

## Introduction

The flux pump works similarly as a DC power supply, with low output voltage and high output current. For characteristic studies of the HTS flux pump, it is necessary to measure its output superconducting DC voltage, which is usually measured by voltmeter at both ends of the stator, and averaging the measurement over one period. Based on the linear-motor type flux pump previously introduced from our laboratory, we propose to directly derive the output voltage of the HTS flux pump from the superconducting closed-loop circuit, with an insulation double pancake coil and soldering resistances as the loads. The output DC voltages had been derived from the voltage-current relationship in different applied magnetic strengths and frequencies.

## Experiment Setup

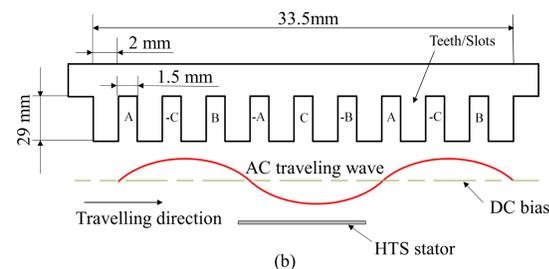
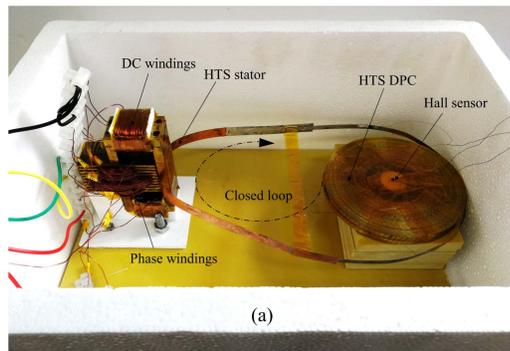


Fig. 1. (a) The experimental setup of the mini-type linear-motor type HTS flux pump device. (b) The cross-sectional diagram of the superconducting stator under the teeth/slots, which shows the AC travelling magnetic wave was DC-biased.

## Experiment results and calculation results

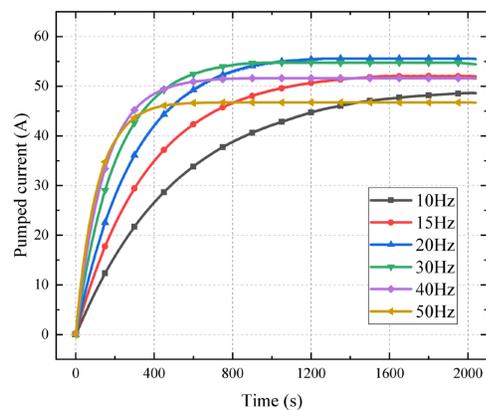


Fig. 2. The pumping current curves in closed loop with different frequency, which is increased from 10 to 50 Hz,  $B_p = 0.45$  T.

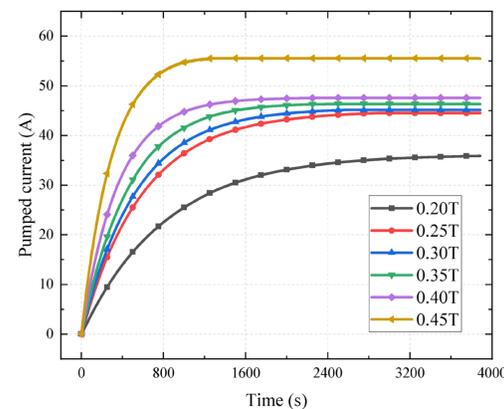
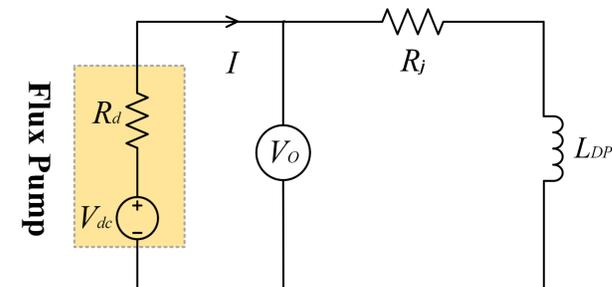


