Simulation for pipes with changing bend angle

Yan Zhan

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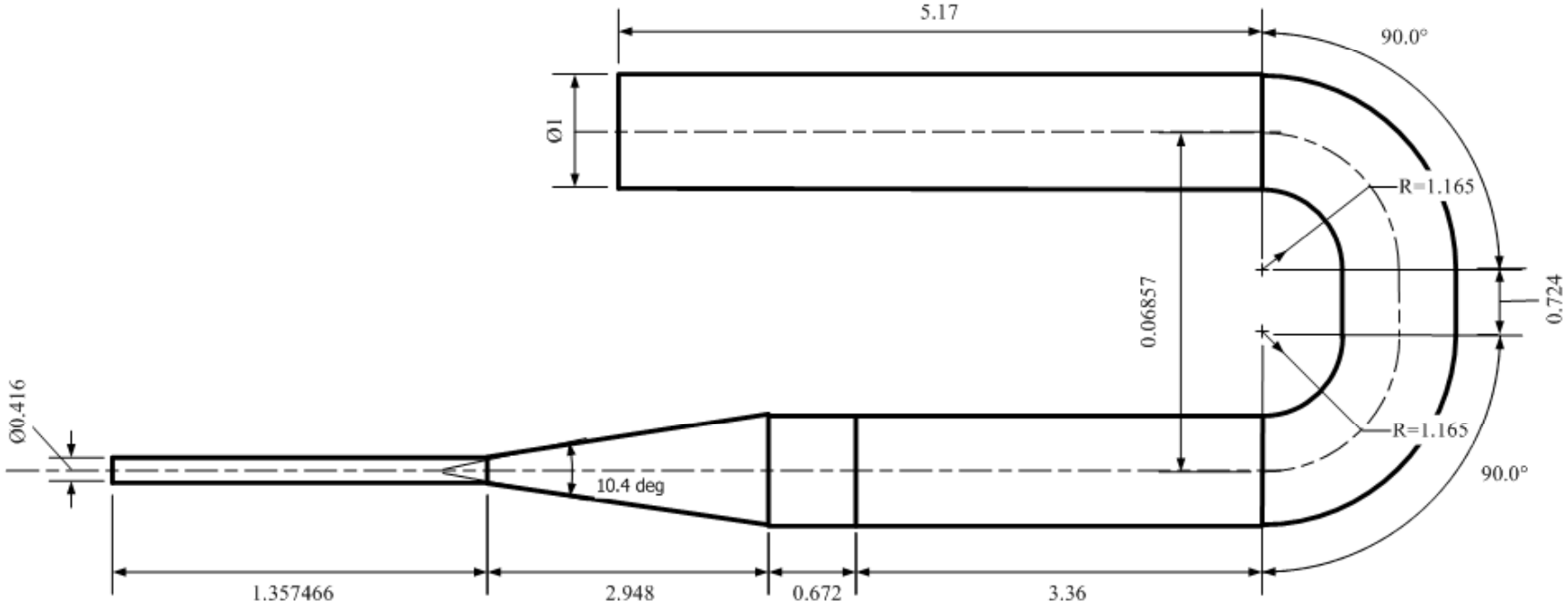
Outline

- Physical Problems
- Mercury flow & Water flow
  - Concepts
  - 0 degree
  - 60 degree
  - 180 degree
- Turbulence level comparison

