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Investigation of Thermal Stability of Quasi-isotropic Superconducting Strand Stacked by 2mm Wide REBCO Tapes and Cu Tapes

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Introduction

A three dimensional (3-D) numerical model which considered the temperature field in axis and radius was built to study the thermal stability of the strand in this paper, including minimum quench energy (MQE) and quench propagation velocity (QPV), and a strand was prepared to examine the thermal stability experimentally as well. Results show that the quasi-isotropic superconducting strand has higher MQE and lower QPV than the previous quasi-isotropic superconducting strand. The results can provide a fundamental analysis for further developing device of high-current electric power transmission with high thermal stability.

Structure of the Quasi-isotropic Superconducting Strand

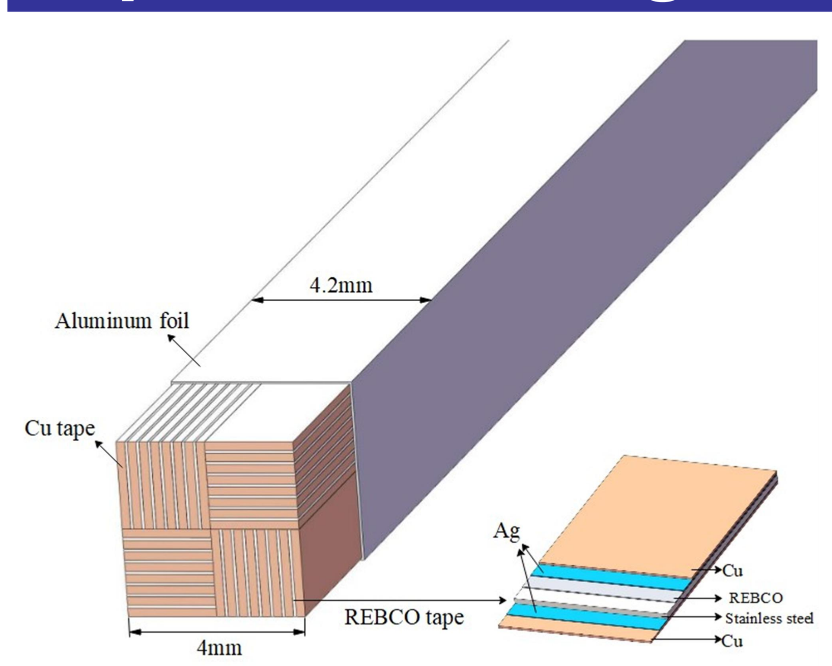

