Test on the linear induction launcher with a new type of 3-phase helical coil

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Introduction

The primary section of a traditional high speed Linear Induction Launcher (LIL) is an array of air-core coils, which can produce axial pushing forces on the projectile while the coils be powered with 3-phase AC currents. For keeping good flight attitude stability, the projectile needs high rotating speed to produce gyroscopic effect, just as a flying bullet shot by a rifle gun. A new type of 3-phase helical coil of stator was put forward in this paper, which is different from the helical coils mentioned in some papers. The construction of the coil is shown in fig.1.

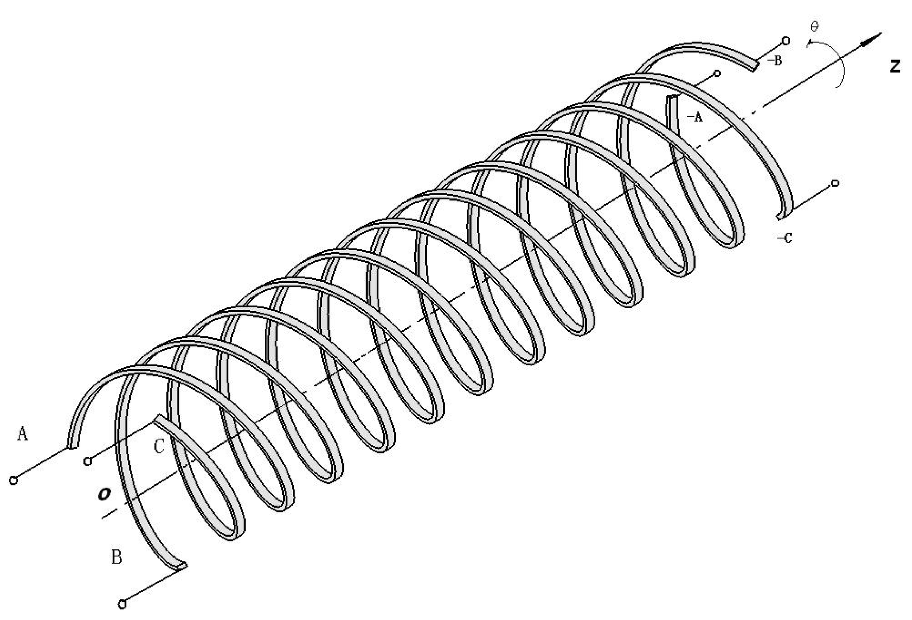

Fig. 1. Construction of the new type of 3-phase helical coil

While the coil was powered with 3-phases AC currents, the ideal current distribution in the cylindrical coordinate system (r,θ,z) is as follows,

$$I_\theta(R,\theta,z,t) = A\sin(2\pi ft+\varphi)\sin\frac{2\pi z}{p_z}\sin 2n_{p\theta}\pi\theta\cos\beta$$

$$I_z(R,\theta,z,t) = A\sin(2\pi ft+\varphi)\sin\frac{2\pi z}{p_z}\sin 2n_{p\theta}\pi\theta\sin\beta$$

Where A is the peak value of the 3-phase AC currents in the coil, and *f* is its frequency, p_z is the dipole distance alone z (Here p_z is equal to the thread pitch *λ*), $n_{p\theta}$ is the dipole number alone *θ*, and *β*is the spiral angle. Of course, the coil may be winded with a lot of wraps as needed. *R* is the coil's average radius can be seen as a constant.

For there is no iron core, it is a linear electromagnetic system. Based on equation (1), a conclusion can be drawn that the coil in fig.1 is a superposition of two 3-phase coils which have same average radius, wraps, and operating currents just shown as fig.2. The first coil has same pz as the coil in fig.1. The second has same npθ as the coil in fig.1.

