Vol-05 Issues 06, June-2021 ISSN: 2456-9348
Impact Factor: 5.004

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International Journal of Engineering Technology Research & Management

IMPROVE QUALITY CONTROLLING FOR TWO DEGREES OF FREEDOM ACTIVE MAGNETIC BEARING WITH ADAPTIVE FUZZY CONTROLLER

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ABSTRACT

Magnetic Bearing is the kind of high-tech products and environmentally friendly. Advantages are rotor non-contact to the stator helped enhancement the engine rotation speed, the engine can help working in special environments where normal bearings could not working. To magnetic bearing active well in all modes of working, the problem is very important controller. However, now the controller for the magnetic bearing of low quality: Non adapts, non steady, control signals are not blocked... So, the paper offers solutions to improve quality controlling for two degrees of freedom active magnetic bearing with adaptive fuzzy controller.

Keywords:

Magnetic bearing, adaptive fuzzy control, control for two degrees of freedom active magnetic bearing

INTRODUCTION

Magnetic bearing is a type of bearing that is capable of non-contact lifting of moving shafts based on the force of a magnetic field. Because the shaft and the stationary part are not in contact with each other, the magnetic bearing is currently considered as a research direction that can bring many breakthroughs to the manufacturing industries based on its outstanding advantages that the mechanical bearing does not have as:

- There is no wear and tear when operating;
- Increased the efficiency of engine based on frictionless motion;
- Environmentally friendly: No lubricating parts;
- Ability to work at high speed;
- The ability to eliminate vibrations in motion;
- Ability to work in harsh environments.

However the disadvantages of magnetic bearing are: High cost and a requirement for controlling of magnetic bearing.

There are many types of magnetic bearings: Active magnetic bearing (AMB), passive magnetic bearing (PMB), Sctive Magnetic Bearing (SMB)… The paper researched to control for two degrees of freedom active magnetic bearing with the following advantages as: good dynamic characteristics and adjustable lifting force.

Basic working principle of magnetic bearing: electromagnetic executive structure

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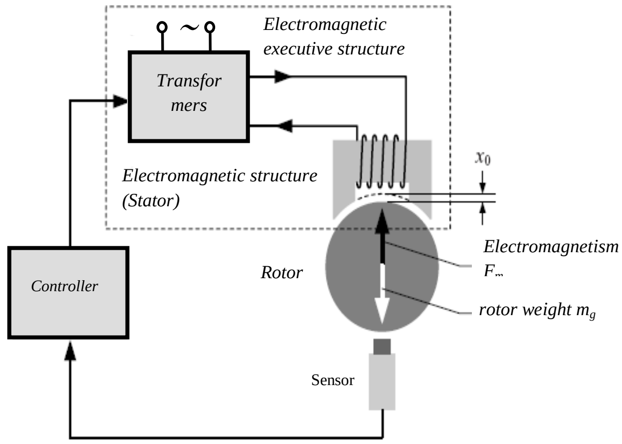

Figure 1.1: Basic structure of one degrees of freedom AMB

A rotor is freely suspended at a predetermined distance x_0 from the electromagnetic device. A non-contact position sensor measures the error between the desired position x_0 from the real position of the rotor x and provides this information to the controller. The controller maintains the position of the rotor at the desired value. This not only satisfies the balance between the resulting gravity F_m and mg_a *(the weight of rotor multiplied by the acceleration of gravity)* at the stationary working point but also achieves chemical stability. It is the the most important quality of the controlling process. Finally, the controller sends a position controlling signal to a power amplifier. From this power amplifier, the signal is converted to a current that is sent to the coil of the electromagnetic device and then the desired electromagnetic force F_m is generated.

Basically, the controlling law works the way as: When the rotor is moved down, the sensor will provide a displacement signal to increase the controlling current. The electromagnetic force increases and pull the rotor returned to its nominal positionFor large scale applications, grid-connected photovoltaic system is used. In some remote areas or islands, the electrical grid has not reached yet, so the photovoltaic system used to provide electricity for on-site loads prevails.

MATHEMATICAL DESCRIPTION OF TWO DEGREES OF FREEDOM ACTIVE MAGNETIC BEARING

To design a controller for the object needs to build a descriptive mathematical model for the object.

The building a mathematical model for magnetic bearings needs to analyze and calculate for magnetic flux, reluctance, inductance, flux density, accumulated energy and magnetic force in the x and y displacement directions of the axis.