Fig. 1. the schematic diagram of the quasi-isotropic superconducting strand

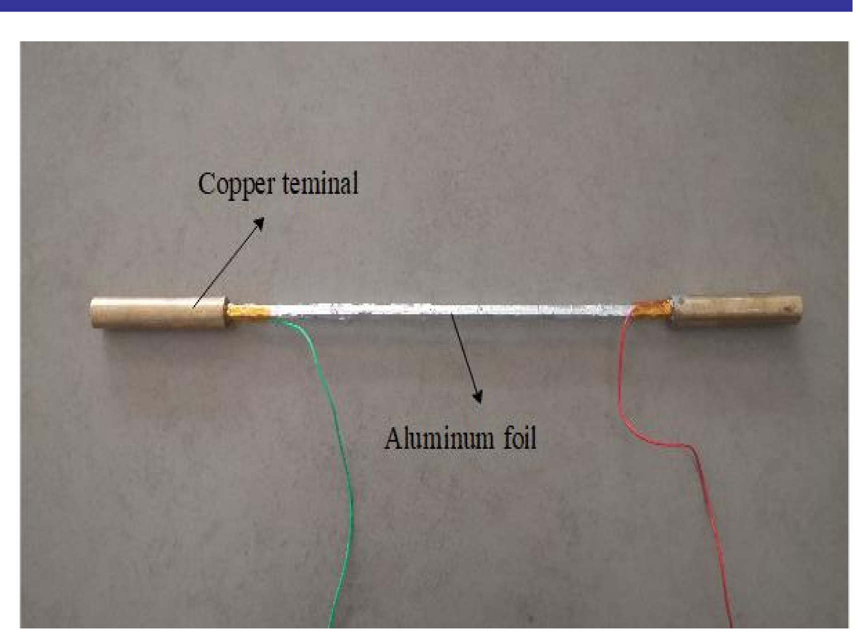

Fig. 2. The prototype of the strand

Numerical Model

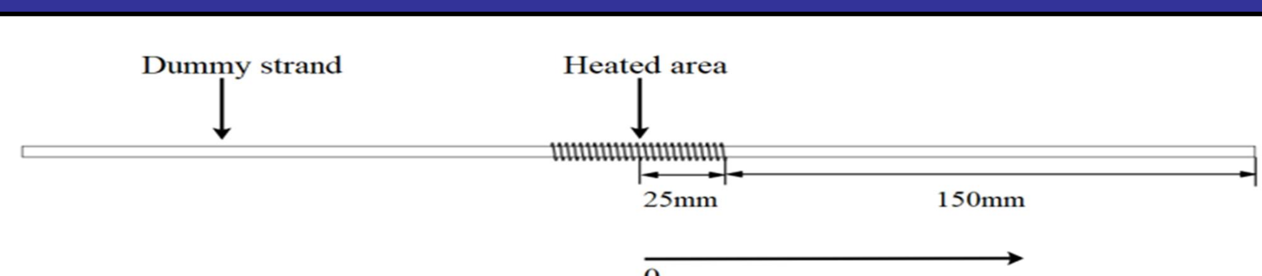

Fig. 3. Schematic view of the heating area in the quasi-isotropic superconducting strand.

$$(\gamma C)_{\mathrm{eff}}(T)\frac{\partial T}{\partial t}=\nabla(K_{\mathrm{eff}}(T)\nabla T)+G_{\mathrm{d}}(t)+G_{\mathrm{j}}-G_{\mathrm{q}}$$

T: temperature of the strand (K),

t: time (s),

$(\gamma C)_{\mathrm{eff}}(T)$: effective specific heat (J/m³·K),

$k_{\mathrm{eff}}(T)$: effective thermal conductivity (W/m·K),

$G_d(t)$: heat disturbance per unit volume(W/m³),

G_j: joule heat per unit volume(W/m³),

G_q: cooling per strand surface over a unit (W/m³).

Numerical Results

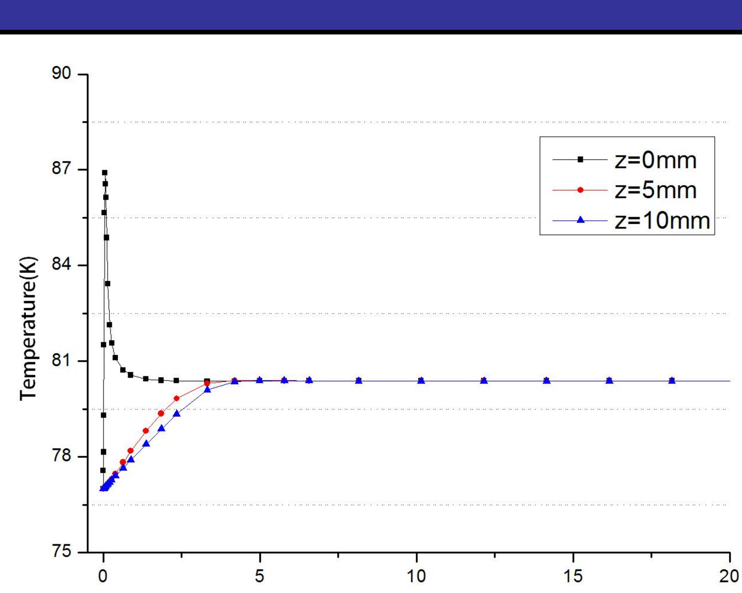

Fig. 4. the temperature of some points(Z=0,5,10cm) along the axis of the strand with I_O=0.9I_{C77K} and heated term of 12.8J.