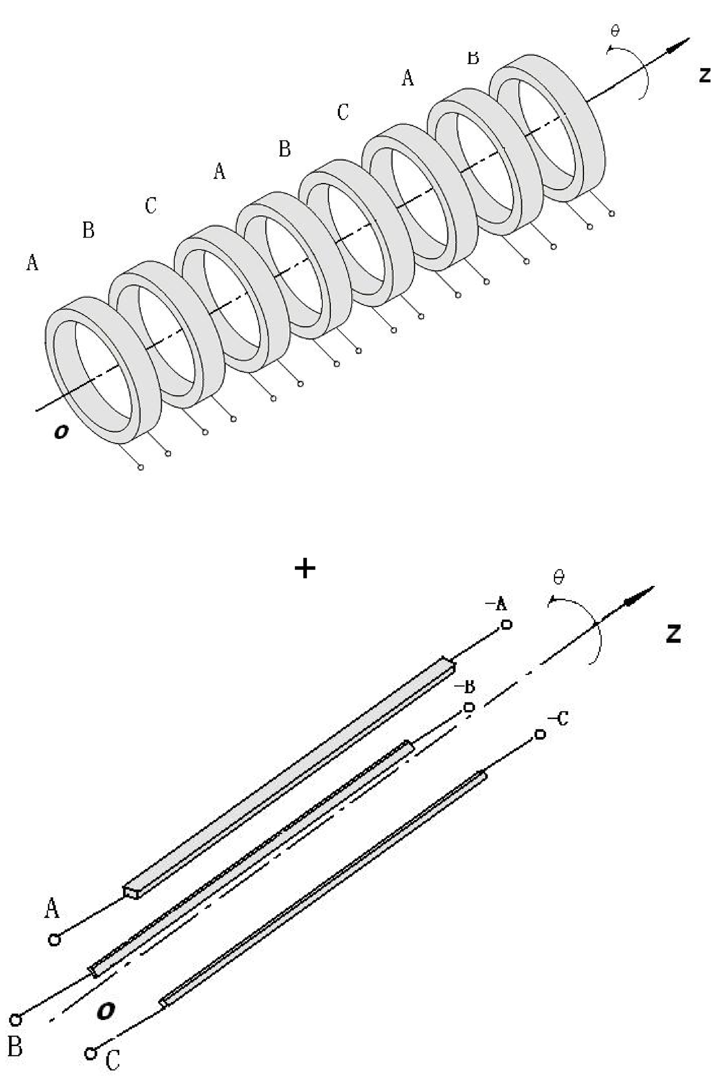

Fig. 2. Coil in fig.1 can be seen as superposition of two different coils

Experiment arrangement

Fig.3 is a photo of the completed coil fixing on a winding machine, and the small image in the left-top corner is its 6 helix bobbin which was made of PVC. The inner diameter of the coil is 23 mm. The outer diameter is 40mm. The coil's Length is 120 mm (not including the length of ends). Its spiral angle β is 55° . The coil was 120° lap-winded with Φ1 mm enameled wire. Each coil has 40 wraps. The 3-phase coil was star connected, so the npθ=1. The dipole distance pz is 60 mm.

