Cable Design and Related Issues in a Fast-Cycling Superconducting Magnets

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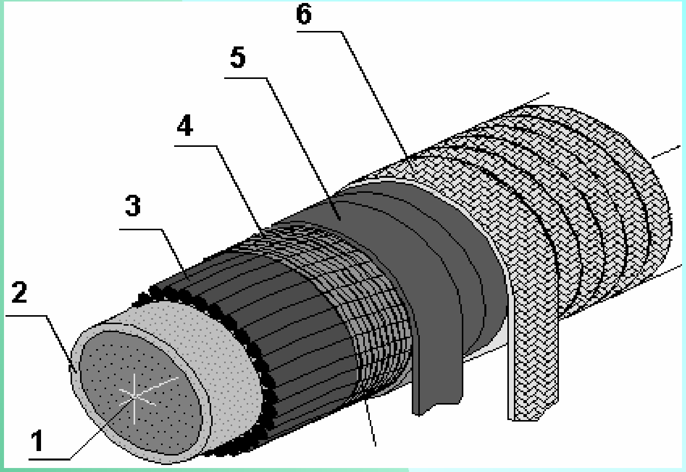
- Hollow superconducting cables for a fast-cycling synchrotrons are considered.
- The essential features of the cable designed for the Nuclotron at JINR are presented.
- New versions of a hollow NbTi superconducting cable are described.
- The first test results with the cable has been designed for an operating current of 12 kA at B = 2 T, dB/dt = 4 T/s and pulse repetition rate f = 1 Hz are presented.
- The further possibilities of the using hollow cables for the both as 4-6 T dipoles operating at repetition rate of 0.5 Hz and low field (B = 1-1.5 T) magnets operating at f = 10-20 Hz are discussed.

THE NUCLOTRON CABLE



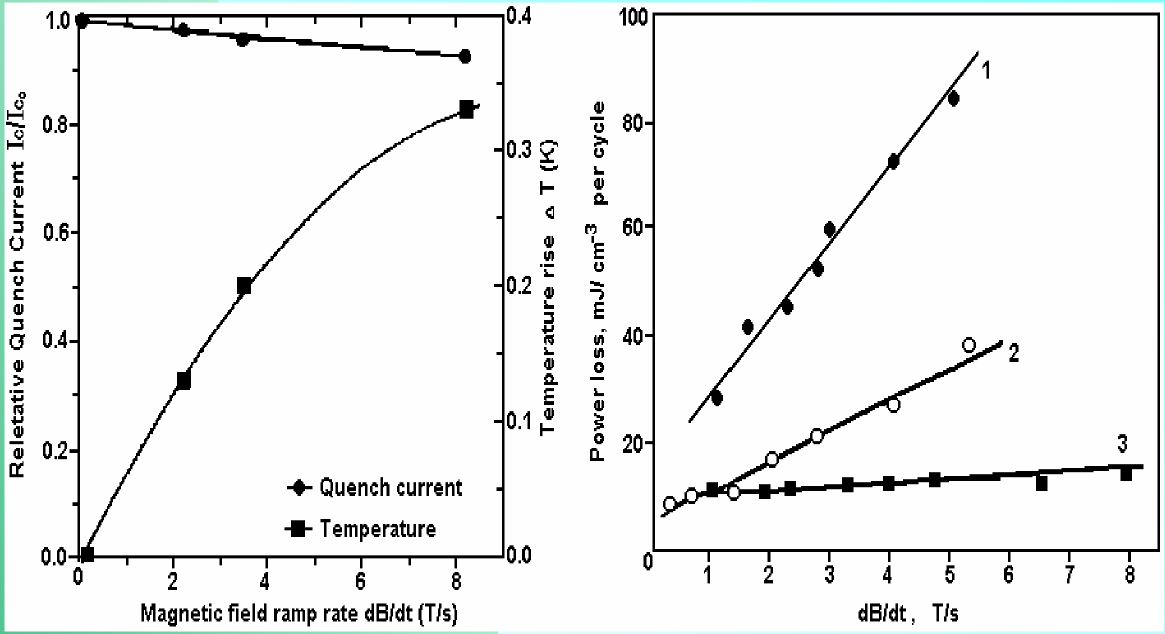
General view of the Nuclotron HSC:

1- two-phase helium, 2-copper-nickel tube,
3- superconducting wire,
4- nichrome wire, 5-kapton tape,
6 -glassfiber tape.

The optimization of all parameters was made to obtain the following operating performances at f = 1 Hz pulse repetition rate:

- quench current higher 7500 A
(at B = 2 T and field ramp dB/dt = 4 T/s,)
- AC power losses per NbTi volume q = 68 mJ/cm^3 per cycle.

