Levitation Force Characteristics of High-Temperature Superconducting Bulks in a High Magnetic Field

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INTRODUCTION

The levitation force increases with the increase of the external magnetic field. In recent years, HTS bulks have been able to achieve a trapped magnetic field of more than 10T with an external magnetic field of 18 T. Because the high magnetic field is very difficult to obtain, and the device for producing the high magnetic field is extremely expensive, few previous studies have given the levitation force characteristics of HTS bulks in high magnetic field. In this study, in order to obtain a high external magnetic field, we used 5T Cryogen-Free magnet (Job Number 3226, Cryogenic Limited) as the magnetic field source. It can be studied that the levitation force of the HTS bulk mainly depends on its critical current density, which is anisotropic. If we change the angle between the external magnetic field and the *c*-axis of HTS bulks, the levitation force can be changed. It can be also studied that increasing the external magnetic field gradient can give rise to the levitation force. Therefore, the effect of the external magnetic field gradient on the levitation force of a HTS YBCO bulk in high magnetic field was studied in this research. Besides, we explored the relationship between the angle and the levitation force by changing the angle between the external magnetic field and the *c*-axis of the bulk.

CONCLUSION

- It is further confirmed that the levitation force increases with the increase of the external magnetic field in high magnetic field.
- The levitation force of the HTS YBCO bulk reaches its maximum when the gradient of external magnetic field reaches its maximum, which proves that the external magnetic field gradient plays a decisive role in the levitation force in high magnetic field.
- The angle between the external magnetic field and the *c*-axis of the the HTS YBCO bulk was set to θ, and the levitation force decreases with the increase of θ.
- Based on the formula proposed in Yang's paper, which is more suitable for low magnetic field, a correction coefficient ζ was added to make the new formula more compatible with the experimental data.

EXPERIMENTAL

Fig. 1 shows the physical diagram and schematic illustration of the levitation force test platform. In order to make full use of the magnetic field in the 300 mm clear room temperature bore of the 5 tesla Cryogen-Free Magnet system, the levitation force test platform was designed and built. The angle between the external magnetic field and the *c*-axis of the HTS YBCO bulk was set to θ. Four angles (θ=0°, 30°, 60°, 90°) have been selected to study the relationship between the angle and levitation force.

Fig. 1. The levitation test platform. (a) Schematic illustration of the levitation force test platform, (b) physical diagram of the levitation force test platform, (c) The fixture of the HTS YBCO bulk and its rotation axis, (d) The specific rotation modes of the HTS YBCO bulk.

