Levitation performance of YBCO bulks below the liquid nitrogen temperature zone

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Background

The HTS Maglev

In 2000, Wang *et al*. developed the first manned HTS maglev test vehicle. For the advanced technology and application of HTS maglev vehicle, it has great prospect and economic potential.

The study of levitation force

The relationship between the temperature and levitation force of multiple bulks under different field-cooling heights (FCHs) have not been studied. Moreover, compared with previous researches, the results obtained by measuring the levitation force in the vacuum range are more accurate and closer to engineering applications.

Abstract

High-temperature superconducting magnetic levitation system has the intrinsic advantage of self-stabilizing levitation without external control. The levitation force and the guidance force are important parameters of HTS Maglev system. Many experiments and studies have been done to study the levitation force during liquid nitrogen (LN_2) temperature zone and suggest that the levitation performance of YBCO bulks is better at lower temperature. However, the relationship between levitation force of multiple YBCO bulks and the temperature below the LN_2 temperature zone is seldom studied. Therefore, it is necessary to investigate the levitation performance of multiple bulks at temperatures below 77 K. A low temperature experimental platform was set up based on SCML-01. By this system, measurements of levitation force versus temperature and levitation force versus field cooling heights (FCHs) can be performed at temperatures from 50 K to 90 K. The experimental results showing that the decreasing temperature is beneficial to improve the levitation performance of HTS bulks, and as the temperature decreases the rate of the levitation force increase becomes gently. And the effect of the temperature on the levitation force is considerably minute in low FCH. Moreover, the low temperature could also reduce the hysteresis loop area. According to the experimental data, the most suitable FCH at different temperatures and the lowest cost can be found between the consumption of the bulks and the cryogenic system when designing the HTS Maglev cryogenic system. The results are important for the engineering application of the HTS Maglev train.

Key words—multiple YBCO bulks, low temperature, levitation force, refrigerator.

The low temperature platform

In the experiments, eight rectangular three-seeded YBCO bulks (64*32*13) were used. The permanent magnet guideway (PMG) consists of rectangular NdFeB permanent magnets arranged in a Halbach array.

