Effect of magnetic pitch, τ_m to the slot type linear oscillatory actuator thrust characteristics

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1. ABSTRACT: Slot type linear oscillatory actuator (ST-LOA) is one type of linear motor. It uses to produce direct linear oscillatory motion without any motion translation part thus reduce system component and complexity. The performance of the ST-LOA is depending on its structure parameters. Therefore, in this paper, the effect of magnetic pitch, τm on its thrust characteristics is observed. It is to acquire a model of the ST-LOA that produces the highest thrust, F at low cogging force, Fc and current, I. In the end, the best model of the ST-LOA has been proposed. It produces maximum force, Fmax of 980 N at 5 A of current, I with having a magnetic pitch, τ_m of 24.5 mm.

Keywords: *Finite Element Method; Linear Motor; Thrust Characteristics*

1. INTRODUCTION

The linear motor is a type of motor that produces direct linear motion with an absence of motion translator such as belt, gears, ball screw, etc. The linear motion can be in long stroke or short-stroke oscillation depending on the application needs. For short stroke oscillatory motor is called a linear oscillatory actuator (LOA). Nowadays, the design and development of the LOA have reached various scopes such as multi-degree-of-freedom of LOA [1] and magnetic spring [2]. The LOA is also being used in various applications such as in-home appliances [3], automotive [4], etc. In this paper, a slot type LOA (ST-LOA) design and performance are discussed.

2. BASIC PRINCIPLE OF THE ST-LOA

The structure ST-LOA discussed in the paper is as shown in Figure 1. It has 5 coils embedded inside the stator yoke (ST) to create the stator, and 4 permanent magnets (PM) installed side by side with 5 moving yoke (MY) to create the mover. The mover will move along its axis to produce oscillatory motion.

The ST-LOA can be designed either using FEM software or a mathematical model by utilizing a magnetic equivalent circuit [4]. However, in this paper, the ST-LOA was designed using FEM software which is ANSYS Maxwell. Several models of ST-LOA was developed by considering the various value of magnetic pitch, τ_m. The performance of each model of the ST-LOA was compared and the best model was proposed.

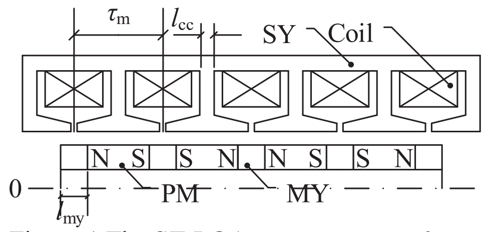


Figure 1 The ST-LOA structure at $x = 0$ mm.

3. MODELLING AND SIMULATION OF ST-LOA

The flow of the study of magnetic pitch effect to the ST-LOA thrust characteristics is as shown in Figure 2. It starts with setting several fixed structural parameters such as the total radius, r_{LOA}, shaft radius, r_s, coil width, w_c, and the PM length, l_{pm}. Initially, the magnetic pitch, τ_m, has been set to 20.5 mm. The magnetic pitch, τ_m, is measure through two styles which are from the center of MY to the adjacent MY and from the center of the coil to the adjacent coil. The magnetic pitch, τ_m, was varied along the study to observe its effect on the thrust. On the specific magnetic pitch, τ_m, the MY length, l_{my}, and distance between the coil, l_{cc} need to be determined accordingly by consideration of fixed coil width, w_c, and PM length, l_{pm}. The magnetic pitch, τ_m, was set to 22.5 mm, 24.5 mm, and 26.5 mm. On every value of magnetic pitch, τ_m, the thrust will be simulated using ANSYS Maxwell software and compare to acquire the best model.

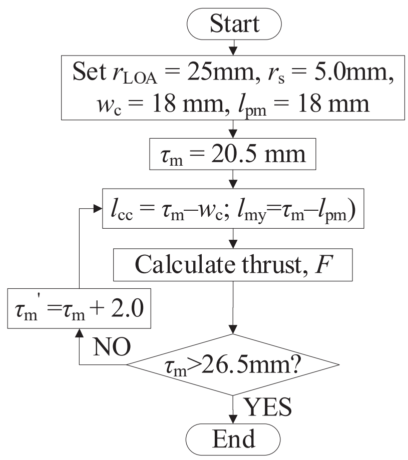


Figure 2 ST-LOA Design.

