Superconducting quadrupole magnets in the interaction region of CEPC

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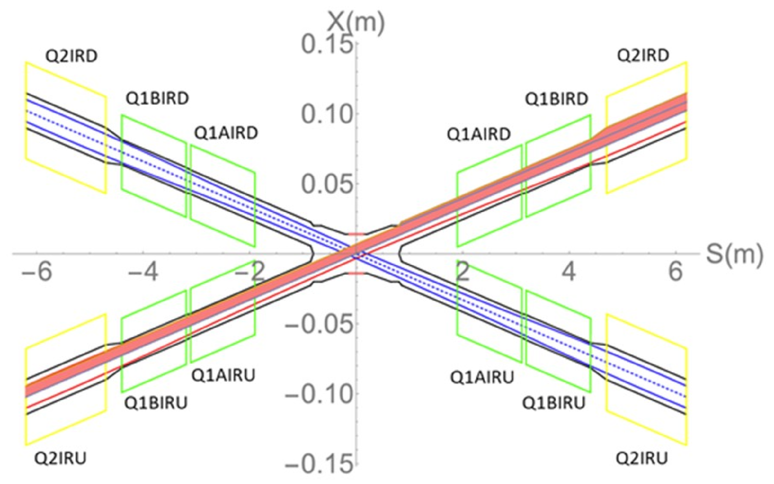
1 Abstract

This poster presents research on a dual-aperture superconducting quadrupole magnet of CCT type without iron core shielding, which is being designed for the interaction region of the CEPC project. It mainly introduces the direct-winding magnet design scheme and the development of direct-winding technology for fabricating CCT magnets.

2 Introduction

The accelerator of CEPC is now in the engineering design phase, which places more stringent requirements on the design of the superconducting quadrupole magnets in the interaction region. The need to reduce both the weight of the superconducting magnets and the deformation of the cantilevered support has led to the proposal of an ironless magnet solution. As the dual aperture magnets are not shielded by iron yokes, crosstalk will affect the magnetic field quality. For this reason, we propose the ironless dual aperture superconducting quadrupole magnet without correction coils.



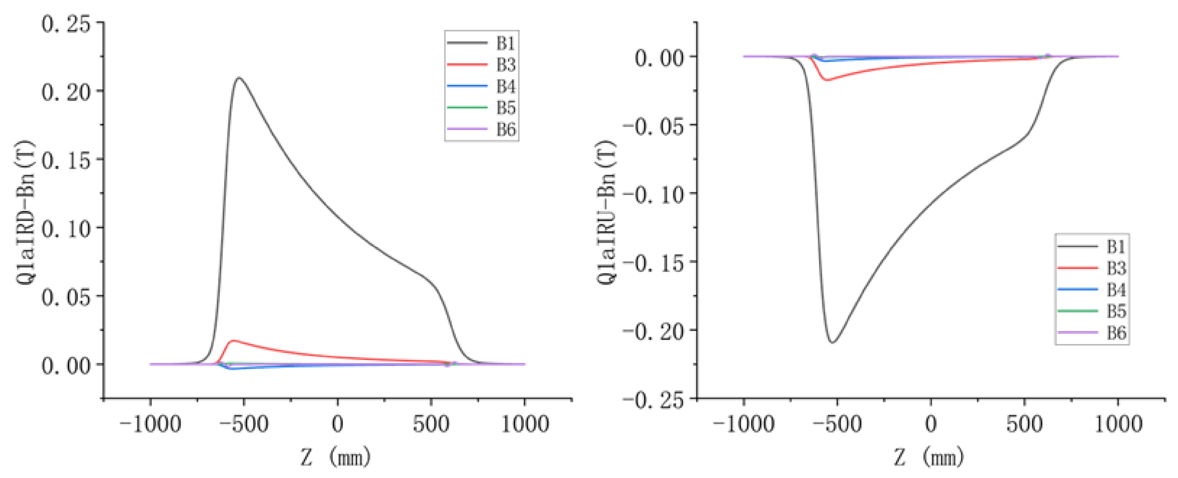
Layout of SCQ magnets in the interaction region.

3 Purpose

The dual-aperture superconducting quadrupole magnet Q1a, with the interaction region closest to the interaction point and the smallest distance between the two apertures in the Higgs mode, is taken as an example. The magnetic field quality problems caused by crosstalk and edge effects between the two apertures of the magnet are solved to meet the EDR requirements for the Q1a magnet.