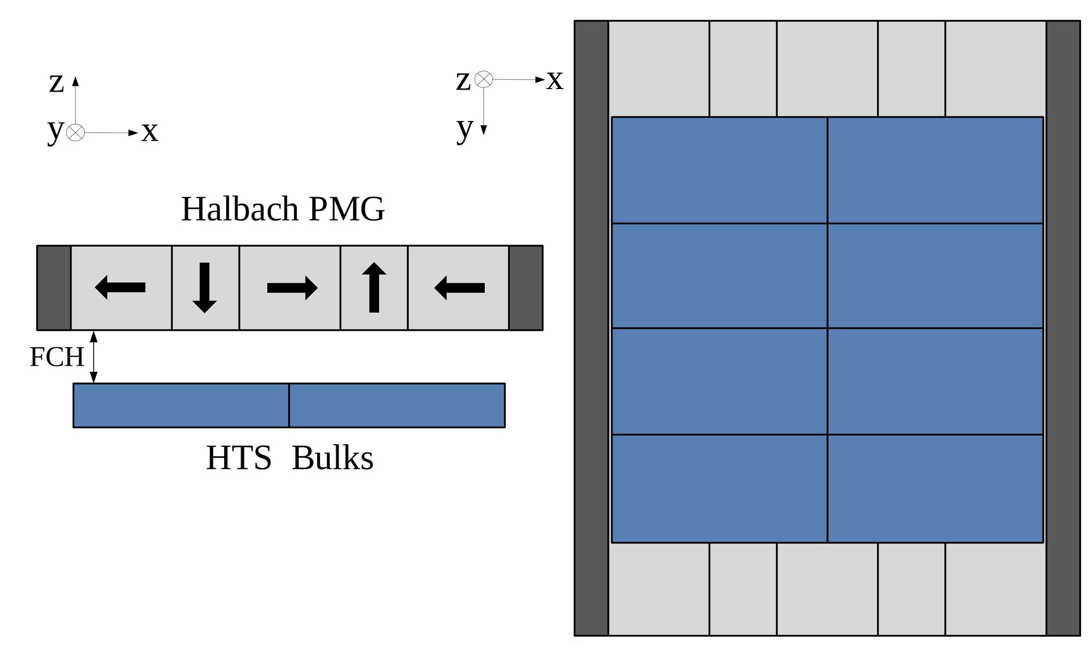

Fig. 1. Schematic of the PMG cross section and bulk array under the PMG

The levitation force of YBCO bulks is measured using the HTS maglev measurement system SCML-01

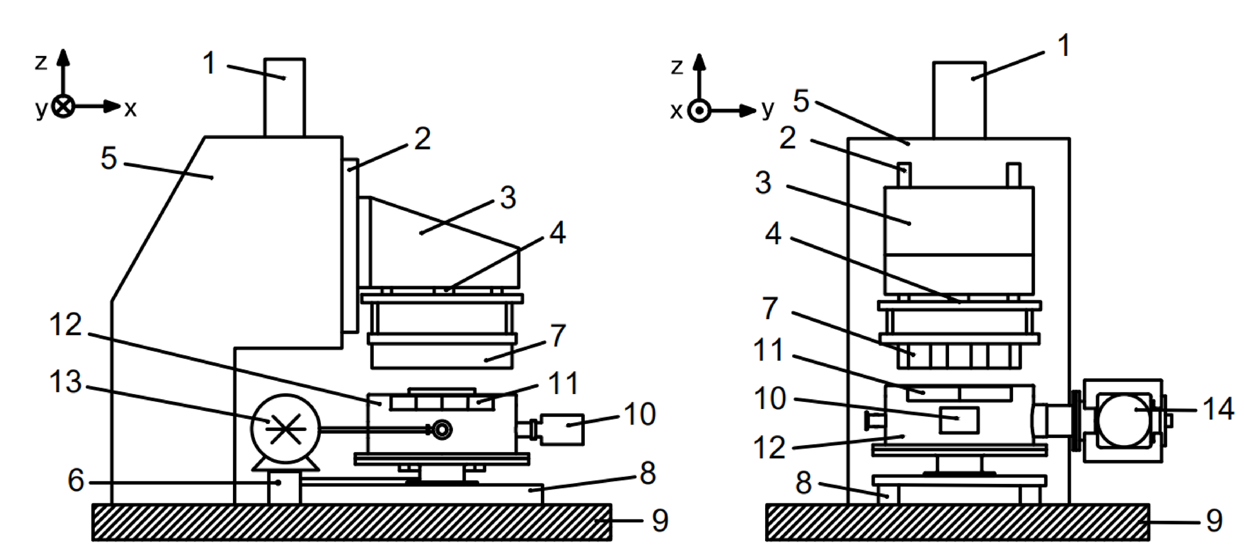

Fig. 2. Schematic of the updated SCML-01 together with a low temperature platform (a) is the side view and (b) is the front view. 1 Vertical servomotor, 2 Vertical guideway, 3 Cantilever, 4 Guidance force sensor, 5 Vertical column, 6 Horizontal servomotor, 7 PMG, 8 Horizontal drive platform, 9 Base, 10 Vacuum gauge, 11 HTS bulks, 12 Cryogenic container, 13 Vacuum pump, 14 Refrigerator.

Resutls and Discussion

The levitation force curves versus vertical distance between YBCO bulks and Halbach PMG when the FCHs are 20 mm, 30 mm and 40 mm.

