§28. Design Method of High Temperature Superconducting Gas Cooled Current Leads

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General design equations[1] derived from one dimensional energy balance equations are solved to evaluate such generalized characteristics of gas cooled current leads made of high temperature superconducting (HTSC) material as the heat flow from the ends of the leads Q_c [mW/A], the geometrical dimension of conductor D [A/m] and the pressure drop of the cooling gas $\Delta P/C_f$ [PaAs^{2}m^3/kg^2]. In the equations, a general cooling parameter γ_0 indicates the geometrical dimension of the conductor and cooling channel of the leads, and appears as a single parameter. HTSC current leads are operated in the temperature range from 4.2K to 77K under the condition of self-sustained cooling.

Figure 1 shows generalized characteristics of HTSC current leads made of YBCO material. Optimum current leads in fully normal conducting state are taken as the reference leads to estimate characteristics in the superconducting state. The heat flow from the cold end of the reference leads in the superconducting state is evaluated to be 0.4 mW/A in the case of $\gamma_0 > 1.0\times10^{-3}$ m$^{1.2}$/A$^{1.2}$. The change in the geometrical dimensions allows further reduction of the heat flow from the cold ends. However, the larger geometric dimension accelerates the temperature rise time of the conductor in the case of an accidental quench of the HTSC leads.

Thermal runaway of the conductor is analyzed by the use of a generalized rise time of the temperature of the conductor of various geometrical dimensions in the case of stoppage of the cooling gas with the consideration of the quench propagation. The maximum permissible temperature of the conductor is assumed to be 300K to prevent leads from any damage. The rise time of 10 minutes is considered to be sufficient to sweep the operational current of the magnet down to zero. These criteria seems to be reasonable in actual operations. For design example taken the criteria into account, values of D can be increased three times as large as that of the reference leads of l=0.35m and $\gamma_0=1.5\times10^{-3}$ m$^{1.2}$/A$^{1.2}$. In this case, the heat flow from the cold ends is estimated to be decreased to values less than 0.1mW/A.

Various high performance HTSC current leads of $Q_c < 0.1$mW/A can be designed simply by the use of the design chart and the generalized rise time analysis in consideration of the criteria of the actual operation of the magnets.

Nomenclature

d	Hydraulic diameter [m]
f	Cooling perimeter [m]
I	Current [A]
l	Conductor length [m]
m	Mass flow rate of helium gas [kgs^{-1}]
ΔP	Pressue drop of cooling gas [Pa]
Q_c	Heat flow from cold end normalized by the current [mW/A]
r	Ratio of length along cooling pass to l
s	Cross-sectional area of conductor [m^2]
s_g	Cross-sectional area of cooling channel [m^2]

$\gamma_0=FSd^{-0.2}S_g^{-0.8}$, $F=f/I$, $S=s/I$, $S_g=s_g/I$,
$D=Il/s$, $G=m/s_g$, $C_f=r\,G^2S/d$

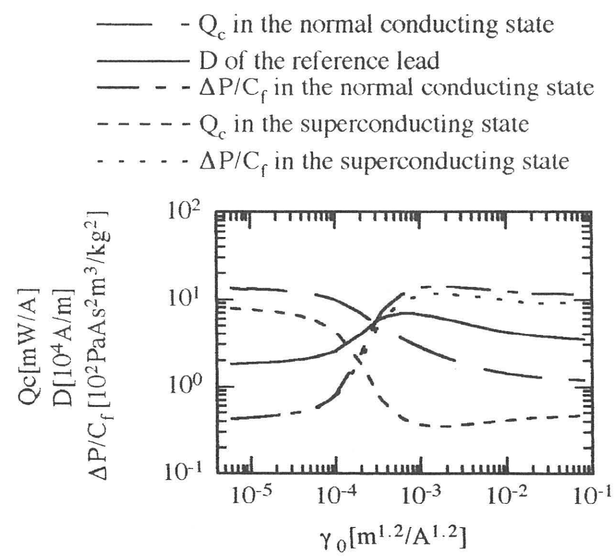

Fig.1. Generalized characteristics of HTSC current leads made of YBCO material

References

1) Maehata, K. et al., Cryogenics 33 (1993) 680