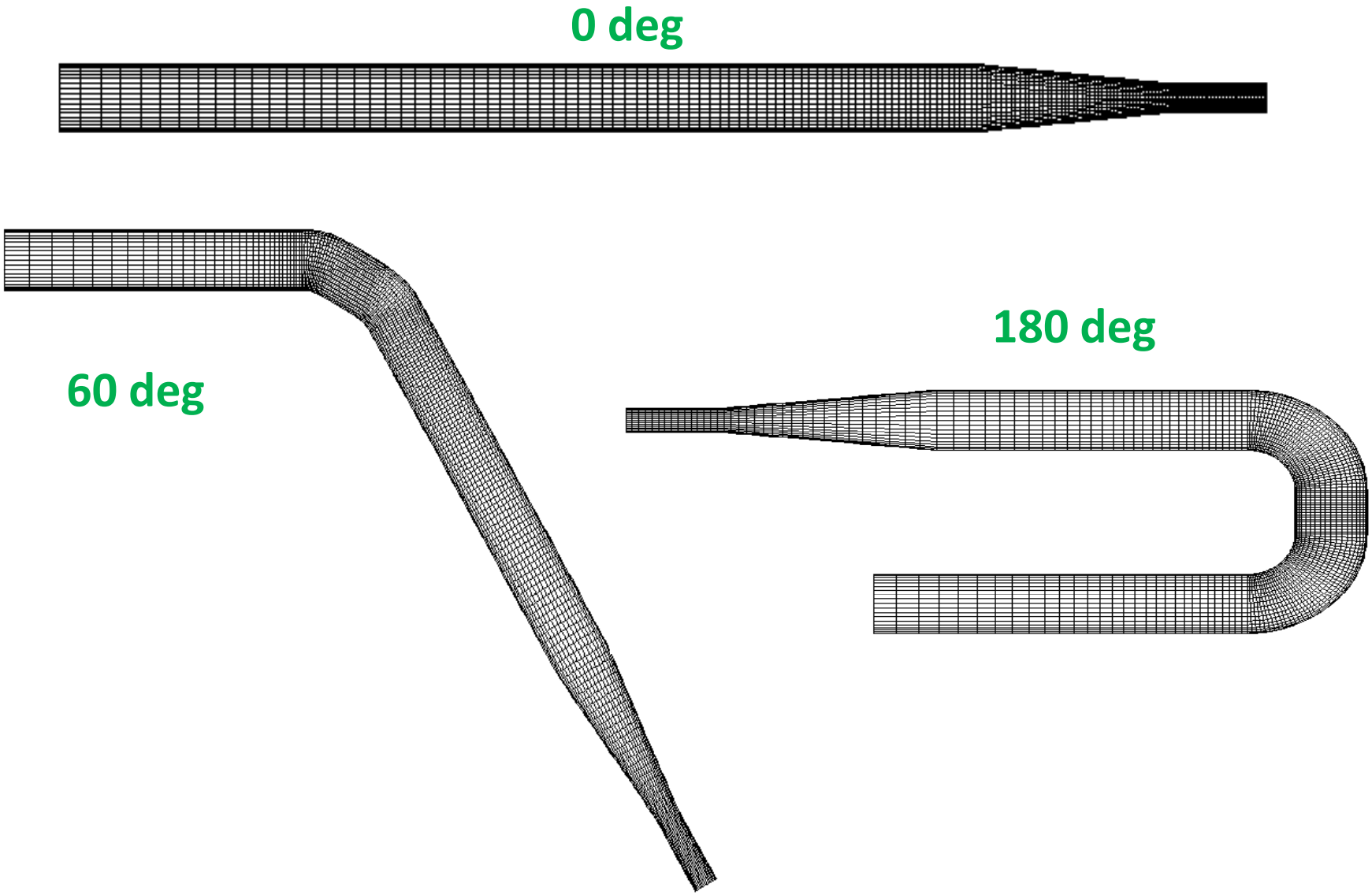
Physical problems (1)

Isothermal mercury/ water flow through a bend pipe into the air environment



Medium	Reynolds Number	Inner Diameter	Inlet Velocity	Inlet Pressure	Ma	Y values (y^+=1)
Mercury	8.05×10^5	0.884”	4.04 m/s	18.5 bar	2.878×10^{-3}	0.72 µm
Water	8.05×10^5	7”	4.04 m/s	18.5 bar	2.751×10^{-3}	5.74 µm

Physical problems (2)



Concepts

Turbulent kinetic energy (TKE)

for U = U + U´ (Flow = mean + turbulent)

then Kinetic Energy = MKE + TKE

Where $TKE = \frac{1}{2}(u'^2 + v'^2 + w'^2)$

Turbulent dissipation (e)

It is the viscous conversion of mechanical energy to heat.

$$e = -\nu\left(\frac{\partial u'}{\partial x}\frac{\partial v'}{\partial y}\frac{\partial w'}{\partial z}\right)$$

