The Role of Fin Geometry in Heat Sink Performance

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Agenda

- Introduction
- Assumptions
- Entropy Generation Rate
- Results and Discussion
- Conclusions
- Acknowledgment

Assumptions

- Isothermal fins with adiabatic tips
- Air flow normal to fin axis
- Steady, laminar and 2-D flow
- Incompressible fluid with constant properties
- Negligible radiation heat transfer
- No heat sources within the fin itself
- No contact resistance between fin and base surface

Entropy Generation Rate for a Pin-Fin

Bejan (1996):

$$\dot{S}_{gen} = \frac{Q^2 R_{th}}{T_\infty^2} + \frac{F_D U_\infty}{T_\infty}$$

$$R_{th} = \frac{1}{k\, A_c\, m \tanh(mH)}$$

$$F_D = C_D \left(\frac{1}{2} \rho U_\infty^2 \right) A_p$$

$$C_D = \frac{C_1}{\sqrt{Re_{\mathcal{L}}}} + C_2 + \frac{C_3}{Re_{\mathcal{L}}}$$

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Dimensionless Entropy Generation Rate

$$N_s = \frac{1}{Re_{\mathcal{L}}\sqrt{C_5\, Nu_{\mathcal{L}}\, k_{eq}}\tanh(\gamma\,\sqrt{C_6\, Nu_{\mathcal{L}}\, k_{eq}})} + \frac{1}{2}\, C_D\; B\,\gamma\, Re_{\mathcal{L}}^2$$

$$C_5 = \frac{P\, A_c}{\mathcal{L}^3} \qquad \text{and} \qquad C_6 = \frac{P\,\mathcal{L}}{A_c}$$

$$Nu_{\mathcal{L}} = \frac{h\mathcal{L}}{k} \qquad \text{and} \qquad Re_{\mathcal{L}} = \frac{U_\infty\,\mathcal{L}}{\nu}$$

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Parameters for Different Geometries

Parameters	Geometry			
	Plate	Circular	Square	Elliptical
$\mathcal{L}$	L	d	s	$2a$
A_c	tL	$\pi d^2/4$	s^2	$\pi\, a\, b$
A_p	LH	dH	sH	$2\, a\, H$
P	$2(L+t)$	$\pi\, d$	$4\, s$	$4\, aE(e)$
C_1	1.357	5.781	0	$-4.1(0.67 - \exp(0.733\epsilon))$
C_2	0	1.152	2	$1.1526\epsilon^{0.951}$
C_3	0	1.26	0	$\frac{-8.5 + 9.92\epsilon^{\cdot 4}}{.88e - 1 + \epsilon^{\cdot 4}}$
C_4	0.75	0.593	0.102	$0.75 - 0.16\exp(-0.018\epsilon^{-3.1})$
C_5	$2\epsilon_1(1+\epsilon_1)$	$\pi^2/4$	4	$\pi^4\, \epsilon\, /16E^2(e)$
C_6	$2(1+\epsilon_1)/\epsilon_1$	4	4	$16E^2(e)/\pi^2\, \epsilon$
n	$1/2$	$1/2$	0.675	$1/2$

