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Magnetic Levitation Characteristics above Electromagnets

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Introduction

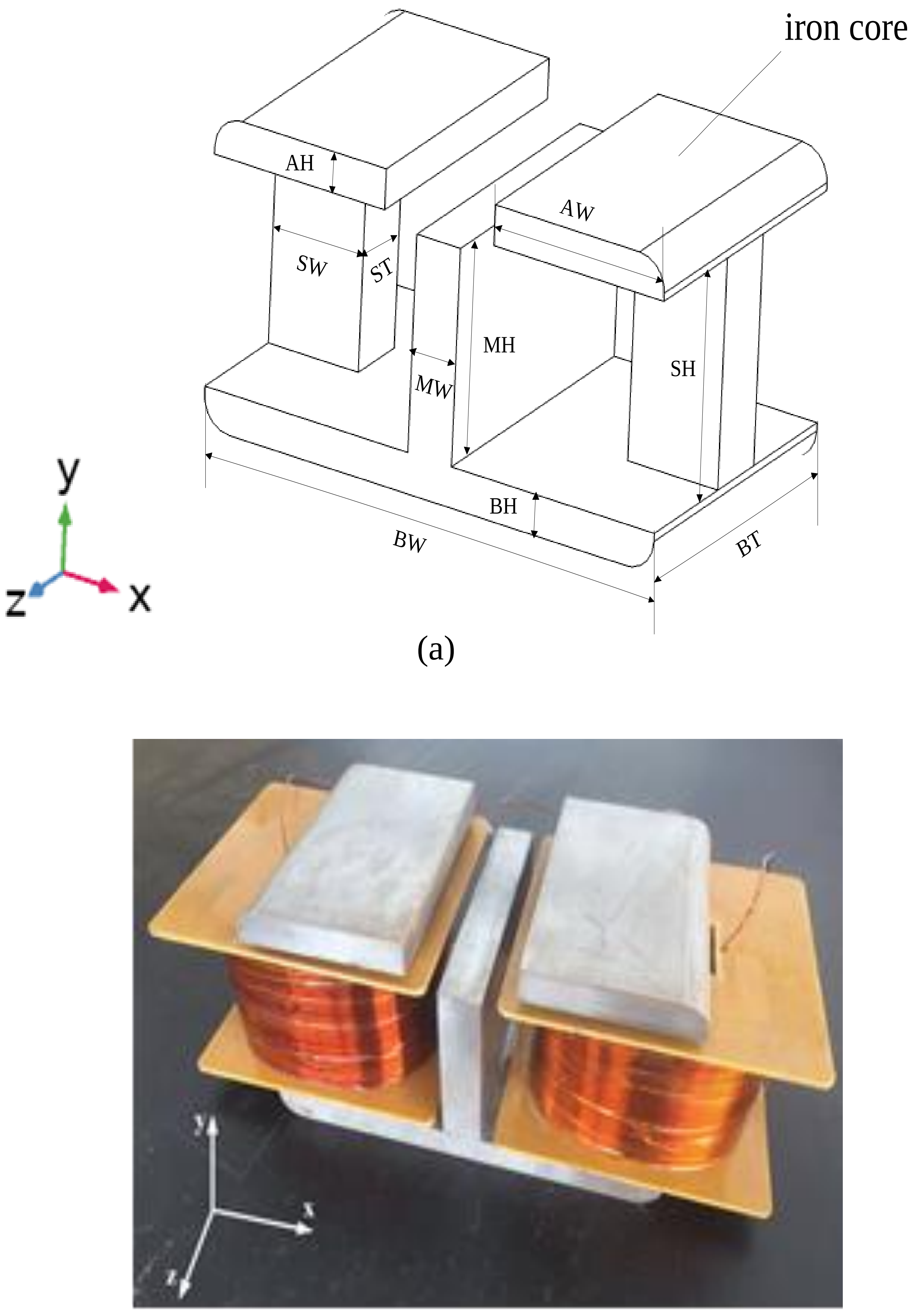
The design and modeling of electromagnet guideway (EMG) specimen for high-temperature superconducting (HTS) maglev is presented. The target of our EMG specimen design is to form EMG for HTS-EM maglev system. In principle, EMG can adopt a segmented instant excitation (SIE) mode to realize a minimum levitation power loss as well as sufficient levitation and guidance forces for the vehicle. The SIE mode allows to energize the section of EMG where the vehicle reaches and power off as the vehicle has passed. Moreover, the current of EMG can be adjusted to meet the needs of HTS vehicles with different loads, which realizes the active control. For this, we investigate the magnetic levitation characteristics of HTS-EM system. The homogeneity of magnetic fields along the guideway generated by one of the designed EMG specimens with different excitation currents were studied by simulation and experiment. The EMG specimens with different geometries were made for comparative analysis. The transverse magnetic fields above different EMG specimens were simulated and measured for observing the relationship between the transverse magnetic field and force. Then, we investigate the effect of different EMG specimens on levitation force and guidance.

