One Arc PMSM for Telescope Tracking System

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ABSTRACT

This paper explores one Arc PMSM for Direct Drive Telescope tracking system. By the Arc PMSM, we can very easily manufacture one direct drive system for large telescope. Direct drive system has many advantages over more traditionally used friction and rack/pinion drive. The advantages include high stiffness, no friction, easy alignment and low maintenance. The paper discusses the design process of the Arc PMSM, especially the methods to reduce the torque ripple.

Keywords: Direct drive, segmentation, Arc PMSM, torque ripple

1．INTRODUCTION

Modern large telescope will be endowed with advanced imaging systems and active optics, resulting in very high peak angular resolution. The drive system for the telescope must consequently be able to guarantee a tracking accuracy better than the telescope angular resolution, in spite of unbalanced and sudden loads such as wind gusts and in spite of the telescope's structure that, because of its size, can not be infinitely stiff. [1] A direct drive system has been chosen to handle the hard problem in the view of direct drive system's many advantages over more traditional friction and rack/pinion drive. What's more, the direct drive technology has been successfully used in the VLT and Japan's SUBARU telescope. As direct drive technology develop, it might push to more reliable and cheaper solutions for future telescope complex motion system.

One Arc PMSM is designed to study and research the direct drive problem and reliability for Chinese future great telescope. However, this requires the design and realization of unusually large torque motors, which must be manufactured piecewise and assembled on-site. Furthermore, in spite of their very large size, the torque motors must be controlled with a very high control bandwidth; the torque slew rate must be extremely steep too.

For all the reasons listed, it is very hard to realize such a motor by traditional method. A non-conventional motor approach has been adopted in the Arc PMSM designed for the tracking system of the modern large telescope. The paper study details the improved design approach adopted for the Arc PMSM.

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2 . The Arc PM Synchronous Motor

The Arc PM Synchronous Motor is formed by:

It is a radial gap surface permanent magnet motor, 120 poles, which is consisted of 15 stator units and segmented rotor. Each unit of the Arc PMSM can be regarded as one "small powerful motor", more units can be modified more powerful motor unit. The whole Arc PMSM are modified five "demanded motors" that each can meet the requirement of the experiment. In the experiment, only two "demanded motors" are mounted in order to reduce the cost.

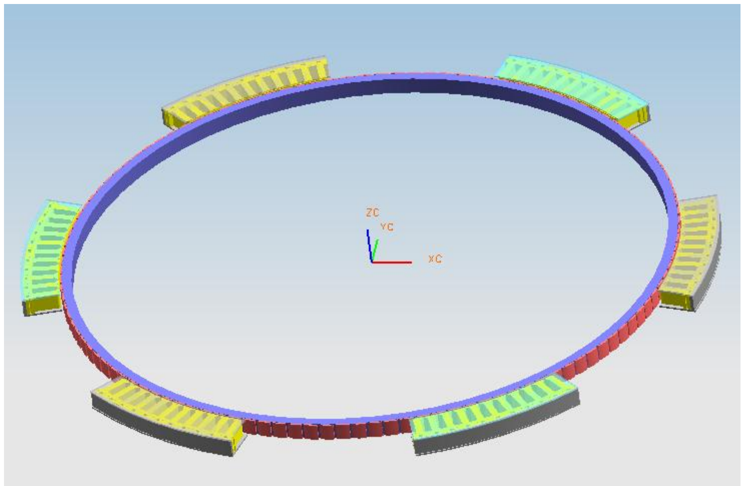

Figure-1 Arc PMSM Model

The rotor part is disc-shaped, and realized in arc segments. Permanent magnets are pasted on the rotor disc and protected by a stainless steel structure. The multi-pole field generated by the magnets is directed perpendicular to the rotor axis (YC).

