Comprehensive Analysis and Experiment on a Permanent Magnet EDS System Employing an Annular Halbach Structure

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I. INTRODUCTION

With the rapid development of rare earth materials, the permanent magnet electrodynamic suspension (PMEDS) technology has gained a new development opportunity. The development of traditional PMEDS systems is constrained by the inherent magnetic resistance. Main work of this paper is to discuss how to convert magnetic resistance into propulsion, and discuss the influence of structural parameters on force by comprehensive simulation and experimental analysis methods.

II. THE INTEGRATION MODEL

In order to provide the levitation and propulsion efficiency of PMEDS, this paper proposes a study on a special PMEDS system called as electrodynamic wheel (EDW). An annular Halbach permanent magnet array was designed to rotate above a conductor plate. We build a 3D physical model of EDW and briefly analyze how it works. Further, the potential structural parameters of the EDW are analyzed.

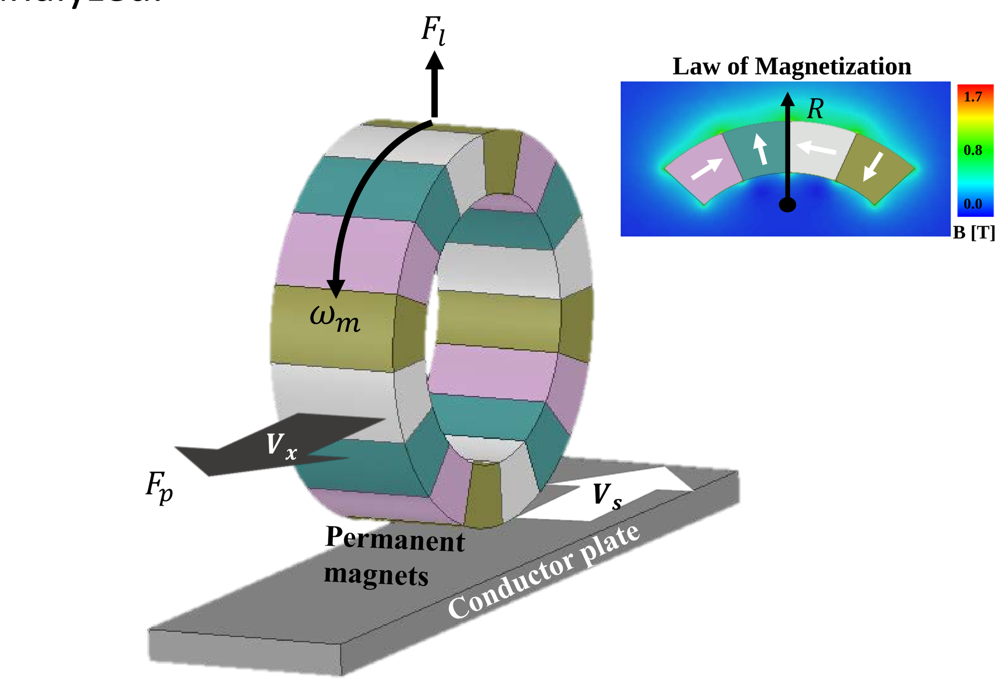

Fig. 1. Schematic diagram of 3D physical model of the EDW.