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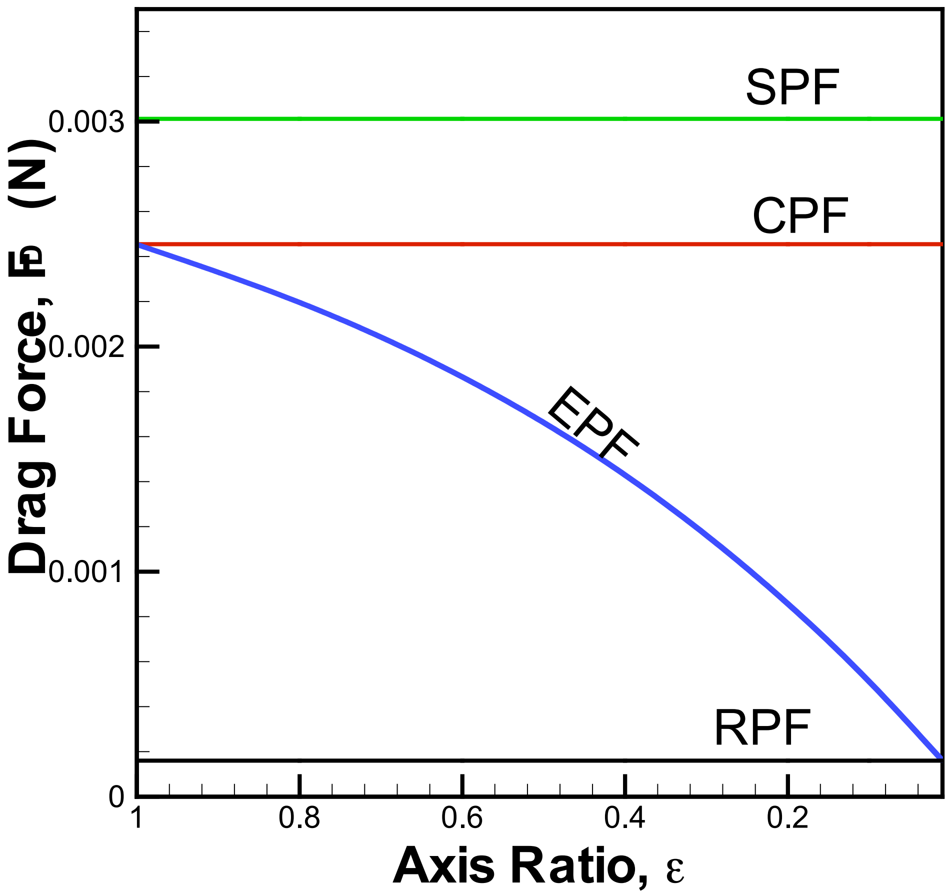
Effect of Axis Ratio on Drag Force



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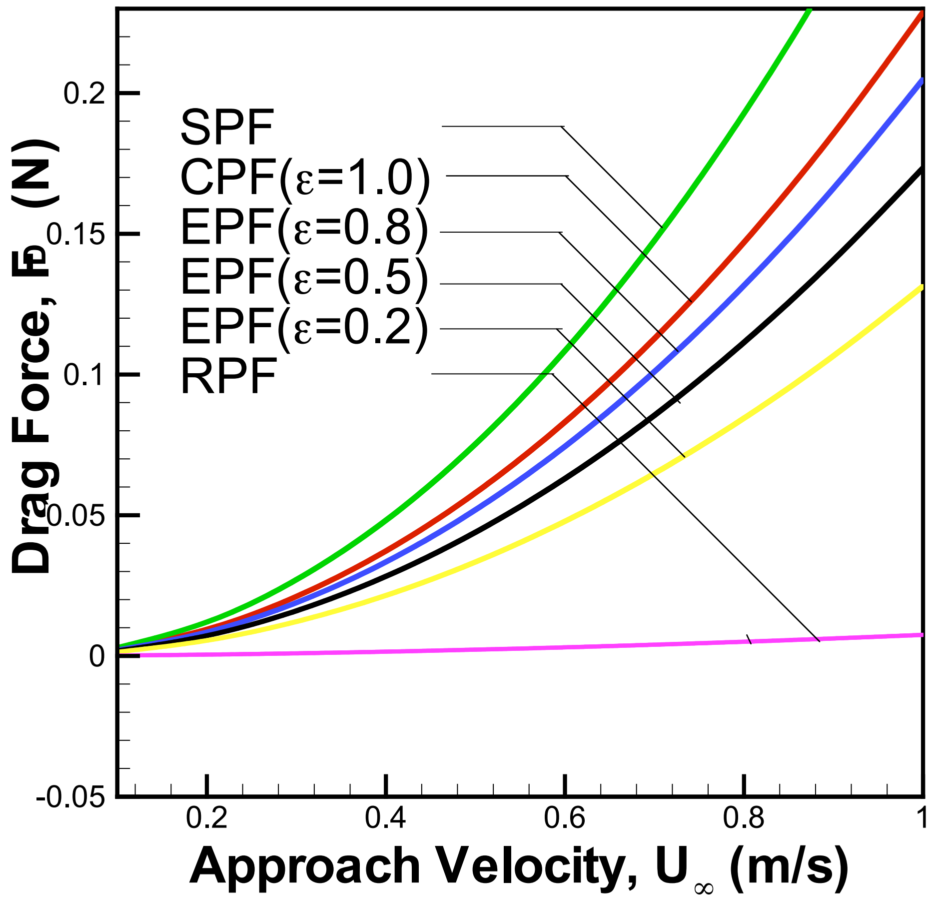
Effect of Approach Velocity on Drag Force