From the two equations representing the radial force through magnetic induction and current

$$F = \frac{S}{2\mu_0}(B_+^2 - B_-^2) \qquad (2.1)$$

$$F_1 = \frac{L_0}{2g}\cos\left(\frac{\pi}{8}\right)i^2 \qquad (2.2)$$

To control the radial force, the current or magnetic induction must be controlled. Determining the current has much more advantages than determining the magnetic induction. Because:

- Lower cost and less complicated determination, the sensors can be installed in the available controller.
- Determining the flux is more complex and expensive.

Expressing the radial force as follows:

$$F_1 = \frac{k_i'}{4}i_1^2 \qquad (2.3)$$

$$F_3 = \frac{k_i^{'}}{4} i_3^2 \qquad (2.4)$$

With:

$$k_i^{'} = \frac{2L_0 \cos(\pi/8)}{g}$$

The above relationship is nonlinear. Relationship between radial force and current is linearization. The currents are divided into two parts: the polarizing current I_b and the current that controls the magnetic force i_b

$$i_1 = I_b + i_b \qquad (2.5)$$

$$i_3 = I_b - i_b \qquad (2.6)$$

With $i_1 > 0$ and $i_3 > 0$

Radial force acts on the axis in the x direction:

$$F_x = F_1 - F_3 \qquad (2.7)$$

Therefore:

$$F_x = k_i' I_b i_b \qquad (2.8)$$

When I_b is constant, F_x is proportional to i_b, the radial force F_x and the controlling current of the force i_b are linear.

With $k_i = k_i^{'} I_b$: the force - current factor. We have:

$$F_x = k_i\, i_b \qquad (2.9)$$

With $k_i = k_i' I_b$ and k_i are referenced as a force-current factor.

The radial force can be drawn for the magnetic bearing under radial load as a function of the current i_b current and the X-axis displacement of the rotor:

$$F_x = k_i i_{bx} + k_x x \qquad (2.10)$$

With: i_{bx} is the current that controls force in the X-direction.

The force factor – the current and the force – the displacement is calculated as follows:

$$k_i = 2L_0 \left(\frac{I_b}{g}\right) \cos\left(\frac{\pi}{8}\right) \qquad (2.11)$$

$$k_x = 2L_0 \left(\frac{I_b}{g}\right)^2 \cos\left(\frac{\pi}{8}\right) \qquad (2.12)$$

Through analysis, we have a diagram of the controlling structure of the magnetic bearing as follows:

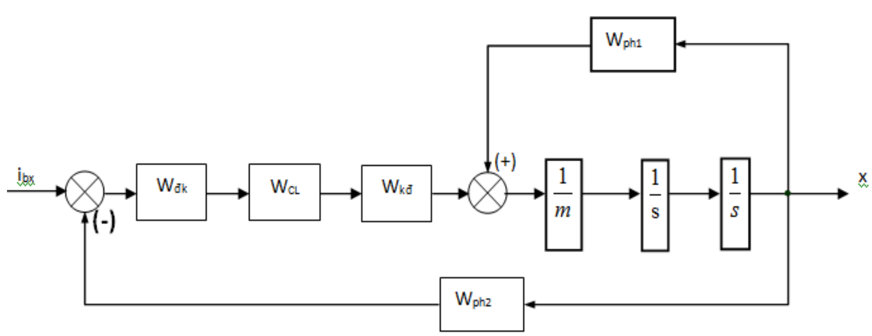

Figure 2.1: The diagram of the controlling structure of magnetic bearing

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The diagram and short transfer function of magnetic bearing:

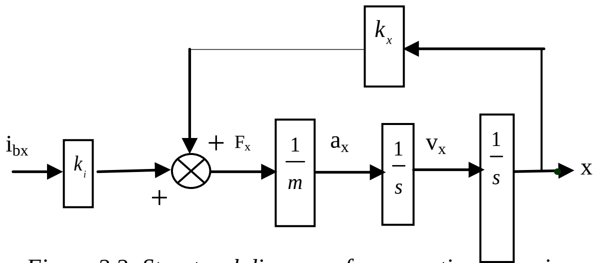

Figure 2.2: Structural diagram of a magnetic suspension system using magnetic energy in one direction

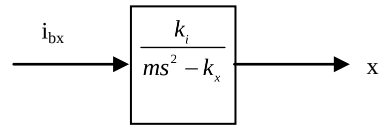

Figure 2.3: Simplified structure diagram

The transmission function of magnetic bearings is unstable, so it must be stabilized by negative feedback or correction

DESIGNING ADAPTIVE FUZZY CONTROLLER TO IMPROVE QUALITY CONTROLLING FOR TWO DEGREES OF FREEDOM MAGNETIC BEARING

The adaptive fuzzy controller was selected for its advantages as:

- The mathematical model of the research object is nonlinear so fuzzy logic is selected.
- Although Controlling with the PID controller has the quite good result, applying fuzzy algorithm to alignment will give better results when the object's parameters change in a wide range.

