3D Electromagnetic Analysis of Tubular Permanent Magnet Linear Launcher

(Tue-Af-Po2.06)

Hao Chen[1], Kun Liang[1], Rui Nie[1], Xiao Liu[1]

1. China University of Mining and Technology, Xuzhou 221116, China.

CUMT

Introduction

A short stroke and large thrust axial magnetized tubular permanent magnet linear launcher (TPMLL) is presented in this paper. To achieve greatest thrust, sensitivity analyses on some parameters are conducted with the 3D finite element (FE) model of the TPMLL. Then its 2D FE model is established according to the final geometry dimensions for precise electromagnetic analyses. The electromagnetic thrusts calculated by 2D and 3D finite element method (FEM) and got from prototype test are compared. Moreover, the prototype static and dynamic tests are conducted to verify the 2D and 3D electromagnetic analysis. The combined simulation between the control system and the 3D FE model of the TPMLL is built to verify the correctness of established FE models.

Structure and FE Modeling

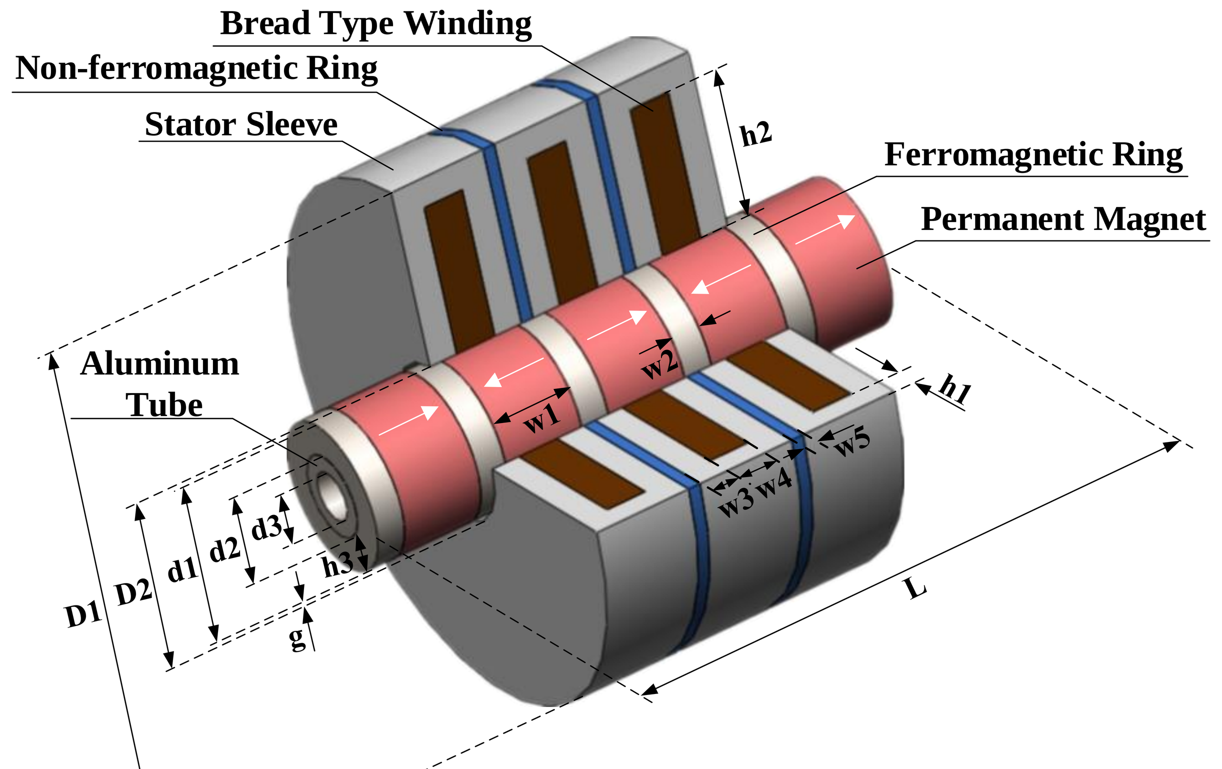

Fig.1. 3D geometric structure of TPMLL

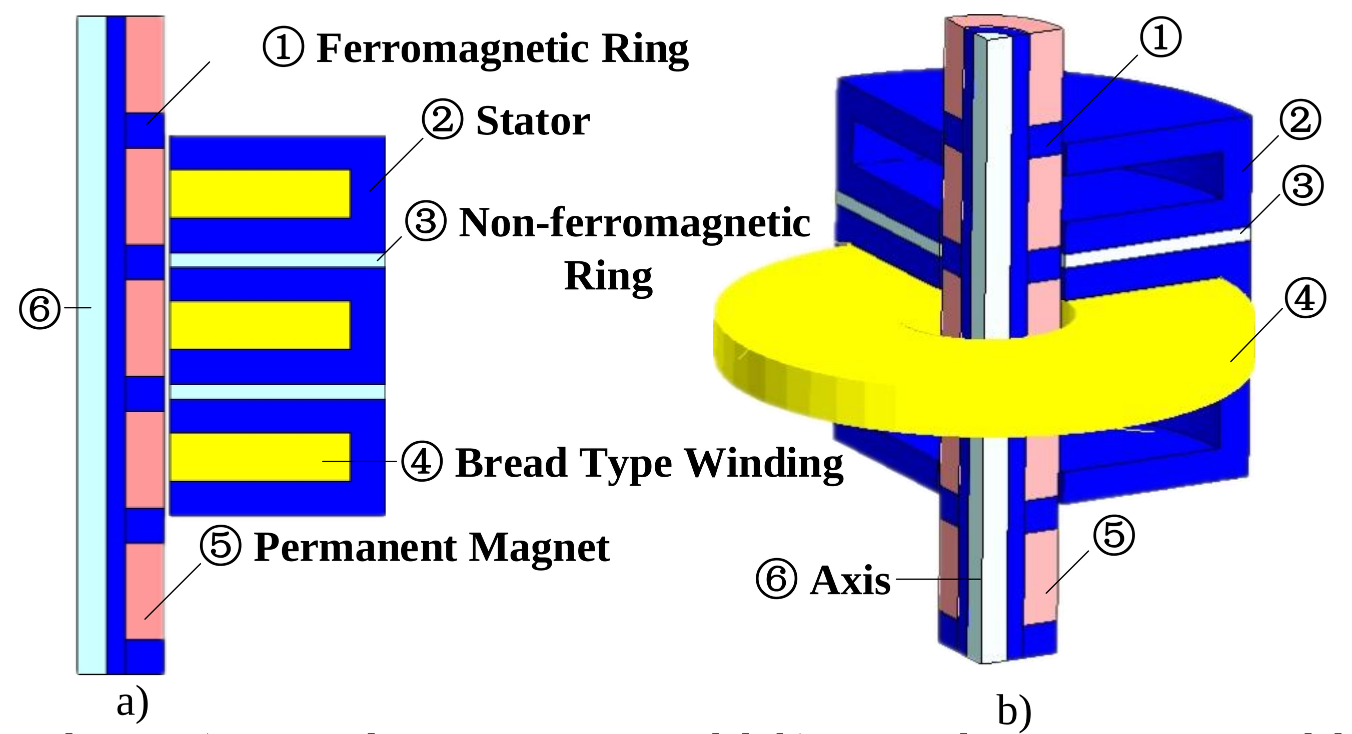

Fig.2. EF Simulation: a) 2D axial symmetric FE model; b) 3D axial symmetric FE model

