Thermal performance of two different glass fibers based VIP

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Outline

1. Core materials
2. Experiments
3. Heat transfer path
4. Conclusions

Vacuum Insulation Panel

VIP = Core material + Envelope + Getter

Table 1 various core materials for VIP

Core material	Thermal conductivity (mW/mK)	Typical gas pressure $P_{1/2}$ (hPa)
Glass fiber	1.5-3	1-5
Fumed silica powder	4-5	600-800
Precipitated silica powder	5-7	100-200
Perlite powder	6-8	2-10
Polyurethane foam	7-9	1-2

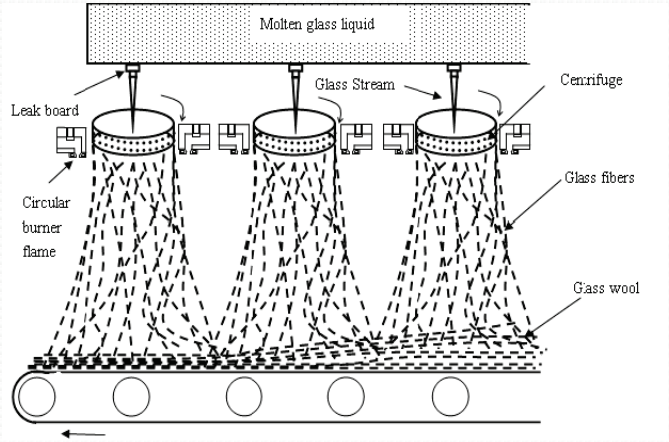
Source: Roland Caps, et al. (2008) and J.S. Kwon, et al. (2009)

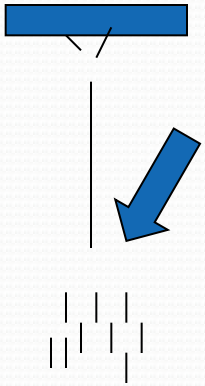
Short glass fiber

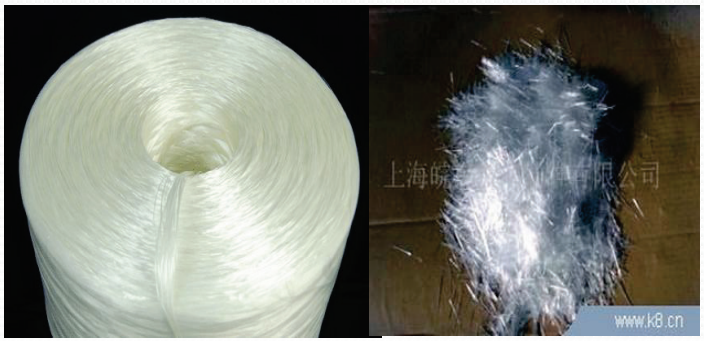
1. Centrifugal glass fiber (CF),
   glass fluid was thrown through high speed centrifugal pan.

2. Aerocor (flame) glass fiber (AF)
   glass fiber was formed by high speed air flow

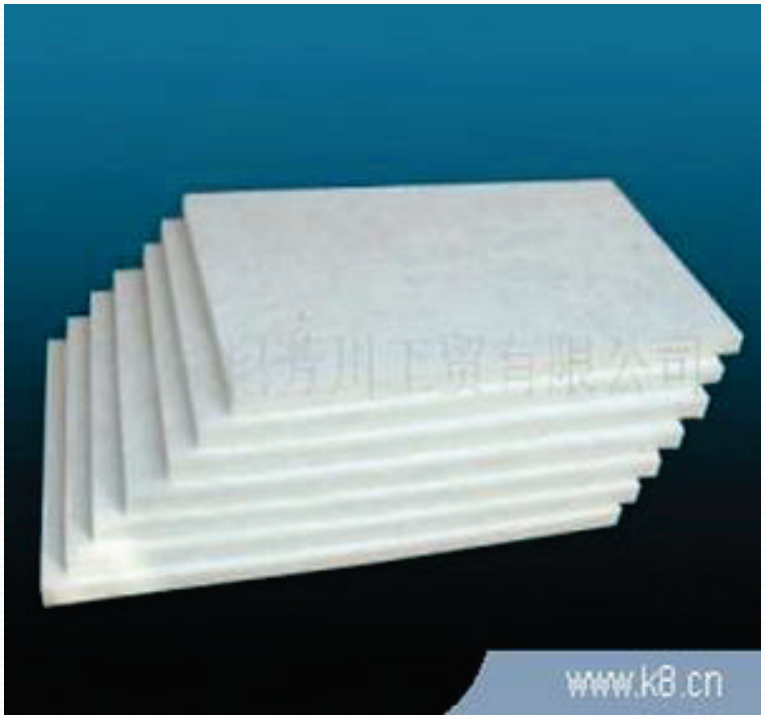
3. Short filament glass fiber (FF)
   cut from long continuous filament glass fiber