The paper chose the design method of adaptive fuzzy controller according to the linear transmission model and applied Lyapunov method to adaptive adjustment for output gain.

Consider the object described by the equation:

$$\frac{dy}{dt} = -ay + bu \qquad (3.1)$$

The sample model has the equation:

$$\frac{dy_m}{dt} = -a_m y_m + b_m u_c \qquad (3.2)$$

Control signal:

$$u = K_1 u_c - K_2 y_c \qquad (3.3)$$

With error:

$$\varepsilon = y_m - y \qquad (3.4)$$

We need to adjust K_1 and K_2 so that $\varepsilon \rightarrow 0$.

The structure of the adaptive fuzzy controller according to the linear transmission model is as figure 3.1

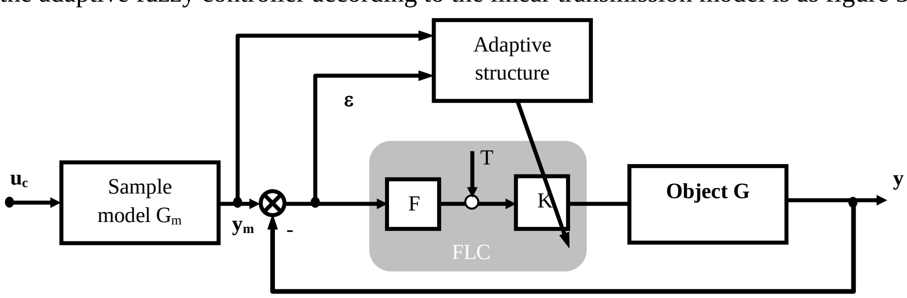

Figure 3.1: FMRAFC adjusted output amplification gain

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With the adaptive law according to Lyapunov considers for one variable parameter:

$$\frac{dK}{dt} = yu_c\varepsilon \qquad (3.5)$$

Because u_c in (3.5) is y_m, we get the adaptive adjustment law for the output amplification gain K according to Lyapunov:

$$K = \gamma y_m \varepsilon \qquad (3.6)$$

Inside:

+ γ: the convergence factor of the adaptation algorithm.

+ u_c and y_m: the input / output signal of sample model.

Simulation on Matlab - Simulink:

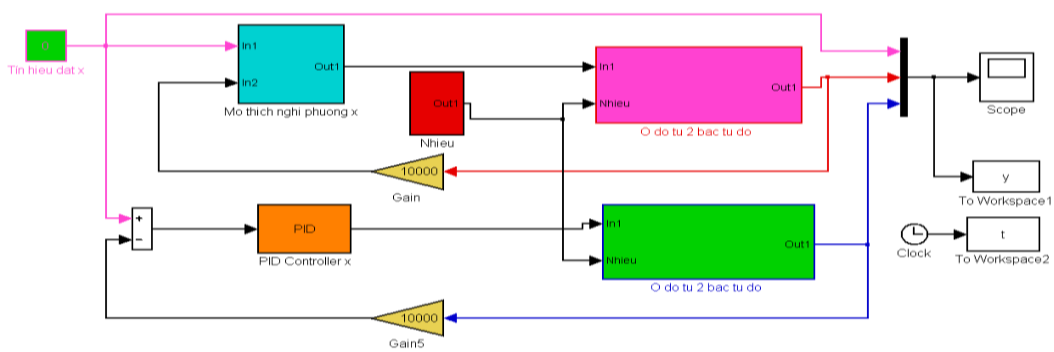

Figure 3.2: The diagram of simulation according to the adaptive method and PID method

Inside the adaptive fuzzy controller according to the sample model has the structure:

