Research on a field-modulated tubular linear generator with quasi-Halbach magnetization for ocean wave energy conversion #1147

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The Ocean Energy Convert System with the FMTLPMG

With the rapid develop of energy crisis and environmental problems, the utilization of renewable energy is attracting an increasing attention in the world. However, the traditional linear generator in WEC usually has disadvantages of large weight and low power density due to the average low speed of ocean waves. Some of them are hard to manufacture and may cost a lot. Furthermore, the complex structure will reduce the stability of the generator device and make it inapplicable for long-term operation in the sea.
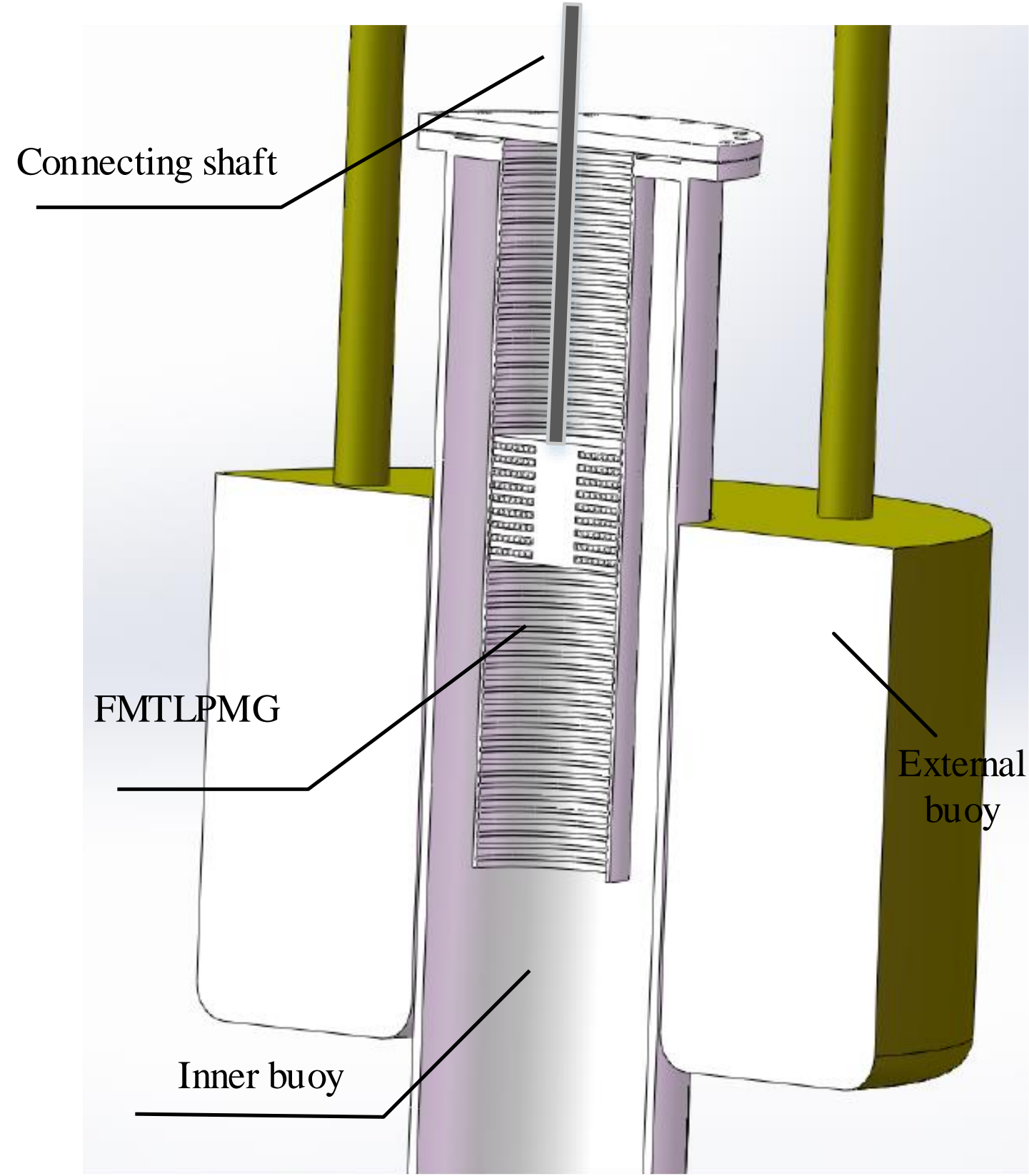