Design of EMG specimen

The EMG specimen consists of two multi-turn coils and an iron core, as shown in Fig. 1. The structure of the iron core is presented in Fig. 1(a) and the levitation space is above the middle post. The two side posts are respectively wound with the two coils that are connected in series and energized by a DC supply. The specifications of the EMG specimen are shown in TABLE I. The coils do not extend beyond the frame of the iron core in the z-axis direction so that there is a small gap even no gap between the EMG specimens when forming an EMG.

TABLE I
Specifications of Electromagnet

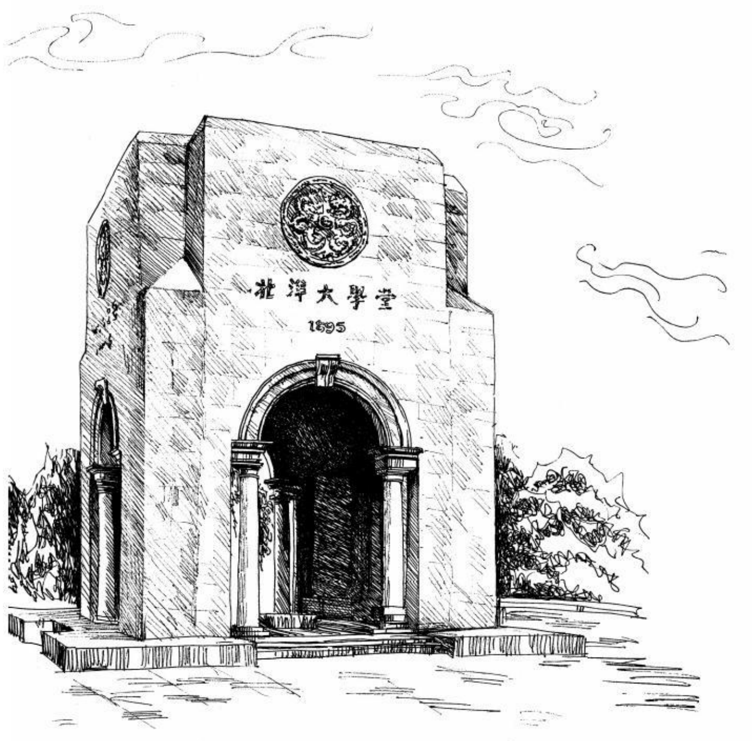
Coil	Insulated Copper wire diameter (mm)	1.08
	Number of each coil turns	1692
	Number of coils	2
Dimensions of Iron core (mm)	SW	41.25
	ST	26.5
	SH	85
	MW	20
	MH	80
	BW	206
	BH	15
	BT	120
	AH	15
	AW	78



(a)

(b)

Fig. 1. (a) Structure of EMG specimen iron core
(b) Photograph of the designed EMG specimen



Experiments

For investigating the homogeneity of magnetic field created by the EMG specimen, the experiments and simulations were carried out on the designed 80_20 (MH is 80 mm and MW is 20 mm) EMG specimen.

The B_y of transverse magnetic fields of different EMG specimens were measured and simulated for comparative analysis.

The levitation forces were respectively obtained by adjusting current of EMG coils and moving HTS bulk in vertical movement. Levitation force obtained by adjusting current was firstly conducted by placing the normal state HTS above the center of different EMG specimens. After cooling the bulk, the coil is fed with current, during which the levitation force was recorded.

Levitation force obtained by the bulk vertical movement are carried out as follows. The HTS bulk is placed above the center of the EMG specimen, and then coil is energized with current. After bulk is cooled, the vessel is moved vertically, during which the levitation force is simultaneously recorded.

The HTS bulk is placed at the height of 5mm to the center surface of different EMG specimens at the presence of magnetic. The lateral movement is initiated followed by the cooling process. The guidance forces were measured and recorded during the lateral movement loop.