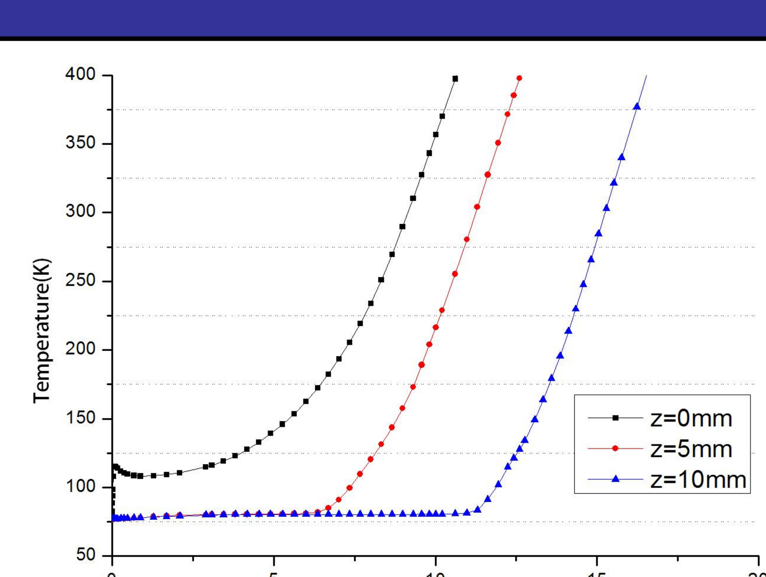

Fig. 5. the temperature of some points(Z=0,5,10cm) along the axis of the strand with I_O=0.9I_{C77K} and heated term of 17.9J.

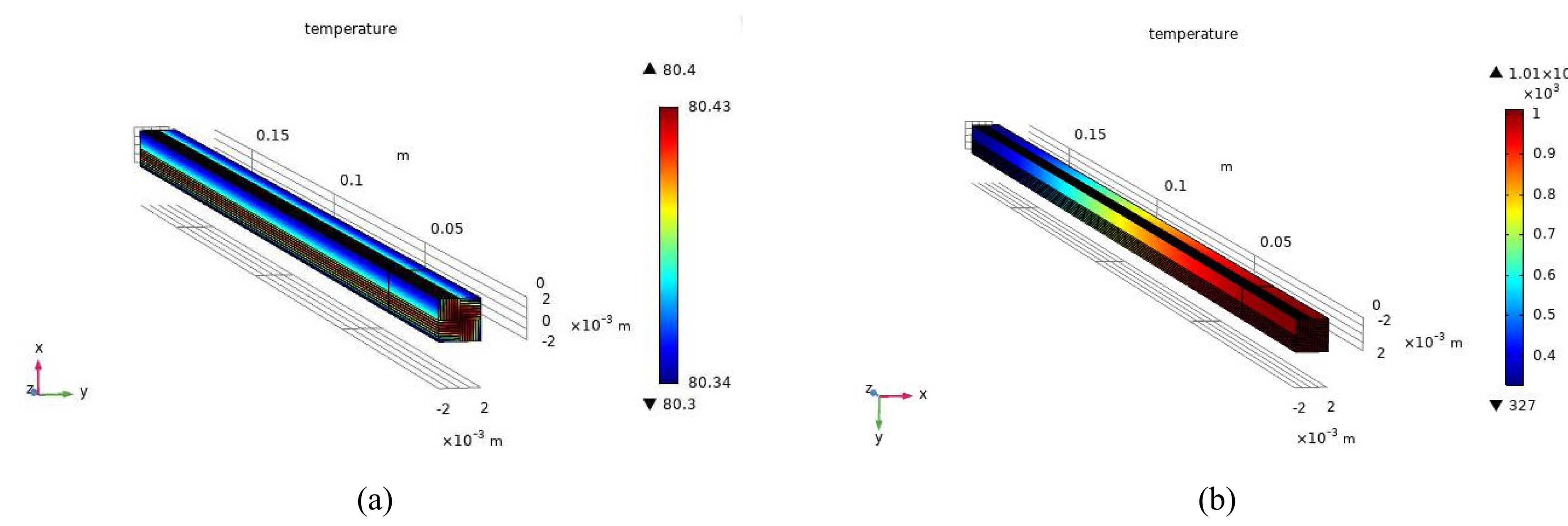

Fig. 6. The three-dimensional quench simulations of the strand（I_O=0.9I_{C77K}） with heated term of 12.8J(a) and 17.9J(b) at final state(t=20s).