Item	Value	Unit
Position from the IP	1900	mm
Magnetic field gradient	142.3	T/m
Reference radius	7.46	mm
Magnetic length	1210	mm
Distance between two aperture beam lines at tip	62.71	mm
Integrated field harmonics	≤3×10-4	-
Dipole field in aperture	≤300	G

Requirements of Q1a magnet.



Uncorrected CCT Q1a magnet multipole components.

4 Method

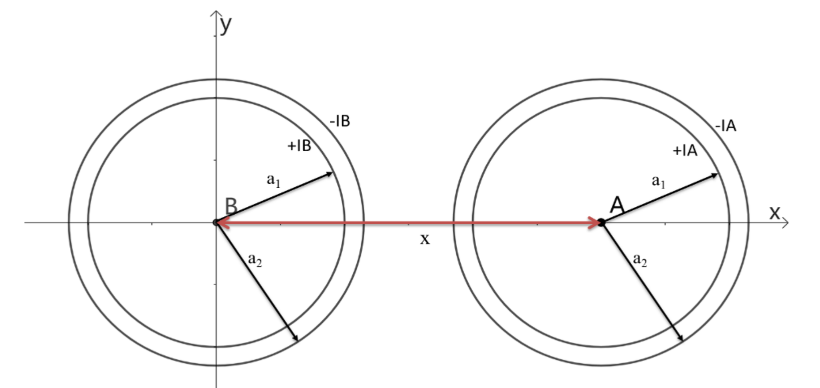
The CCT coil path can be expressed by the equation, and the surface current density is used to derive the corresponding current density distribution of the coil and the magnetic field it generates. Therefore, by modifying the coil path equation, the current density distribution of the coil can be adjusted and new multipole magnetic fields can be added without the corrector coils.

Modified CCT coil path equation:

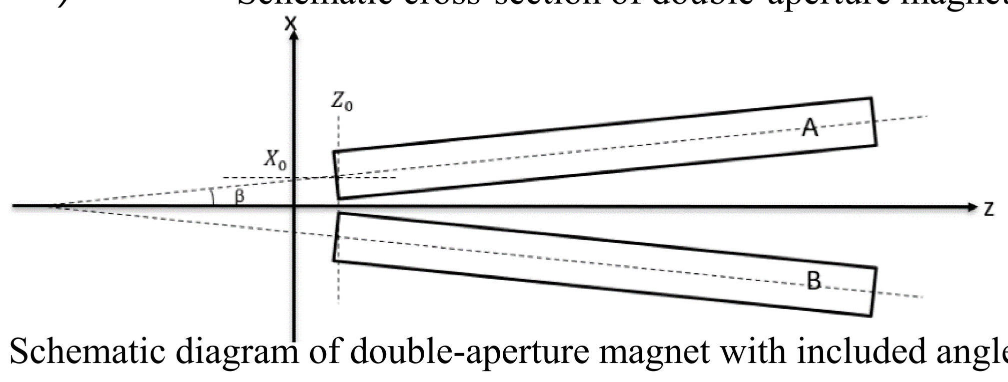
$$\vec{P}(\theta) = \begin{cases} R\cos\theta \\ R\sin\theta \\ \dfrac{R}{n\tan(\alpha)}\sin(n\theta) + \dfrac{w\theta}{2\pi} + z' \end{cases}, -\pi N \le \theta \le \pi N$$

$$z' = \sum_{n_1}\left(C_m \frac{R\sin(n_1\theta)}{n_1 \tan\alpha}\right) + \sum_{n_2}\left(D_m \frac{R\cos(n_2\theta)}{n_2 \tan\alpha}\right)$$

$$\begin{cases} C_A = (-1)^{n-1} C_{n+m-1}^{n-1} \dfrac{I_B}{I_A}\left(\dfrac{R}{x}\right)^{n+m} \\ C_B = (-1)^{2n+m-1} C_{n+m-1}^{n-1} \dfrac{I_B}{I_A}\left(\dfrac{R}{x}\right)^{n+m} \end{cases}$$



Schematic cross-section of double-aperture magnet.

