Direct Thrust Control by Direct Gap Flux Measurements for Linear Induction Motors

Jun Wu, Wenwu ZHou, ZHiqiang Long & Wensen CHang
Mechatronics & Automation School
National University of Defense Technology
Changsha, Hunan, China, 410073
E-mail: junwu@tom.com

ABSTRACT : In urban maglev system, linear induction motors (LSMs) provide propulsions. Because of edge effects, it is hard to obtain accurate observers for flux and thrust in direct thrust control system. To overcome the shortage, this paper has proposed a simple method to set coils to measure the gap flux directly since the gap is large enough to mount coils among surface of the primary core. Based on the measurements, a kind of direct thrust control has also been put up to enhance the propulsion. Simulations are showed in the end.

1 INTRODUCTION

With the development of science and economy, urban maglev transportation may be adopted in more and more cities for its outstanding advantages. In the urban maglev system, LIMs with short primary provide the thrust since they have simple structure and are easy to maintain. Because they are generally regarded as a kind of induction motors whose stator are stretched into a line, control models always refer to those of cage rotor induction machines. Because of edge effects at both longitude and transverse sides of the primary, some modifications have to be done based on the traditional model of induction motors. Furthermore, since models parameters are changing for temperature variation and geometrical configuration of reaction rails especially when LIMs are in dynamic states, the assessments of primary flux and thrust are hard to do. Also these evaluations are too complex to be realized in simple digital controllers[2]. This paper introduces a simple measurement and assessment for gap flux in direct thrust control. It is simulated to demonstrate effectiveness in the propulsion in the end.

2 DESIGN OF COILS AND GAP FLUX APPROXIMATION

For rotary induction motor, because there is less air gap between stator and rotor, it is hard to mount a sensor to measure gap flux directly. Hence, flux observers are always used in vector control and direct torque control. These methods, which have developed for long times, are effective for torque controll. Compared with these rotor motors, control methods for LIMs are less researched. Different from round and symmetry structure of rotary motor, LIMs have much more complex gap flux for the edge effects and the flux models are different from those of induction motors too. Figure 1 shows the distribution of gap flux along the primary which is a kind of exponent curve related with the primary speed. In figure 1, L is the length of the primary[2].

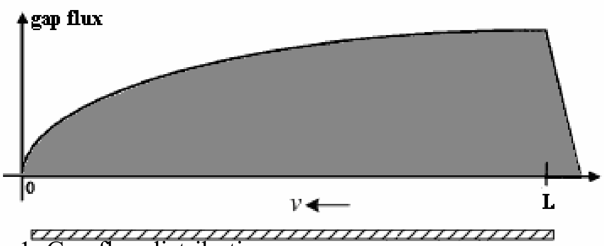

Figure 1: Gap flux distribution

Although gap flux distributes complexly, there is still a way to overcome the obstacles. Since the gap distance between the primary and the secondary are much larger than the rotary motor, it is easy to mount several measure coils along the primary core for flux detection. In figure 2, three coils have been embedded in the middle of each winds. These coils are placed at three points: the two edge sides and the middle point. With the measure coils, gap flux can be measured directly nevertheless the primary is moving or still. Each coil connects to the processing circuits mounted besides the edge of LIMs. Details can be seen in figure 2, figure 3 and figure 4.

The voltage induced by the coils is given as

$$U_a = -N\frac{d\phi}{dt} \tag{1}$$

Where ϕ is the gap flux;

N is the number of turns;

U_a is the output voltage.

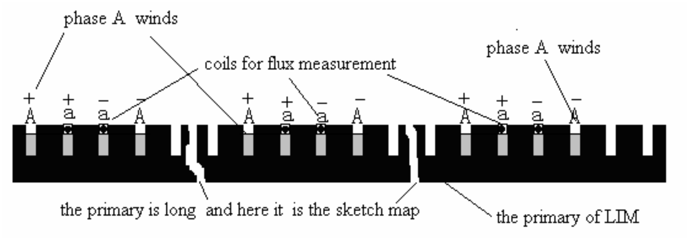

Figure 2: Mounting map for the simple measurement

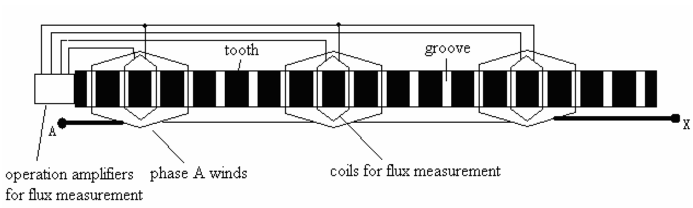

Figure 3: Lines connect coils to circuits

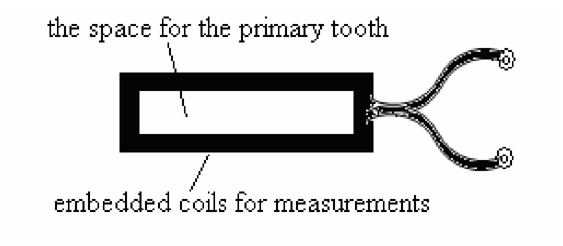

Figure 4: Structures of coils

Integration of equation (1) can yield the gap flux[1], so circuits are designed as the following. Each circuit has their own coils.