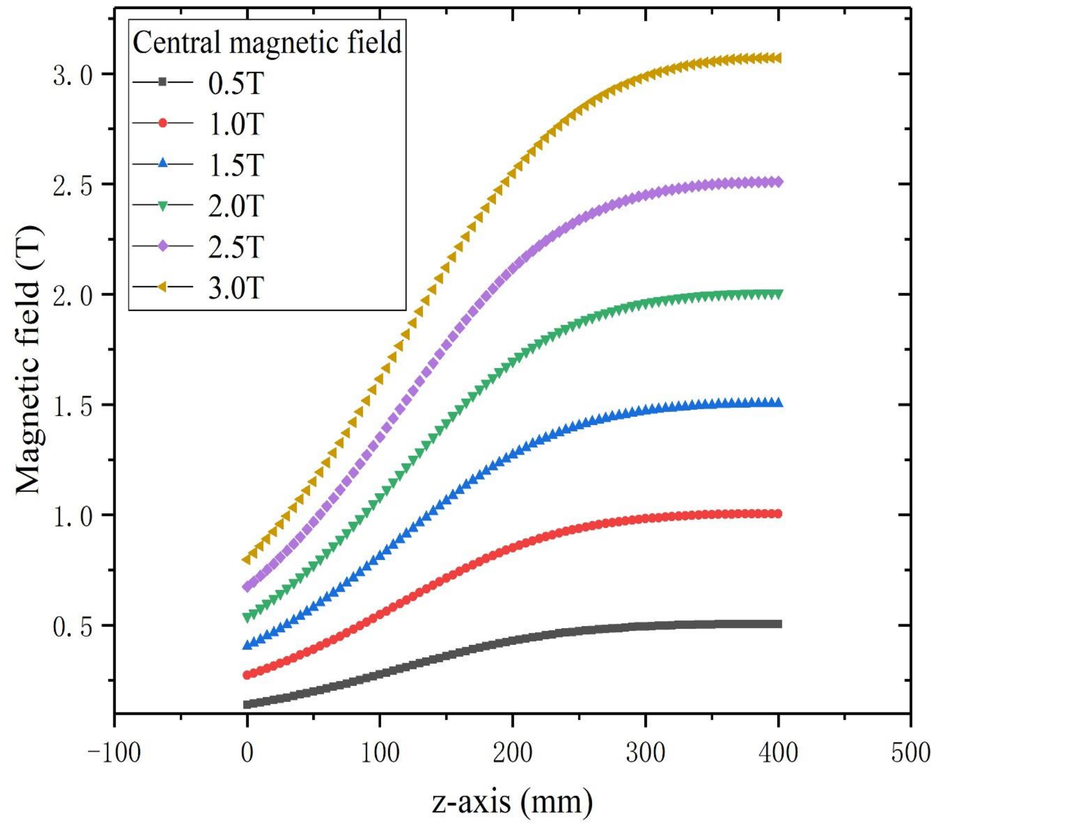

Fig. 2. Magnetic field distribution of the 5 TESLA Cryogen-Free Magnet system along the *z*-axis.

The center axis of the 5 Tesla Cryogen-Free Magnet system was set to the *z*-axis, the *z*-axis coordinate of the system surface was set to zero, and downward direction was defined as the positive direction. In the preparation stage of the experiment, the distribution of the magnetic field of the *z*-axis was measured and the results are shown in Fig. 2.

RESULTS AND DISSCUSSION

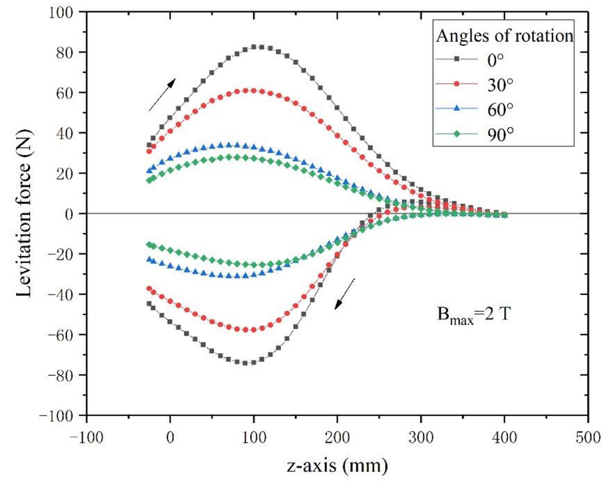

Fig. 4. Levitation force of the HTS YBCO bulk after rotating at different angles when the central magnetic field is 2 T.

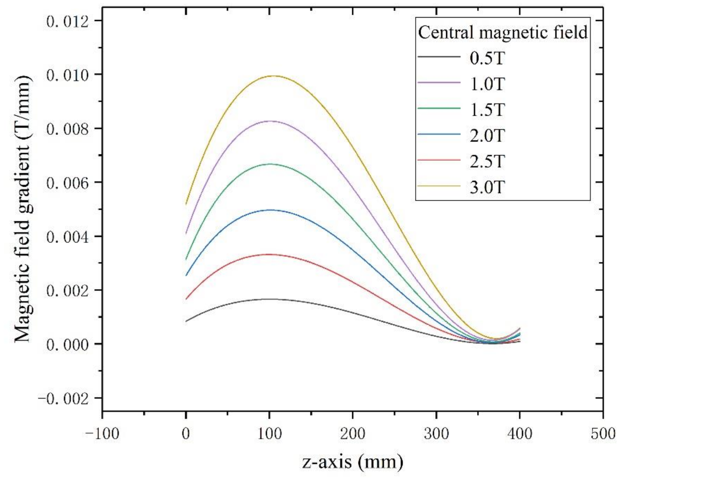

Fig. 6. Magnetic field gradient distribution of the 5 TESLA Cryogen-Free Magnet system along the *z*-axis.

Correction coefficient ζ was proposed to improve the formula proposed in Yang's paper.

$$F = \zeta * (F_0/k) * (k(\cos\theta)^2 + (\sin\theta)^2)$$

$$k = F_0/F_{90}$$

$$\zeta = 1.220 - 0.244B + 0.025B^2$$

where F is the levitation force of a HTS YBCO bulk, F_0 is the levitation force when θ is 0°, F_{90} is the levitation force when θ is 90°, B is the central magnetic field of the 5 tesla Cryogen-Free Magnet system and ζ is the correction coefficient. Table 2 shows that the new formula has a good match with the experimental data.

Table II. Comparison of calculated and measured values

Central magnetic field (T)	Angles	Levitation force (N)		
		Calculated value		Measured value
		No ζ	Contains ζ	
2	30°	68.85	57.12	60.82
	60°	41.47	34.50	33.54
2.5	30°	79.02	60.53	63.94
	60°	46.62	35.71	33.12
3	30°	86.44	61.63	66.9
	60°	50.02	35.66	33.04

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