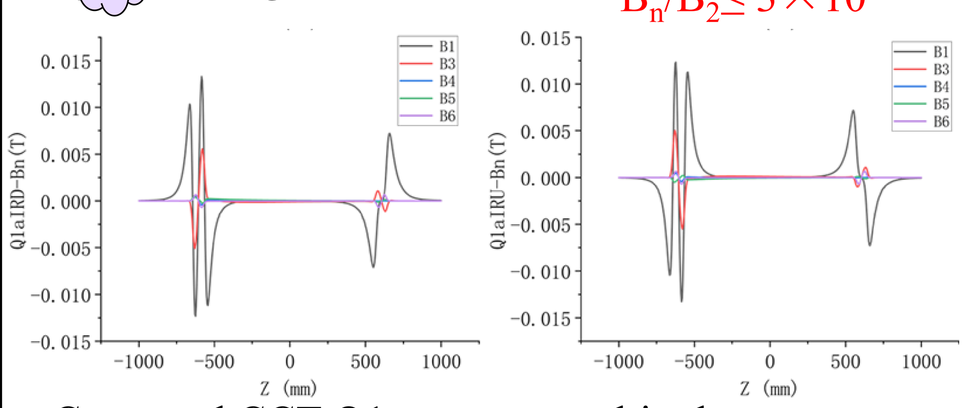


Schematic diagram of double-aperture magnet with included angle.

The beam crossing angle between the two apertures of the superconducting magnet in the CEPC interaction region is 33 mrad, so the distance between the two apertures varies with position.

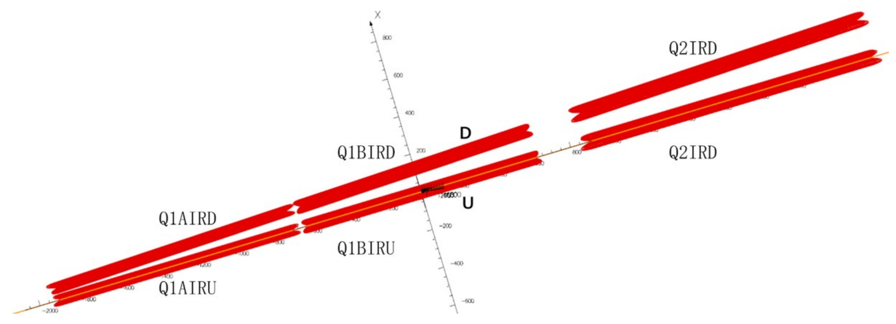
$$x = 2 \times \left[\left(Z_0 + \frac{R}{2\tan(\alpha)}\sin(2\theta) + \frac{w\theta}{2\pi} + z'\right)\tan\beta + X_0\right]$$

5 Result

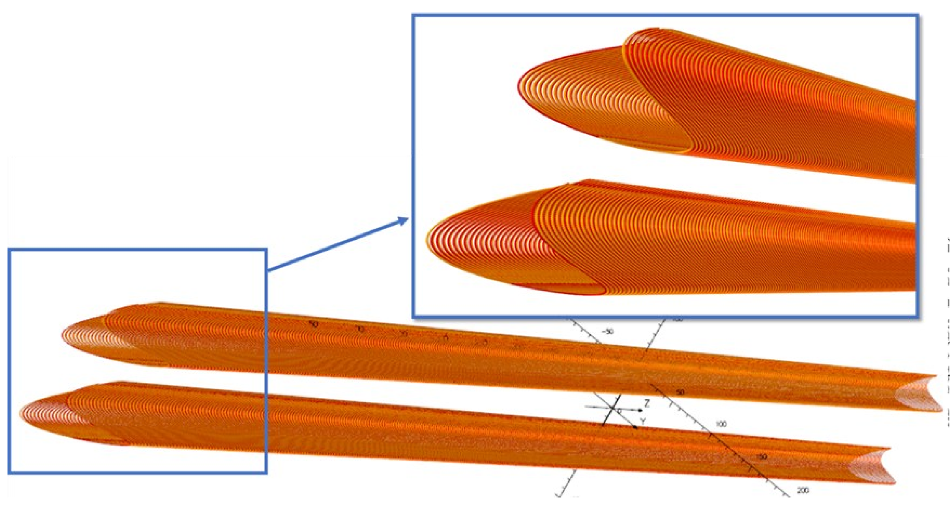


Corrected CCT Q1a magnet multipole components.