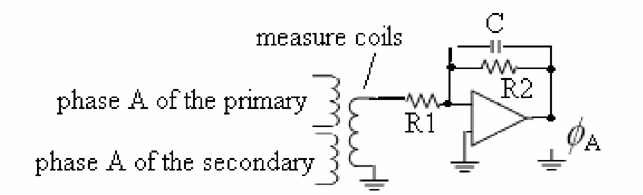

Figure 5: Integration circuits for flux

As figure 1 shows, the profile of flux is an exponent function related with the primary speed. Based on the three point fluxes which are directly measured, point a, b and c, the real distribution of gap flux can be approximated as a polygon from o to a, b, c, L and fl, fc, fb, fa, o. The area covered by exponent curve can be approximated as that covered by several lines. That is,

$$S_{curve} \approx S_1 + S_2 + S_3 + S_4 \tag{2}$$

Where S_1 is the area of triangle 1;

S_2 is the area of trapezoid 2;

S_3 is the area of trapezoid 3;

S_4 is the area of rectangle 4.

This evaluation is simple and easy to be realized as it showed in figure 6. By this method, the whole flux can be calculated with fewer errors.

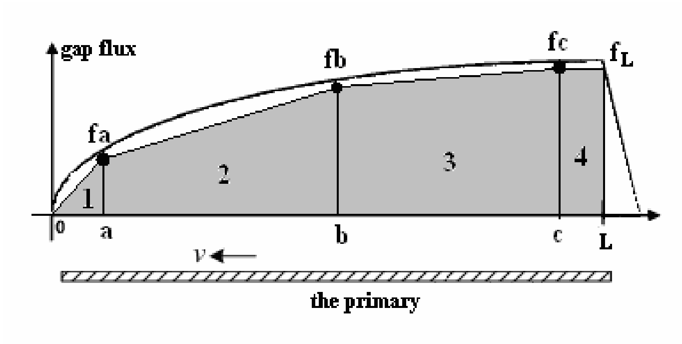

Figure 6: Gap flux approximation

3 DIRECT THRUST CONTROL AND SIMULATIONS

In figure 8, direct flux measurement replaces flux observer in direct thrust control method [3],[4].

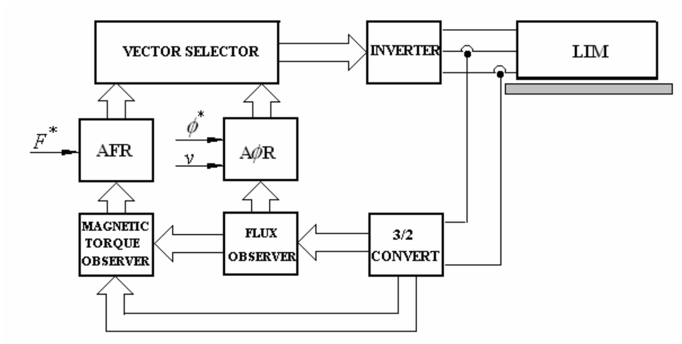

Figure 7: The ordinary control method

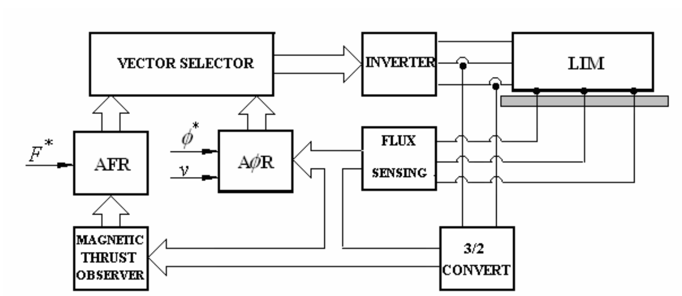

Figure 8: The proposed control method

Based on the two methods, simulation has been done for comparison. Figure 9 is the efficiency comparison. It shows that the proposed method can increase the efficiency greatly. Figure 10 is the thrust comparison. It shows that ripple of the proposed is larger than that of ordinary. Figure 11 is the magnetic current comparison. It shows that magnetic current in the proposed method is lower than the ordinary.