The FMTLPMG proposed in this paper is combined with the magnetic field modulated technique can accelerate the traveling speed of the magnetic field by the teeth in the primary. Simultaneously, equipped with quasi-Halbach magnetized permanent magnet, it can improve the air gap magnetic density and reduce the volume and weight of the generator to some extent.
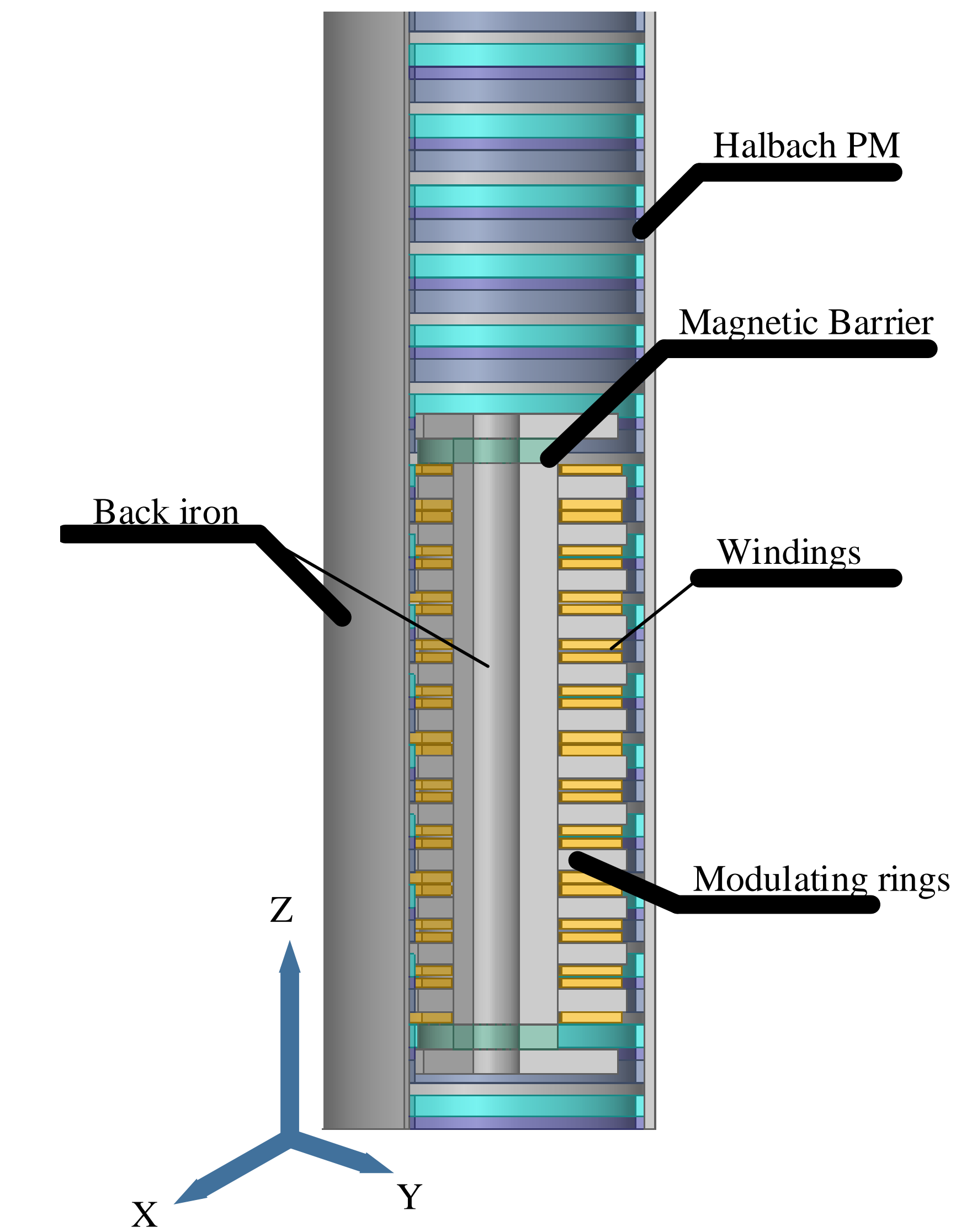
Fig. 1. The ocean energy convert system with the FMTLPMG .