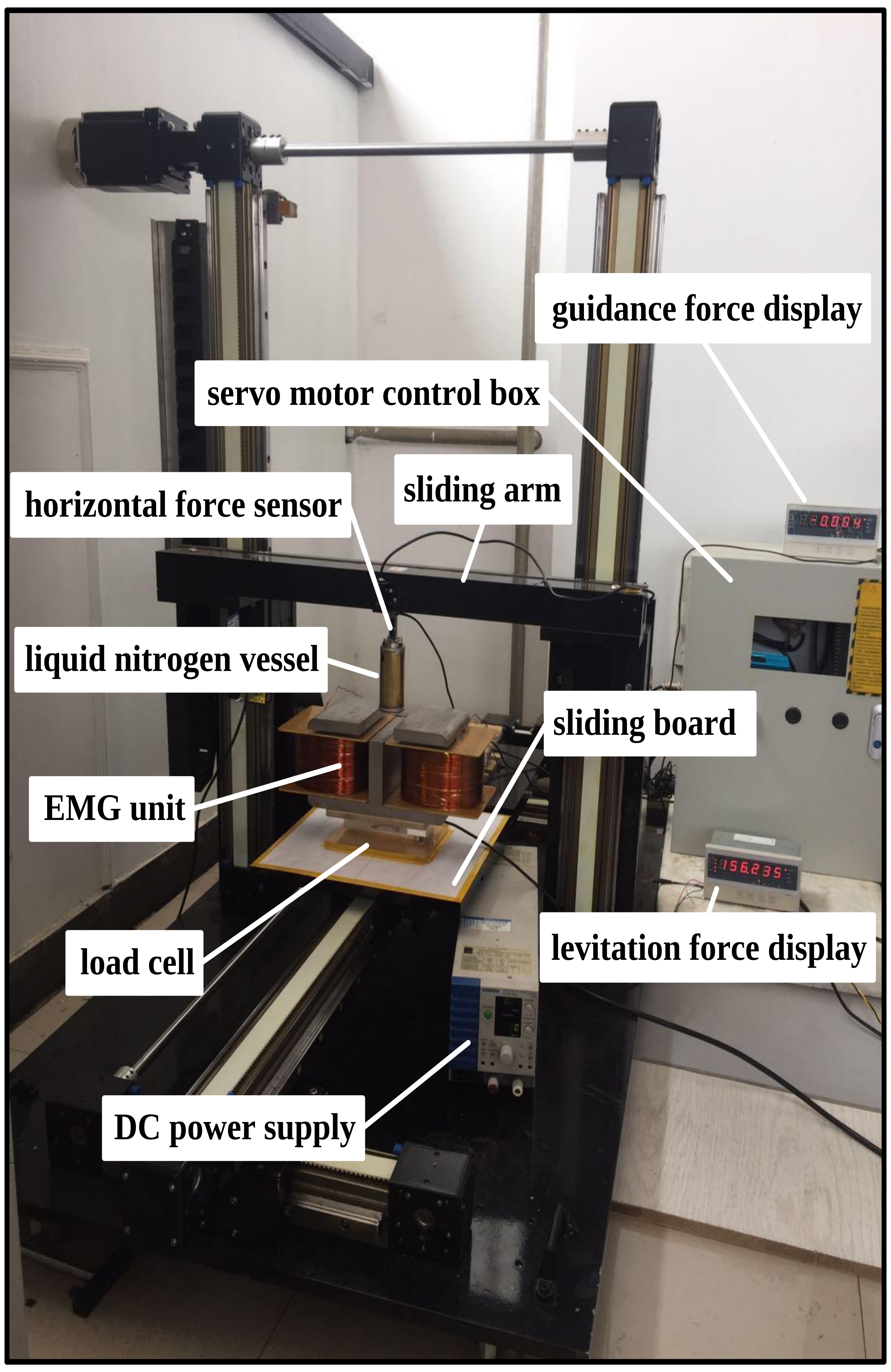


Fig. 2. The measurement system for HTS-EM maglev study

Results

Magnetic field homogeneity

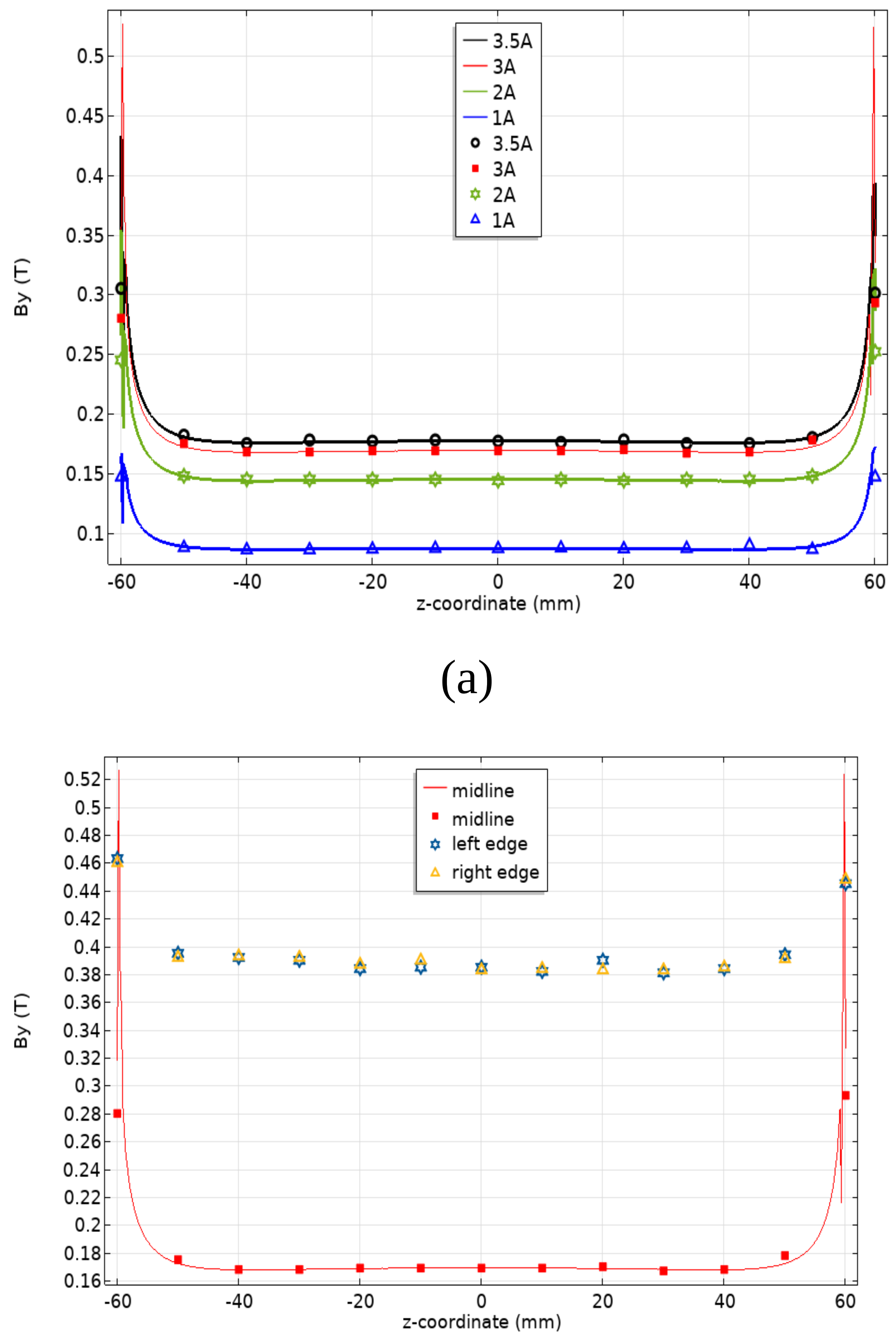


Fig. 3. (a) B_y of EMG specimen surface midline along z-axis with different excitation currents. (b) By of midline, left and right edges of EMG specimen surface along z-axis with excitation current of 3A