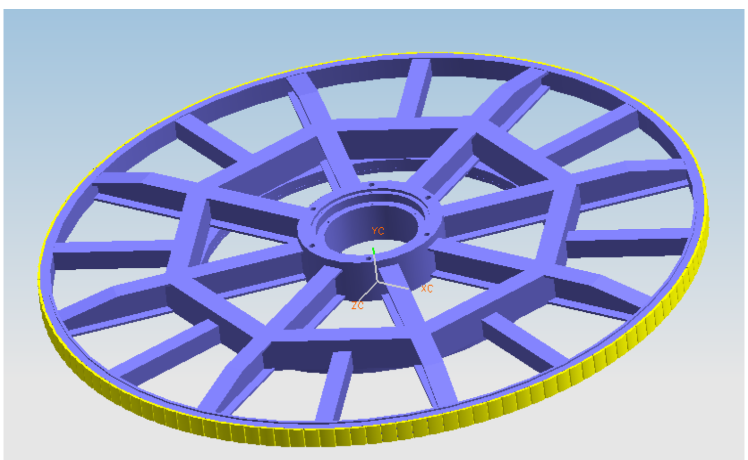

Figure2-the rotor model of Arc PMSM

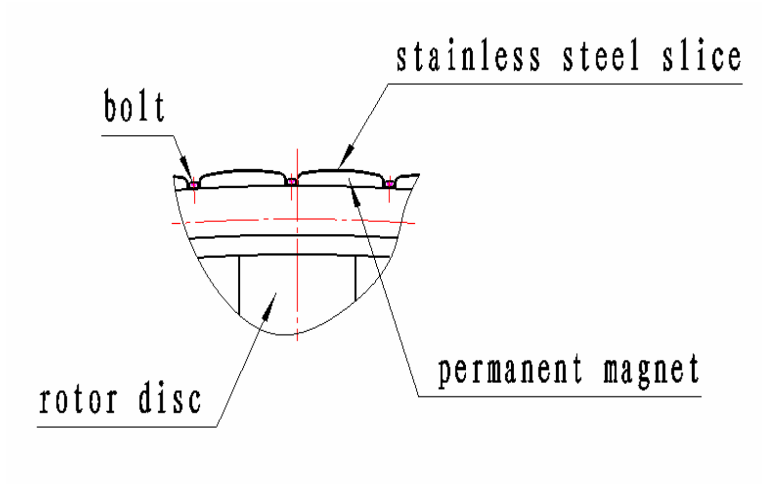

Figure-3 structure of the rotor and permanent magnet

The model of the rotor is shown as figure-2. The rotor structure is designed to meet the demand of the experiment environment, while some conditions would not be considered in real modern telescope, which would reduce the cost sharply. However, the available structure for the telescope is modeled and simulated.

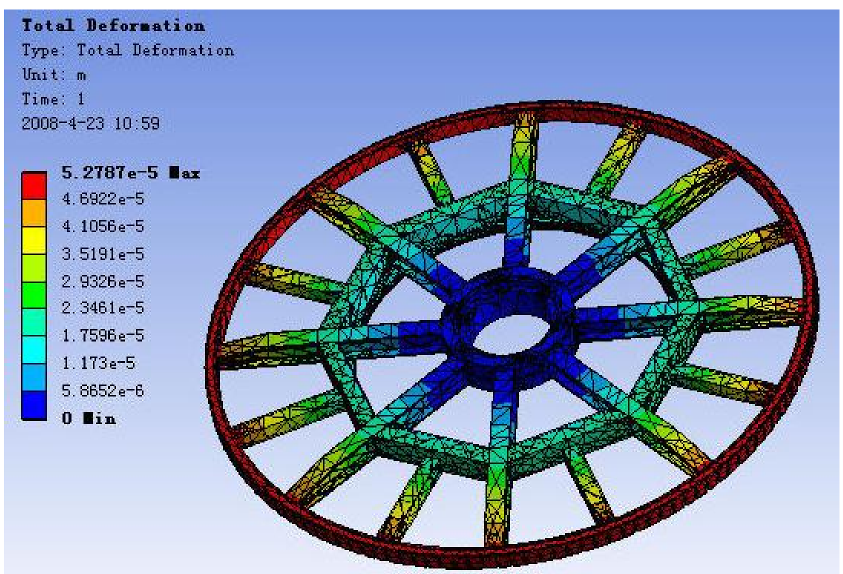

Figure-4 the FEM analysis result of the rotor

In figure-4, only the self gravity of the rotor is considered and the result explores that the deformation of the rotor is very small and can be corrected by manufacture and adjustment.