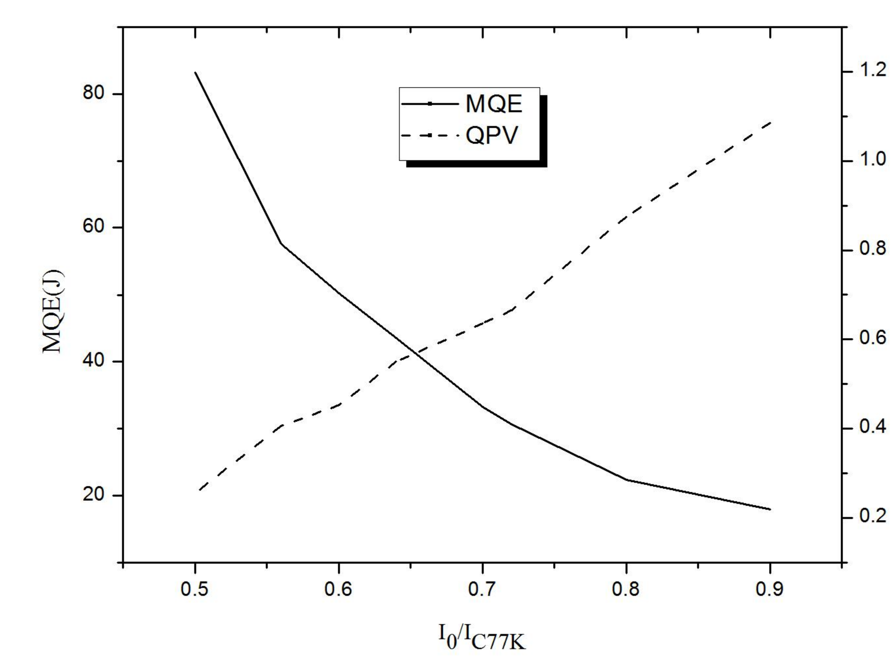

Fig. 7. MQE and QPV of the strand in different normalized current.

MQE decreases with the increase of I_O/I_{C77K} because when the operating current increases, the generated joule heat per second grows which accelerates the accumulation of the heat. the strand quenches more easily and the quench propagation velocity is higher.

Experiment

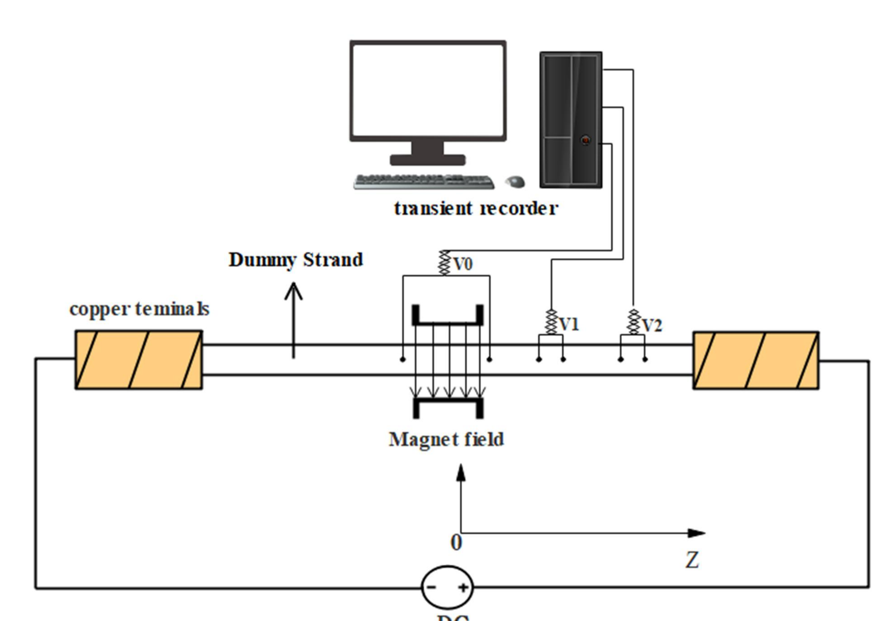

Fig. 8. Schematic view of the experimental system.

