometric size. For the passive magnet is located inside the body, it is more limited by space, so its geometric size must be small. Two permanent magnets respectively generate their own magnetic field around themselves. The direction, intensity, gradient and other parameters of the magnetic field must meet certain requirements in order to achieve effective energy transfer.

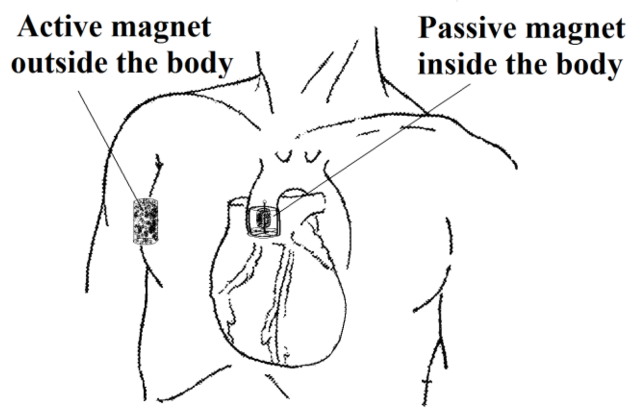

Fig.1. Location of the Active and passive permanent magnet

For the non-contact permanent magnetic driving device of the blood pump, the speed stability is a very important performance index. For the active magnet and passive magnet are separated by a larger distance and the passive magnet is small, the instability of the delivery system will be increased. If the rotation of the active magnet and passive magnet is out of sync, they will not transfer torque. This means that the blood pump inside the human body will lose momentum.

In order to reduce the speed fluctuation of the passive magnet and the possibility of out of sync, we have added a damping system on the permanent magnet of the driving device. The damping system consists of the conductive and non-magnetic metal layers fixed on the pole surface of permanent magnet.

In the work process of the non-contact permanent magnetic driving device, if the speed of the active magnet and passive magnet is the same, there is virtually no relative motion between the magnetic field generated by the active magnet and the metal material layer fixed on the passive magnet surface, therefore no significant eddy current is induced in the metal layer; if the speed of the active magnet and passive magnet is different, there is a relative motion between the magnetic field generated by the active magnet and the metal material layer fixed on the passive magnet surface, therefore eddy currents are induced in the metal layer. The interaction between the eddy current and the magnetic field will generate a torque. The torque will impede the relative movement between the active magnet and passive magnet. Through this process, the damping system can suppress the speed fluctuation of the passive magnet in the transmission, increase the stability of the transmission speed and reduce the possibility of out of sync.

III. FIELD AND TORQUE CALCULATION

In order to obtain the magnetic field and eddy current distribution and transmitted torque of non-contact permanent magnet driving device for the power supply of the blood pump of artificial heart, we carry out the finite element analysis of it. Fig. 2 shows the magnetic flux density vector distribution obtained by calculating the three-dimensional magnetic field of the active magnet and passive magnet.

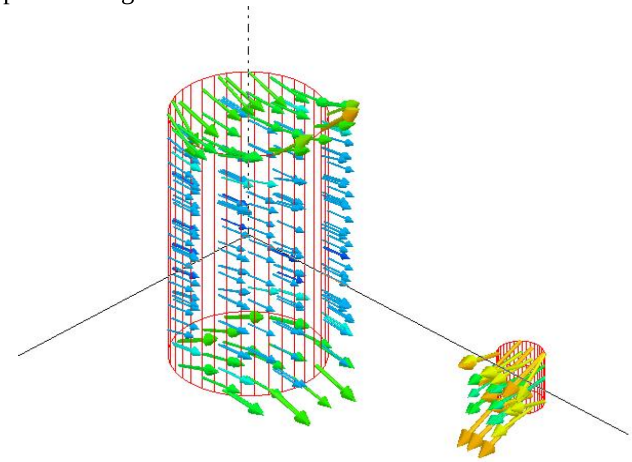

Fig. 2. Magnetic flux density vector distribution of active and passive magnet.

Through the finite element analysis, we know that the system can deliver the enough torque when the spacing between the active and the passive magnet axis is 120 mm. This torque fully meets the artificial heart blood pump energy transfer request.

Through the comparison between the calculated results with the damping system and without the damping system, we know that the damping system can produce larger damping torque in the speed fluctuations of the passive magnet in the work process of the non-contact permanent magnetic driving device, that the stability of the transmission speed is greatly increased.

In addition, the research’s findings can also be used for the reference for other non-contact permanent magnet gear drive problems.

IV. REFERENCES

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