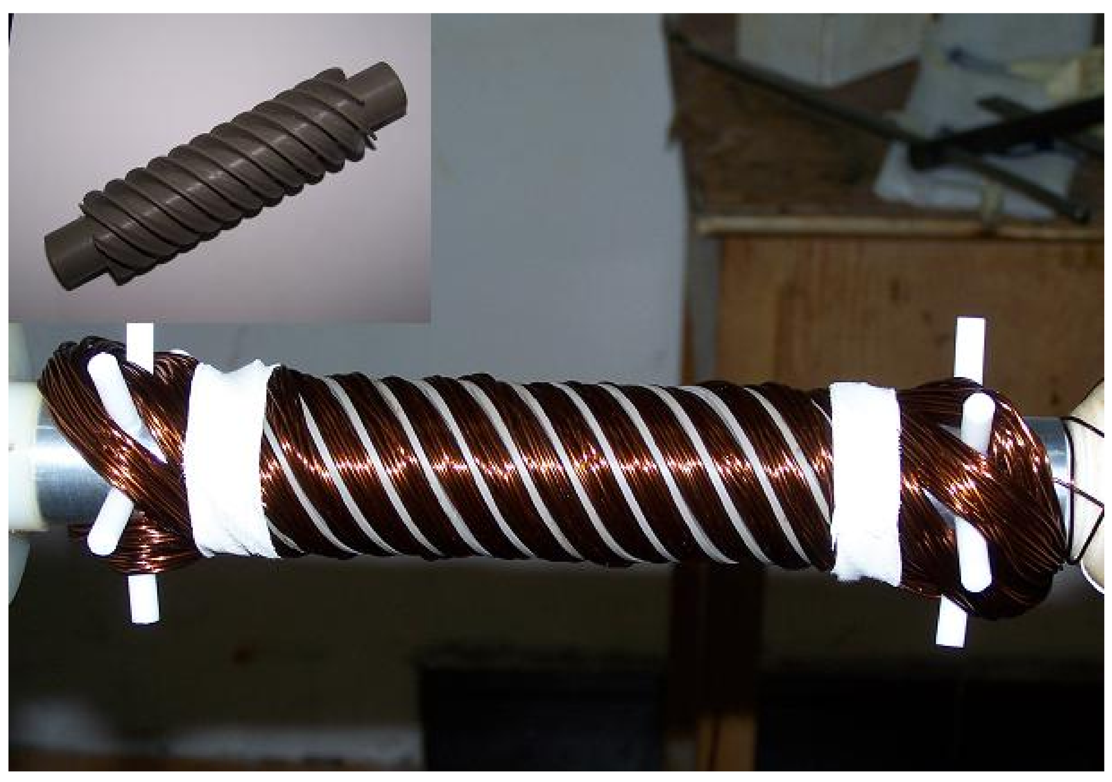

Fig. 3. Completed 3-phase helical coil and its PVC bobbin

Shown as fig.4, the projectile was made of aluminum alloy 5083. Its inner diameter is 16 mm, outer diameter is 20 mm, and the lenth is 60mm. The weight is 18.3 grams.

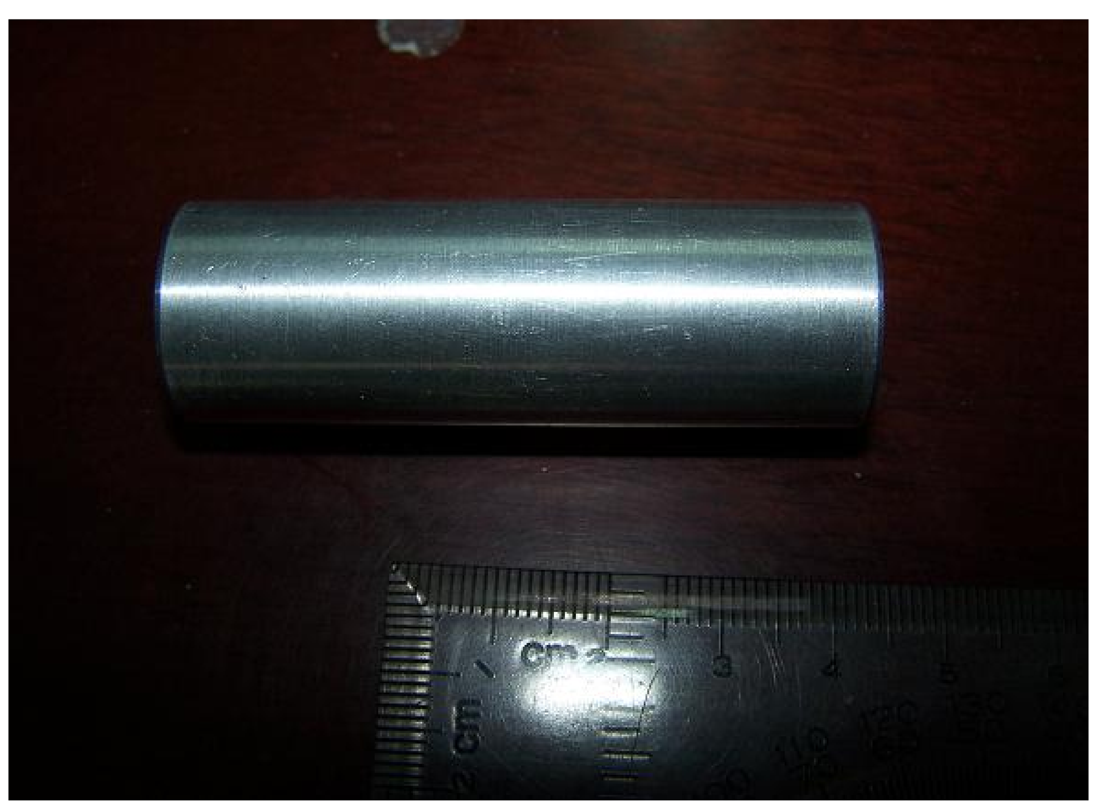

Fig. 4. The aluminum alloy projectile

Fig.5 is a picture of the experimental facilities including a 3-phase switch, a shunt, the 3-phase helical coil and a photoelectric position sensor. The coil was covered and sticked with tapes on a PMMA board. The shunt was installed in series between the switch and one phase of the coil to capture the current intensity. The photoelectric position sensor was set at the muzzle to measure the speeds of the projectile. The small image in the top-right corner is one of the moving speed signals iamges of the projectile caught by OSC. To measure the rotating speed, the projectile was painted six 4 mm wide black stripes parallel to its axial, after moving speed has been gained. The coil was excited by the commercial power source through a 3-phase autotransformer. The frequency is 50 Hz. The available minimum pulse time from switch on to off is 0.1 second. The projectile's initial position is at the center of the coil.