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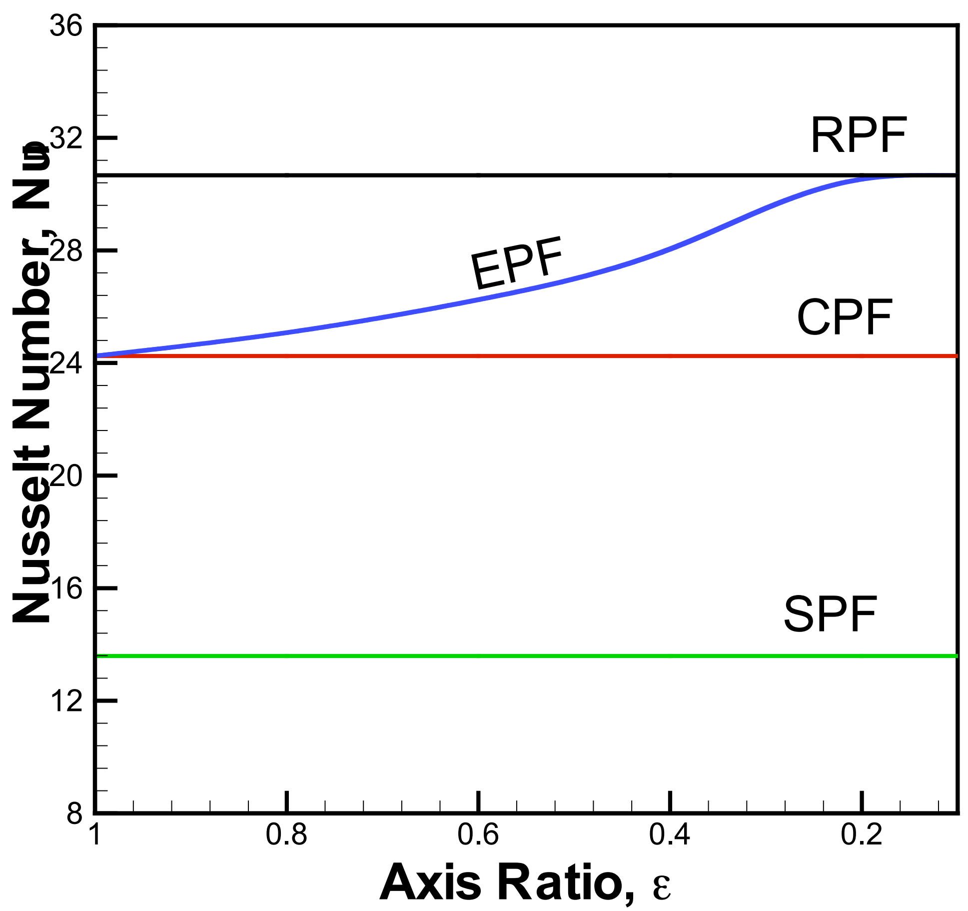
Effect of Axis Ratio on Average Heat Transfer