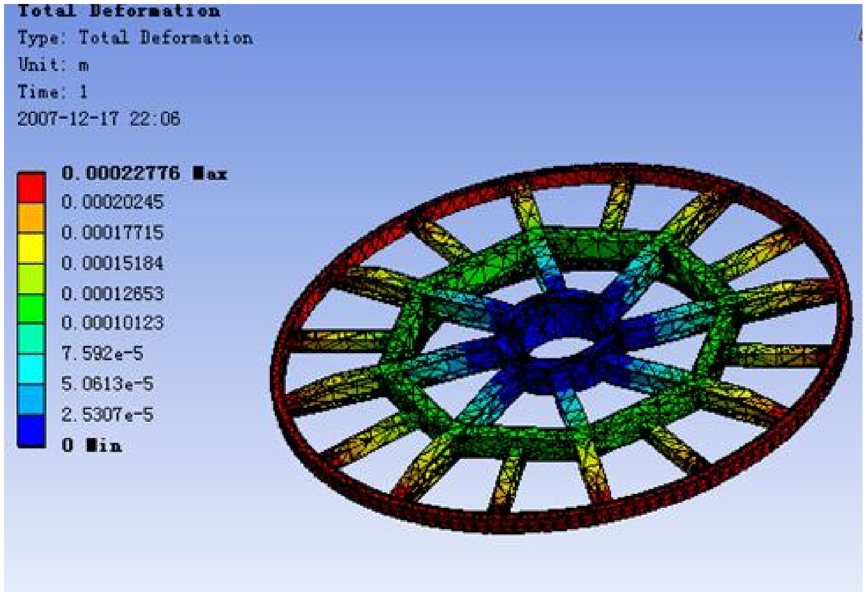

Figure-5 the FEM analysis result of the rotor

In figure-5, only considering act one 20000N.m torque acting on the rotor and the result indicates the deformation of the rotor can not be ignored. In fact, the Arc PMSM is mounted on our experiment bed and would not work at such high torque condition in our experiment. So such design is advised to be used in our experiment motor.

The whole motor is made of 15 stator units, each surrounding an arc of the rotor disc (Fig.1). One stator unit is composed of 9 segments (8 poles) (Fig-6): Each stator unit can be regard as one "small powerful motor" and work respectively. A segment section is shown in Fig-6. Each stator unit is simple fixed on the base by slot and bolt (Fig-7).