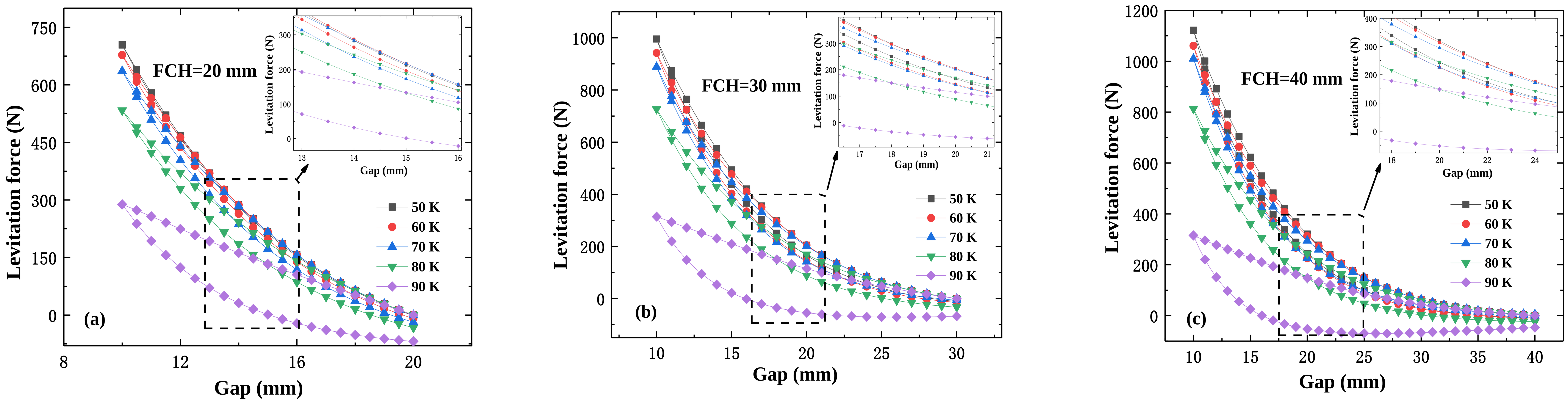

Fig. 3. Levitation force curves of HTS bulks under different temperatures of 50 K, 60 K, 70 K, 80 K and 90 K in the case of FCH 20 mm, 30 mm, 40 mm

Table I
Levitation force at 10 mm under different temperature condition in the case of FCH 40 mm, 30 mm, 20 mm

Levitation force (N)	T=50 K	T=60 K	T=70 K	T=80 K	T=90 K
FCH=40 mm	1121.5	1060.6	1001.0	812.9	315.1
FCH=30 mm	995.2	941.8	888.9	726.5	314.4
FCH=20 mm	704.1	677.9	636.0	533.4	288.7