The Topology and Principle of FMTLPMG

The FMPMTLG is a combination of magnetic field-modulated technic and quasi-Halbach magnetized permanent magnet. It is known that slots and teeth arranged alternately on the linear generator's primary will cause cyclical magnetic field changes in air gap. The magnetomotive force generated by the permanent magnet, will be effected by this mutative permeability, and then produces a series of harmonics in the magnetic field. The relations can be described as

$$p_{m,k} = |mp + kn_s|$$
$$v_{m,k} = \frac{mp}{mp + kn_s} v_r$$
$$p_s = p_{1,-1} = n_s - p$$

where $p_{m,k}$ is the pole pairs of harmonics, p is the pole pairs of the magnets, n_s is the number of teeth, and v_r is the speed of secondary, $v_{m,k}$ is the speed of harmonics, p_s is primary winding pole pairs. The Fourier analysis of the air-gap magnetic field reveals that if $m = 1$, $k = -1$, it can lead to the largest amplitude of harmonics. It is known that the faster changing rate of magnetic field induces a higher electromotive force (EMF). Thereby, the volume and weight of the linear generator is reduced and the efficiency of the direct-drive wave conversion system is improved.

Fig. 2. The topology of the FMTLPMG with quasi-Halbach PMs.

Optimization Deign Results and Comparison

The proposed machine is compared with the traditional quasi-Halbach tubular linear motor . As shown in Fig. 3. , the back EMF is about 39% higher than the traditional machine at the same volume. The detent force has decreased about 8 times than the traditional machine. This make it more easier to produce electric in the sea and reduce the buoys' dimension.
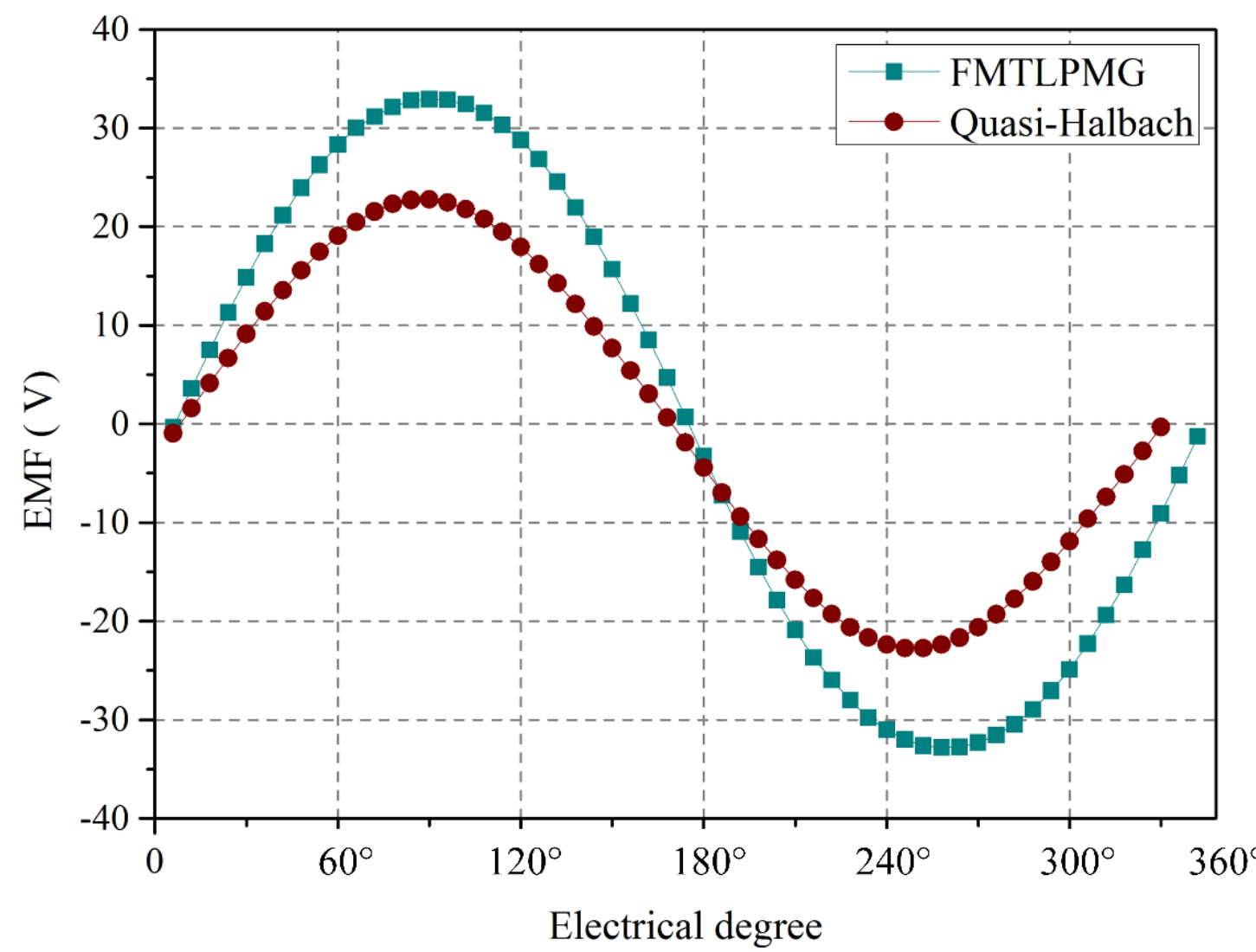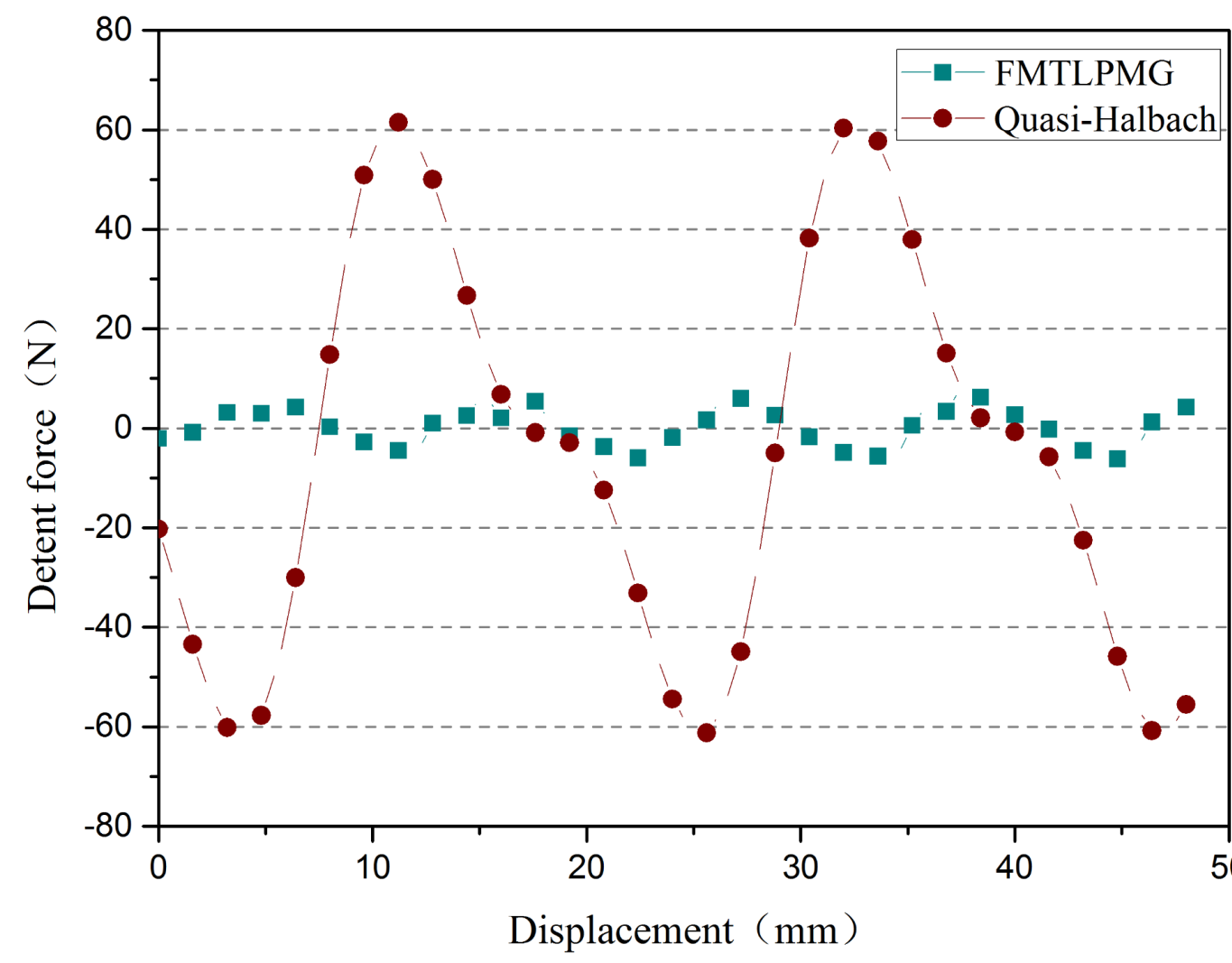