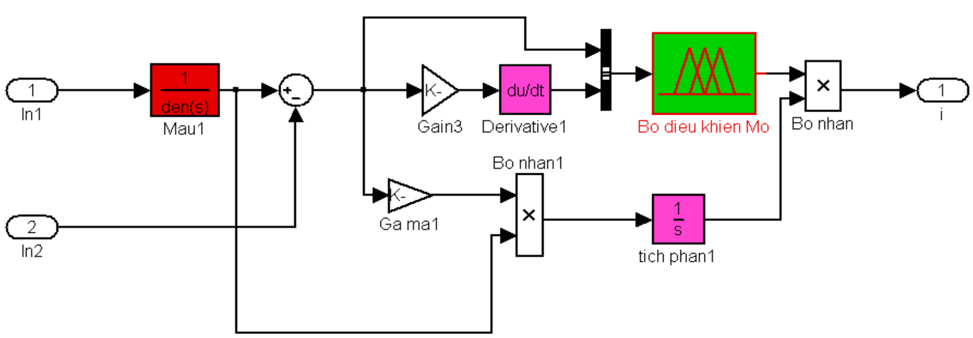

Figure 3.3: Simulation diagram structure of the adaptive fuzzy controller according to the linear transmission model

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Simulation results and the comparison of adaptive fuzzy controller with PID controller

+ In case of no impact of interference:

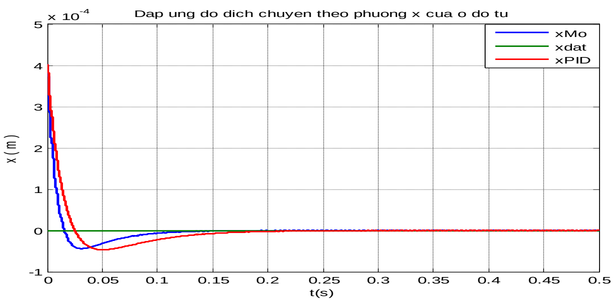

Figure 3.4: Response along the x-axis of the bearing from eccentricity 0,4mm

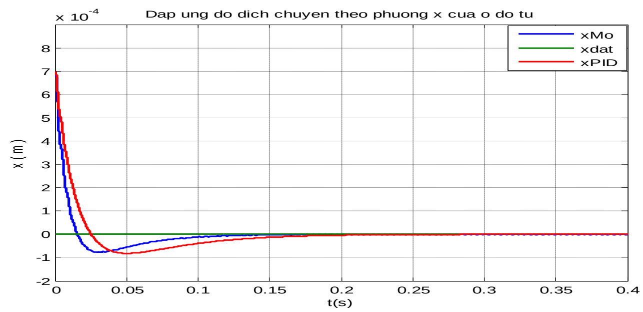

Figure 3.5: Response along the x-axis of the bearing from eccentricity 0,7mm

+ In case of the impact of interference:

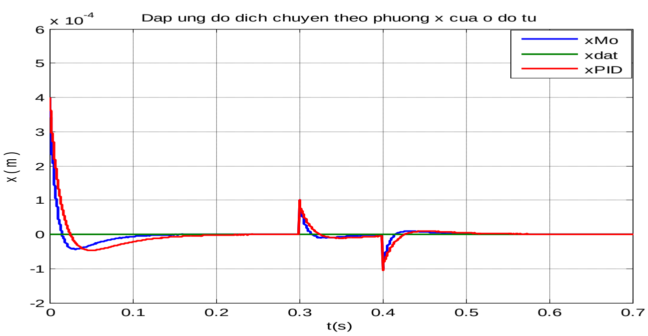

Figure 3.6: Response along the x-axis of the bearing from eccentricity 0,4mm

The simulation results shown that the adaptive fuzzy controller has improved quality compared to the PID controller (over-adjustment and transient time is shorter). This shown the correctness of the control algorithm and the adaptive fuzzy control method shown the possibility of applying modern control methods to magnetic bearings.

CONCLUSION

The paper presented some overview of magnetic bearings and mathematical description for two degrees of freedom active magnetic bearings. The paper gave a solution to improve the control quality of two degrees of freedom bearing control with an adaptive fuzzy controller. Results simulated by Matlab-simulink and experimented on real equipment (in the laboratory) showed better control quality than the PID controller (even when there is impact interference).

ACKNOWLEDGEMENT

This research was supported by a grant for the university research from the TNUT (Thai Nguyen University of Technology). We thank our colleagues from the TNUT who provided insightand expertise that greatly assisted the research.

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