According to these comparisons, some analysis can be done. Because the gap flux can be directly measured, the values can approximate the real distribution which can induce a high efficiency. But in the ordinary method the gap flux is regarded as a modified constant distribution. It may induce more errors especially when the primary is moving. On the other side, the proposed method needs lower magnetic current at the same time. The simulation has testified it. Since the flux approximations depend on the sensing values, if there are many disturbs during the processing circuits, there will induce some larger ripples. Considering that the vehicles possess large inertias, the high frequency ripples will be filtered and will not impact the velocity of whole train.

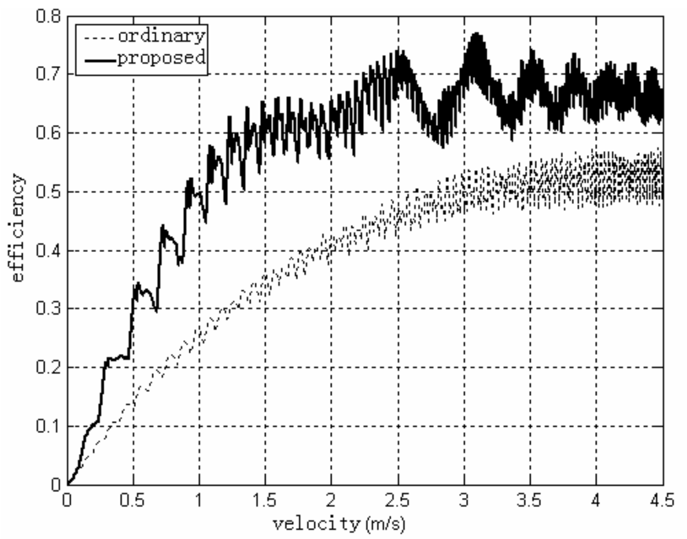

Figure 9: Efficiency comparison between proposed and ordinary method

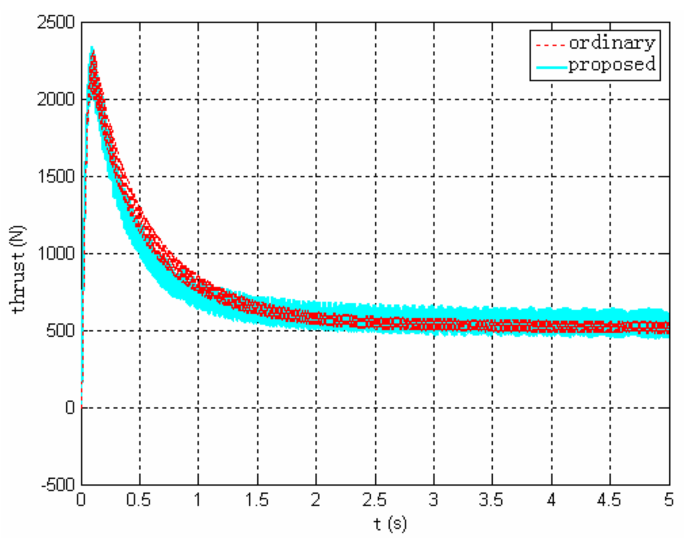

Figure 10: Efficiency comparison between proposed and ordinary method

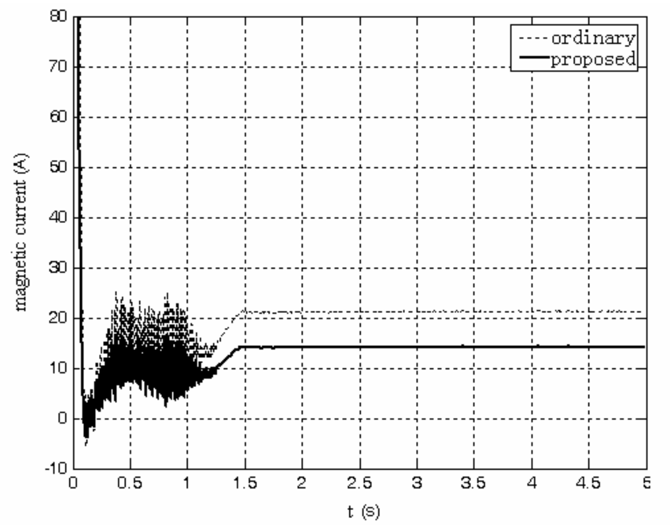

Figure 11: Magnetic current comparison between proposed and ordinary method

4 CONCLUSIONS

Attributed by end effects, the gap flux distributions of LIMs are quite different from the rotor induction motor. The observation model of flux is difficult to be realized for LIMs. Considering that the gap distance is larger enough to mount gap flux sensor, a kind of coils has been proposed to measure flux and simple approximation in direct thrust control is testified by simulation. It shows that the method can improve efficiency and decrease the magnetic current. It will be useful for energy saving in maglev train system. Further researches and applications will be continued in the next step.

5 REFERENCES

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