Fig. 3. The back EMF at 0.4m/s

Fig. 4. The detent force of different machine

In order to verify the result of the FEA result，experience has been done at a wave tank. This tank can produce waves in different amplitudes and frequencies.
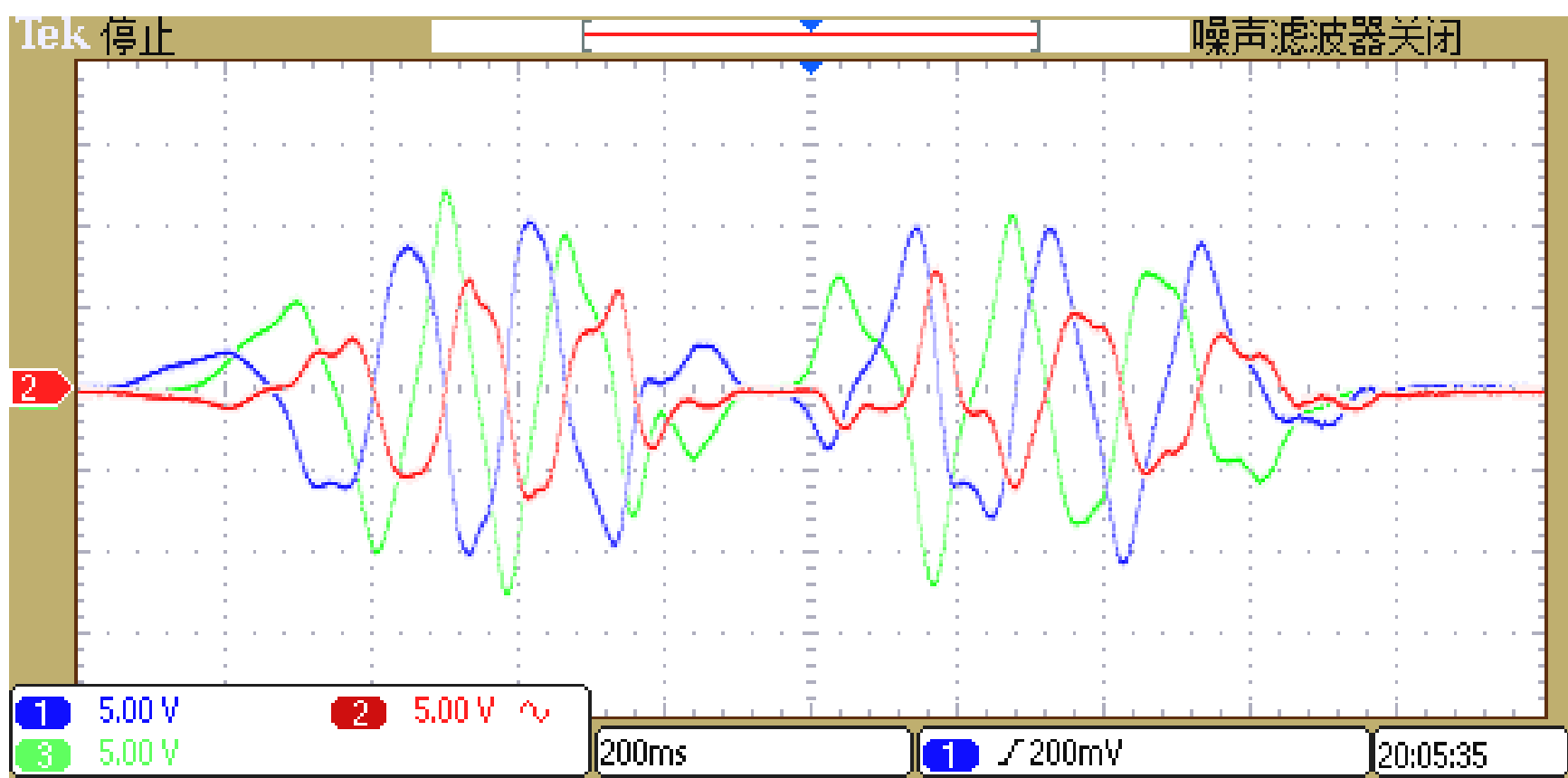

