The 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 Depth, D $[m]$
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 $[uL/min]$

2 Describing the Flow

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

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

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 $[m/s]$

$$v = \frac{Q}{A} * 1.67 \times 10^{-11} \tag{4}$$

where the constant 1.67×10^{-11} ensures dimensional consistency.

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.

$$Nu = 0.023 * Re^{4/5} * Pr^{1/3} \tag{7}$$

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.

The heat flux, q $[W/m^2]$

$$q = h * (T_w - T_{in}) \tag{9}$$

where h is the heat transfer coefficient, T_w is the wall temperature, and T_in is the inlet temperature.

2.3 Pressure Loss

The pressure loss, dP $[Pa]$

$$dP = \frac{fL\rho v^2}{2D} \tag{10}$$

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.

2.4 Outlet Temperature

The outlet temperature, T_{out} $[K]$

$$T_{out} = T_{in} + \frac{q}{Q\rho c_p * 1.67 \times 10_{-4}} \tag{11}$$

where T_{in} is the inlet temperature, q is the heat flux, Q is the flow rate, ρ is the fluid density, and c_p is the specific heat of the fluid. The constant $1.67 \times 10_{-4}$ ensures dimensional consistency.

3 References

Primary reference: Ch.3 (Single-Phase Liquid Flow In Minichannels and Microchannels) of Kandilikar, S. Heat Transfer and fluid flow in minichannels and microchannels.