Design and Analysis of a New Double-stator Dual-magnet Linear Magnetic-gereed Machine

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Abstract—This paper proposes a new double-stator dual-magnet linear magnetic-gereed (DSDM-LMG) machine, which adopts a new hybrid structure. It artfully incorporates the magnetic-gearing effect and flux-memory capability together, which can offer the high force output with flux control capability. The keys are the utilization of flux-modulation segments for achieving the gearing effect and the use of dual magnets for controlling the airgap flux density. The finite element analysis is performed to verify the validity of this linear machine.

Index Terms—Dual-magnet, linear machine, magnetic-gereed machine, memory machine, flux control.

I. INTRODUCTION

Linear magnetic-gereed machines have attracted attention for direct-drive applications since they can offer high force output with the contactless gearing effect [1]-[3]. However, their operating speed range is relatively narrow due to the difficulty in flux control. Flux-memory machines are another attractive candidate with the distinct advantage of magnetic field memory function, which is favorable for wide-speed operation [4]-[6]. However, their development has been biased on the rotational morphology.

The purpose of this paper is to propose a new double-stator dual-magnet linear magnetic-gereed (DSDM-LMG) machine. Namely, it adopts the double-stator structure to increase the force production, the flux-modulation segments to produce the magnetic-gearing effect and the dual-magnet structure to achieve the flux-memory capability.

II. MACHINE DESIGN

Fig. 1 shows the proposed machine structure, which consists of an in-between mover, two stators, and two sets of flux-modulation segments. The mover has 16 effective pole-pair NdFeB PMs mounting on both surfaces. The stators accommodate the armature windings, the AlNiCo PMs and their magnetizing windings. Each set of flux-modulation segments is located between the stator and the mover, which functions to provide flux modulation for achieving the gearing effect, hence amplifying the force or reducing the speed for different industrial applications.

In order to achieve the gearing effect, the pole-pair arrangement of the machine is governed by [1]-[3]:

\[ p_m = N_{fms} - p_s, \text{ and } G_r = \left( p_s - N_{fms} \right) / p_s, \]

where \( p_m \) is the number of effective pole pairs of the mover, \( p_s \) the number of stator armature pole pairs, and \( N_{fms} \) the number of flux-modulation segments. For this machine, \( p_m = 16 \), \( p_s = 2 \), \( N_{fms} = 18 \), and \( G_r = -8/1 \).

III. VERIFICATION RESULTS

The AlNiCo PM is positively utilized to perform online tuning of magnetization. Differing from the NdFeB PM, the AlNiCo PM exhibits nonlinear behavior as shown in Fig. 2(a). Particularly, it can readily be demagnetized and remagnetized, partially or fully. Because of this feature, a piecewise-linear hysteresis model of the AlNiCo PM [6] is incorporated for the finite element analysis as shown in Fig. 2(b).

The proposed machine is particularly suitable for direct-drive linear applications, such as oceanic wave energy converters, free-piston power generators or linear high-force low-speed actuators. Also, its flux-memory capability enables it to provide a wide speed range of operation.

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Fig. 1. Proposed DSDM-LMG machine.

Fig. 2. Operating characteristics of PMs. (a) B-H curves. (b) Hysteresis model of AlNiCo PM.

Fig. 3. Airgap flux density waveforms. (a) Full-magnetizing level. (b) Half-magnetizing level. (c) Zero-magnetizing level.

Fig. 4. No-load EMF waveforms under different magnetizing levels.

Fig. 5. Thrust force waveforms under different magnetizing levels.

Fig. 6. Static force waveforms under different magnetizing levels.

REFERENCES