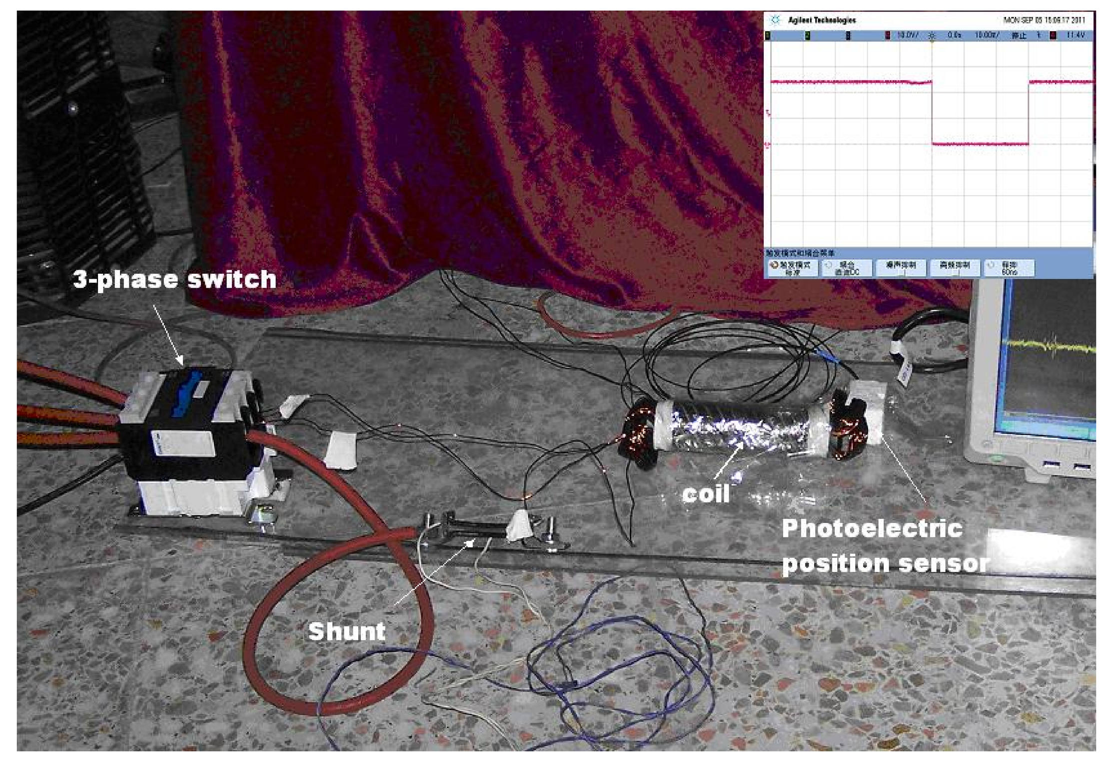

Fig. 5. The experimental device and one image of the speed signals

Experimental Results

Table 1 lists one set of experimentally measured data of the small helical coil launcher. Because the switch on/off operation time is preset but not a closed-loop control according to projectile-position, too much electric energy was consumed than actual requirement of one launch process. And friction also leaded to low efficiency.

TABLE 1 Partial experimental parameters and values

Parameter	Experimental data
Max Velocity[m/s]	2.0
Rotating speed[rpm]	580
Voltage[V]	80
Peak Current[A]	45
K.E. [J]*	0.034
Energy Expended[J]	756
Efficiency[%]	0.0045

*including linear kinetic energy and rotational energy.

Conclusion

This paper suggested a new type of asynchronous linear launch device with 3-phase helical coil, which demonstrate that both thrust force and rotating torque applied on the projectile. An 18.3 g aluminum alloy motor was accelerated to 2.0 m/s, 580 rpm speed. The research gave a new idea of building high speed and high hit precision EM asynchronous linear launcher.

Future investigation will be concerned with developing more theoretical and numerical computation, building a perfect sophisticated experimental device with higher sensitivity detection and control system. Also, bigger projectile mass, higher muzzle velocity, rotating speed and launching efficiency will be aimed at and examined in the future.

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