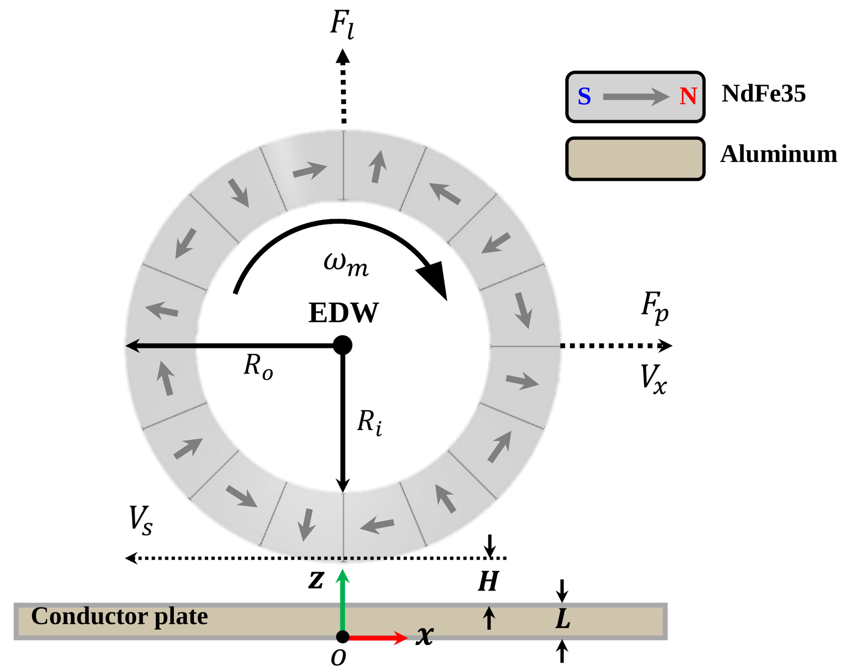

Fig. 2. Schematic diagram of the 2D parametric FEM analysis model.

Table I. Simulation Parameters In ANSYS Maxwell

Parameter	Rotational speed S (rpm)	Model Depth D (mm)	Air gap H (mm)	Outer Radius R_o (mm)	Pole Pairs P	Inner Radius R_i (mm)	Conductivity σ (*10^7 S/m)	Thickness L (mm)
Value	0-8000	35	10	50	Varied	Varied	Varied	Varied

III. MODEL VERIFICATION

The EDW model is simplified to a 2D FEM simulation model by ANSYS Maxwell, then we analyzed the potential parameters affecting levitation to propulsion ratio (LWR) and the levitation to propulsion ratio (LPR). Subsequently the radius and pole pair of the permanent magnet wheel as well as the conductivity and thickness of the conductor plate were optimized.

A. Radius of Wheel

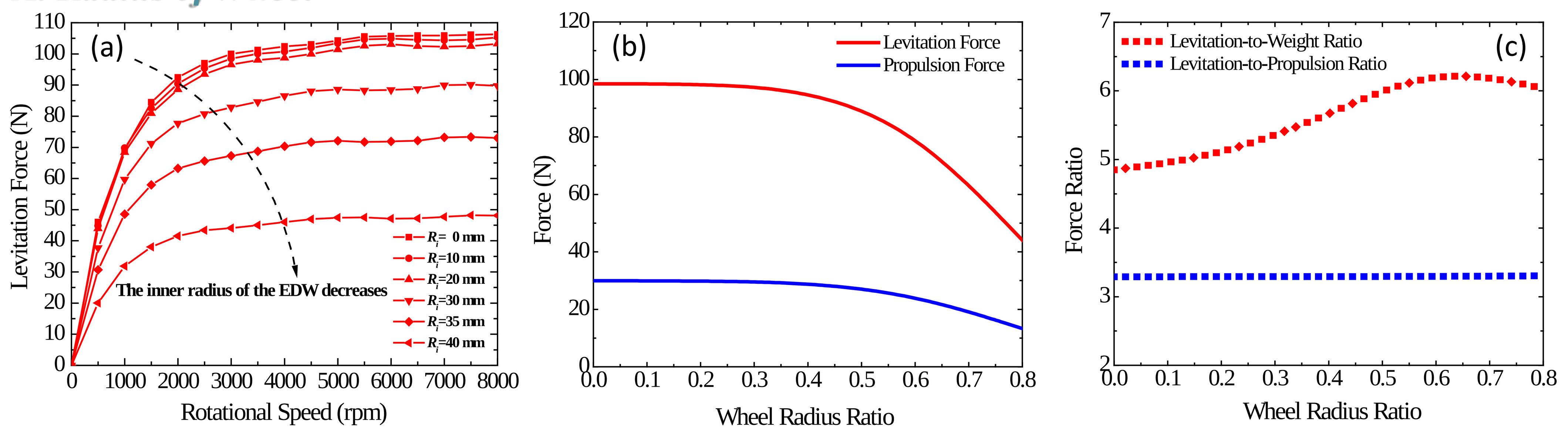

Fig. 2. The influence of the radius of the wheel on the levitation force.(a) The variation curve of levitation force with the increase of rotation speed, (b) the variation curve of levitation and propulsion force increasing with radius ratio, (c) Optimal levitation efficiency interval of EDW model.

