The modified naive method for evaluating a microchannel cooling solution

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The Naive Method function allows the user to calculate the heat flux q, pressure loss dP, and outlet temperature T_{out} for a simple microchannel cooler which consists of straight rectangular channels.

1 Input

The Naive Method function takes the following input

1. Channel Length, L $[m]$
2. Channel Width, W $[m]$
3. Channel Height, H $[m]$
4. Fluid Density, ρ $[kg/m^3]$
5. Fluid Viscosity, μ $[Pa * s]$
6. Fluid Specific Heat, c_p $[J/(kg * K)]$
7. Fluid Thermal Conductivity, k $[W/(m * K)]$
8. Fluid Inlet Temperature, T_{in} $[K]$
9. Wall Temperature, T_w $[K]$
10. Flow Rate, Q $[m^3/s]$

2 Describing the Flow

The cross-sectional area $[m^2]$

$$A = WH \tag{1}$$

The wetted perimeter $[m]$

$$P = 2(W + D) \tag{2}$$

The hydraulic diameter $[m]$

$$D_h = 4\frac{A}{P} \tag{3}$$

The fluid velocity $[m/s]$

$$v = Q/A \tag{4}$$

2.1 Dimensionless Flow Parameters

The Reynolds number for the flow $[ul]$

$$Re = \frac{\rho v D_h}{\mu} \tag{5}$$

where ρ is the density of the fluid, v is the speed of the flow, D_h is the hydraulic diameter, and μ is the viscosity of the fluid.

The Prandtl number for the flow $[ul]$

$$Pr = \frac{c_p \mu}{k} \tag{6}$$

where c_p is the specific heat of the fluid, μ is the viscosity of the fluid, and k is the thermal conductivity of the fluid.

The Nusselt number for the flow $[ul]$ is calculated using the Reynolds number and the Prandtl number. This is an empirical relation known as the Dittus and Boelter equation, for fully developed flow in a circular pipe.

$$Nu = 0.023 * Re^{0.8} * Pr^{0.4} \tag{7}$$

2.2 Heat Transfer

The heat transfer coefficient, h $[W/(m^2 * K)]$

$$h = \frac{Nu * k}{D_h} \tag{8}$$

where Nu is the Nusselt number, k is the fluid thermal conductivity, and D_h is the hydraulic diameter.

For each δL along the length L of the channel,

$$T_{out} = \frac{\delta E}{\rho Q c_p} + T_{in} \tag{9}$$

where δE is

$$\delta E = 4hW\delta L(T_w - T_{in}) \tag{10}$$

Finally, the heat flux q $[w/m^2]$ can be calculated as

$$q = \frac{1}{4WL} \sum \delta E \tag{11}$$

2.3 Pressure Loss

The pressure loss, dP $[Pa]$

$$dP = \frac{fL\rho v^2}{2D} \tag{12}$$

where f, the Fanning friction factor, is $(64/Re)$, L is the channel length, ρ is the fluid density, v is the fluid velocity, and D is the channel depth.