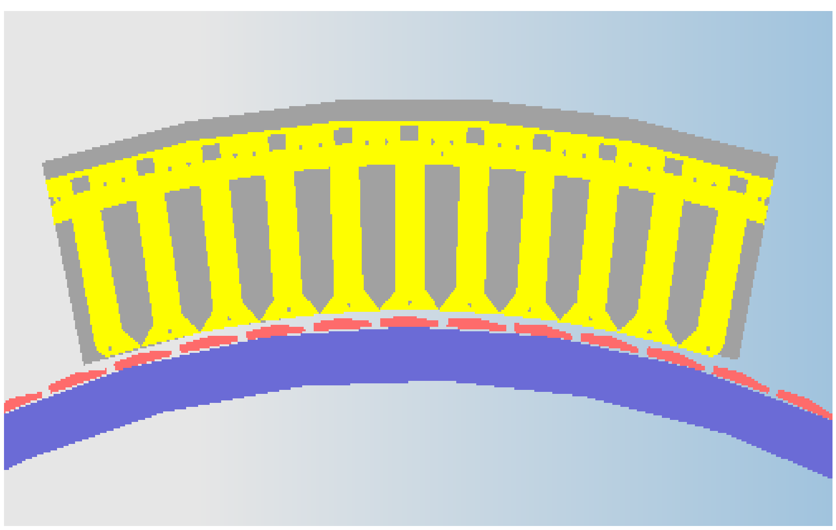

Figure-6 model of one stator unit

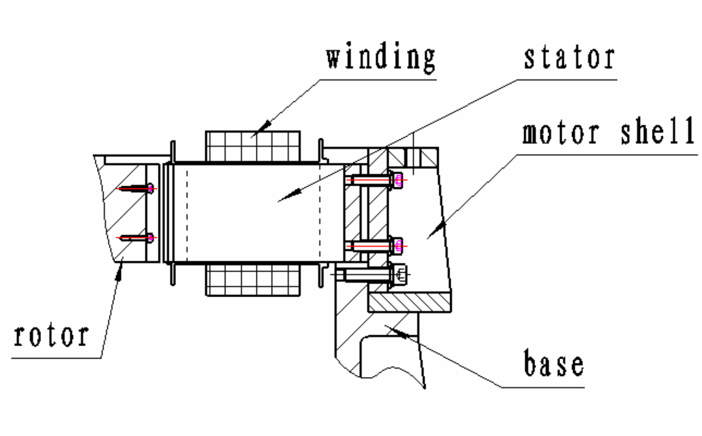

Figure-7 section diagram of the rotor and stator

The same motor principle can be used for both the azimuth drive (AZ) and the altitude drive (AL). The AZ drive is placed at the bottom of telescope and must carry the whole telescope mass. Thus, the AZ torque requirement is very large. While the AL only drive the altitude part of the telescope, which the mass is far lighter than the whole telescope. What's more, the altitude drive speed is far lower than the AZ. In the design for the experiment bed the AZ motor consist of 15 stator units and segmented rotor. Table 1 gives the AZ Arc PMSM Specification.

Arc PMSM Specification	
Specification	**Azimuth Motor**
Rated rms cont. torque(N.m)	12000
Speed Range	10°~1″/s
Acceleration	0.0349rad/s^2
Outer diameter(m)	2.5
Motor Thickness(m)	0.1
Motor poles	120
Air gap (mm)	2.5

Table 1- Arc PMSM Specification

The proposed design, innovative for the Arc motor is characterized by a number of key advantages

1. The air gap (set to 2.5mm) is easily adjusted, unit by unit, during on-site installation.

2. The addition or removal of any stator unit does not result the imbalance of the machine, and no magnetic force is applied between segments.

3. Each stator unit can be regard as one "small powerful motor" and run respectively, although one stator unit is out of work, the whole motor can still run normally.

4. The stator unit can be removed easily because each stator unit is simple fixed on the base. Disassembly can then be carried out without need of specific tools.

3. Motor Torque Ripple

The requirement of a very sharp position control implies a very low torque ripple. Torque ripple exists in most motors, which can be thought to be mainly consisted of cogging toque and reluctance torque. It is very important to know the origin of the torque ripple and control them as low as possible.

3.1 Cogging torque

Cogging torque can be classified as slot cogging and “segment” cogging [2]. Slot cogging is the normal phenomenon that arises from the variation in the tangential force due to the interaction between the magnets and the lamination stacks of the segments. Segment cogging is due to the fact that the motor is not fully populated with winding segments and the magnets will be exposed to no iron areas, which is due to the fact that the magnet segments don't create a perfect curve because of such huge diameter motor. The variation in torque due to segment cogging is stronger than the variations created by the slot cogging. Various techniques have been tried to minimize the cogging, some of which are sloth teeth shaping, magnet skewing and phase staggering of segments, while the segment cogging can be reduced by optimizing the shapes and dimensions of the segment for a defined air gap.

3.2 Reluctance torque

The reluctance torque is associated with the magnetic flux created by the windings, [2] without considering the magnets. In 3-phase motors, this interference appears if the rotor ring suffers from inaccuracies like out-of roundness, eccentricity. As it is impossible to produce a motor with a perfectly round and centered rotor, the reluctance torque is always present on a rotary motor.