Transverse magnetic field with different EMG specimens

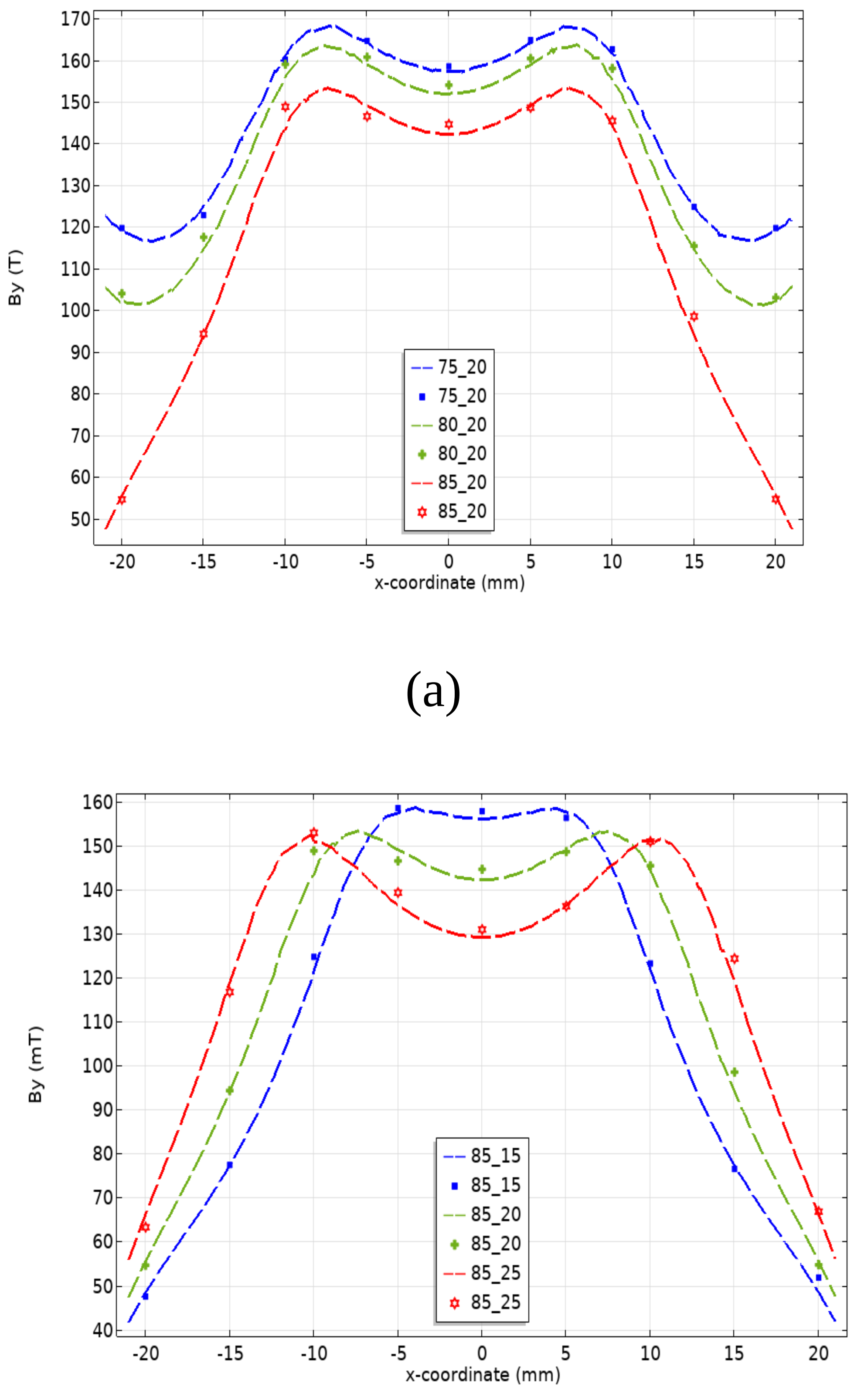


Fig. 4. B_y of measured values (points) and simulation results (dashed lines) with excitation current of 3 A using (a) different MHs and same MW EMG specimens (b) different MWs and same MH EMG specimens.