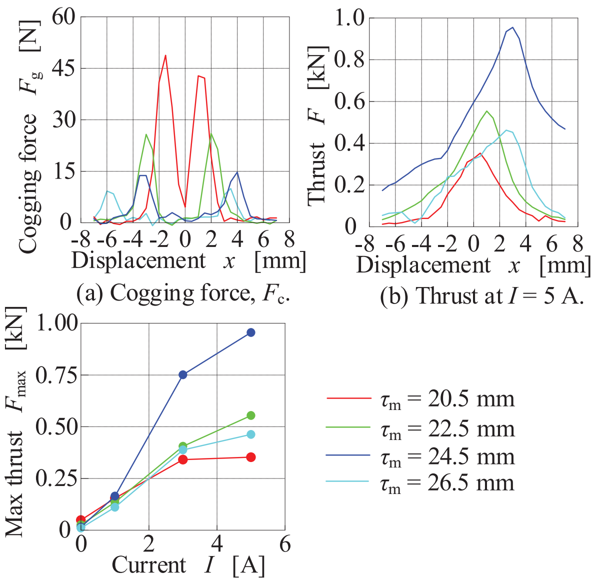
4. THRUST CHARACTERISTICS OF THE ST-

LOA

The thrust characteristics of the ST-LOA are as shown in Figure 3. The thrust was simulated at current from 0 to 5 A. Due to the existence of PM in the ST-LOA structure, it is essential to measure the thrust at 0 A that called cogging force, F_c since it may cause deterioration to the thrust. The cogging force, F_c of the ST-LOA is as shown in Figure 3 (a). It is shown that the ST-LOA with the magnetic pitch, τ_m of 26.5 mm produces the lowest cogging force, F_c while the model with the magnetic pitch, τ_m of 20.5 mm produces the highest.

Thrust characteristics of the ST-LOA at I = 5 A on varies the magnetic pitch, τ_m is as shown in Figure 3 (b). All the ST-LOA models having the same thrust pattern. The thrust increase as the mover displacement moves from negative displacement until it reaches maximum value before reduced as the displacement move to the positive displacement. It is shown that the ST-LOA with the magnetic pitch, τ_m of 24.5 mm produces the highest max. thrust while the model with the magnetic pitch, τ_m of 20.5 mm produces the lowest.

The performance of the ST-LOA also can be evaluated using several other performance characteristics as in [6]. The performance characteristics use in this study are max thrust to cogging ratio, F_{max}/F_c, and thrust constant, k_f. The comparison of performance characteristics of the ST-LOA is as listed in Table 1. It is shown that the ST-LOA with magnetic pitch, τ_m of 24.5 mm can be regarded as the best model compared to its counterpart. It has the highest both F_{max}/F_c and k_f and shows its capabilities to produce high thrust, F at low cogging force, F_c and current, I.



(a) Cogging force, F_c. (b) Thrust at I = 5 A.

(c) Max thrust F_{max} vs current, I.

Figure 3 Thrust characteristics of the ST-LOA.

Table 1 Comparison of ST-LOA performance

τ_m	F_{max}/F_c	k_f
20.5	7.9	97
22.5	23.2	126
24.5	69.3	245
26.5	46.7	125

5. CONCLUSION

The effect of magnetic pitch, τ_m, to thrust characteristics of the ST-LOA has been focused on. The study begins with the development of several ST-LOA models which have a different value of the magnetic pitch τ_m. The ST-LOA models then were simulated using ANSYS Maxwell software to acquire its thrust characteristics. The thrust characteristics were then compared and the best structure of the ST-LOA was proposed. Based on the comparison, the ST-LOA model with the magnetic pitch τ_m of 24.5 mm was selected as the best model of the ST-LOA.

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