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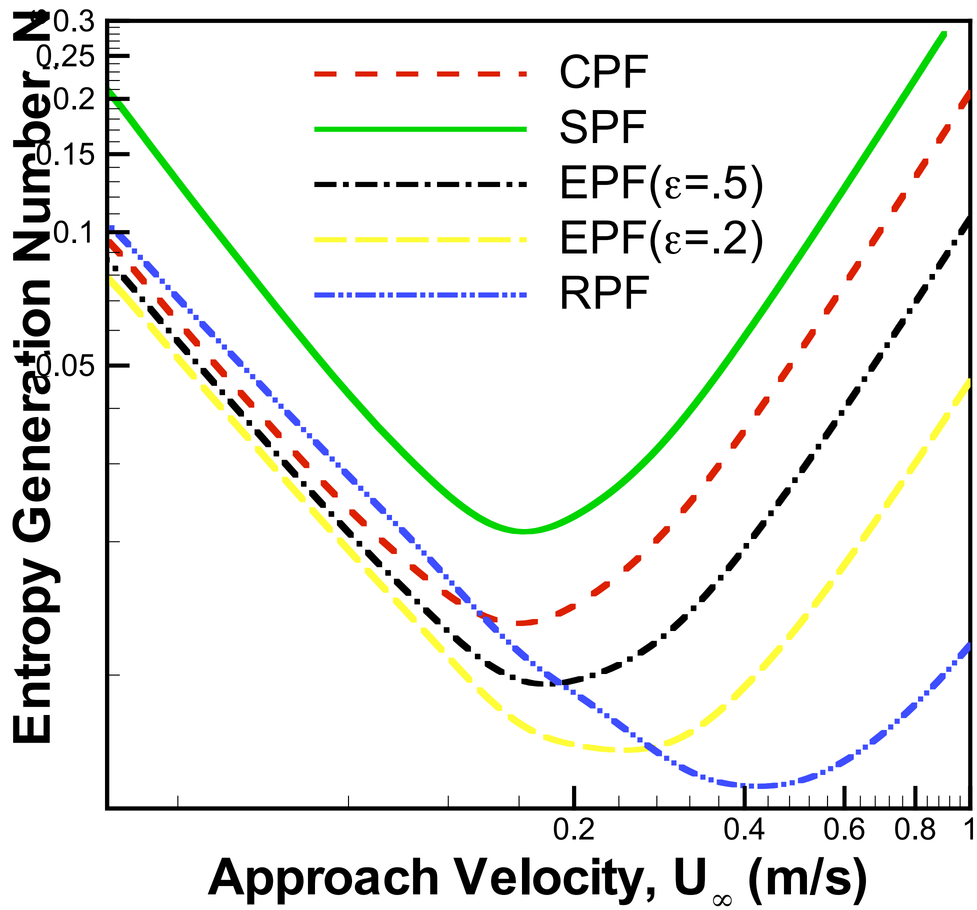
Effect of Approach Velocity on Average Heat Transfer



