Study on Parametric Calculation of Magnetic Bearing Based on Modelica

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***Abstract*—Magnetic bearing is a typically mechanical and electrical integration product, which is highly integrated technical representative of multi-disciplinary. It is leads to great difficulty in research and development. This complex device involves many fields and has the characteristics of complex structure and many parts. Based on the above , the modeling technology of the simulation system model plays an increasingly important role. In the field of magnetic bearing, the modelica is introduced to multidisciplinary and cross domain joint simulation modeling. It can achieve multidisciplinary integration under the unified modelica platform. This paper describes the characteristics and parameters modelica design and simulation of magnetic bearings based modelica. This research on the design and content of magnetic bearing based on modelica is for joint simulation of the whole system in the future.**

I. Paper Guidelines

A. Introduction

With the development of science and technology, product design is becoming more and more complicated. Magnetic bearing design not only involves multipleareas but also updates frequently. Magnetic bearing is a complex system of mechanical, electronic, hydraulic, control and other disciplines. But, most traditional modeling software supports only a single field of modeling and simulation. Therefore, there are many difficulties in modeling and Simulation of multi domain such as magnetic bearing, for example, the accuracy and efficiency of simulation are not high. Secondly, the performance of the active magnetic bearing is influenced by many parameters such as structural parameters, electromagnetic parameters and control parameters, and the structural design of other auxiliary parts also needs reference.

In view of this situation, this paper proposes a multi domain unified modeling method based on Modelica language to model the parameterization of magnetic bearing. It is convenient for the designer to debug parameters and optimize the structure in the later stage.

B. Introduction of magnetia bearings

Magnetic bearing is studied in this paper, used in centrifugal compressor. Magnetic bearing is used to suspend the rotor in the air by magnetic force, so that there is no mechanical contact between the rotor and stator[1]. The principle is that the magnetic induction line is perpendicular to the magnetic suspension, and the shaft core is parallel to the magnetic suspension line[4].It uses almost no load shaft core to support the magnetic levitation line to form the whole rotor suspended and balanced on the running track.

With the development of modern market, people pay more and more attention to the high efficiency, energy saving, pollution-free and high reliability of products. The magnetic bearing is a relatively late development of non-contact bearings. It has a series of advantages such as high speed, low energy consumption, no mechanical wear, low noise, no pollution, long life and so on.

Magnetic levitation technology has a wide range of applications, involving industrial, civil and military fields. Magnetic levitation products cover high-speed precision spindle, maglev flywheel battery, magnetic levitation artificial heart pump, magnetic levitation train, satellite, long-range missile guidance and attitude control, UPS for military communication, High speed rotor of aero engine, submarine vibration control and transmission noise, tank, armored vehicle power storage, maglev smelting, handling technology, etc. As for maglev technology, magnetic levitation bearing and maglev train are the research hotspots at home and abroad. The most widely used is the magnetic bearing

C. Modelica

Modelica is a modeling language by a Swedish Non-profit Organization Development Association Modelica[2]. It is an object-oriented language suitable for modeling large-scale complex isomerism physical systems, which can be used free.

Modelica as a new modeling language[3], many advanced modeling ideas are well embodied in language. The reason that it can describe the multi domain model is that, from the point of view of energy, it constructs a multi domain coupling model according to the generalized Kirchhoff's law and the law of conservation of energy, so that many fields of physical system are described by mathematical equations. In the generalized Kirchhoff's law, a physical system is regarded as an energy system that is connected by a number of components through a port. The energy transfer between components is described by flow variables and potential variables.

Based on Modelica language modeling, the most prominent feature is declarative modeling. Declarative modeling focuses on the accurate description of physical objects[4]. It focuses on the following two parts: describing the attributes and behaviors of objects. Describing the object itself means using mathematical equations to represent the physical laws of the object itself.The behavior of describing objects is to describe the interaction interfaces between objects and objects. The Modelica model is modeled by equation, and based on physical model. The mathematical description of the Modelica model is differential, algebraic and discrete equations.

D. parametric calculation of magnetic bearing

The main structure of magnetic bearing is divided into two parts: stator and rotor. The stator is composed of electromagnets and coils. The electromagnet is a soft magnetic material. Radial magnetic bearings are most commonly used for silicon steel. It is the same as the rotor material, forming a magnetic circuit. The radial magnetic bearing stator coils are mainly divided into three forms: trapezoidal trough, rectangular groove and circular groove. Different groove types lead to different functions of bearing, and the radial size of trapezoidal groove is small, and the transition is not smooth. The full rate of the circular groove is high and the radial size is large. So a circular groove is chosen. Figure 1 shows the structure diagram of the radial magnetic bearing.

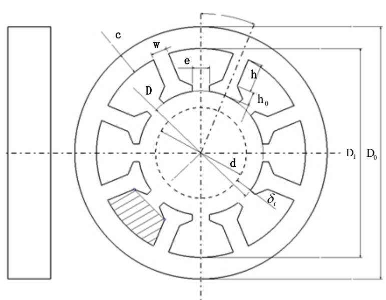

Figure 1 structure diagram of the radial magnetic bearing.

From Figure 1, the main structural parameters of radial magnetic bearings are as follows: rotor diameter D, air gap Sigma _r, stator slot bottom diameter D_1, stator outer diameter D_0, magnetic pole width W, magnetic pole height h and so on. Some parameters affect each other, for example, the magnetic pole spacing e is related to the air gap Sigma _r, and generally takes 10~20 times of the air gap. The rotor outer diameter D is determined according to the rotor parameters of the motor.