THE NUCLOTRON CABLE

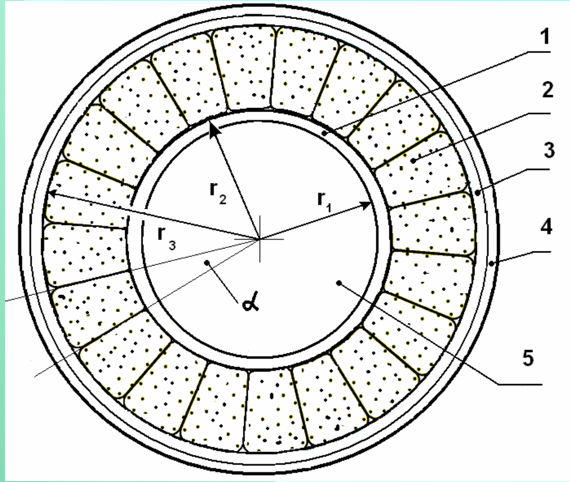


LEFT – **quench current degradation and the superconductor temperature rise versus external magnetic field ramp rate.**

RIGHT – **the eddy current power loss for different cable samples (Nuclotron cable corresponds to curve - 3).**

- Up to now there are no other SC cables with similar properties.
- The degradation at dB/dt=4T/s is only 4.8 %.
- Weak dependence of eddy current loss on the magnetic field ramp rate

NEW OPTIONS of HOLLOW CABLE



Hollow superconducting cable based on keystoned wires:

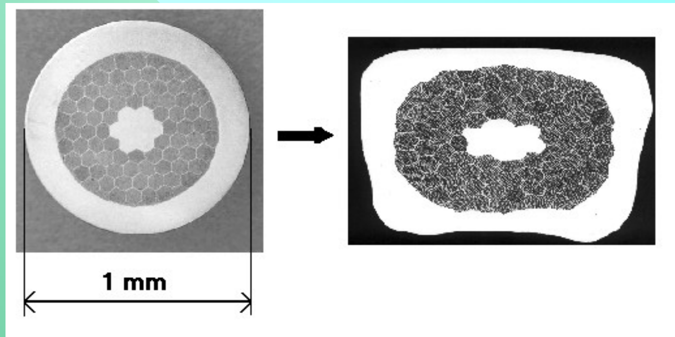
1 – copper-nickel tube, 2 – profiled superconducting wire, 3 – nichrome wire,
4 – electric insulation layers, 5 – channel for coolant, a - the wire angular size.

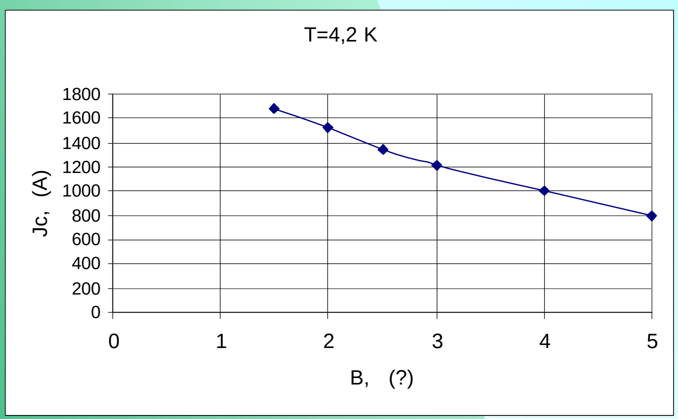
- **design and test the cable (option HSC-K1) for an operating current of 12 kA at B = 2 T, dB/dt = 4 T/s and pulse repetition rate f = 1 Hz;**
- **investigate the possibility to reach an operating current of 30 kA at B = 6 T, dB/dt = 2…4 T/s and pulse repetition rate f = 0.5 Hz. (option HSC-K2)**

NEW OPTIONS of HOLLOW CABLE

	HSC-K1	HSC-K2
OPERATING PARAMETERS:		
- magnetic field, T	2	6
- current, kA	12	30.0
- helium temperature, K	4.6	4.6
- ramp rate, T/s	4	4
AC LOSSES:		
- per NbTi volume, mW/cm^3	45.2	30.1
- per 1 m coil length, W/m	3.8	20.4
Helium channel diameter, mm	4	4.6
Copper-nickel tube diameter, mm	5	5.6
Number of strands	15	12
Strand cross-section, mm^2	0.789	3.62
Cu/NbTi ratio	1.38	1.38
Nb50-Ti50 filament diameter, μm	6	4
Twist pitch of filaments, mm	5	5
Bending nichrome wire diameter, mm	0,2	0,3
Cable diameter with insulation, mm	7.16	10.52
Structural current density, A/mm^2	234	248

NEW OPTIONS of HOLLOW CABLE





The dependence of the wire's critical current on external magnetic field.