- **The optimal radius ratio is 0.68 in the default EDW structure parameters and simulation environment.**

B. Pole Pair of Wheel

C. Conductivity and Thickness of Conductor Plate

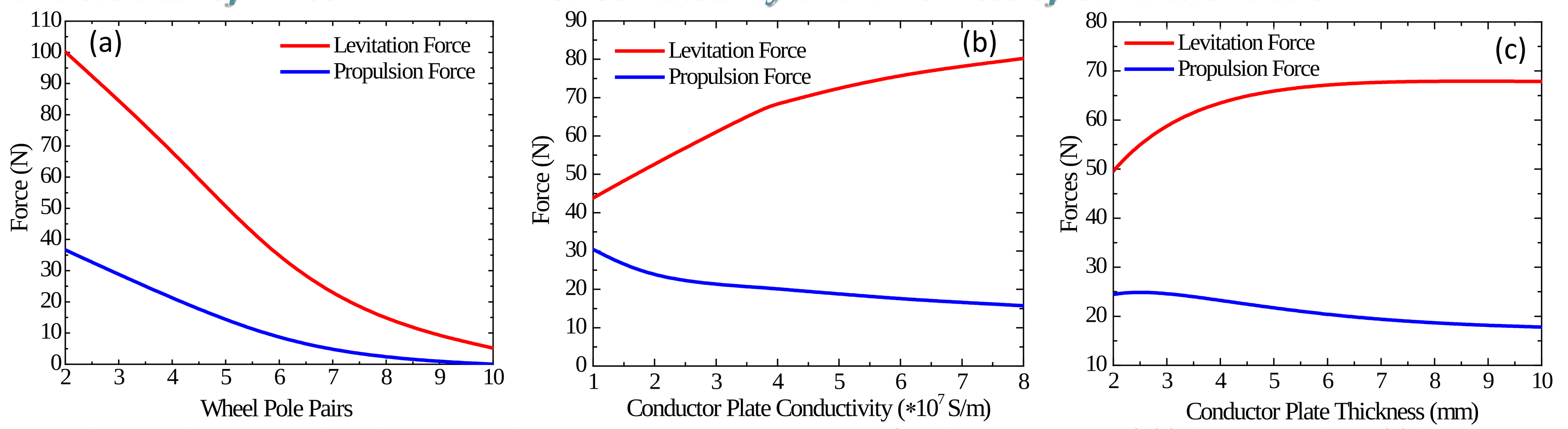

Fig. 3. Levitation force and propulsion force changes of the EDW with the structural parameters (Rotation speed: 3000 rpm). (a) The pole pair of EDW, (b) the conductivity of conductor plate, (c) the thickness of conductor plate.

- **The results indicate that the magnetic wheel adopts the 4-pole pair structure to achieve the best levitation force and propulsion force , and matched conductor plate is suggested to be adopted 6-mm-thickness pure aluminum.**

IV. EXPERIMENTAL VERIFICATION

In order to explore the practical application of the EDW model, we built a PMEDS test platform with double EDW structure. The PMEDS experiment platform can realize the synchronous collection of levitation force and propulsion force from 0 to 8000 rpm. In this study, levitation and propulsion tests were carried out at a constant speed of 1500 rpm to verify the simulation results. The experimental results show that the error is about 8.8%, and the LWR of the experimental EDW was 5.2. Therefore, the PMEDS system can provide the stable levitation and propulsion simultaneously.