The value of air gap Sigma _r is related to D of rotor outer diameter, generally DD = 100, _r=0.2~0.6, d>100, sigma _r=0.6~1.2. According to the geometric relationship, the stator inner diameter D, the groove bottom diameter D_1 and the stator outer diameter D_0 can be obtained.

$$\begin{cases} D = d + 2\sigma_r \\ D_1 = D + 2\ (h + h_0) \\ D_0 = D_1 + 2c \end{cases} \quad (1)$$

When the maximum magnetic density B_max of the electromagnetic parameters and the maximum current I_max of the coil are selected, the following formula can be used to obtain the A_cu of the slot surface of the coil, and the shadow area in Figure 1 is shown.

$$\begin{cases} A_{cu} = \frac{N p \pi d_w^2}{4\lambda} \\ d_w = \sqrt{\frac{I_{max}}{\pi \varepsilon_0}} \\ B_{max} = \mu_0 \frac{n I_{max}}{(2\sigma_r)} \end{cases} \quad (2)$$

Where lambda is the trough full rate, the general value is at 0.5~0.7. D_w is the diameter of the coil. ε _0 is the sectional area and current coefficient, which is usually found in the electrician's manual. Synthetically obtain:

$$A_{cu} = \frac{B_{max} * \sigma_r}{(2 * \lambda * \mu_0 * \varepsilon_0)} \quad (3)$$

It can be seen from the formula that the area of the coil slot will also be determined after the determination of the air gap Sigma _r and the maximum magnetic density B_max. According to the geometric relation

$$A_{cu} = \alpha * h * (D_1 - h) - h * w \quad (4)$$

The height of the magnetic pole h can be obtained. In general, the magnetic pole height is h_0= (0.1-0.3) h, and the magnetic pole width W is determined by the arc length of the pole shoe (l= PI *D/Np E). W= (0.5~0.8) l. Yoke width c=w,The maximum bearing capacity of a pair of magnetic poles

$$F_{max} = \frac{B_{max}^2 * A_a * \cos\alpha}{\mu_0} \quad (5)$$

Based on the above theory, Modelica language is used for modeling and simulation. Parametric modeling can be realized by using the method of formula modeling. It is convenient to adjust and analyze the later parameter calculation. Using the core formula to model the code as follows:

```
model ModelD0
  import Modelica.SIunits;
  Real D;
  Real L;
  Real A;
  Real Alpha;
  Real e;
  Real AW;
  Real h;
  Real D1;
  Real D0;
  Real D2;
  Real h0;
  Real c;
  Real t;
  parameter Real N = 8;
  parameter Real s = 0.005;
  parameter Real FM = 200;
  parameter Real u0 = 4 * Modelica.Constants.pi * 1e-7;
  parameter Real tc = 0.5;
  parameter Real B = 1;
  parameter Real x = 0.5;
  parameter Real z = 0.75;
equation
  D = L;
  L = (e * N - 2 * Modelica.Constants.pi * s + sqrt(A)) / (2 * Modelica.Constants.pi);
  A = ((2 * Modelica.Constants.pi * s - e * N) * (2 * Modelica.Constants.pi * s - e * N) + 4 * Modelica.Constants.pi * N * FM * u0) / (tc * B * B * cos(Alpha));
  e = 10 * s;
  Alpha = Modelica.Constants.pi / N;
  AW = Alpha * h * (D1 - h) - h * t;
  D1 = D2 + 2 * (h + h0);
  h0 = 0.1 * h;
  AW = (2 * B * s) / (4 * x * u0 * z);
  D0 = D1 + 2 * c;
  c = t;
  t * c = 0.5;
  D2 = D + 2 * s;
end ModelD0;
```

Figure 2 Using formula to model code.

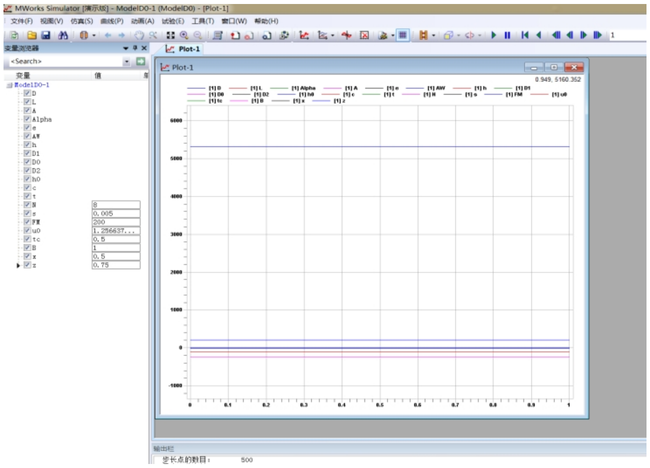

Figure 3 Simulation results

E. Conclusion

The structure of active magnetic bearing is complex, and its performance is influenced by structural parameters, electromagnetic parameters and control parameters, and the design cycle is long. Modelica is a widely accepted multi-domain modeling language. It has many similarities with the C language and is easy to use. In the field of multi domain modeling, the difficulty of modeling is greatly reduced. Parameterized design method, using Modelica language modeling, does not need to be restricted by fields and tools. It greatly improves design efficiency and saves cost. It is the assembly of magnetic bearing system integration has important significance.

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