INDUCTIVE MEASURING DEVICE FOR CRITICAL CURRENT DENSITY

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***Abstract* - The measuring device works like a transformer with shorted secondary winding and has the form of high temperature superconducting tube. Having an inductive character, it escapes any galvanic contact with superconducting material so it's a major advantage.**

Keywords: *high temperature superconductors (HTSC), critical current density (J_c), critical magnetic field (H_c), critical current, superconducting state*

1. INTRODUCTION

The superconducting state of material is stable only if the temperature, the current and the magnetic field are lower than the critical values: T_c, J_c respectively H_c. Critical values of the parameters are in the relationship namely $J_c = J_c(H_c, T_c)$. High T_c superconductors (HTS), based on Y or B_i, are immersed into liquid nitrogen pool of a cryostat so that their temperature $T = 77K$ are lower than the maximum critical temperature $T_{c\max} \geq 90K$ usually. In this case, the relationship between J_c and H_c is $J_c = \alpha \cdot H_c^p$ (Yrie-Yamofuje model). The material parameters α, β depend on the material nature but also on the mechanical and heat treatments (extrinsic parameters). The values of α, β result from the experimental correlation $J_c = J_c(H_c)$.

The following measuring techniques are known: measure in four points (cc) and measure in six points (ac) [1]. This involves preparing plane probe from HTS material, upon each probe is plated with four respectively six contacts. The interface between HTS and galvanic contacts introduces parasitical electric resistance which sensible disturbs results of measure.

The following measuring device, possessing an inductive character, escapes any galvanic contact with HTS so it is a major advantage.

2. DESIGN OF MEASURING DEVICE

Fig. 1 illustrates an axial section through the measuring device. The equipment consists of the cupper measuring solenoid 1 inductive coupled with the HTS tube 2. The solenoid has tapping of winding for the turns number control. Assembly is immersed into liquid nitrogen pool 3 of a cryostat 4. The top flange 5 of the cryostat is pierced by tube 6 through which are passed for the tappings of winding. Power supply of the solenoid is an ac voltage control source STR, voltage and current are recorded by a storage oscilloscope OSC.

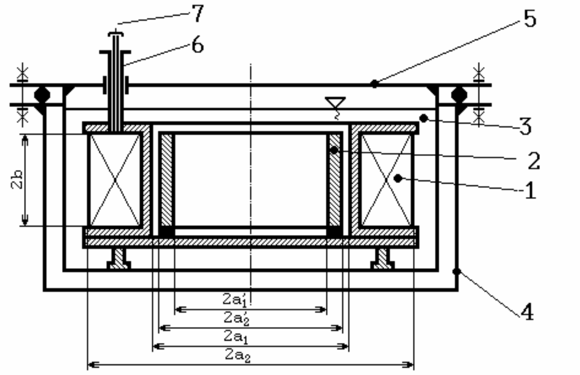

Figure 1: Axial section through the measuring device

3. OPERATION PRINCIPLE

Measuring device works like a transformer with shorted secondary winding and has the form of the HTS tube.

If the current I_1 in the solenoid is lower than the activation value I_a, the secondary winding is in superconducting state and it acts as magnetic shield. At once I_1=I_a, electromagnetic induced shield currents exceeds the critical value I_c of superconducting tube and the transition to the resistive state will occur. This allows magnetic field to penetrate the tube that will proceed to increasing the device impedance and to limiting the solenoid current at value I_0.

Fig. 2 shows the equivalent electric circuit from which results :

$$\frac{I_a}{I_0} = \left[\frac{1 + \left(\frac{\omega L_1}{R_1} \right)^2}{1 + \left(\frac{\omega L_1}{R_1} - \frac{\omega^2 M^2}{R_1 \omega L_1} \right)^2} \right]^{\frac{1}{2}}$$

A good electromagnetic coupling between solenoid and tube leads to clear maxim value of I_1 namely a highly accurate detection of I_a.

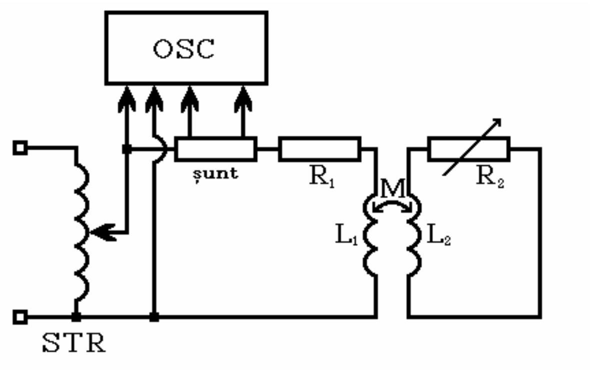

Figure 2: The equivalent electric circuit

4. CORRELATION CRITICAL MAGNETIC FIELD-CRITICAL CURRENT DENSITY $H_C=H_C(I_C)$

The maximum value of the current in the solenoid corresponds to the critical current I_c in the superconducting tube and it is recorded by the storage oscilloscope. The procedure to establish a point (H_c, J_c) of the correlation $H_c(J_c)$ is :

- L_1, L_2, M parameters of the equivalent electric circuit (fig. 2) are computed with formula [2];
- the critical current in the tube is :

$$I_c = \frac{I_a M}{L_2}$$

and the corresponding critical current density is :

$$J_c = \frac{I_c}{2b\left(a_2^{'} - a_1^{'}\right)}$$

- the critical magnetic field H_c (magnetic field at medium plane in a point on the tube surface) is computed with formula [3].

5. CONCLUSION

The measuring device has the following advantages :
a) The inductive character expels any galvanic contact with HTS;
b) Allows measuring the critical current density in circumferential direction;
c) The value of the applied field it's easy to obtain with turns number control and with voltage control;
d) Directly it's measured only one quantity: activation current. The clear maximum value of the primary current allows accurate detection of the activation current;
e) The functional relations from which it's computed the critical magnetic field and the critical current density are well known. The axial symmetry of the magnetic field distribution leads to the computed error under 5%.

References

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