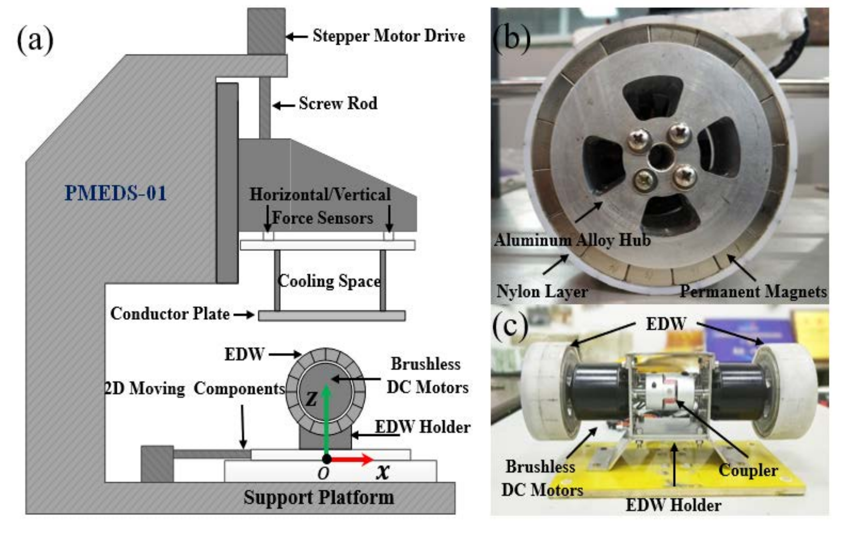

Fig. 4. Permanent magnet electrodynamic suspension test platform. (a) schematic diagram, (b) single EDW section photo, (c) double EDW photo.

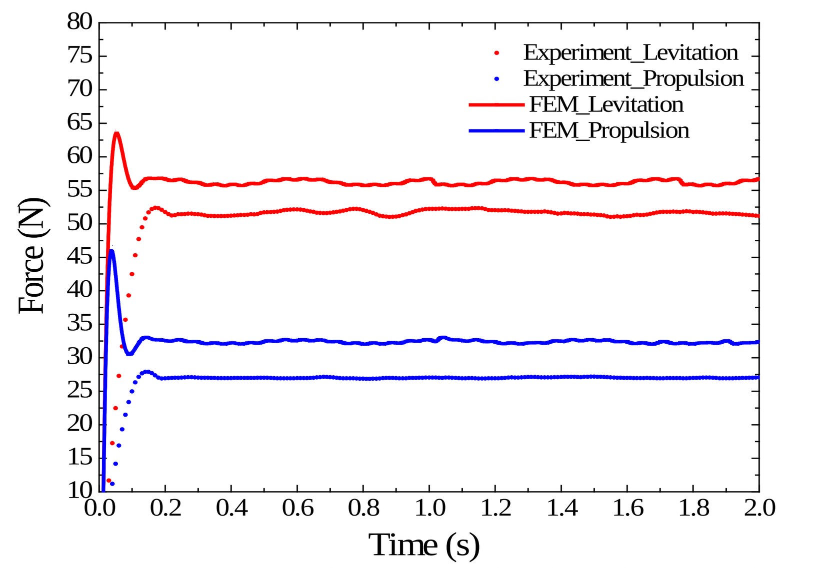

Fig. 5. Comparison of experimental and simulation results of levitation and propulsion (Rotation speed: 3000 rpm).

V. CONCLUSION

The simulation and experiment results show that the PMEDS system employing an annular Halbach structure can realize the integration of levitation force and propulsion force. The LWR was used as the optimization target, and obtain the matching relationship between the geometric parameters of EDW and the conductor plate by simulation in ASYS Maxwell. The detailed structural parameters of EDW as follows:

Table II. Optimized Parameters In ANSYS Maxwell

Parameter	Radius Ratio D_r	Inner Radius R_i (mm)	Pole Pairs P	Conductivity σ (*107 S/m)	Thickness L (mm)
Value	0.68	34.2	4	3.8	6

The PMEDS simulation method and experiment platform can provide valuable reference for the future design of the new Maglev transportation system.

Contact with us!

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The first HTS Maglev–ETT test system "Super-Maglev", 2014.