◆ HSC-K1 test results

- **First batch was fabricated at the Bochvar Institute.**
- **The critical current and AC loss measurements of the wire were performed at the LHE.**
- **The measured value is 1400 A at cable operation conditions B = 2 T and T = 4.46 K. Thus the expected critical current of the new cable, consisting of 15 wires, amounts to 21 kA.**
- **The AC loss at B = 1.05 T and dB/dt = 2.1 T/s is about 22.4 mW per cm**3 of the wire.**

TEST RESULT:

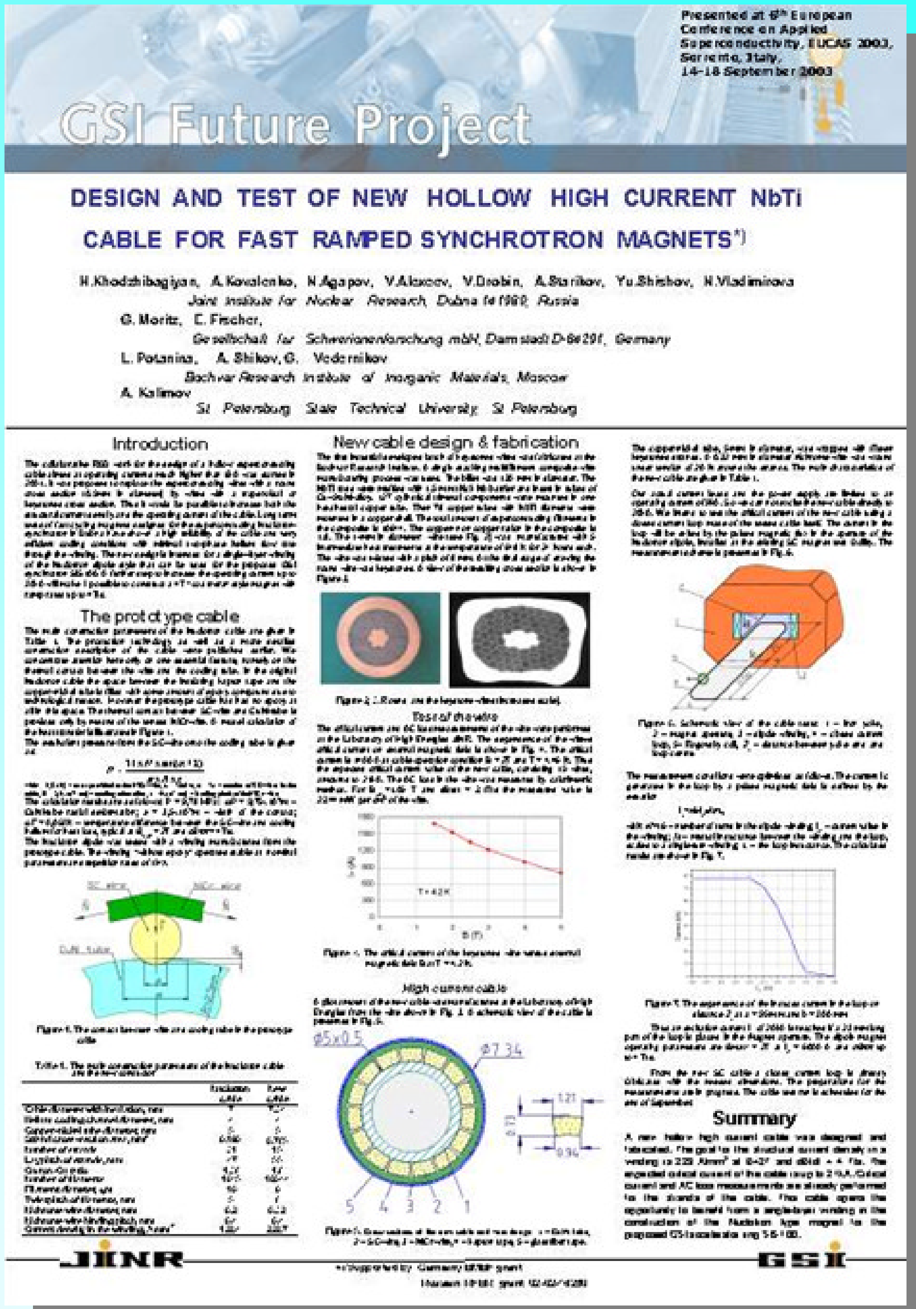
OPERATING CURRENT – 13 kA

at B = 2T, dB/dt = 4T/s, f = 1Hz

was obtained without any training and quenches (dI/dt = 26 kA/s)

