Development of the aluminum stabilized superconductor

Wuxi Toly Electric Works Co.,Ltd.
Zhao Yu , Nov.2024
zhaoyu@toly.com.cn

Contents

公司简介

Toly Electric, to build the world's leading winding wire enterprises

- The company established in 1992, focusing on winding wire research and development and manufacturing, committed to becoming the world's leading provider of green energy transmission solutions
- The company is a high-tech enterprise, provincial specialized new small giant enterprise
- In 2020, Toly Electric joined Gold Cup Group (stock code: 002533), becoming another major brand economy in its winding wire industry and opening a new journey of development

87.5 million RMB
Registered capital

2.84 billion RMB
sales revenue (Year 2023)

55000 MT
Annual production capacity

600+
Number of employees

50000㎡
Covered area

Gold Cup Group

- Gold Cup Electric Apparatus Co., Ltd. founded in September 1999 (stock code 002533), is the leading enterprise of wire and cable industry in the Central and western regions of China, the leading enterprise of flat winding wire in China, and the champion of home improvement cable sales in China.

15.3 billion
sales revenue in year 2022)

4500+
Total number of employees

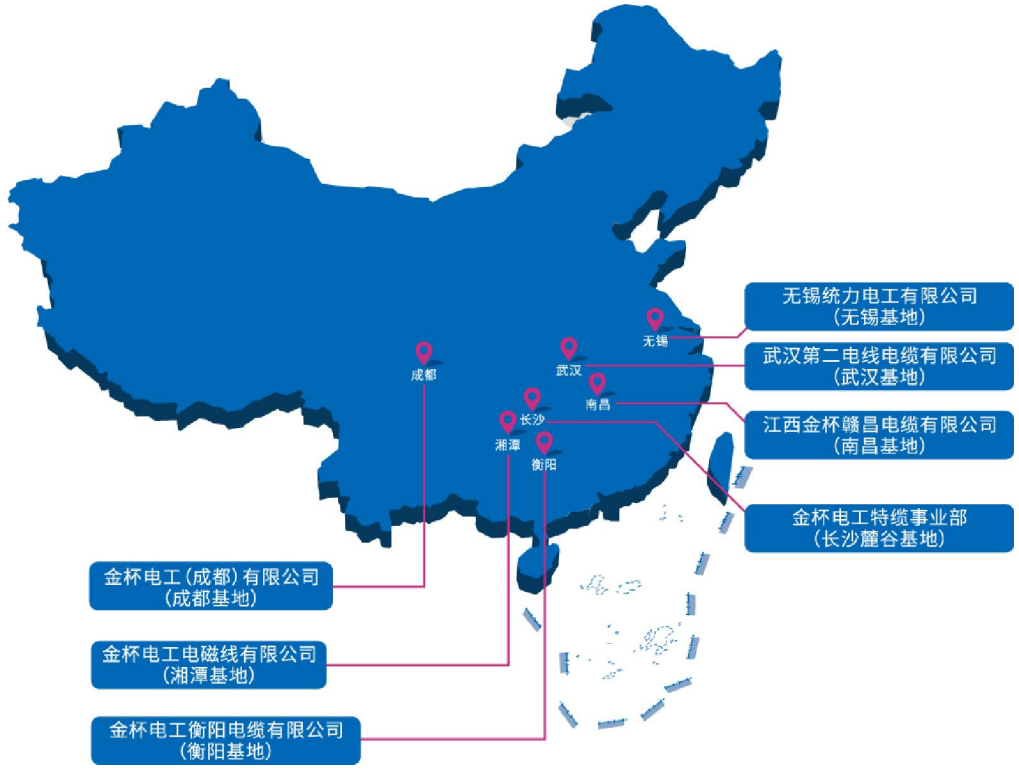
No. 12
2023 China cable industry most competitive ranking

