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超伝導磁石冷却用低温動作振動式ヒートパイプの開発
Development of cryogenic oscillating heat pipes for cooling of superconducting magnets

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1. Introduction

Improvement of superconducting magnets for high magnetic field, high heat load and high electromagnetic force is an important subject to achieve the early realization of nuclear fusion power generation. In HTS magnets, the stability is assured by the larger operating temperature margin and higher heat capacities of component materials of the magnet. However there is a limit on the thermal diffusivity by the solid heat conduction. Furthermore, when the size of the magnet becomes larger, the time constant of the thermal diffusion becomes longer. That means that when a part of the windings of a large scale conduction cooling HTS magnet turns into the normal conducting state large temperature gradients are easily produced in magnets, which could cause degradations of superconducting properties and/or mechanical damages by excess thermal stresses.

2. Oscillating heat pipe (OHP)

A new method of including cryogenic oscillating heat pipes (OHPs) in the HTS coil windings as a heat transfer device has been suggested [1][2]. OHPs were proposed and patented by Akachi [3].The OHP has a long capillary which is bent into many turns and a working fluid with two-phase mixture is filled inside the capillary as shown in Fig. 1. The OHP is a highly effective heat transfer device which can transport several orders of magnitude greater heat flux than the heat conduction of solid metals.

3. Flat-plate cryogenic OHP experiments

In this work, a new flat-plate OHP has been made by channeling on a thin stainless flat plate of which the thickness is 5 mm and tested using N_2, Ne or H_2 as working fluids. The operating temperatures are about 70 K for N_2, 30 K for Ne or 20 K H_2 and the typical overall thermal conductivities of flat-plate OHPs are about 3,500 $Wm^{-1}K^{-1}$, 2,500 $Wm^{-1}K^{-1}$, 1,000 $Wm^{-1}K^{-1}$, respectively. Table 1 summarizes the measured thermal properties of the flat-plate cryogenic OHP. Further investigation on the thermal characteristic of this type of OHPs and the feasibility of application for fusion magnets of flat-plate OHPs are discussed.

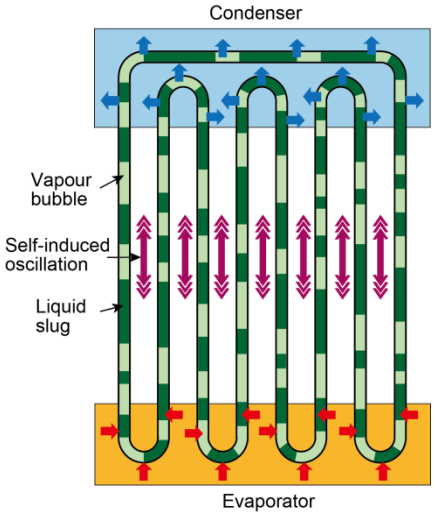

Fig. 1　Schematic representation of oscillating heat pipe (OHP)

Table 1　Thermal properties of the flat-plate cryogenic OHP

Working fluid	Operating temperature (K)	Filling rate of liquid (%)	Effective thermal conductivity ($Wm^{-1}K^{-1}$)
H_2	18 – 24	23 – 60	~850
Ne	26 – 32	23 – 53	~2500
N_2	79 - 84	22 - 45	~3500

References

[1] T. Mito et al, *IEEE Transactions on Applied Superconductivity*, vol. **20**, (2010), pp. 2023-2026.
[2] K. Natsume et al, *Cryogenics*, vol. **51**, (2011) pp. 309-314.
[3] H. Akachi, US Patent, No. 4,921041, 1990.