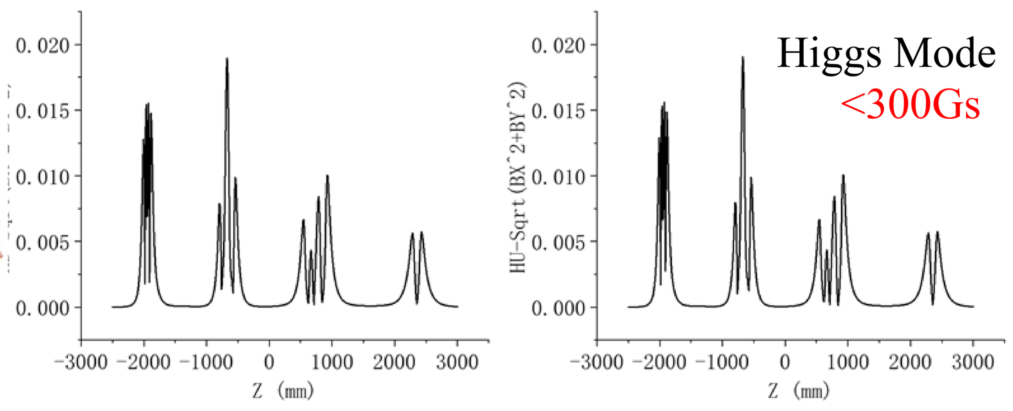
The critical aspect of the magnet combination analysis is to determine whether the magnitude of the dipole field amplitude meets the physical requirements after combining Q1a, Q1b, and Q2.



Q1a, Q1b, Q2 magnets 3D model.

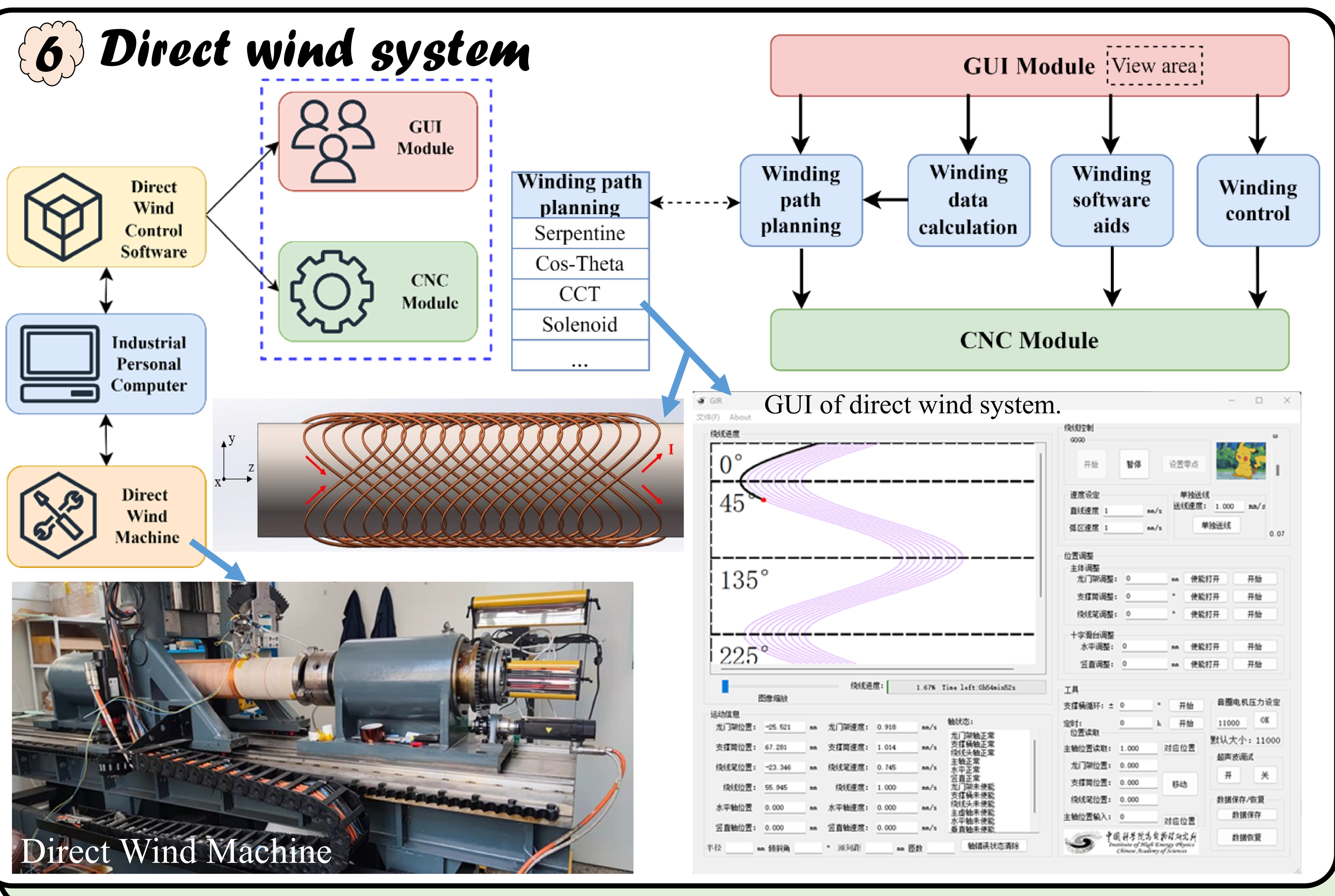


Comparison of single-layer Q1a coil before (red) and after (orange) adjustment.