11
No. of subsidiary corporation

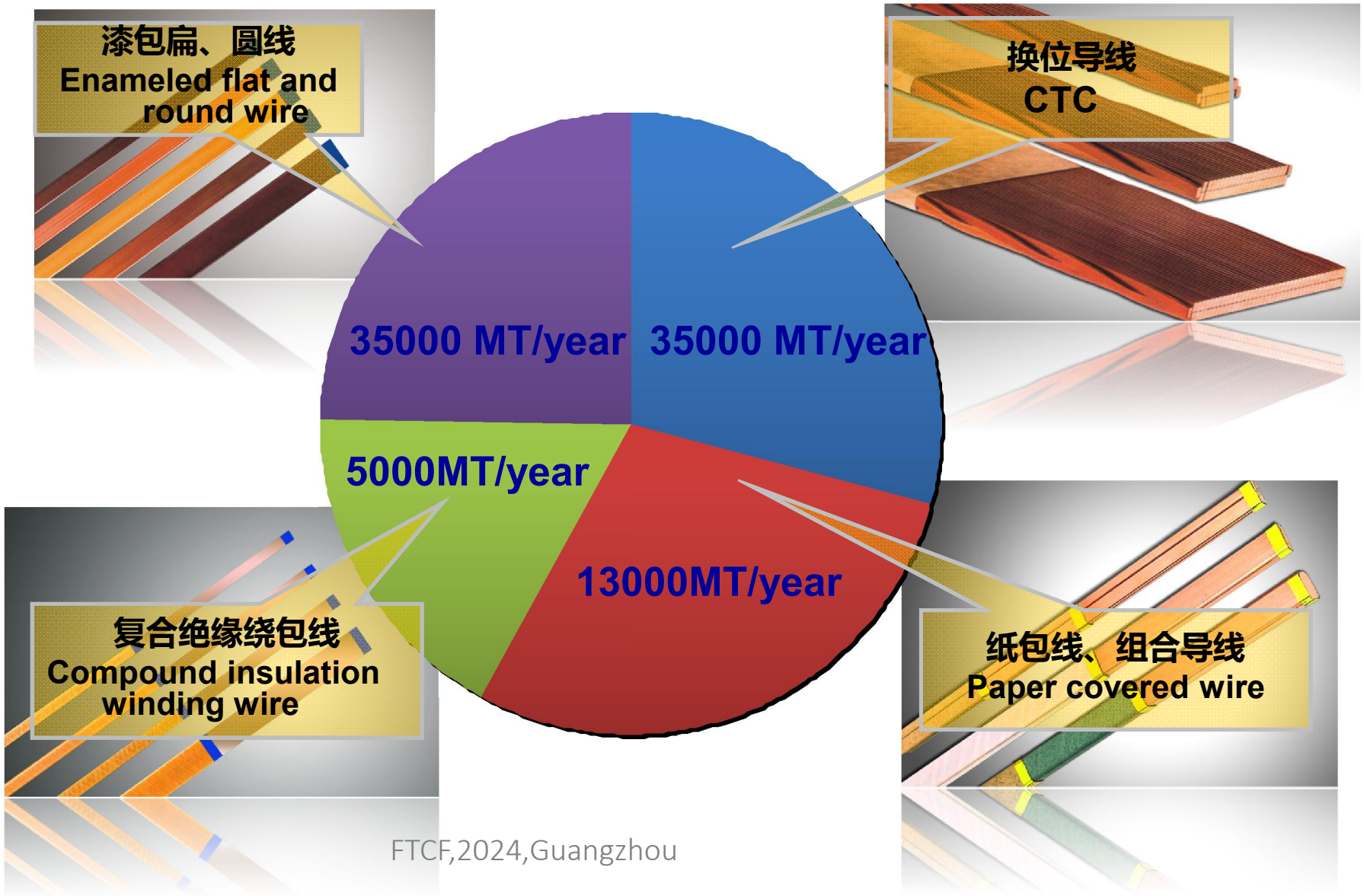
2
National manufacturing industry Green factory

4
National, provincial specialized new Little giant

Five provinces, **Seven** cable industry bases
(The winding wire segment bases are Wuxi and Xiangtan, accounting for about 32% of the group's total operating income)



Product and Capacity



Application fields

统力电工 TOLY ELECTRIC

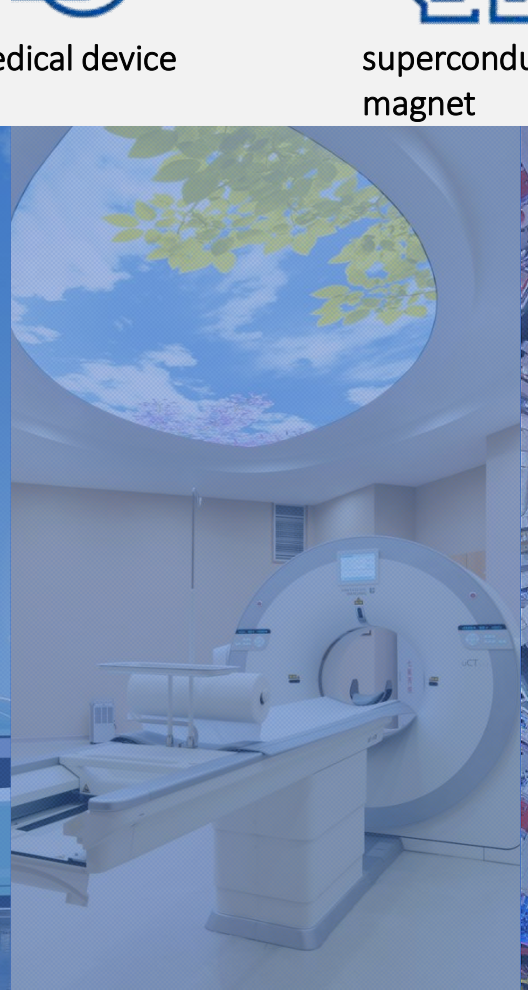
Power transmission and transformation equipment