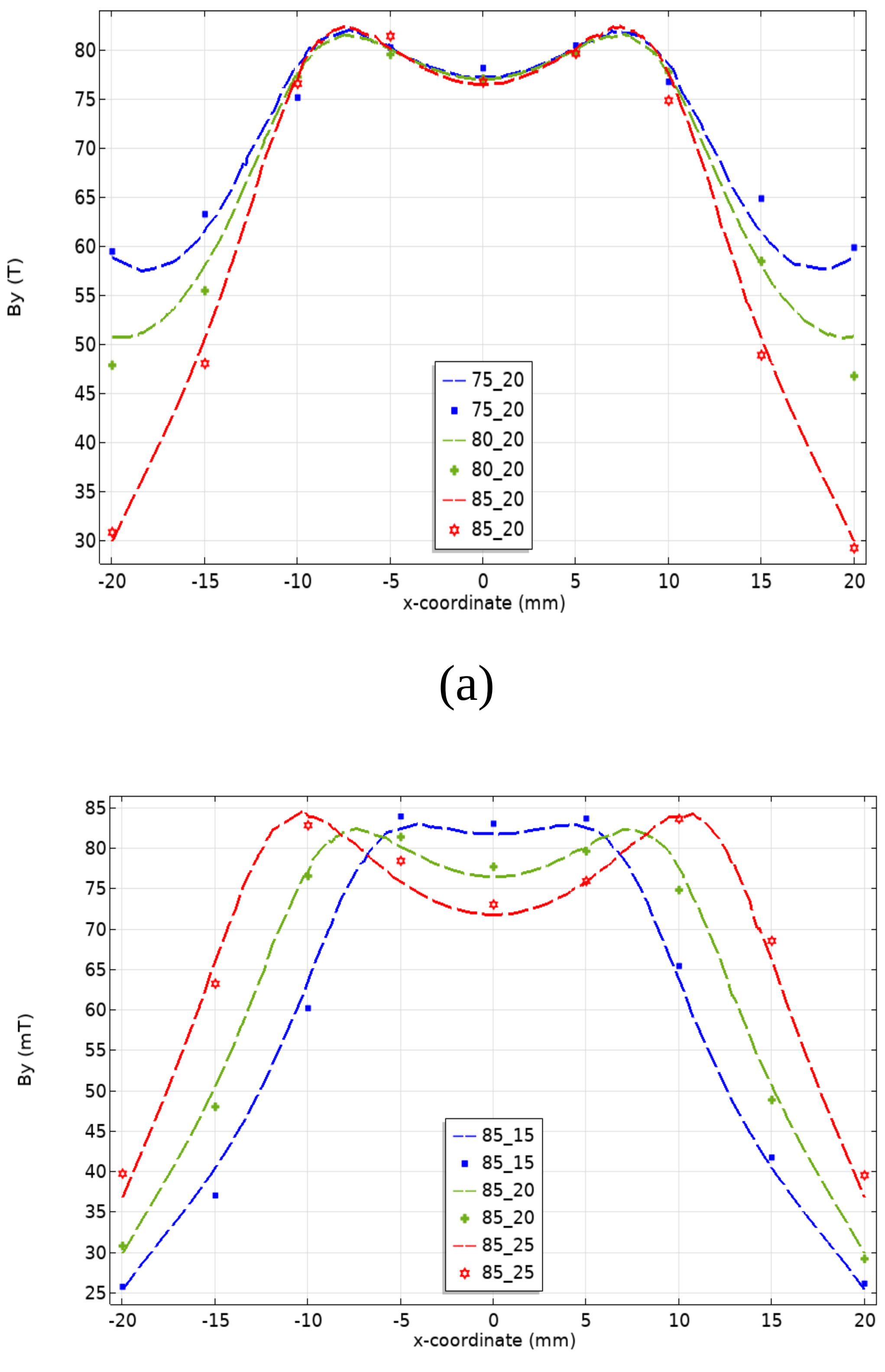
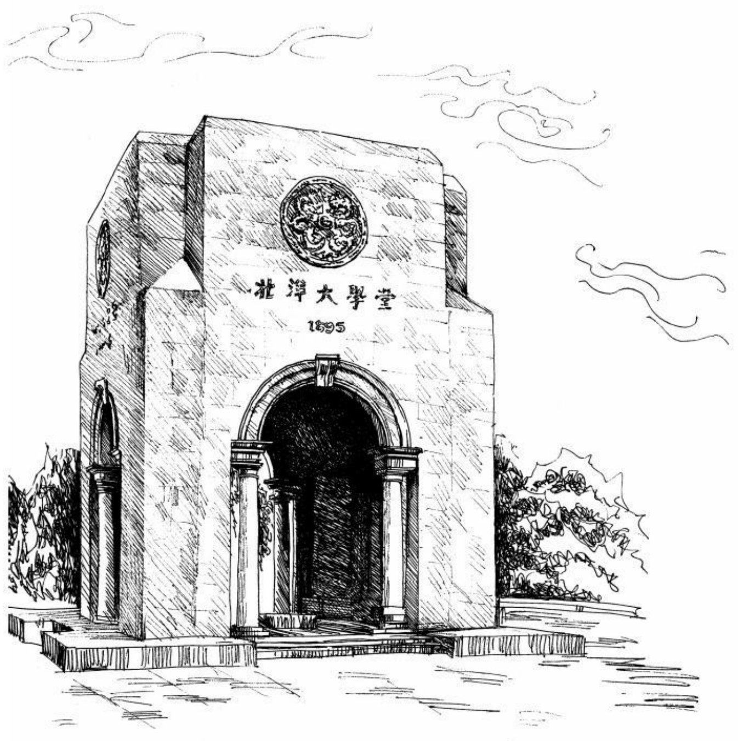


Fig. 5. B_y of measured values (points) and simulation results (dashed lines) with excitation current of 1 A using (a) different MHs and same MW EMG specimens (b) different MWs and same MH EMG specimens.



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Levitation force by adjusting current with different EMG specimens