Core materials prepared by wet process



Core material using AF or CF glass fiber

Core materials using by FF glass fiber

Purpose of this paper

- Comparative the insulation performance of the VIPs with two kinds of glass fibers as core material.

- Study heat transfer mechanism

Experiments

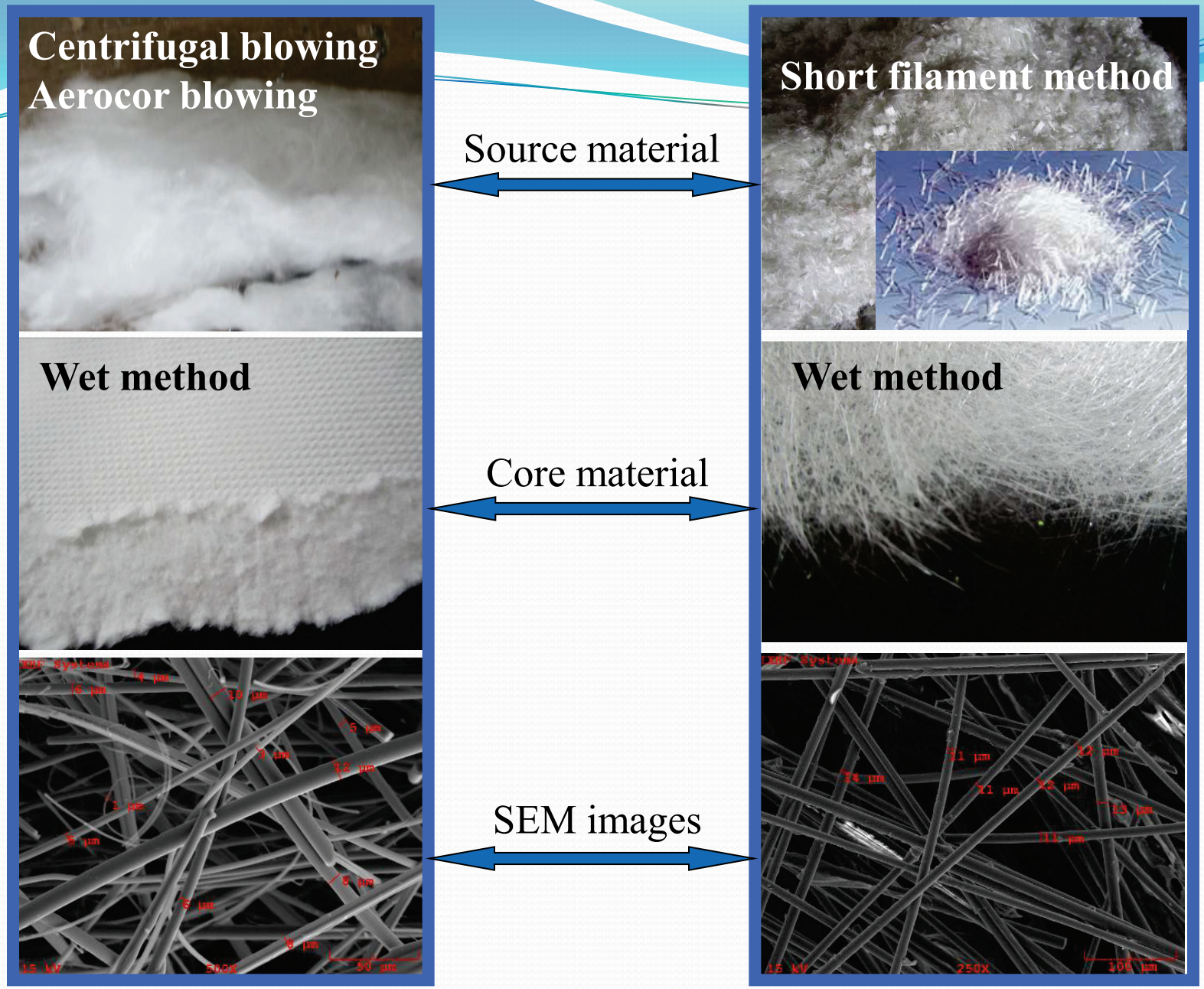
- Process of core material: Wet method;
- Dry conditions: 150℃, 30min;
- Thickness of each layer: 0.5mm, 1mm, 3.3mm
- Size of VIP: 300mm×300mm×25 mm.
- Evelope： PET/AL/PE；
- Vacuum compressure: 0.1 Pa;
- Measure condition： Hot plate 37.7℃ and cold plate 10℃ (Netzsch HFM 436)；