rail transit

new energy

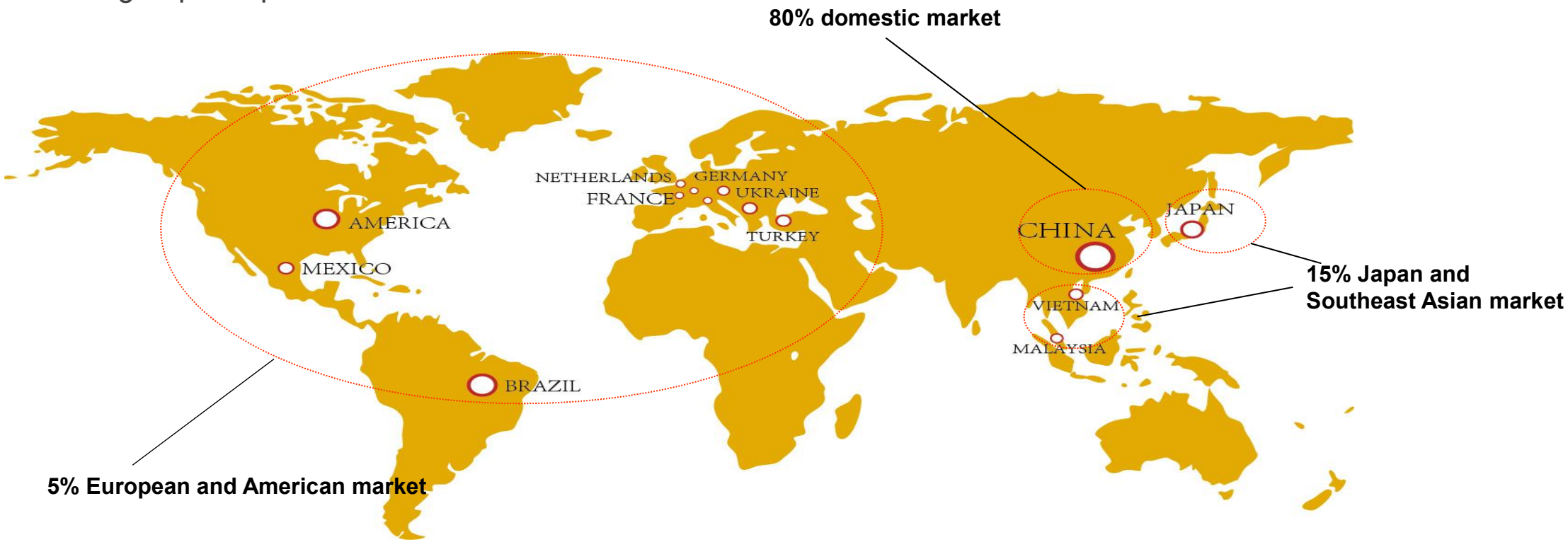
medical device

superconducting magnet



Market distribution and structure

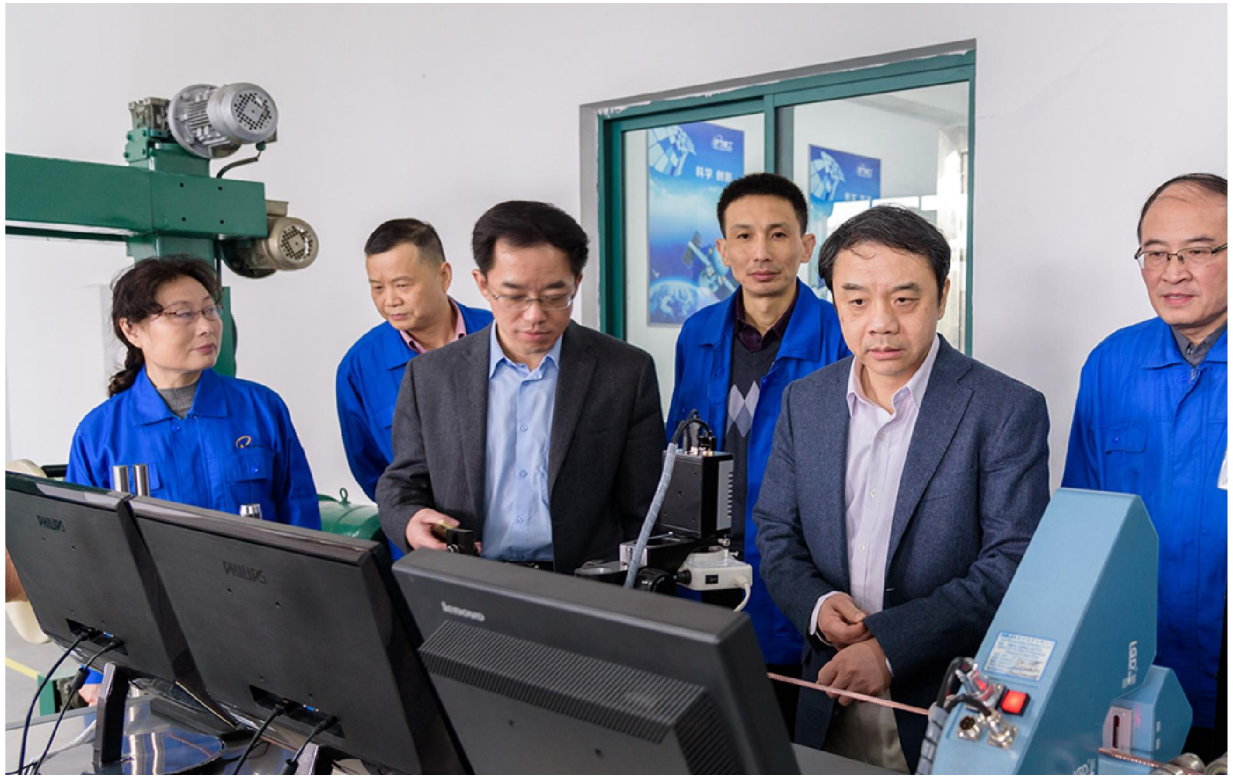
- In addition to domestic customers, the products are exported to more than a dozen countries in Asia Pacific, Europe and the United States, is the qualified supplier of SIEMENS, HITACHI, ABB, GE, TOSHIBA, DAIHEN and other group companies.