Concepts

Static Pressure + Dynamic Pressure = constant

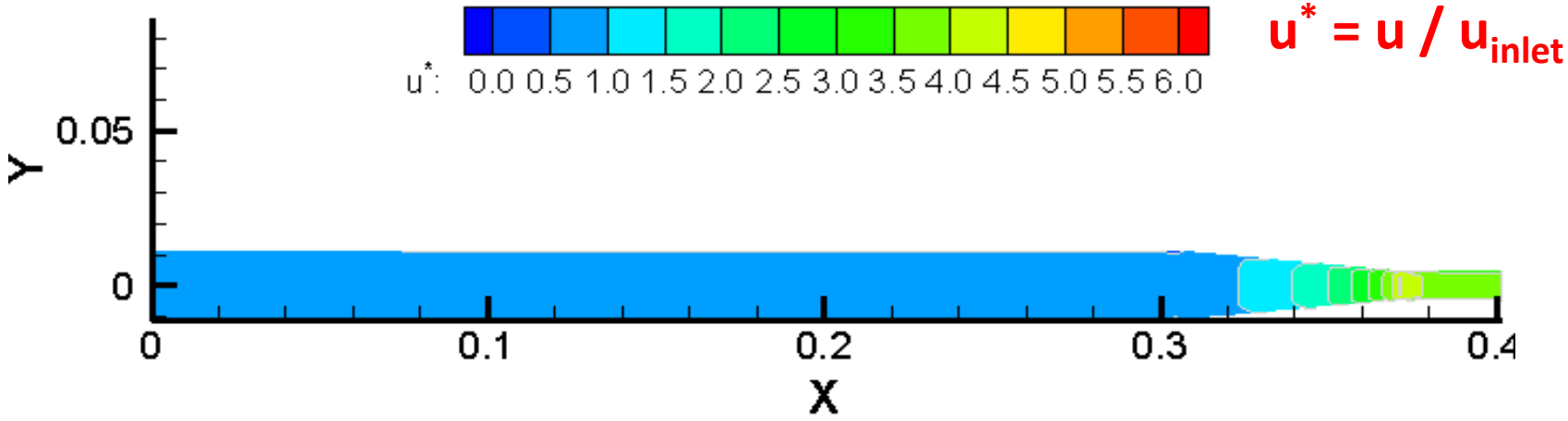
Where

$$P_d = \frac{1}{2} * \rho * u^2$$

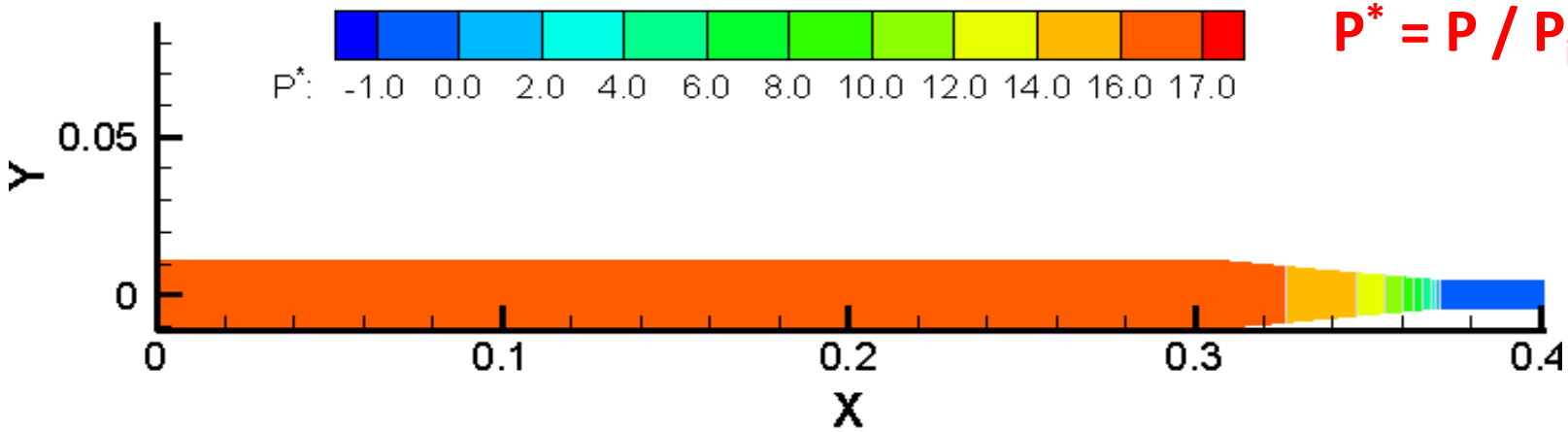
The dynamic pressure of mercury is 13.5 times of that of water.