Combined Simulation

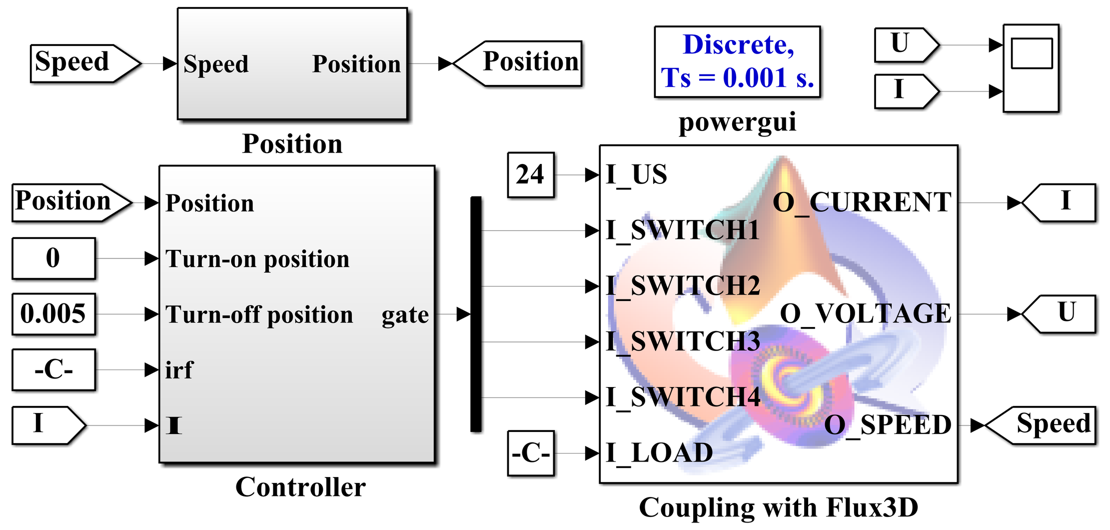

Fig.7. Combined simulation between Simulink and FLUX

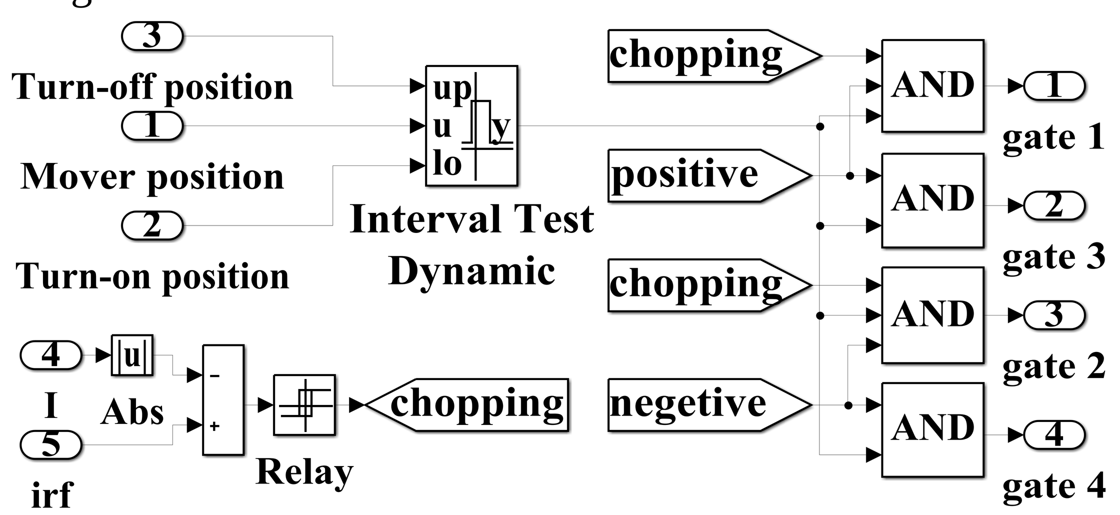

Fig.8. Controller module

Dimensions

According to the parameters in Fig. 1, the initial and final geometry dimensions after sensitivity analysis of TPMLL are shown in Table I.

Table I Initial and final geometry dimensions of TPMLL

Name	Parameters	Initial Dimensions	Final Dimensions
Stator outer diameter	D1	63.0 mm	63.0 mm
Stator inner diameter	D2	17.0 mm	19.0 mm
Ferromagnetic ring outer diameter	d1	16.0 mm	18.0 mm
Ferromagnetic ring inner diameter	d2	10.0 mm	10.0 mm
Aluminum tube diameter	d3	6.0 mm	6.0 mm
Stator yoke thickness	H1	3.0 mm	3.5 mm
Stator slot depth	H2	20.0 mm	18.5 mm
Permanent magnet thickness	H3	3.0 mm	4.0 mm
Permanent magnet width	w1	7.0 mm	10.0 mm
Ferromagnetic ring width	w2	6.5 mm	3.5 mm
Stator tooth width	w3	3.5 mm	3.5 mm
Stator slot width	w4	5.0 mm	5.0 mm
Non-ferromagnetic ring width	w5	1.5 mm	1.5 mm
Air gap thickness	g	1.2 mm	0.5 mm
Mover laminated thickness	L	67.5 mm	67.5 mm

Sensitivity Analyses

To achieve large electromagnetic thrust of TPMLL, the sensitivity analyses on air gap thickness, permanent magnet thickness, permanent magnet width, stator yoke thickness are conducted based on the 3D FE models of the TPMLL.