Application Cases

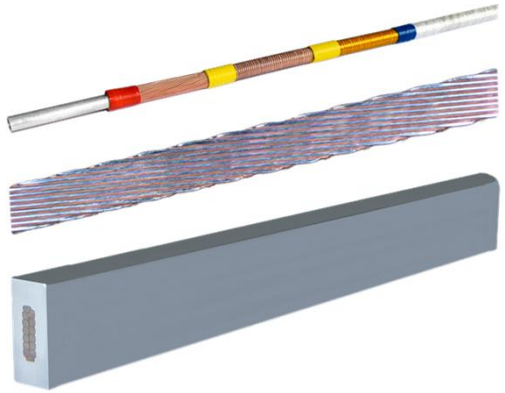
- Changji-Guquan ±1100kV UHV DC transmission project
- Baihetan hydropower Station UHV transmission project
- Wudongde power Station power supply UHV DC project
- Zhangbei ±500kV flexible DC demonstration project
- Indonesia Java power plant 1330MVA transformer project
- Brazil Belo Monte ±800kV HVDC Project
- High-speed rail transit and electric locomotives

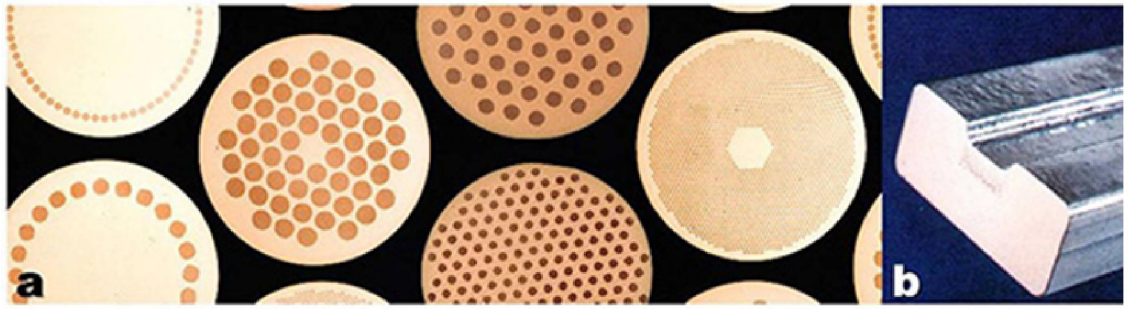
Industrial cooperation of superconducting



- Implementing strategic cooperation with IHEP.
- Implementing strategic cooperation with WST and LUVATA.
- Conducting technical exchanges related to superconductivity with research institutions and universities.

Superconducting cables





- Toly has independently developed a series of superconducting cable products, which are mainly used in the superconducting magnets and MRI and other high-end medical fields of the National Science Engineering equipment.

- **Product categories**

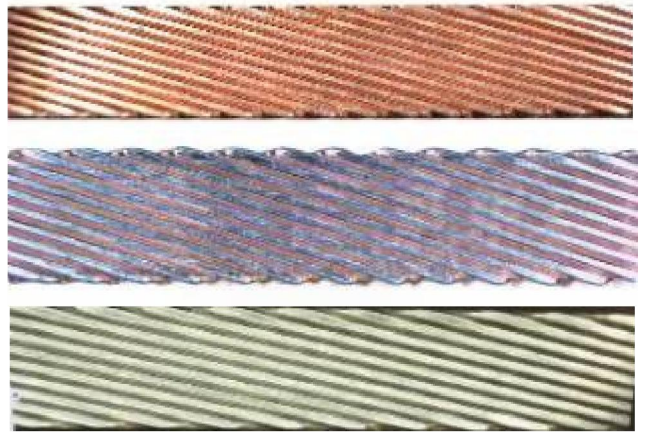
  Superconducting enamelled wire
  Rutherford cable
  Aluminum-stabilized superconductor

Contents

Rutherford cable

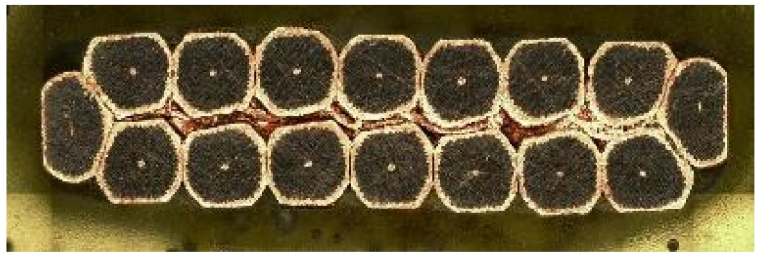
Features

- High filling factor
- High Jc
- High mechanical strength



Parameter design

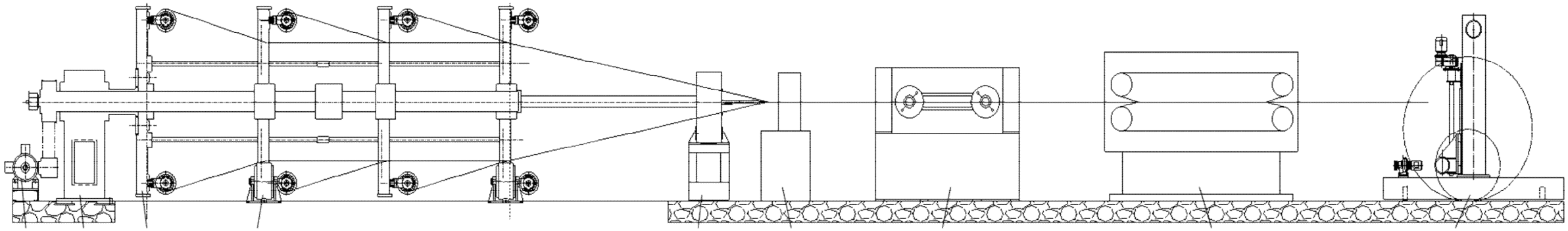
- Number of strands/wire diameter
- Pitch/twisting angle
- Filling factor