Mercury Flow

0 Deg | **60 Deg** | **180 Deg**



$u^* = u / u_{inlet}$



$P^* = P / P_{inlet}$

Mercury Flow

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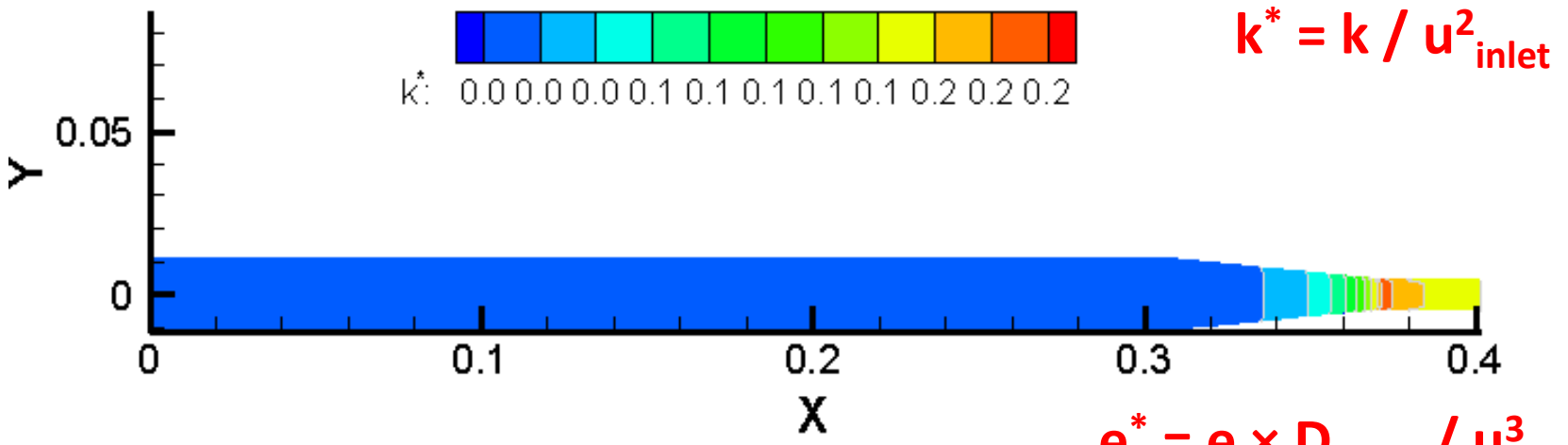
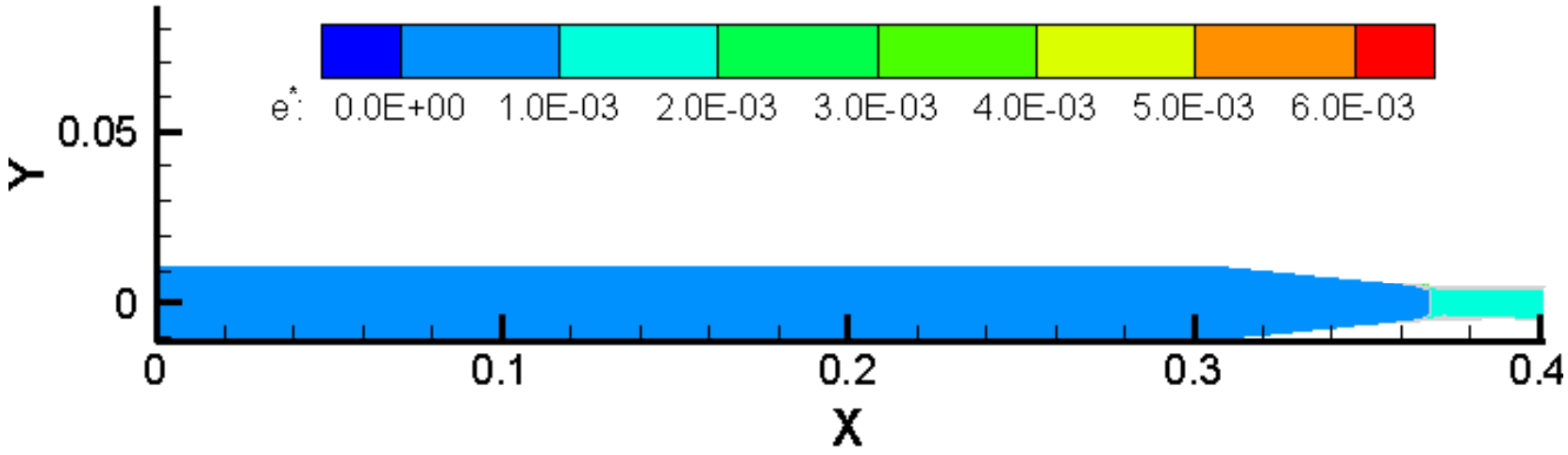


$k^* = k / u^2_{inlet}$

$e^* = e \times D_{outlet} / u^3_{inlet}$



Mercury Flow

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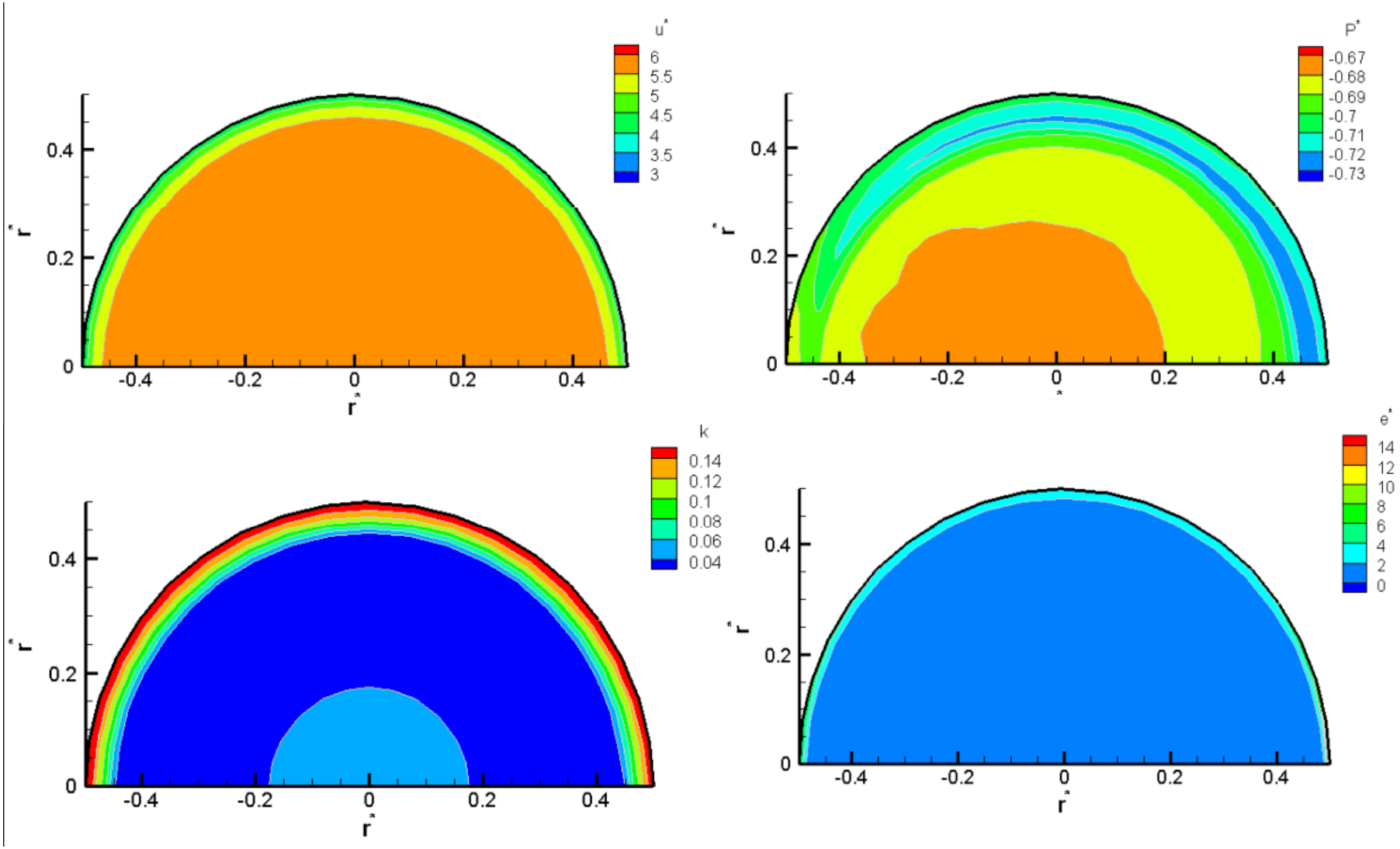