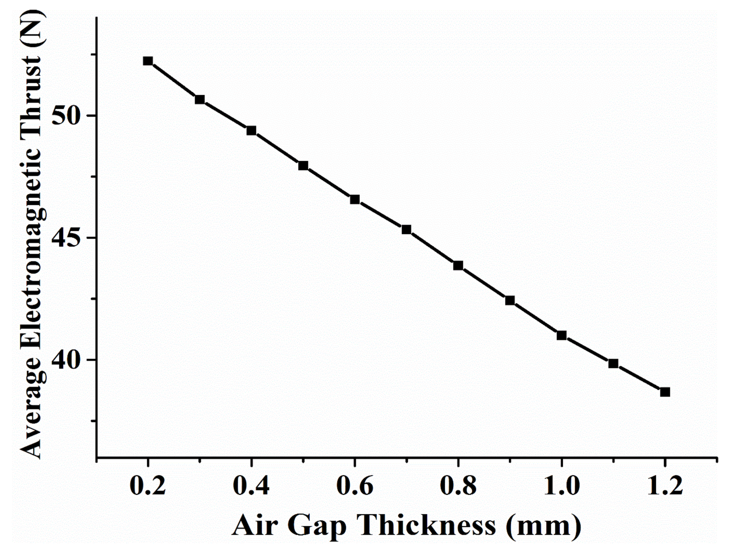

Fig.3. Average thrust in different air gap thickness

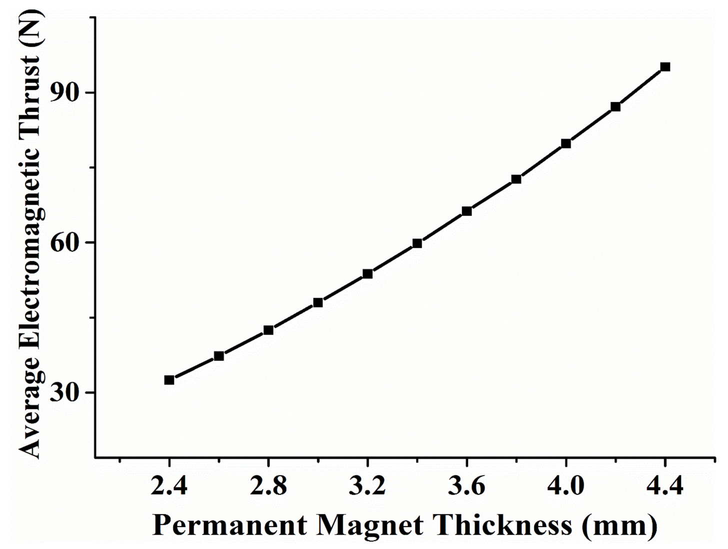

Fig.4. Average thrust in different permanent magnet thickness

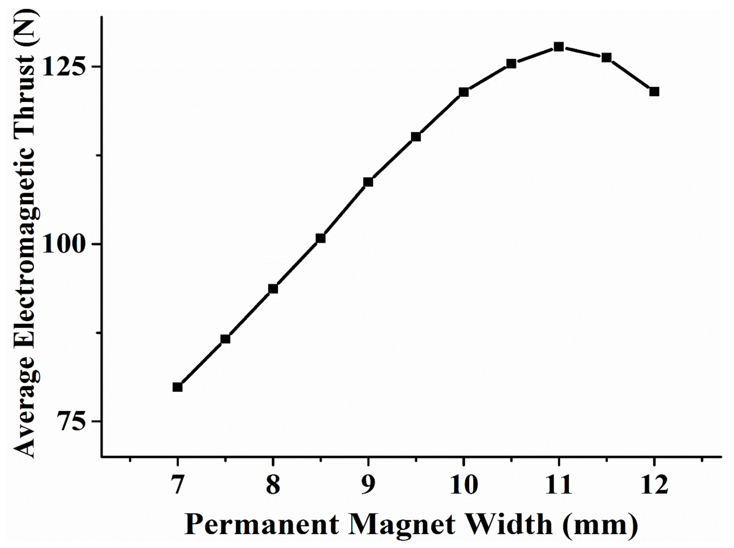

Fig.5. Average thrust in different permanent magnet width

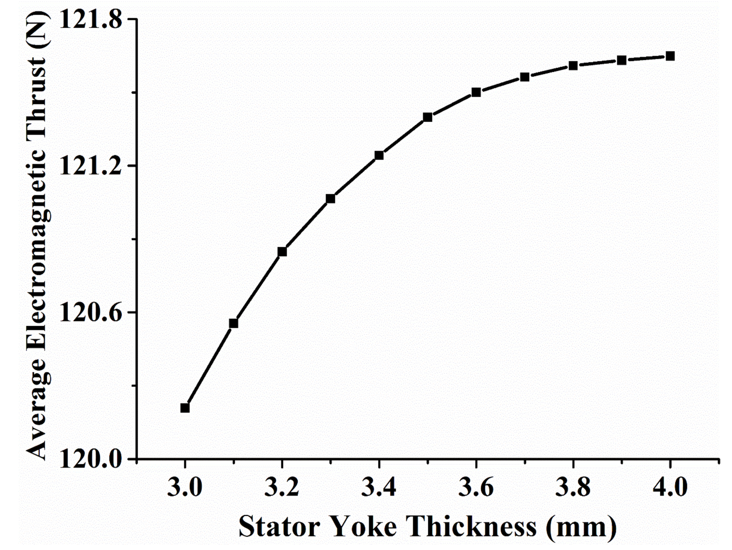

Fig.6. Average thrust in different stator yoke thickness

Experimental Verification

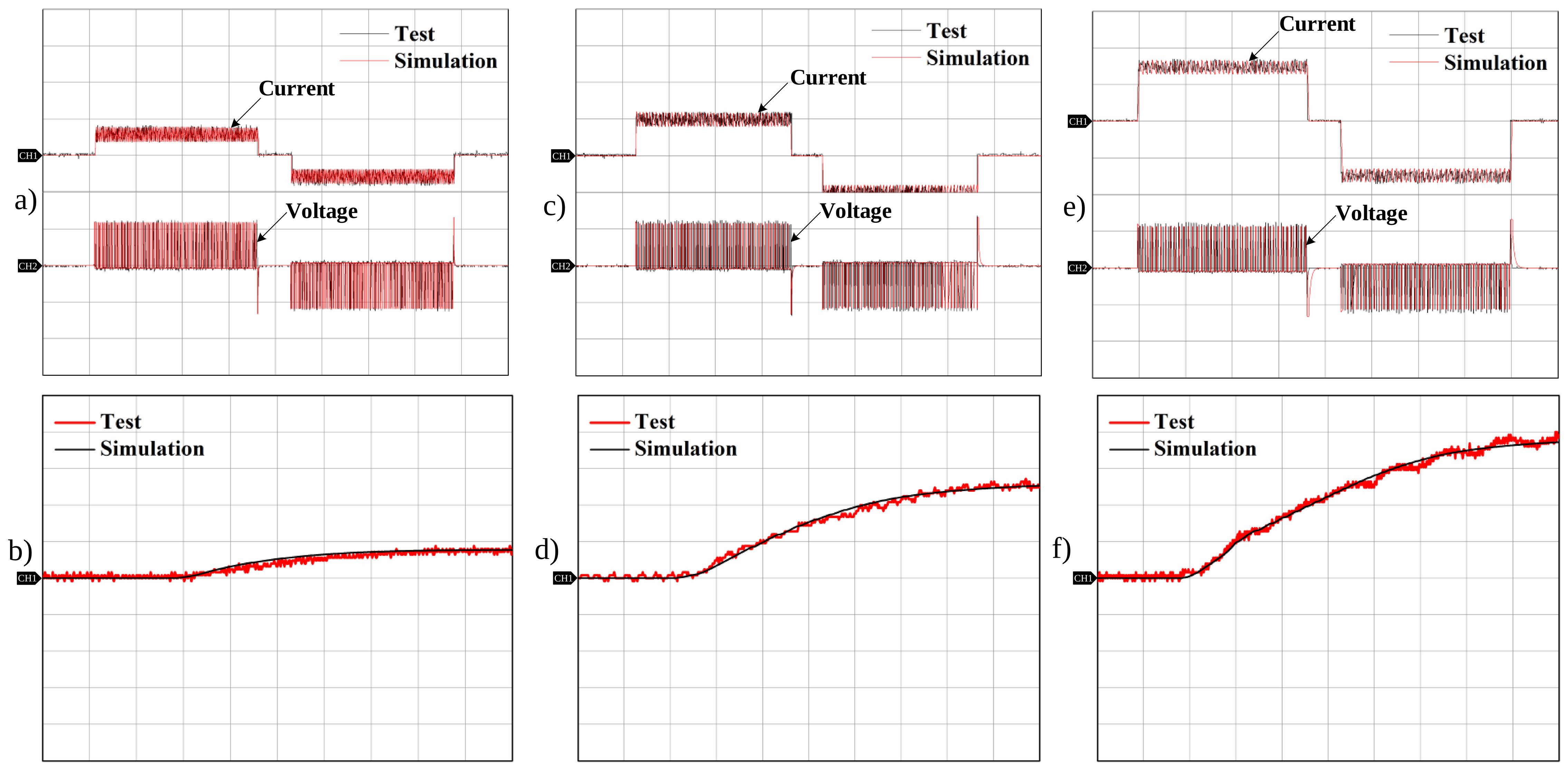