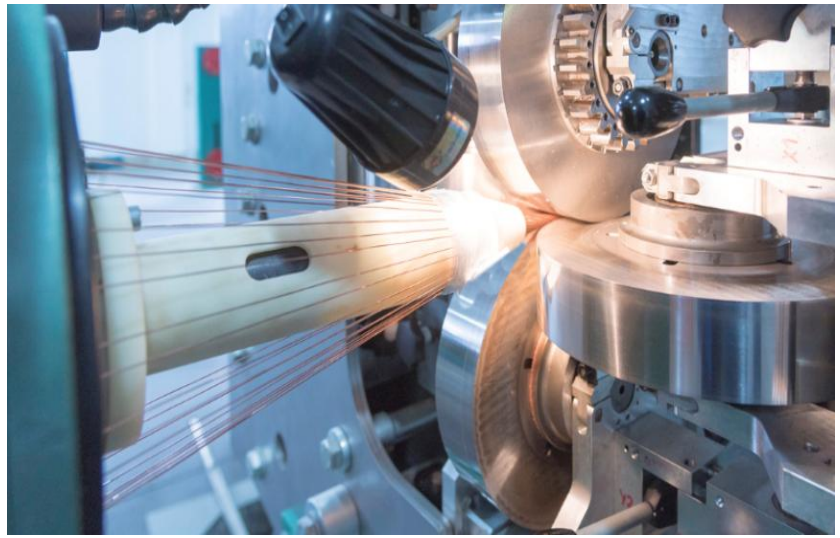
Rutherford cable


machine

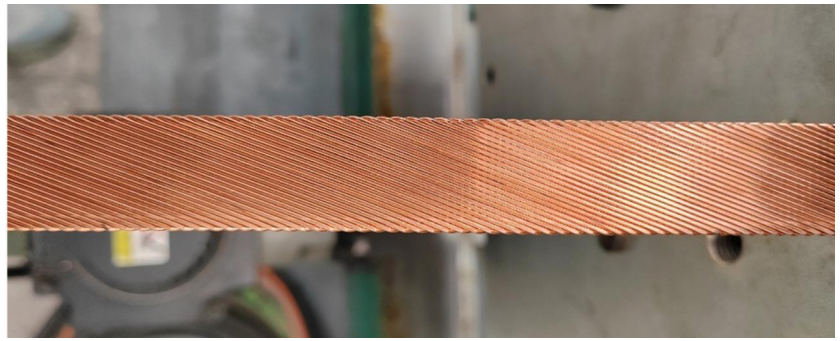
Items	Value
Wire numbers	12×4=48
Diameter	ϕ0.5~1.5mm
Wire tension	0~40N
The speed of rotary movement	12.5rpm
The speed of production	0~10m/min



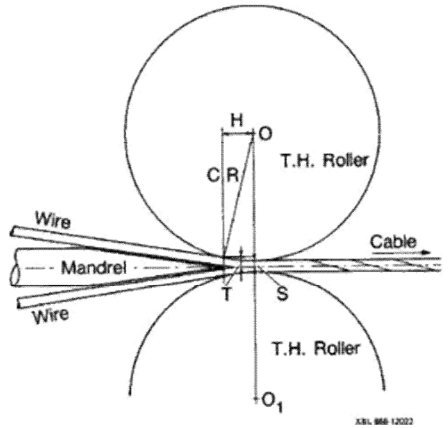
Rutherford cable

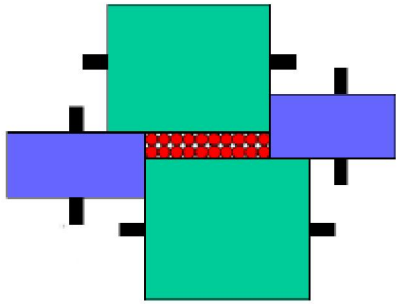


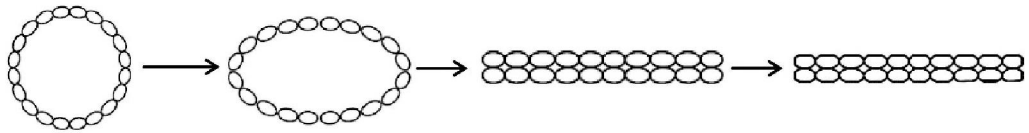
Rolling head



Rutherford cable







Change in cross section of cable

- The processing technology：
  - Twisting
  - Shaping
- The main mould：
  - Mandrel
  - Rolling head

Rutherford cable

- low temperature superconducting Rutherford cables for various magnets.
- 20/24/26/42 strands high field Nb_3Sn superconducting Rutherford cable.