Mercury Flow

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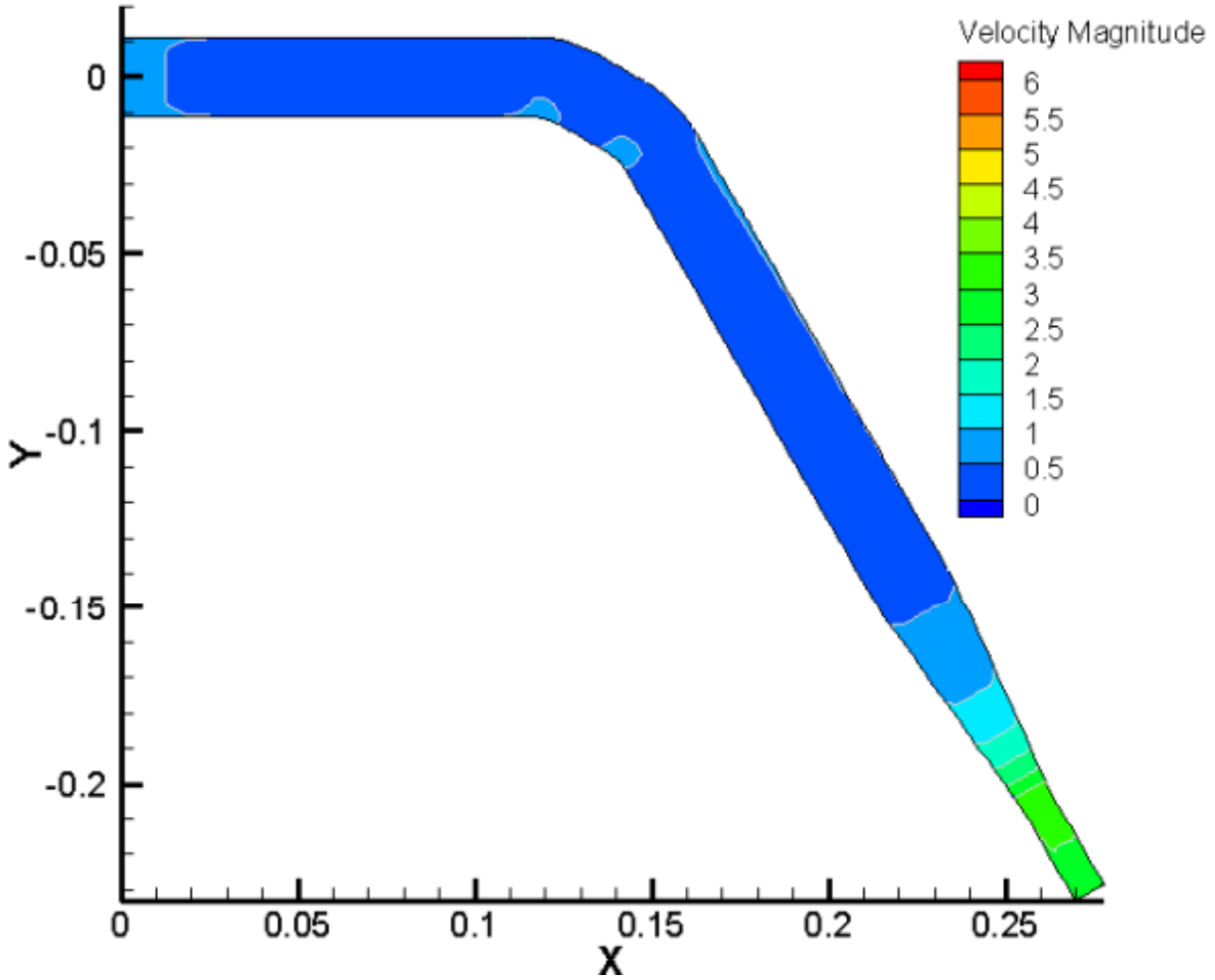