Fig.11. Experimental and simulation curves: a) , c), e) are voltage and current curves respectively at 2Hz, 6Hz, 10Hz; b) , d), f) are the frequency curves respectively at 2Hz, 6Hz, 10Hz.

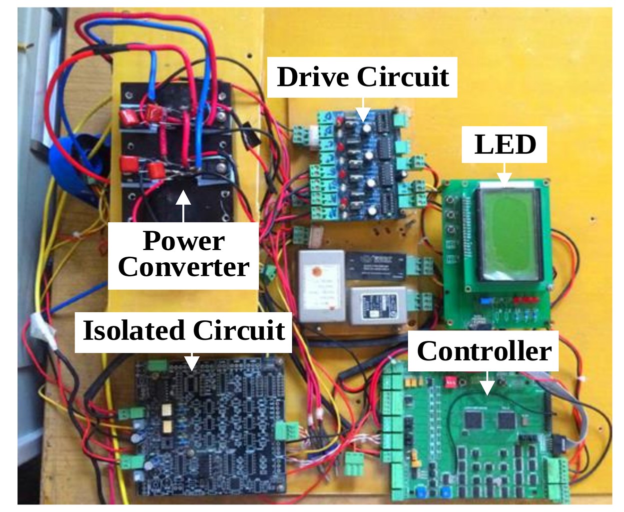

Fig.9. Hardware platform

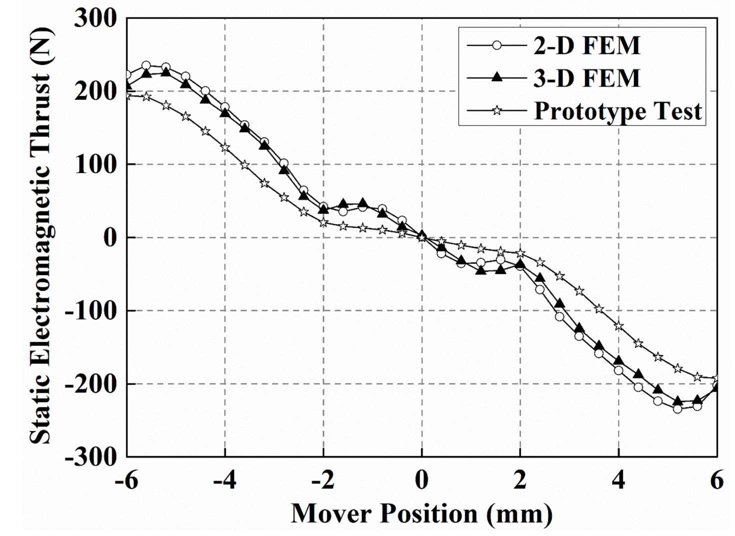

Fig.10. Static Electromagnetic Thrust

Conclusions

A TPMLL with low speed and large thrust is presented in this paper. The sensitivity analyses are conducted to ensure the large average electromagnetic thrust. Its 2D and 3D FE models are established in FE software FLUX to make accurate electromagnetic analysis. The calculated static electromagnetic thrust and the prototype test thrust show that the results calculated by 3D FEM are closer to the test results than those by 2D FEM. In the prototype dynamic tests, the controller outputs different current reference values with different given frequency. The simulation results are consistent with the test results. The frequency response is rapid. Thus, the great dynamic performance of the prototype, effectiveness of the adopted control strategy and the corresponding combined simulations based on the 3D FE model are verified.