FUNDAMENTALS:

EFFECTIVE THERMAL CONDUCTIVITY OF HEAT PIPE WICKS

In the calculation of a heat pipe thermal resistance or effective thermal conductivity, one needs to calculate the effective thermal conductivity of the wick /fluid combination. In this article we look at some common wick structures used in heat pipe construction.

1. WIRE SCREEN

$$K_{eff} = \frac{K_f[K_f + K_s - (1-\varepsilon)(K_f - K_s)]}{K_f + K_s + (1 - \varepsilon)(K_f - K_s)} \qquad (1)$$

M = 1/(d+W) Mesh number
K_f = thermal conductivity of fluid
K_s = thermal conductivity of solid
$\varepsilon = 1-\pi SMd/4$ volumetric porosity of wire mesh
d = wire diameter
W = width of mesh
S = 1.05 crimping factor

Example:
Find the thermal conductivity of a #500 copper mesh screen with wire diameter of 0.00085 in (0.02159 mm).

#500 mesh means mesh number (M) = 500/in

$\varepsilon = 0.65$, $K_{eff} = 1.25$ W/m·K

Simple manipulation of the above formula reveals that increasing mesh number increases conductivity and reducing wire diameter decreases thermal conductivity.

2. GROOVED WICK

$$K_{eff} = K_s[1 - \varepsilon(1 - \frac{K_f}{K_s})] \qquad (2)$$

$\varepsilon = \frac{W}{W+f}$ Liquid void fraction
W = channel width
f = fin thickness

Table 1 shows a simple calculation of effective thermal conductivity of copper/water grooved wick as a function of fin thickness and channel width. It can be seen that by decreasing the channel width, less water and more solid is being used, hence higher thermal conductivity and conversely keeping the width constant, increasing fin thickness increases the thermal conductivity.

W(mm)	f(mm)	ε	K_{eff}(W/m·K)
1	1	0.50	200
1	0.5	0.67	134
1	0.2	0.83	67
0.5	1	0.33	267
0.4	1	0.29	286
0.3	1	0.23	308
0.2	1	0.17	333

Table 1. Effective Thermal Conductivity of Copper/Water Groove

3. SINTERED METAL

$$K_{eff} = K_s\left[\frac{2 + K_f/K_s - 2\varepsilon(1 - K_f/K_s)}{2 + K_f/K_s + \varepsilon(1 - K_f/K_s)}\right] \tag{3}$$

The accuracy of this equation has been proven using laser flash technique.

For example a sintered water copper wick with a porosity of 0.5 yields a thermal conductivity of 163 W/m·K

REFERENCES

1. Chi, S., “Heat pipe theory and practice”, New York: McGraw-Hill, 1976

2. Kosowski., N., Kossson, R., “Experimental performance of grooved heat pipes at moderate temperatures.” AIAA paper 71-409, 1971

3. Maxwell, J., “A treatise on electricity and magnetism” Vol 1, 3rd edn. OUP, 1954(1981)