Contents

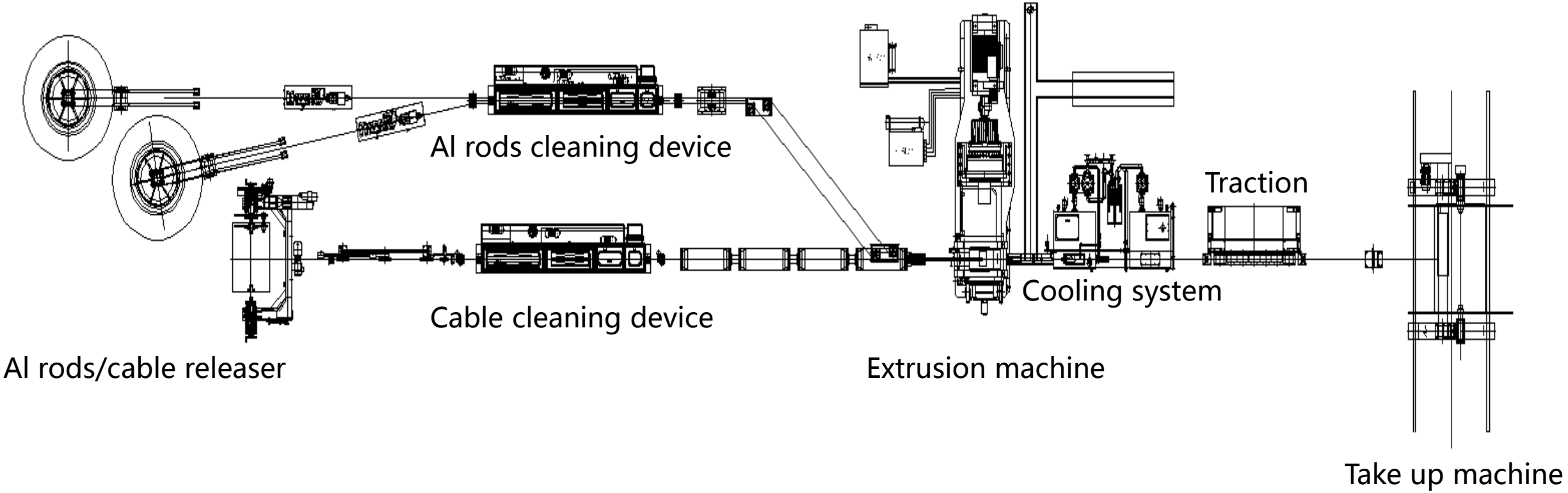
Al-stabilized superconductor

Pre-processing equipment

Extrusion machine

Parameter	Extrusion wheel diameter/mm	Rod diameter/mm	Cable thickness/mm	Cable width/mm
Value	400	2*9.5~12	3.0~30.0	10.0~70.0