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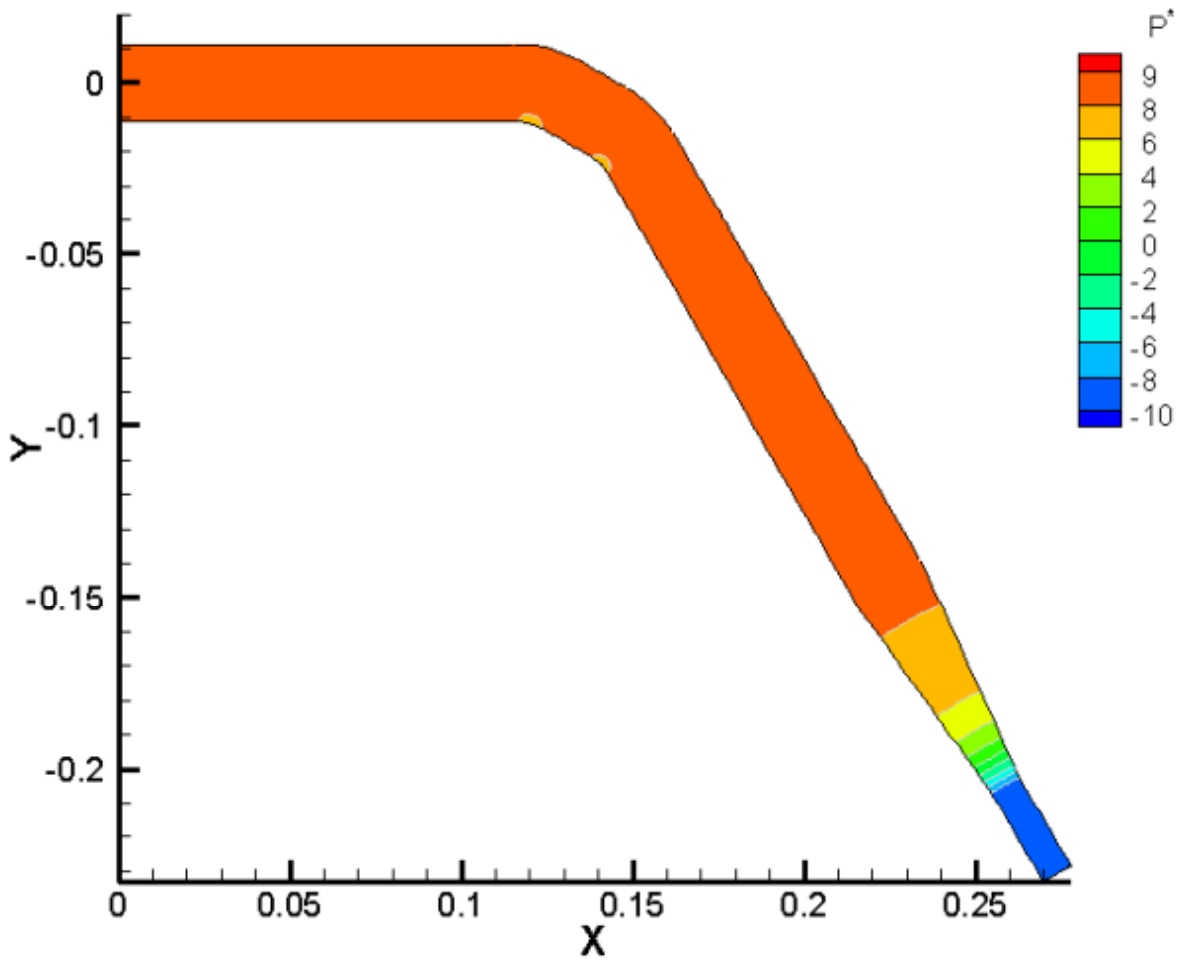