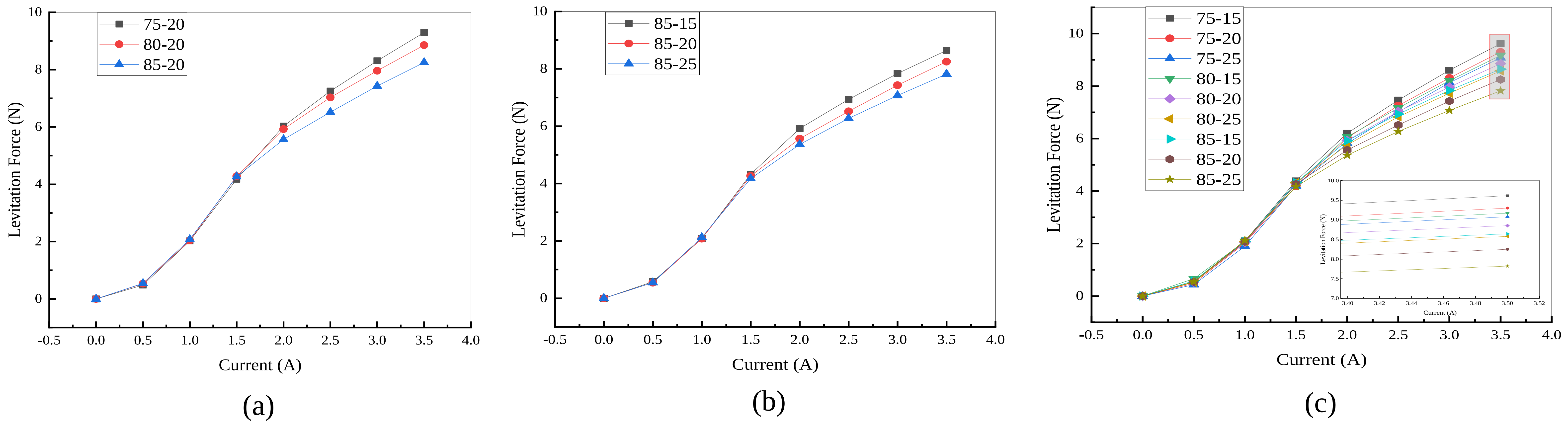

Fig. 6. Levitation force versus current (a) with MW = 20 mm and different MHs (b) with MH = 85 mm and different MWs (c) with all MWs and MHs.

Levitation force by vertical moving with different EMG specimens

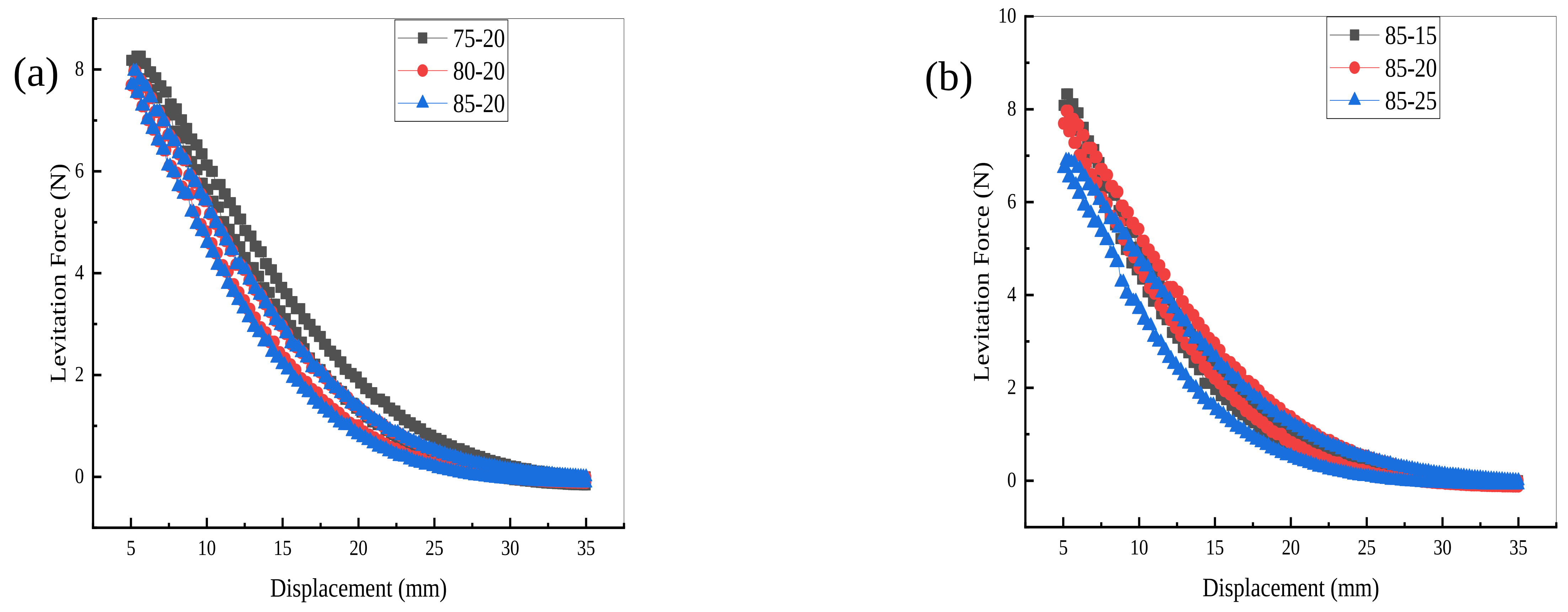

Fig. 7. Levitation force versus displacement with (a) different MHs same MW and (b) different MWs same MH.