Experimental Results

Table 2 Mean diameter, length and composition of several glass fibers

Properties	CF	AF	FF
Mean diameter *d* (um)	3.8	1.9	8/10/13
Mean length *l* (mm)	50	8	15
Composition (EDS, at.%)			
O	37.39	40.79	46.74
Na	11.18	8.99	-
Mg	1.92	1.76	0.80
Al	0.48	1.00	7.86
Si	42.93	38.96	28.39
Ca	6.10	8.50	16.21

Note: CF- centrifugal glass fiber, AF- aerocor glass fiber, FF- short filament glass fibers.



(a) wool-type fibers (b) filament glass fibers

Fig.2 Photographs and SEM images of two types of glass fiber

Table 3 Parameters of six VIP samples Total thickness was about 10mm

Sample	Glass fiber	mean d (μm)	T (mm)	L	λ ($mWm^{-1}K^{-1}$)
#1	70%CF+30%AF	2.8	0.5	20	1.8
#2	70%CF+30%AF	2.8	1	10	2.1
#3	70%CF+30%AF	2.8	3.3	3	2.5
#4	FF	8	0.5	20	1.9
#5	FF	10	0.5	20	2.0
#6	FF	13	0.5	20	3.4

Note: T-thickness of core material, L- number of layers, λ-thermal conductivity

- The thermal conductivity of VIP for samples 1, 2 and 3 decreased with decreasing thickness of each layer.

- For the FF glass fiber, the thermal conductivity of VIP decreased with decreasing fiber diameter.

- It can be seen that more layers would be helpful to reduce the thermal conductivity for the interfaces will block heat transfer from one layer to another layer.

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- **Insulation Mechanism of VIP**