THE NEXT TEST RUN IS PLANNED IN APRIL 2004

MAIN GOAL IS TO REACH QUENCH VALUE OF THE CURRENT



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GSI Future Project

DESIGN AND TEST OF NEW HOLLOW HIGH CURRENT NbTi CABLE FOR FAST RAMPED SYNCHROTRON MAGNETS*)

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Introduction

New cable design & fabrication

The prototype cable

Test of the wire

High current cable

Summary

JINR

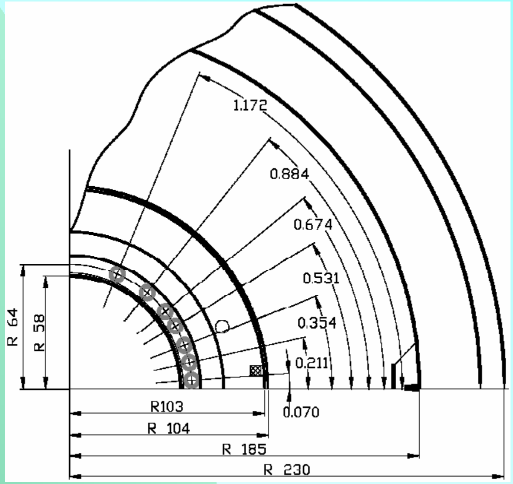
GSI

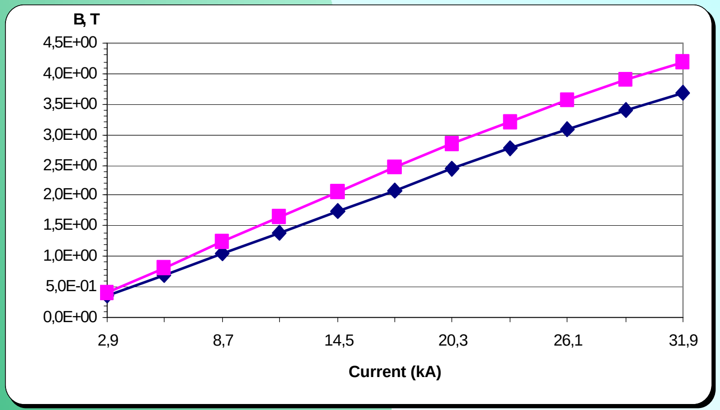
FAST RAMPED 4T DIPOLE

- hollow superconducting cable can be applied to the design and construction of a fast-ramped 4...6 T dipoles of the future synchrotrons with pulse repetition rate of 0.25...0.5 Hz.

- “cosine theta” style of the magnets (dipoles and quadrupoles) should be used in this case.

FAST RAMPED 4T DIPOLE





- THE APERTURE OF 100-110 mm;
- SINGLE LAYER COIL (12-14 TURNS)
- HOLLOW NbTi CABLE MADE WITH KEYSTONED WIRES;
- THE COLD MASS LIMITED TO THE COIL AND COLLAR;
- THE YOKE AT T = 50- 80 K;
- TWO-PHASE HELIUM FLOW (mass flow rate of 2 g/s);
- OPERATING CURRENT OF 30 kA;
- THE FIELD RAMP OF 4-6 T/s;

FAST RAMPED 4T DIPOLE

FUTURE R&D POSSIBLE STEPS :

- reduce the AC power loss in the cable using SC filaments of smaller diameter;
- to study possibility of the using Nb3Sn instead of NbTi wires;
- test some new versions of the cables with keystoned wires;
- design of 6T magnet based on a hollow cable.

SUPERFERRIC MAGNETS AT PULSE REPETITION RATE 10-20 Hz

- The first estimate (up to 10 Hz) was presented at MT-15. The extrapolation was based on experimental data obtained for the Nuclotron dipole with a cold iron yoke.
- recent R&D have demonstrated the possibility to produce the cable with much higher operating current and engineering current density; superferric dipole magnet with the yoke at T = 50-80 K was tested successfully.
- H-type MAGNET WITH THE YOKE at T = 50-80 K is MORE PERSPECTIVE .
- NUMBER OF THE TURNS: 4 or 2 per POLE, OPERATING CURRENT I = 12…25 kA;
- MAGNETIC FIELD: 1.2-1.5 T, APERTURE of 55mm x 110 mm
- MAGNETIC FIELD in the COIL: B = 0.6 - 0.75 T.
- THE FIELD RAMP: dB/dt = 12…15 T/s at f= 10 Hz and dB/dt = 24….30 T/s at f = 20 Hz,

TESTS of EXISTING CABLE and NEW CABLE VERSIONS at OPERATING CONDITIONS SPECIFIED for 10-20 Hz MAGNETS