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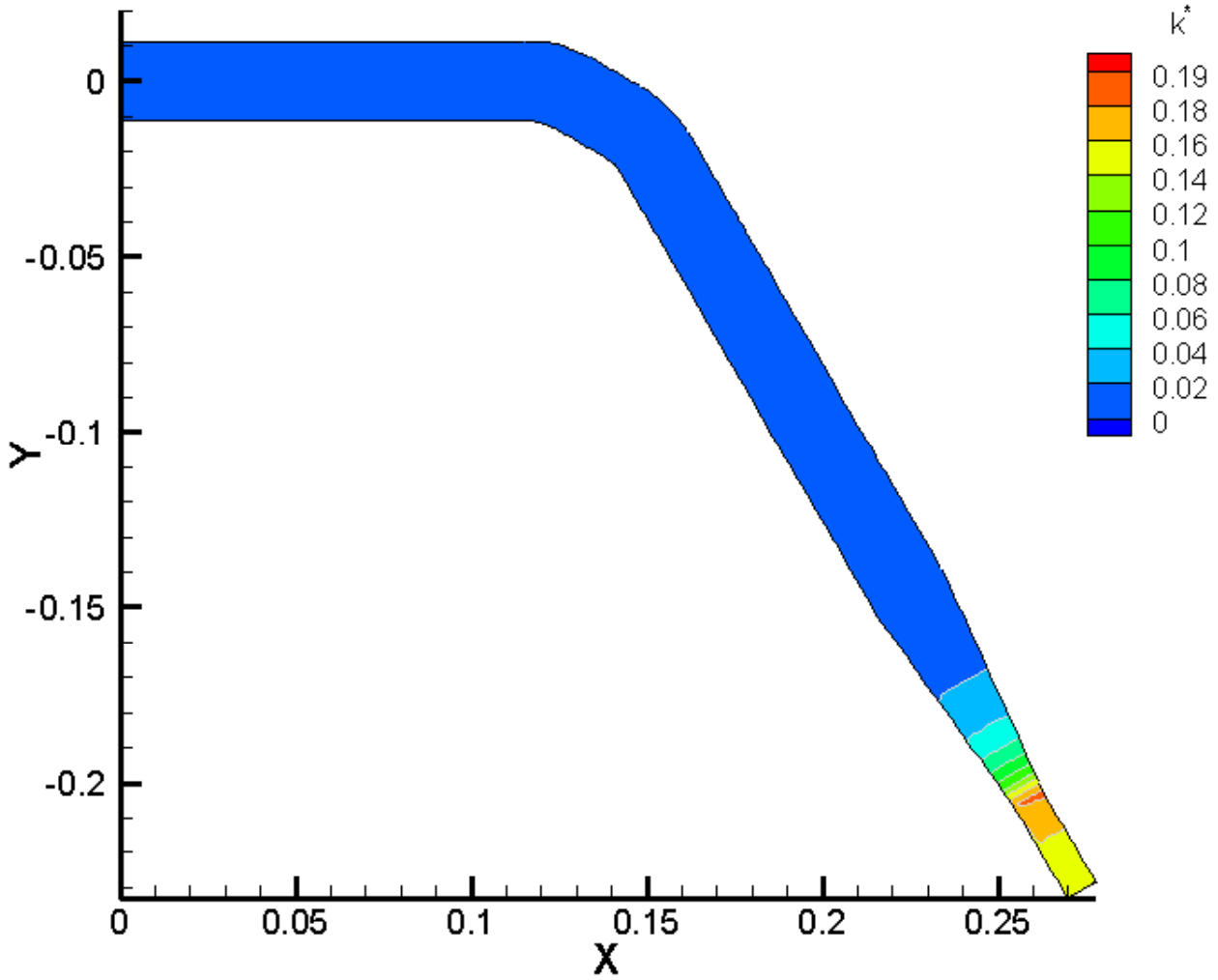

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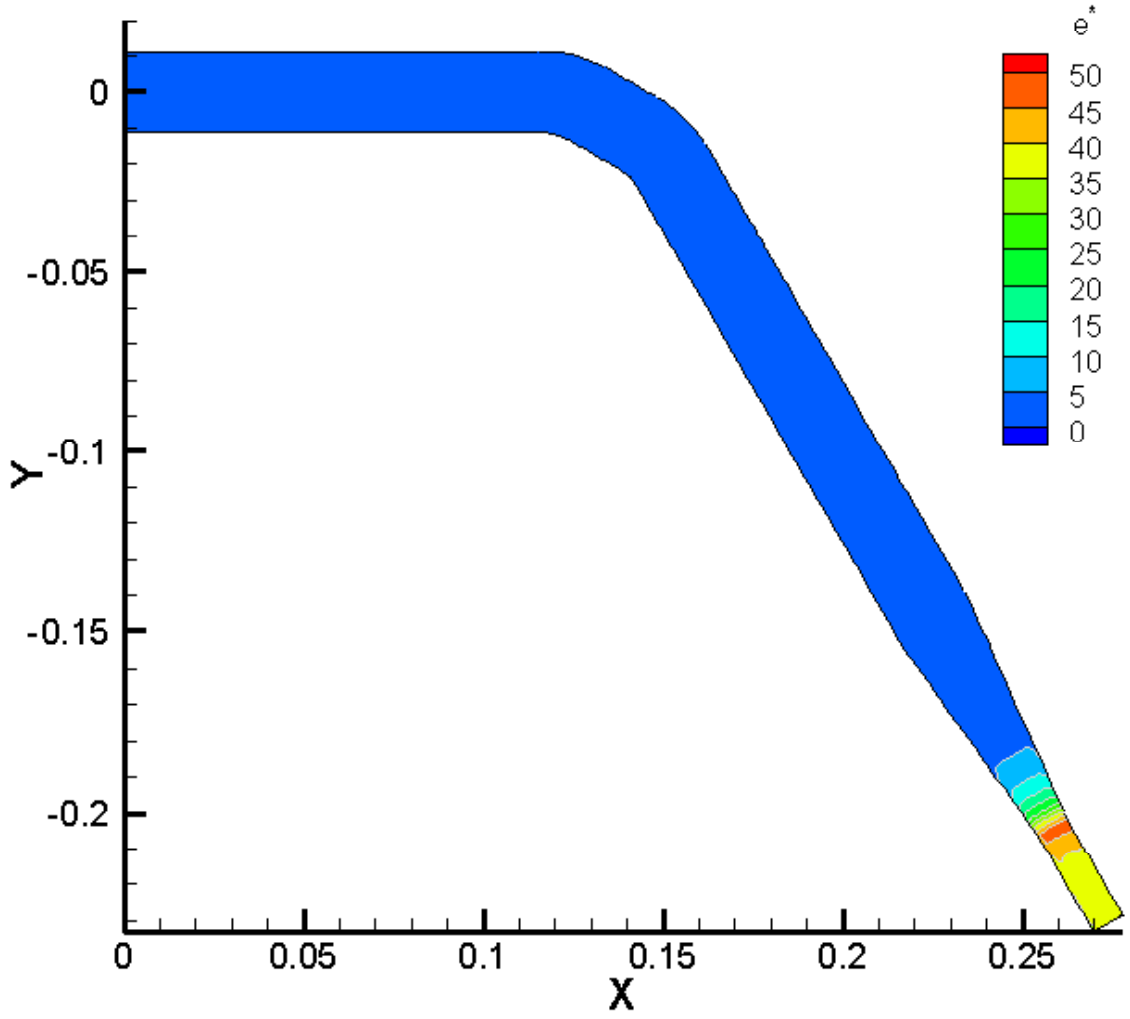