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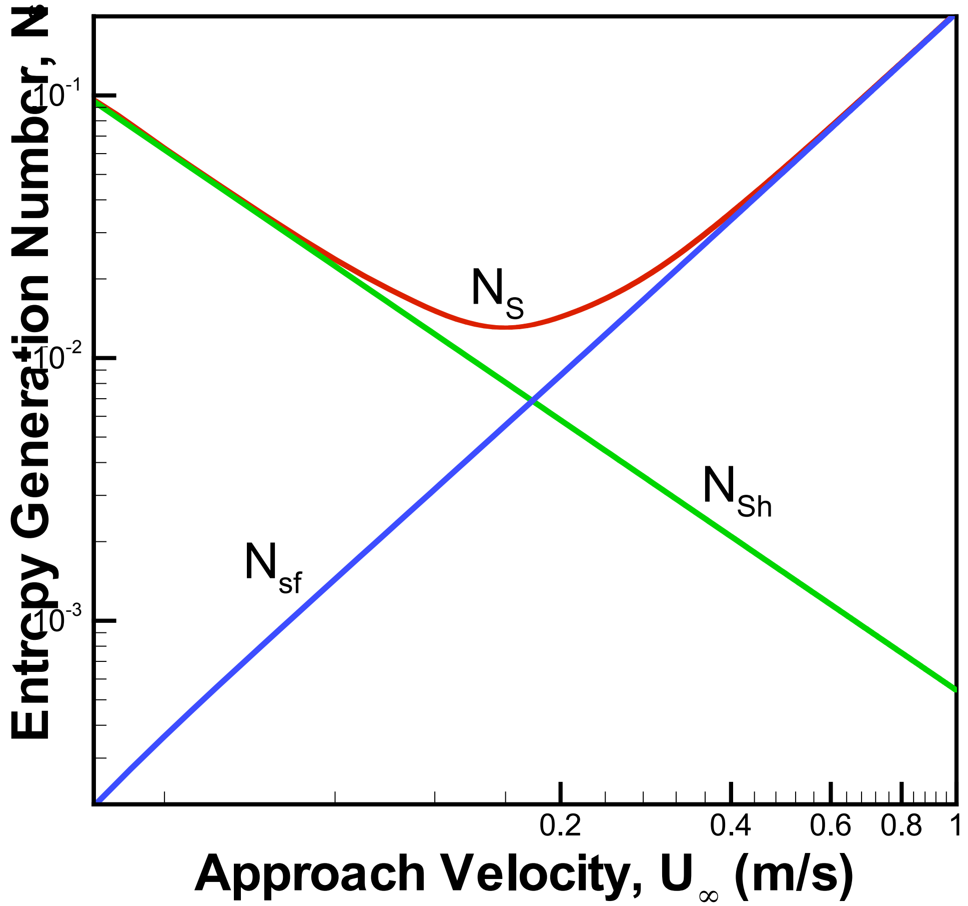
Entropy Generation Rate



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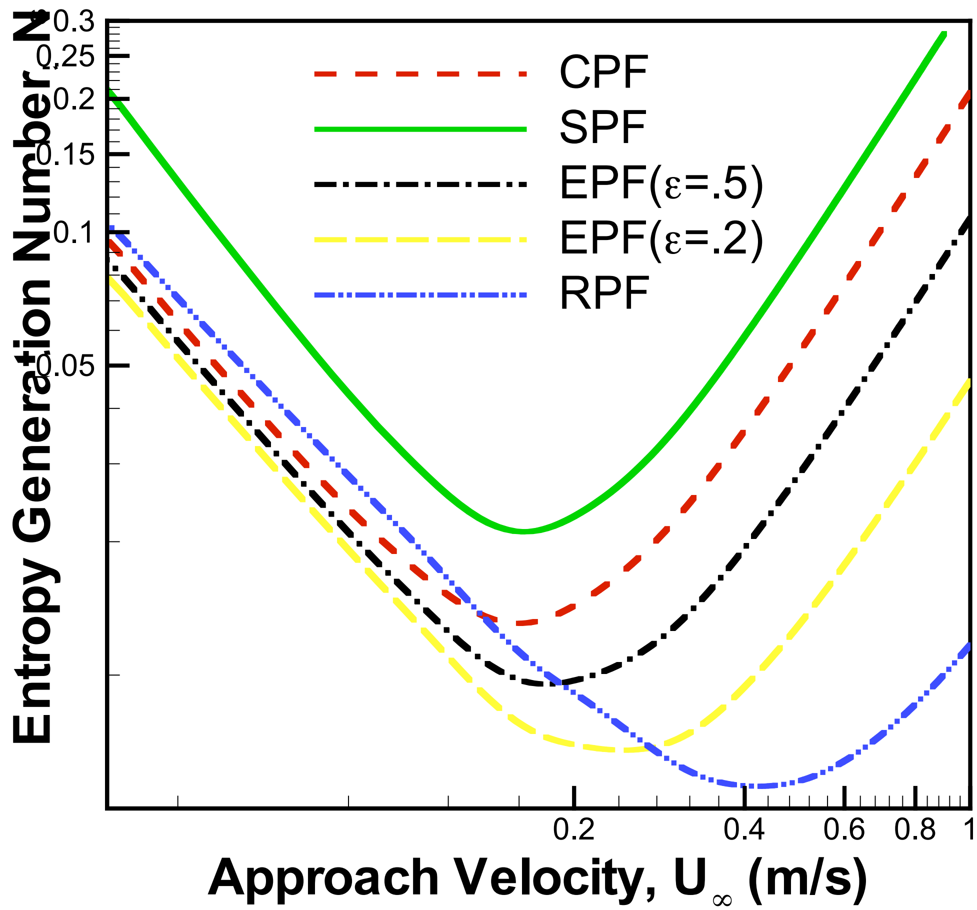
Effect of Approach Velocity on Entropy Generation Rate