3.3 Method

In general, two ways are considered to reduce the torque ripple of the Arc PMSM. One method is from the design of the Arc motor, another is from control system. For some reasons, the project has been postponed and the control method has to be considered after the experiment bad is successfully mounted. The paper mainly discusses the design of the Arc motor

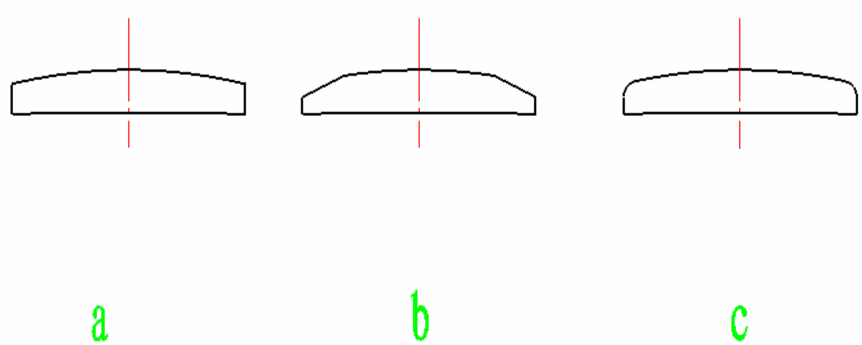

Figure-8 the structure of the permanent magnet

The rotor of the Arc motor is disc-shaped, which is realized in arc segments. 120 Permanent magnets are pasted on the disc. The shape of the permanent magnets is optimized to reduce the cogging torque. Three structures are considered during the design (figure-8). The best choice is considered to be balanced between the performance and the cost of the motor, considering the technique specification and the price of the designed Arc motor, shape c (figure-8) is selected. For larger diameter Arc motor, shape b or more regular structure should be considered a better choice.

In order to reduce the cogging torque, 9 segments(8 poles)in one stator unit is designed, which has been tested to be the best way to get the sine fundamental wave. One stator unit is consisted of 9 silicon steel blades and 2 edge silicon steel blades. The edge silicon steel blade is designed to reduce the edge affect, which is mounted on both side of the stator unit (figure-9) the winding is not coiled on the edge steel blades.