Fig. 5. The voltage at R=10Ω ,H=0.2m, T=2s
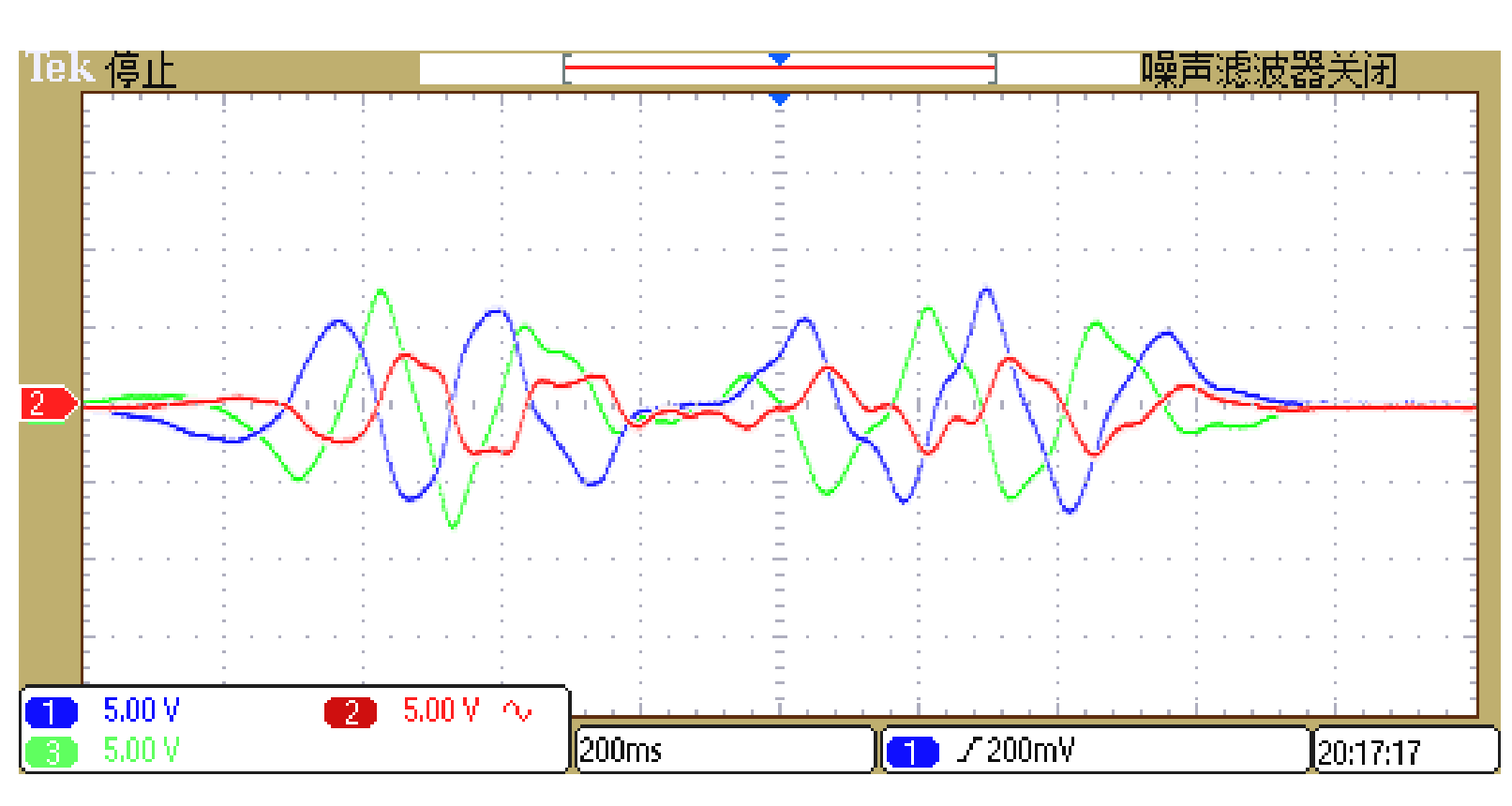

Fig. 6. The experience in the wave tank.

Fig 7 The voltage at R=10Ω ,H=0.15m, T=2s

Conclusion

In this paper, the FMTLPMG is designed which is applied in the ocean wave energy conversion. Base on the the magnetic field modulated technique and quasi-Halbach PMs, the voltage increases about 39% than the traditional machine in the same volume and speed. Also, the detent force of the machine has been deduced about 8 times to 7N. These FEA results is validate in a wave tank.