Al-stabilized superconductor



Extrusion process

Al-stabilized superconductor

Al rods/cable releaser

Ultrasonic cleaning

Extrusion machine

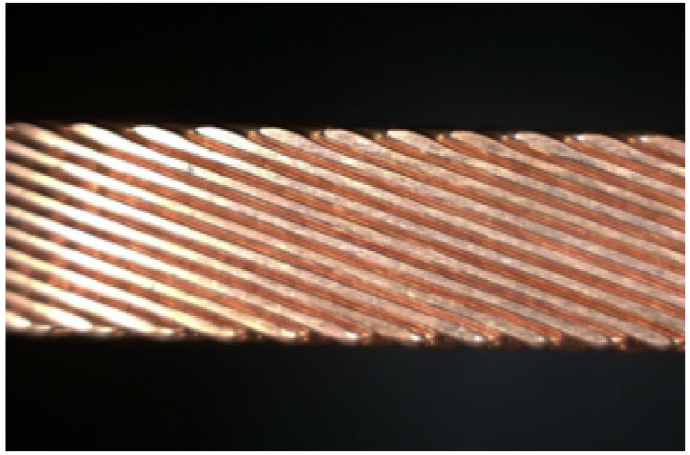
Cooling system

Caterpillar tractor

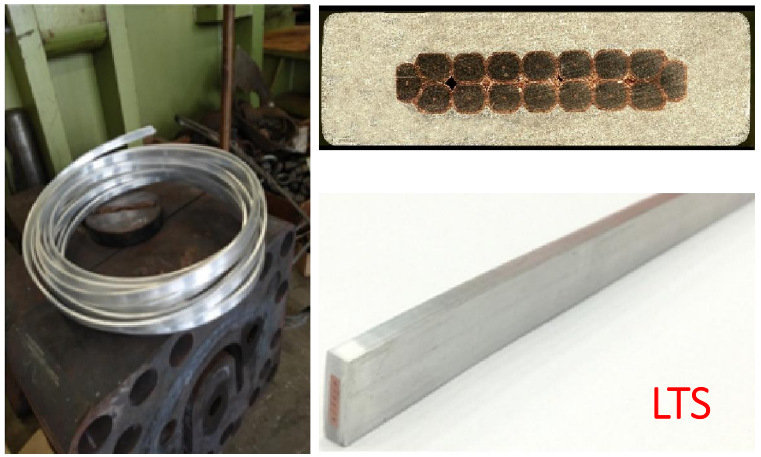
Take-up machine

Al-stabilized superconductor

NbTi strand

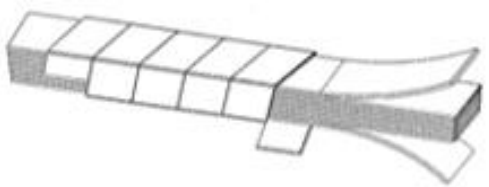


Rutherford cable



Al-stabilized NbTi/Cu superconductor

ReBCO tape



ReBCO Stack Cable

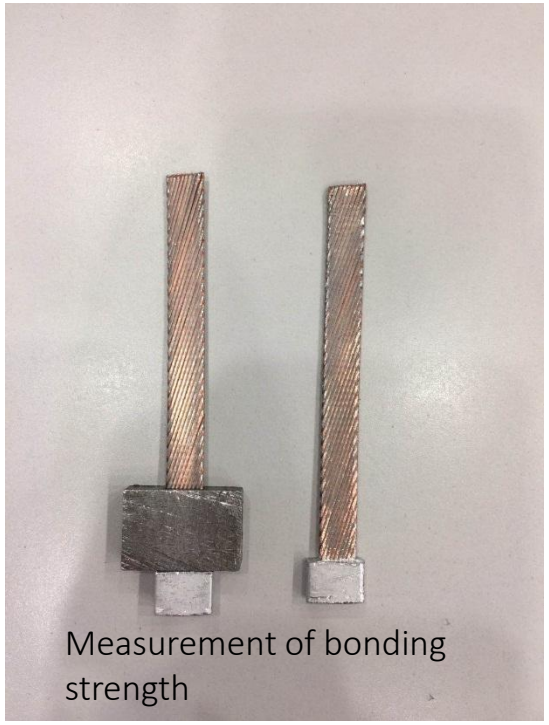
Al-stabilized ReBCO Stacked tape cable

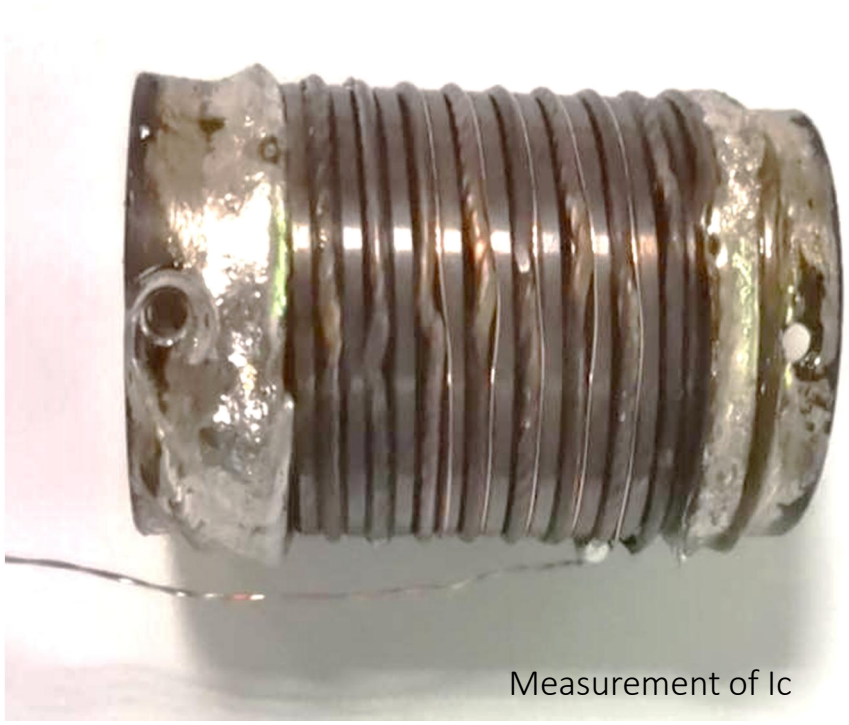
Al-stabilized superconductor for the Emus project

- Successfully developed kilometer level aluminum stabilized NbTi/Cu Superconducting Rutherford Cable , for laboratorial Superconducting solenoid magnets with high field of μ sub sources.

Al-stabilized superconductor for the Emus project

Measurement of dimension


Measurement of bonding strength


Measurement of Ic

Test result:

Parameter	Thickness/mm	Width/mm	Yield strength/MPa	Bonding strength/MPa	RRR（Al）	RRR（Cu）	Ic loss
Test result	4.68~4.70	15.00~15.02	152-160	34~40	832	192	< 3%

Al-stabilized superconductor for the Emus project

统力电工 TOLY ELECTRIC

technical specifications and test results

序号 No.	试验项目 Test Item	单位 Unit	试验要求 Test Requirement	试验结果 Test Result
1	**超导线superconducting wire**			
1.1	超导线类型 Type of superconducting line	----	NbTi/Cu	NbTi/Cu
1.2	超导线规格 Superconducting wire diameter	mm	1.20 ± 0.01	1.20
1.3	超导线铜超比 Copper/Superconducting ratio	----	1.0±0.1	1.081-1.01
1.4	临界电流Ic @4.2K，5.5T（Critical current）	A	Ic≥1350A	1388-1483
2	**铝基材料 Alumium material**			
2.1	铝材 Aluminium material	----	高纯铝，铝含量≥99.995%	99.998%
2.2	铝RRR@0T Aluminium RRR	----	＞500	/
3	**超导卢瑟福电缆 Superconducting Rutherford cable**			
3.1	卢瑟福电缆厚度 Rutherford cable thickness	mm	2.20 ± 0.03	2.20
3.2	卢瑟福电缆宽度 Rutherford cable width	mm	10.30 ± 0.05	10.30
3.3	股数 Number of strands	根	16	16

Al-stabilized superconductor for the Emus project

统力电工 TOLY ELECTRIC

序号 No.	试验项目 Test Item	单位 Unit	试验要求 Test Requirement	试验结果 Test Result
4	**覆铝超导卢瑟福电缆 Al-stabilized superconducting Rutherford cable**			
4.1	覆铝电缆内侧厚度 Al-stabilized cable inner thickness	mm	4.64 ± 0.03	4.62
4.2	覆铝电缆外侧厚度 Al-stabilized cable outer thickness	mm	4.70 ± 0.03	4.68
4.3	覆铝电缆宽度 Al-stabilized cable width	mm	15.00 ± 0.05	15.01
4.4	覆铝电缆圆角半径 Al-stabilized cable fillet radius	mm	0.35 ± 0.03	0.35
4.5	覆铝电缆中铝RRR值 Aluminum RRR value of Al-stabilized cable	----	＞500	832
4.6	覆铝电缆中铜RRR值 Copper RRR value of Al-stabilized cable	----	＞80	192
4.7	覆铝电缆超导临界电流 Critical current of Al-stabilized cable	A	＞17280，@ 4.2 K 5.5T	24017.6
4.8	覆铝电缆（含超导缆）屈服强度 Yield strength of Al-stabilized cable (including superconducting cable)	MPa	＞150	159
4.9	卢瑟福电缆与铝基间剪切强度Bonding strength between Rutherford cable and Aluminum	MPa	＞20	36

Al-stabilized superconductor for detector magnet （LTS）

The process of secondary extrusion

- The first time with high-purity aluminum：10*33mm
- The second time with aluminum alloy：22*56mm