Amplitude of Q1a, Q1b, Q2 dipole field.

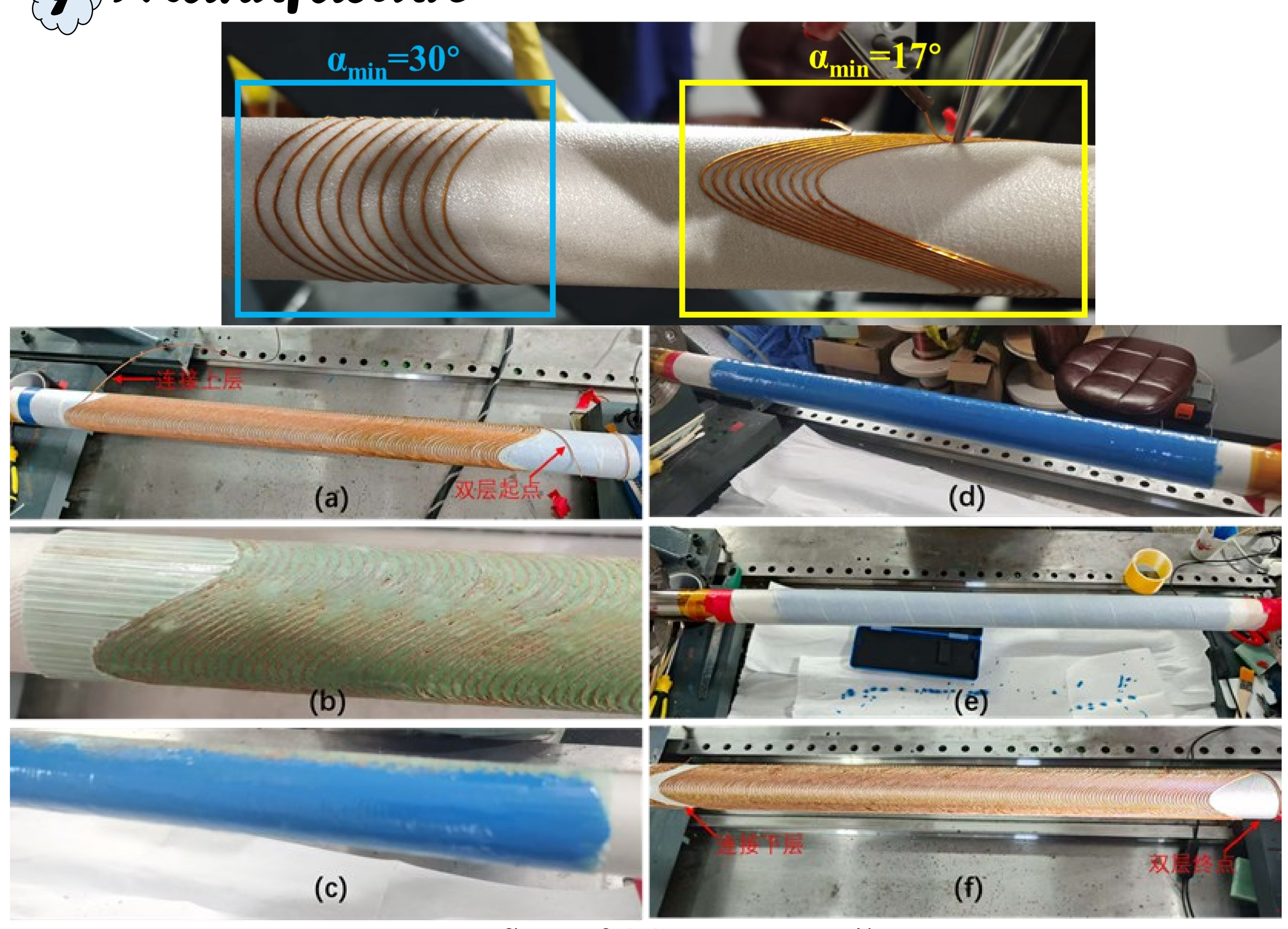
6 Direct wind system



GUI of direct wind system.

Direct Wind Machine

7 Manufacture



Process flow of CCT magnet coils.