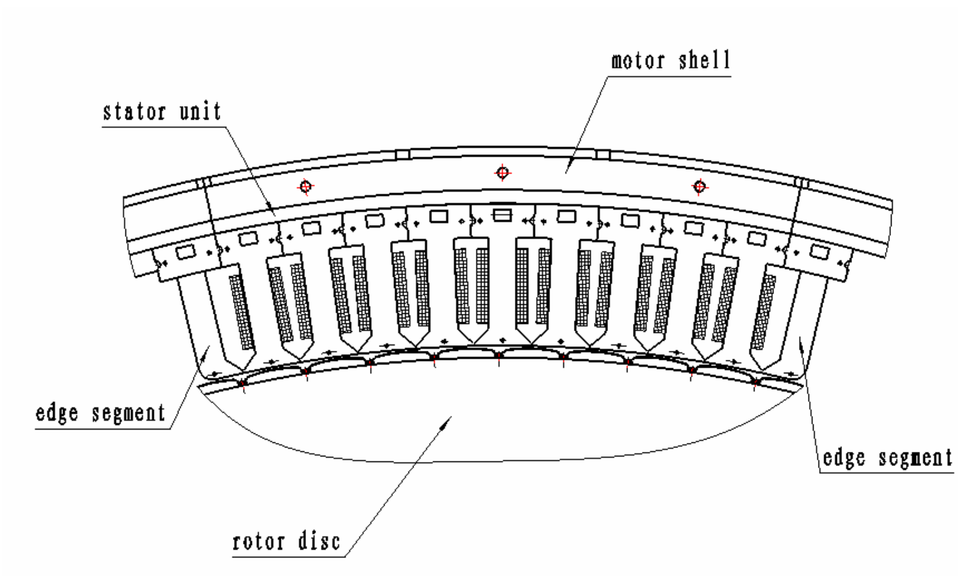

Figure-9 one stator unit structure

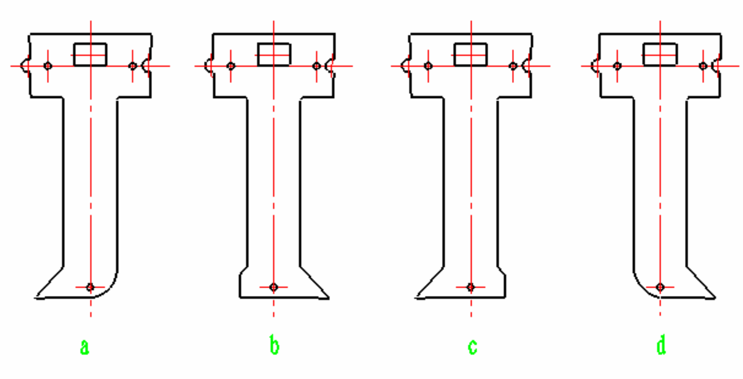

Figure-10 shape of the silicon steel blade

Table 2- the slot data of the silicon steel blade.

h_0	0.5	b_0	0.2
h_1	14.5	b_1	27
h_2	80	b_2	30.73
h_j	30	b_z	25

Another important design idea is adopted to reduce the cogging torque. As normal design, the “pole foot” of the silicon steel blade is full, however, by experiment, we find changing the shape of the silicon steel blade and the overlap them different structure, it can get different fundamental wave. It can be explained that the vector of the fundamental wave can be thought to be composed by two vectors by the cutting part of the silicon steel blade and overlapping them into one armature and more ideal fundamental wave can be achieved by adjusting the shape of the silicon and structure of the armature.

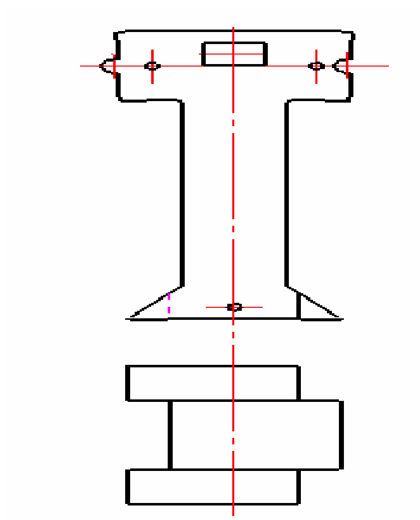
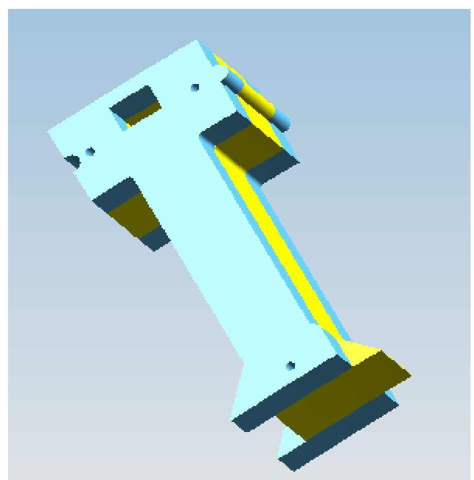

Figure-11 the structure of the segment

4. CONCLUSION

The requirement of a very precise position control of modern telescope implies a very low torque ripple. An Arc PMSM for telescope tracking system should firstly be considered from self design to reduce the torque ripple. The paper discusses some feasible methods to reduce the torque ripple and improve the performance of the motor during the design. For some reasons the project has to be postponed and more research has to be suspended. The Arc PMSM is still being manufactured. So many major tests for this paper have not been finished yet. However, when the Arc motor is mounted and tested normally, an important knowledge of the direct drive technologies for the telescope complex motion system will be collected.

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6. REFERENCE

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