Exploring the impact of geometric variation on electromagnetic performance in a coaxial coil system

Yuxin Yang*, Azadeh Jafari, Will Robertson and Maziar Arjomandi

School of Electrical and Mechanical Engineering, The University of Adelaide, SA 5005, Australia

To optimise coil design for creating an efficient electromagnetic system characterised by high precision, the present study investigates the impact of varying coil geometry on the electromagnetic force generated between a pair of coaxial cylindrical coils. The study utilises a multifaceted approach to identify the relationships between axial magnetic force, air-gap distance and coil radial thicknesses. Systematic changes in coil geometry are made to understand the sensitivity of electrical power consumption to the generation of magnetic force, and an analytical model is used to understand the relationships. In this article, limitations on the conventional magnetic force computation method established by previous researchers are identified. Additionally, the results indicate that using thicker coils significantly increases magnetic force production. This advantageous amplification is counterbalanced by increased coil resistance, inevitably leading to reduced efficiency of electromagnetic force production. A mathematical model is developed here for computing the coil efficiency, and methods are proposed to simultaneously optimise the generation of magnetic force by coils while ensuring high efficiency in electrical power utilisation.

Keywords: Coaxial cylindrical coils, electrical power consumption, electrical power efficiency, magnetic force.

designed to be coaxial, so that the resulting force can be maximised for attracting or repelling the plunger, producing linear or rotary motion, as shown in Figure 1 (ref. 3).

In applications wherein a hybridisation of a permanent magnet and coil-formed electromagnet is utilised, the permanent magnet can be substituted by another electromagnet. This modification enhances the controllability of the system, and also helps amplify the generated magnetic-field strength for an analytical purpose. The magnetic field created by a current-carrying coil can be significantly affected by magnetic fields emanating from surrounding coils, which generates the emergence of interactional forces among these coils, and the force characters are affected by multiple factors[4,5]. Therefore, systematic evaluations of the force efficiency generated between paired current-carrying coils are an important aspect of the cylindrical coil design and development of electromagnetic devices. In addition, understanding the influence of coil geometry on the electromagnetic performance between two cylindrical coils, significantly helps the optimisation of coil-formed electromagnetic devices by enhancing their efficiency.

Given the extensive engineering applications of cylindrical coils, recent research has increasingly focused on systems incorporating single or multiple cylindrical coil pairs. These studies aim to enhance the