Guidance force by lateral moving with different EMG specimens

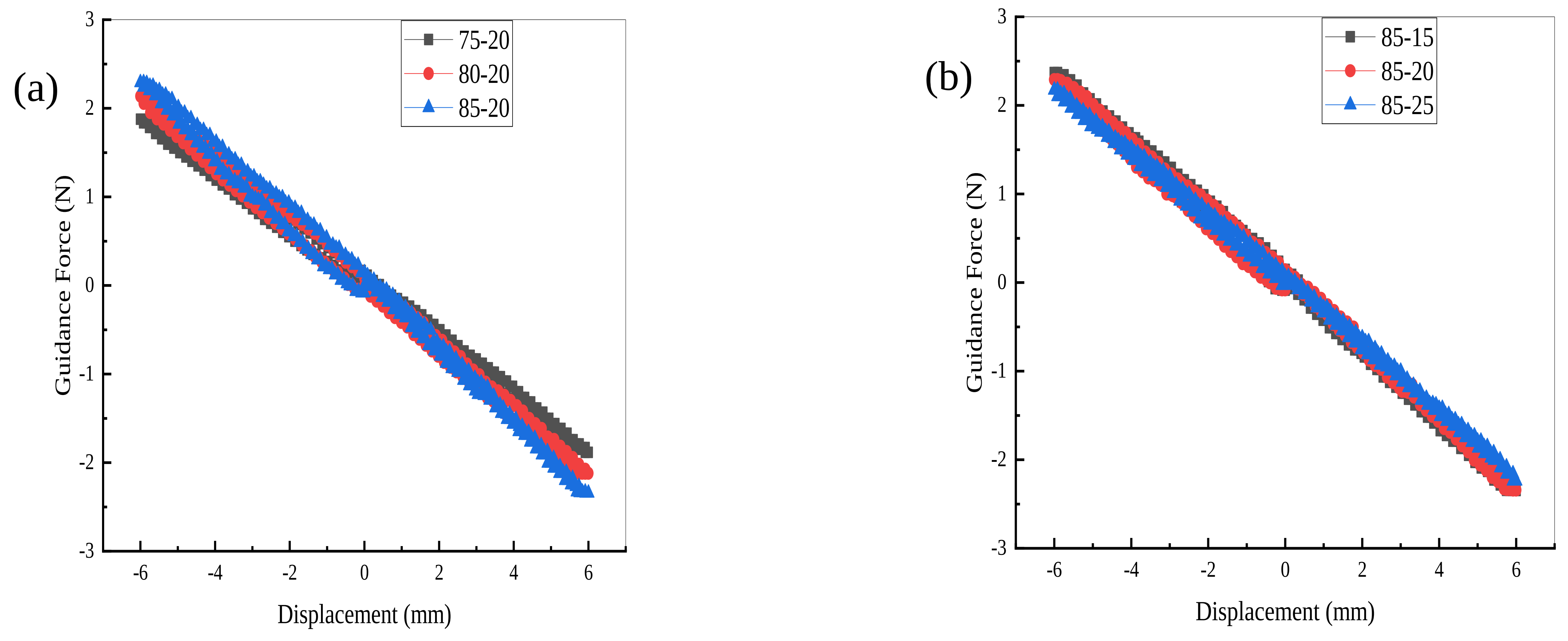

Fig. 8. Guidance force versus current with (a) different MHs same MW and (b) different MWs same MH

Conclusion

The homogeneity of magnetic field of EMG specimen along the guideway has been analyzed by experiment and simulation and the results show the designed EMG specimen has good homogeneity as expected.

The levitation forces obtained by adjusting current and vertical movement are studied with different guideway parameters. The results in this study show that MH = 75 mm performs best in levitation force among the three different MHs that are 75 mm, 80 mm and 85 mm with same MW = 20 mm. MW = 15 mm has the strongest levitation force in different MHs, 15 mm, 20 mm and 25 mm with same MH = 85 mm. These are probably because the magnetic flux change where the HTS bulk locates.

The guidance forces give different results with same parameters, that is, the MH = 85 mm has better performance than the other two MHs, 75 mm and 80 mm with same MW = 20 mm while 85_15 gives the best guidance force in 85_15, 85_20 and 85_25, which is also probably due to the flux change.