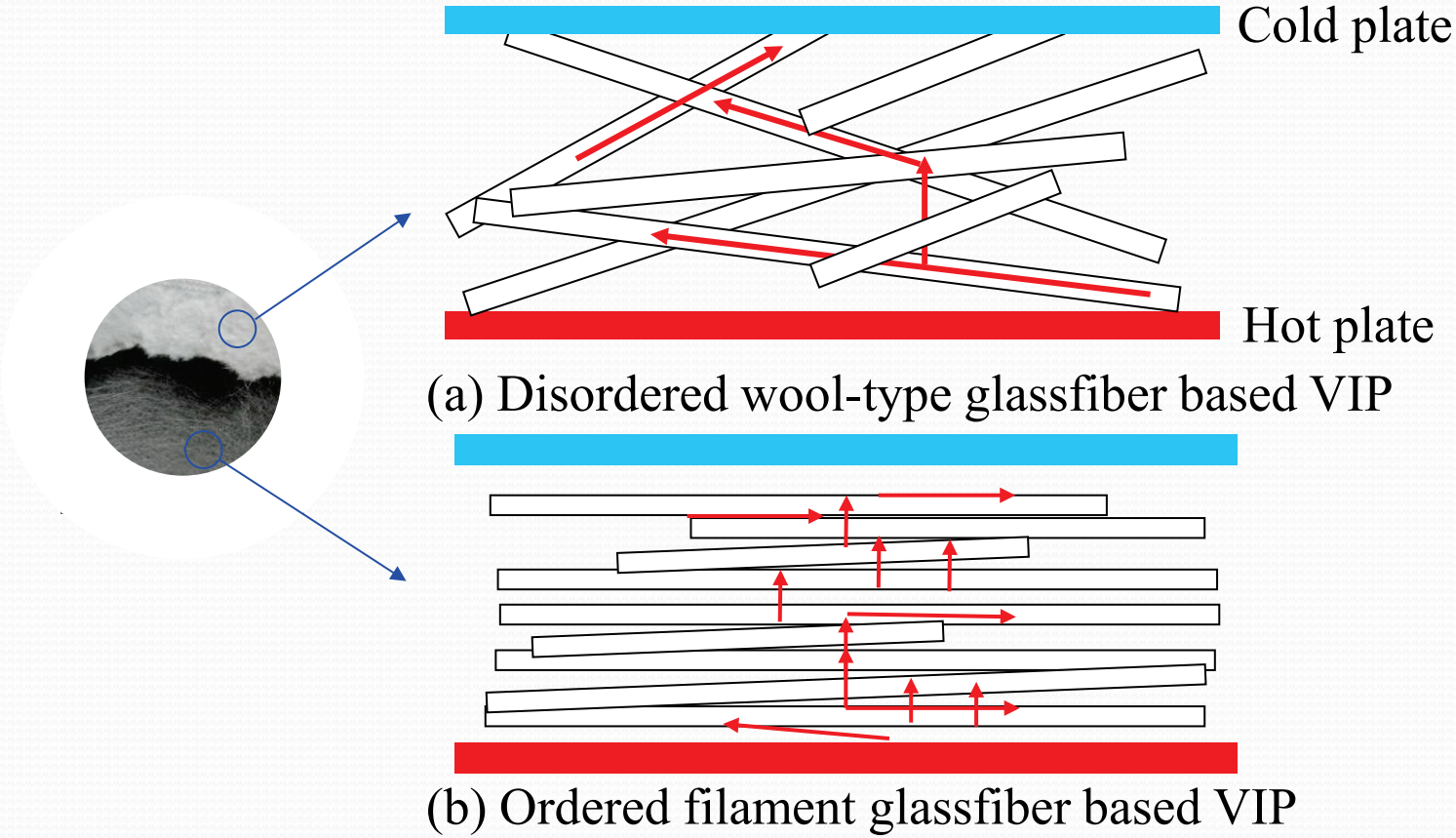
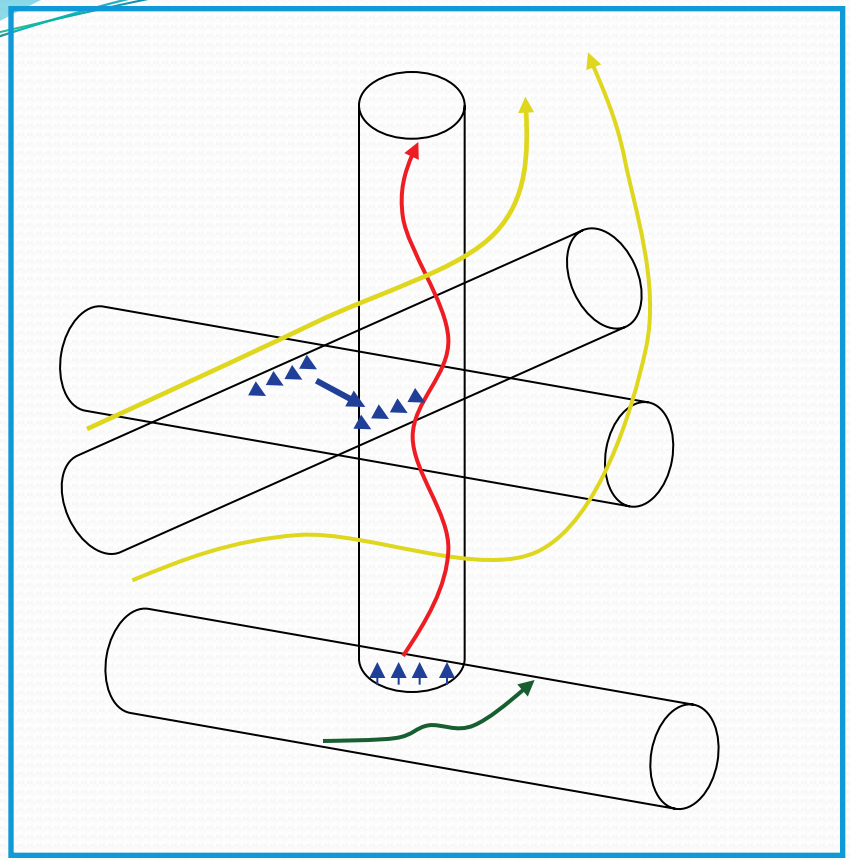
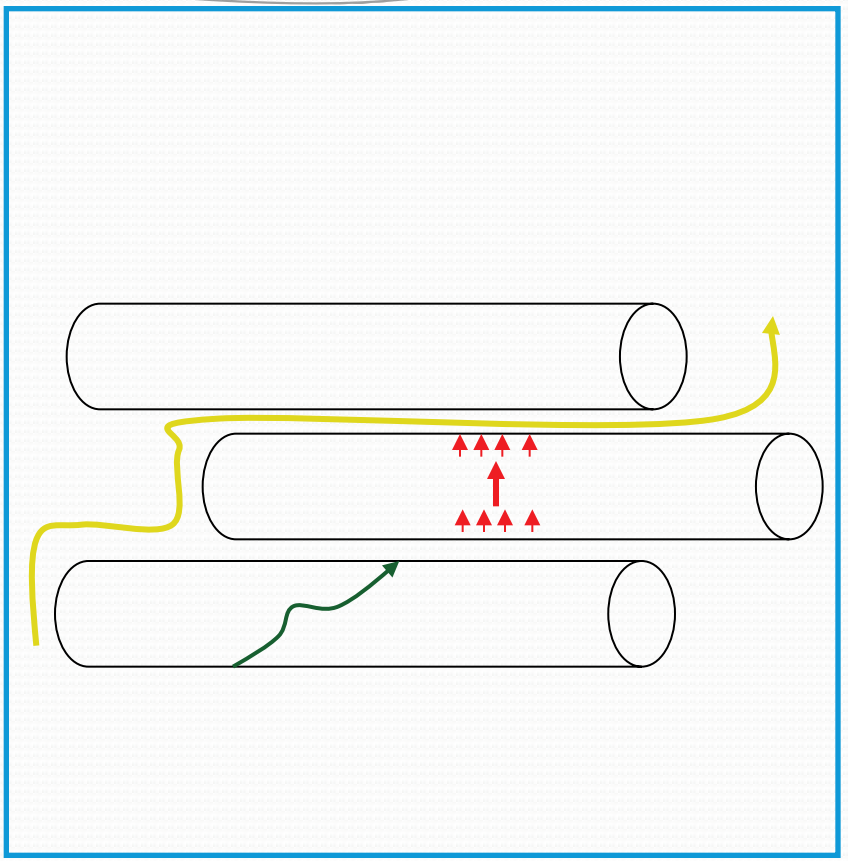


Fig.3 Model of the path of heat transfer



Thermal conduction in disordered glass fiber core material, thermal conduction via along the longitudinal fibers (red arrow), interfaces and contacts point (blue arrows), gas pores (yellow arrows) and radiation (green arrow).



Thermal conduction in ordered glass fiber core material, thermal conduction via interface contact between transverse fibers (red arrows), gas pores (yellow arrow) and radiation (green arrow).

Fig.4 Mechanism of thermal conduction

Comparation of ordered and disordered glass fiber

VIP with disordered glass fiber

- (1) Smooth surface
- (2) Tough
- (3) Low thermal conductivity
- (4) Low production cost
- (5) Nonuniform of fiber diameter

VIP with ordered glass fiber

- (1) Relative smooth surface
- (2) Soft
- (3) Low thermal conductivity
- (4) High production cost
- (5) Homogeneous of fiber diameter

Conclusions

- Increasing the number of core layers reduces the thermal conductivity of VIP.
- For the FF glass fiber, the thermal conductivity of VIP decreases with decreasing fiber diameter.
- Disordered and ordered glass fiber have different heat transfer paths.

The End

Thank you for your attention.