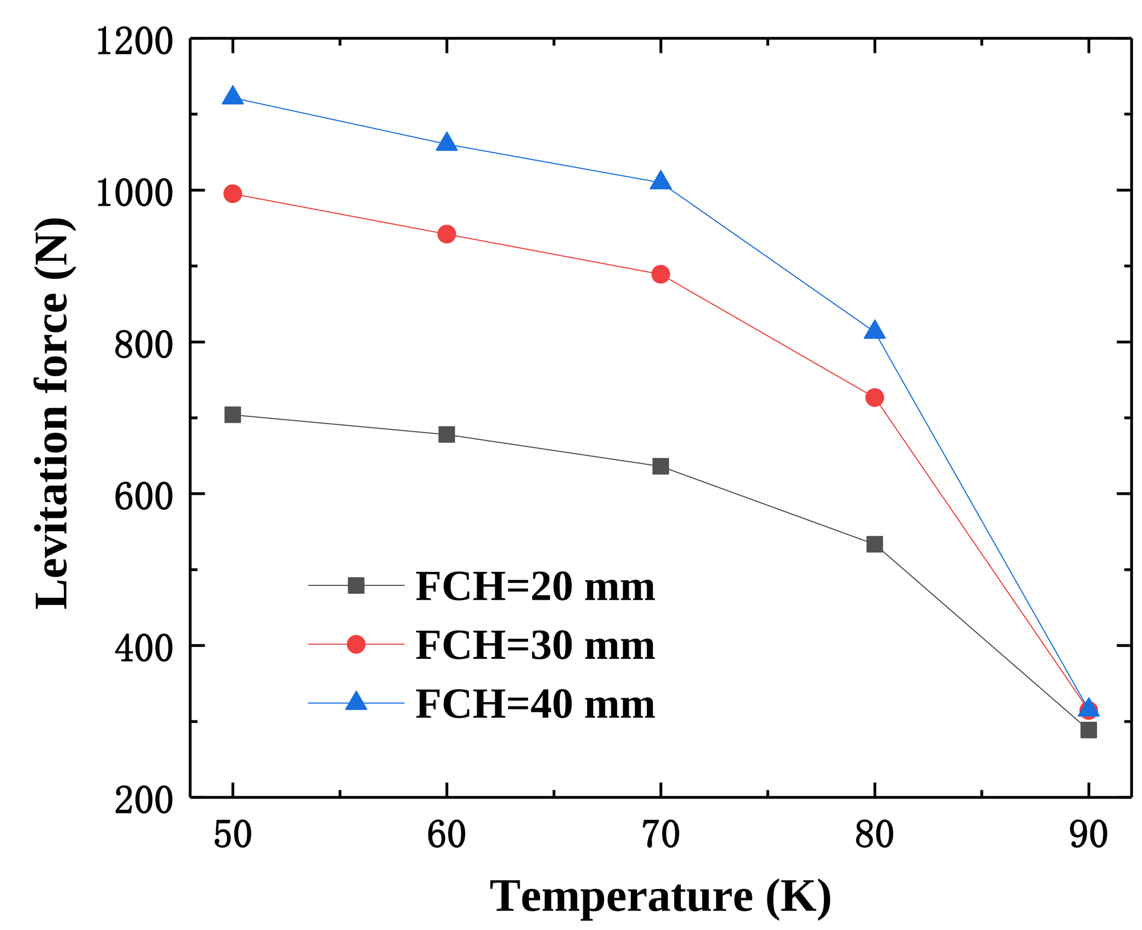

Fig. 4. The temperature variation of the levitation forces by the maximum levitation forces at 10 mm levitation gap in 40, 30, 20 mm FCH

This phenomenon can be described as the change of current density of HTS bulks under different temperature conditions. According to the calculation formula of levitation force:

$$F \propto J_c \frac{dB}{dz} \qquad (1)$$

where F indicates the levitation force, J_c is the critical current density of YBCO and dB/dz is the gradient of magnetic induction at the direction of z. The relationship between J_c and YBCO temperature (T) of YBCO bulk is shown in the formula :

$$J_c \propto J_{c1} \frac{(T_c - T)}{(T_c - T_0)} \qquad (2)$$

where T_c is the critical temperature of YBCO bulk, T_0 is ambient temperature or LN_2 temperature, J_{c1} is the critical current density of 77 K YBCO. As shown in Eq. 2, the temperature decrease of YBCO can directly lead to the enhancement of critical current density (J_c) inside the bulks. As Fig. 3. shown, under the interaction between the higher J_c and the magnetic field supplied by the PMG, the levitation force becomes more superior.

According to the data comparison from 50 K to 90 K in 20 mm, 30 mm, 40 mm FCH, it is found that the original FCH and the temperature is the key element for the enhancement of the levitation force. Especially, we can obtain better levitation performance (1121.5 N) at lower temperature (50 K) in higher FCH (40 mm).

Conclusion

1.The levitation force is larger obviously at lower temperature than at higher temperature near the critical temperature of the YBCO.

2.The rate of the levitation force increase becomes gently between 80 and 50 K . Moreover, with the FCH falling, the growth rate of levitation force measured under different temperature conditions are gradually reduce.

3.The low temperature condition is not only able to take a larger levitation force but also to reduce the hysteresis loop area of levitation curves.

4.In this experiment, we can obtain the greater levitation force from 50 K in 40 mm FCH.