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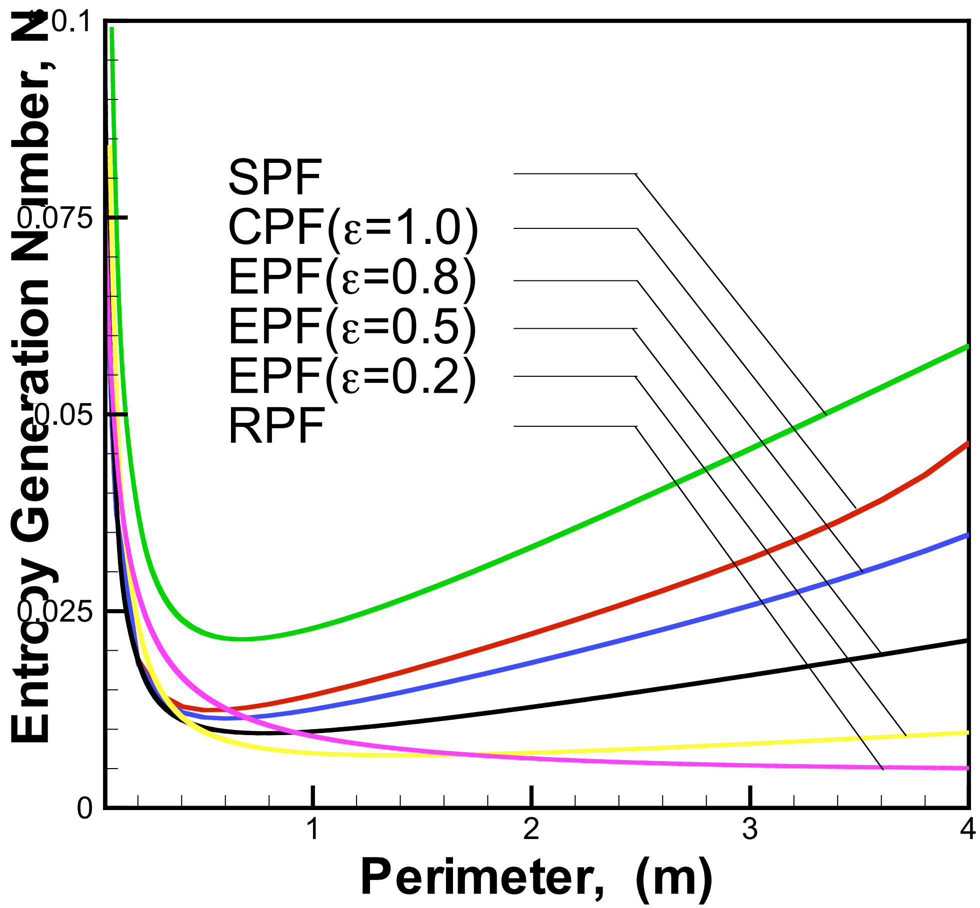
Effect of Perimeter on Entropy Generation Rate