Fig. 3. The pumping current curves in closed loop with different  $B_p$ , which is increased from from 0.2 T to 0.45 T,  $f = 20$  Hz.



$$V_o = IR_j + L_{DPC} \frac{dI}{dt} + U_C \left( \frac{I}{I_C} \right)^n$$

$$I = I_0 (1 - e^{-(1/\tau)t})$$

$$\tau = \frac{L_{DPC}}{R_j + R_d}$$

Fig. 4. The equivalent circuit diagram of the linear-motor type HTS flux pump for the HTS INS DP, and linear-motor type HTS flux pump output voltage calculation formula.

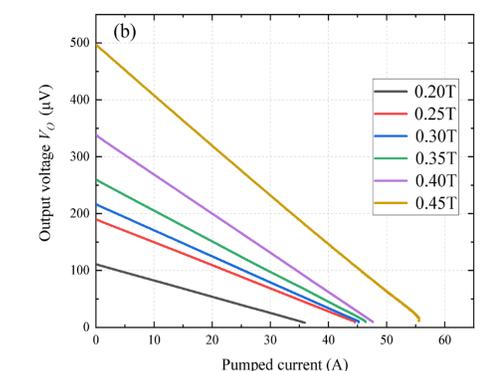
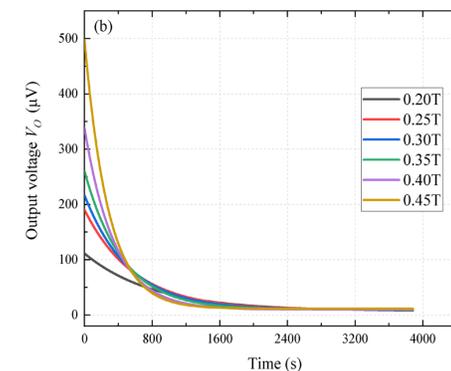
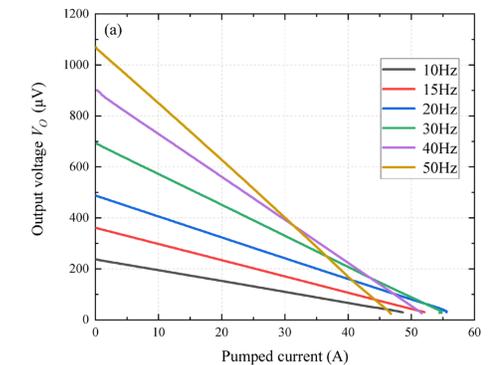
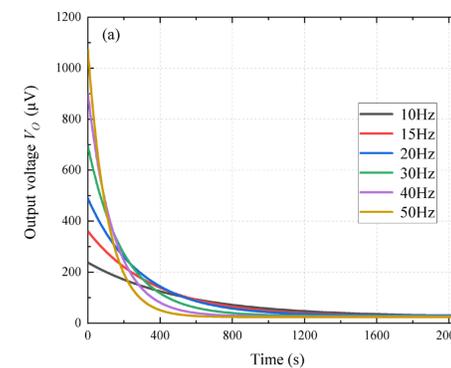


Figure 5. The calculation results of the relationship between output voltage and time of (a) different frequency and (b) different  $B_p$ .

Figure 6. The relationship between output voltage and pumped current with (a) different frequency and (b) different  $B_p$ .

## Conclusion

By using different peak values and frequencies of the applied AC travelling magnetic wave, we obtained the pumping characteristics of this linear-motor type flux pump, the experimental results show that the flux pump output voltage increases as the magnetic field and frequency increases. This phenomenon is consistent with explanation with the guided flux flow caused by the macroscopic magnetic coupling effect.