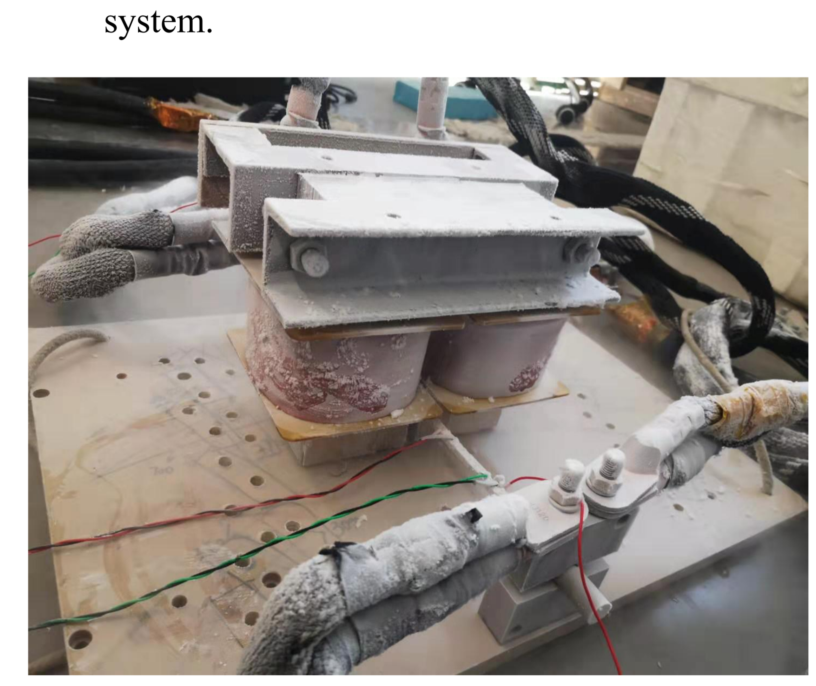

Fig. 9. View of the experimental set-up.

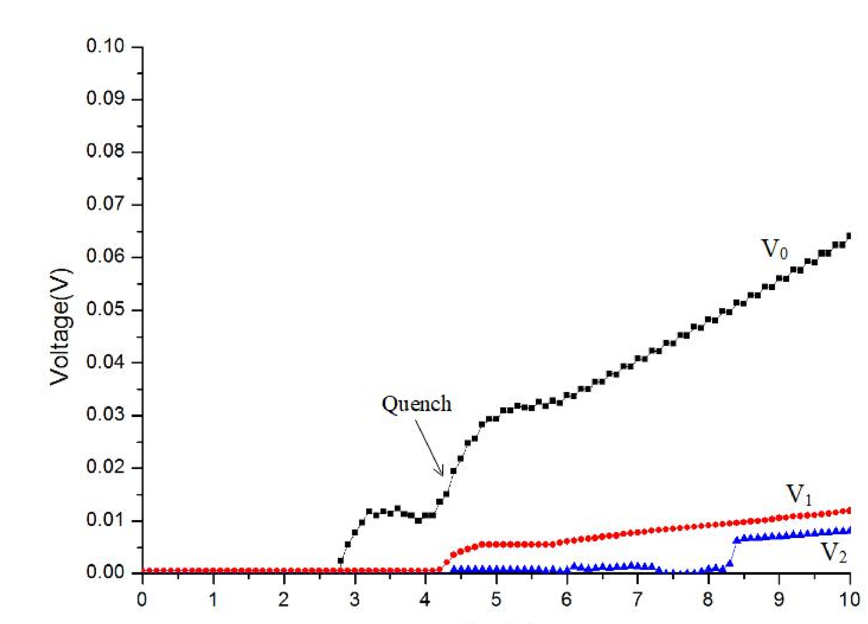

Fig. 10. Voltage development of the quasi-isotropic superconducting strand stacked by REBCO tapes and copper tapes with I_O=0.9I_{C77K} 1350A）and heated term of 34.1J.

Table. I. simulation and experimental results of the strand at 77 K

I_O/I_{C77K}	MEQ (J)		QPV (cm/s)	
	Simulation	Experiment	Simulation	Experiment
0.7	66.5	66.5	0.64	0.63
0.8	44.8	48.0	0.87	0.91
0.9	35.8	34.1	1.08	1.22

Conclusion

- Simulation results are in good agreement with the experiment.
- The strand has higher thermal stability than the previous quasi-isotropic superconducting strand（The axial MQEs measured by them are ~10-30 cm/s and the axial QPVs are ~2-5 cm/s）.
- Due to its good thermal stability, this quasi-isotropic superconducting strand stacked by REBCO tapes and Cu tapes can be applicated in high-current electric power transmission with high stability.