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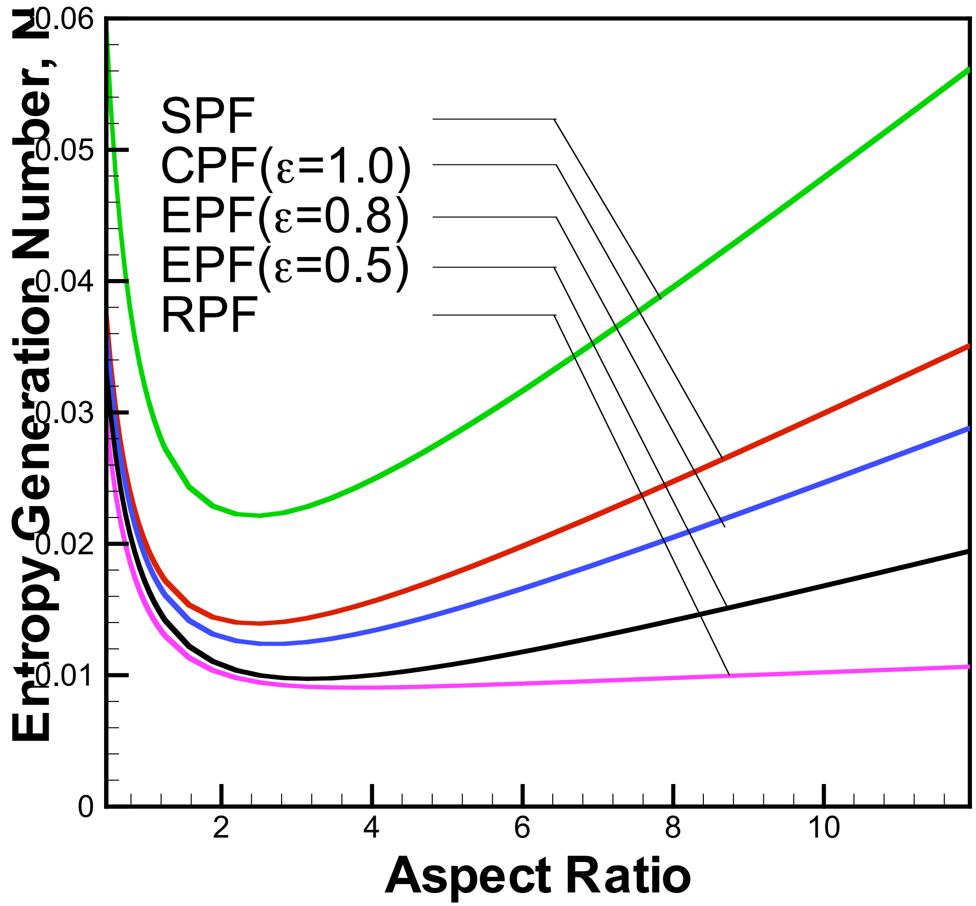
Effect of Aspect Ratio on Entropy Generation Rate



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Conclusions

- ✓ Optimum dimensionless entropy generation rate exists for each geometry depending upon approach velocity, perimeter, and aspect ratio.
- ✓ Square geometry is the worst choice from the point of view of entropy generation rate.
- ✓ Circular geometry appears as the best for low approach velocities and small perimeters.

Conclusions

✓ Flat plate gives the best results for high approach velocities and large surface areas.

✓ Elliptical geometry offers high heat transfer rates and lower drag coefficients for medium approach velocities and larger surface areas.

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