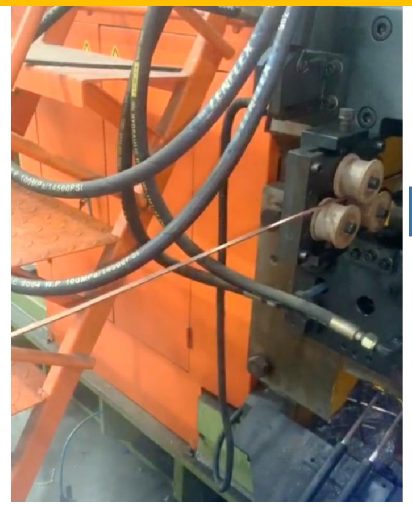
Doped aluminum alloy materials

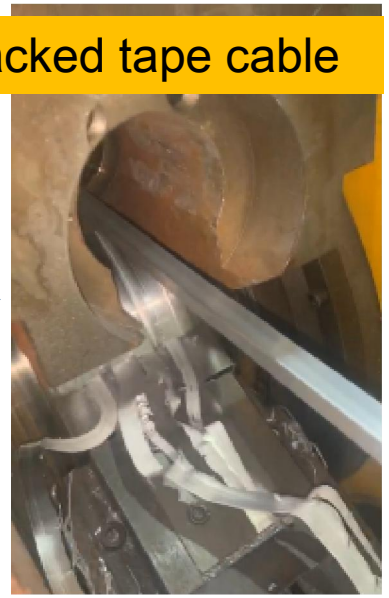
- Goals: high mechanical strength, high RRR value

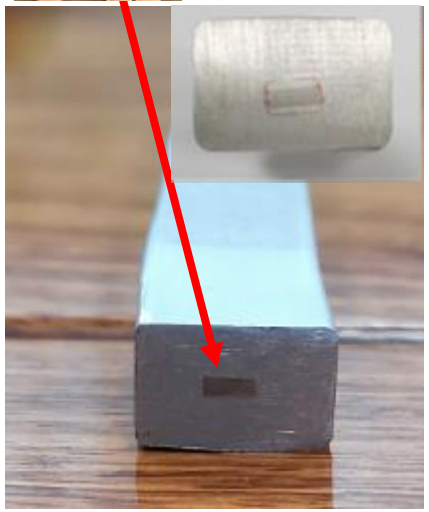
Al-stabilized superconductor for detector magnet （HTS）

The process of ReBCO Stack Cable

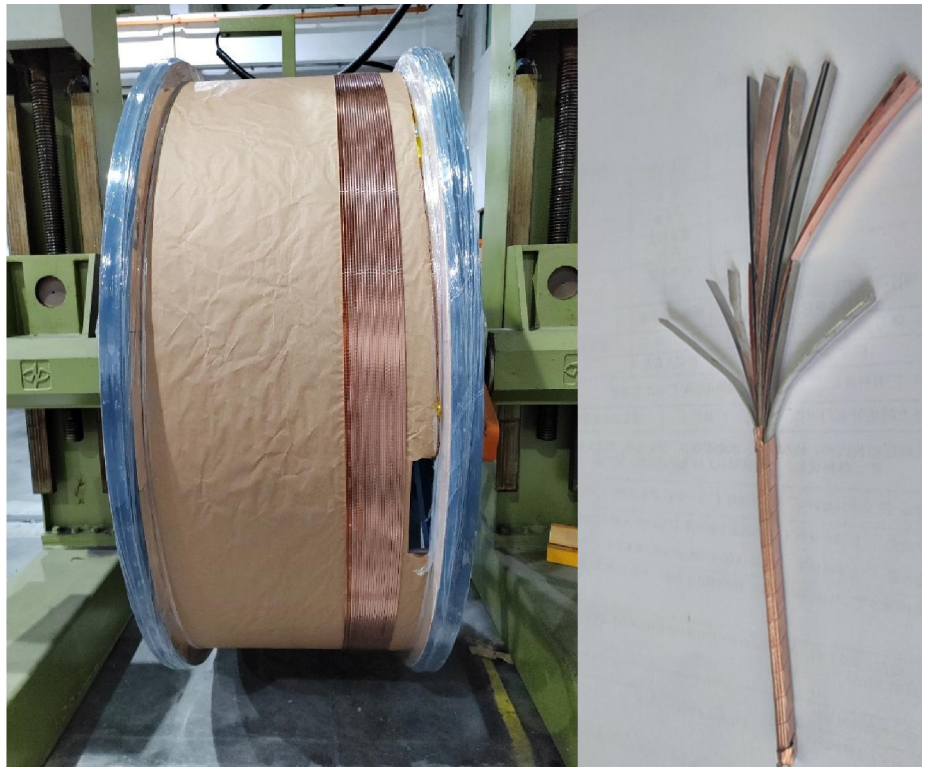
The process of Al-stabilized ReBCO Stacked tape cable







Al-stabilized superconductor for detector magnet （HTS）



ReBCO Stack Cable

Al-stabilized ReBCO Stacked tape cable

- Al-stabilized ReBCO Stacked tape cable
  - Tensile strength of aluminum rod ：60MPa
  - Temperature of the cavity mold ：450℃

Contents

Summary

- Through the research and development of superconducting cable, toly has built our technique and quality system for superconducting cable.

- Toly has cooperated with domestic research institutions to develop a variety of superconducting cables for magnets and medical equipment, and has achieved phased results.

- In the future, Toly will also focus on manufacturing customized superconducting cables for high-energy physics, accelerators and detectors.

谢　谢！

Thank you！