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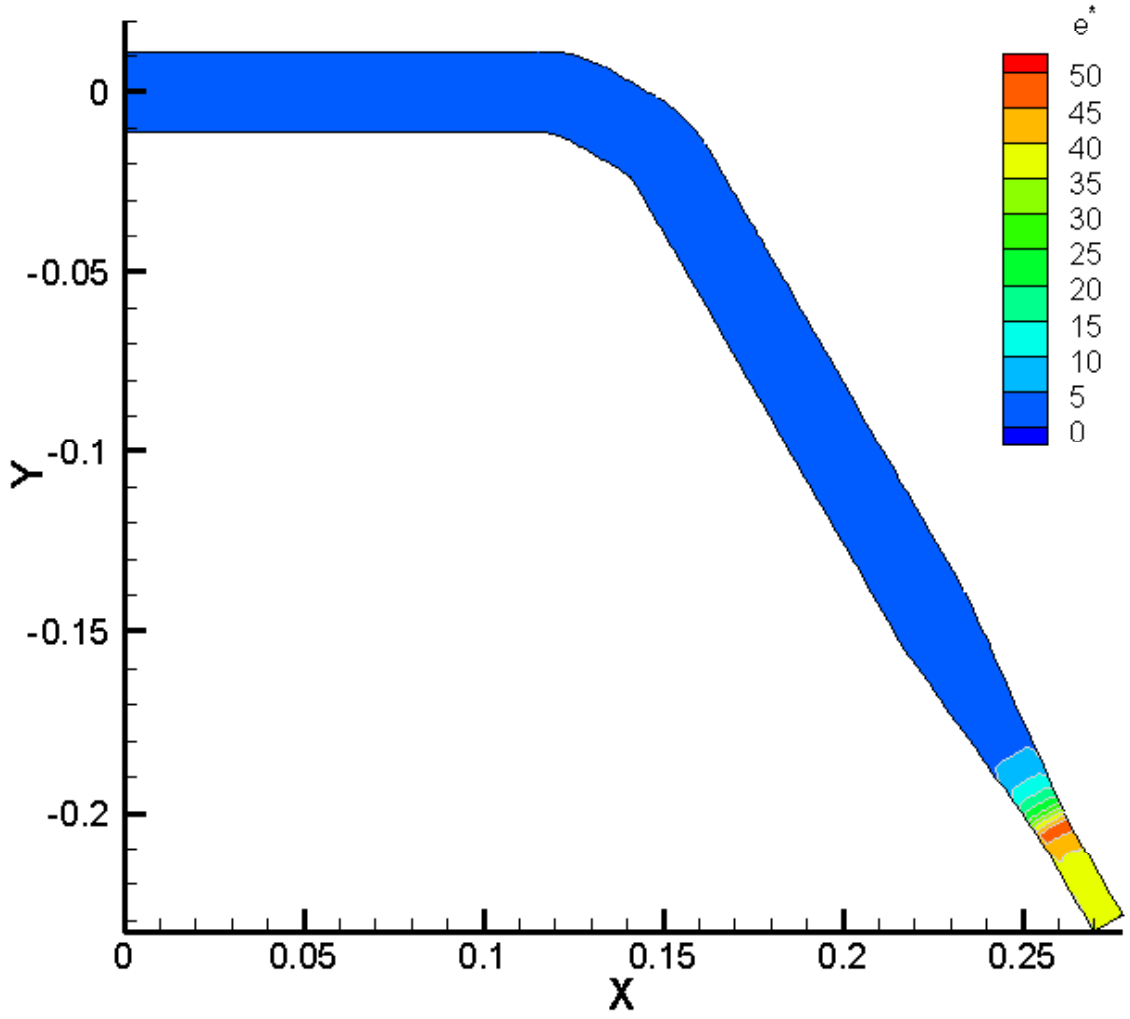

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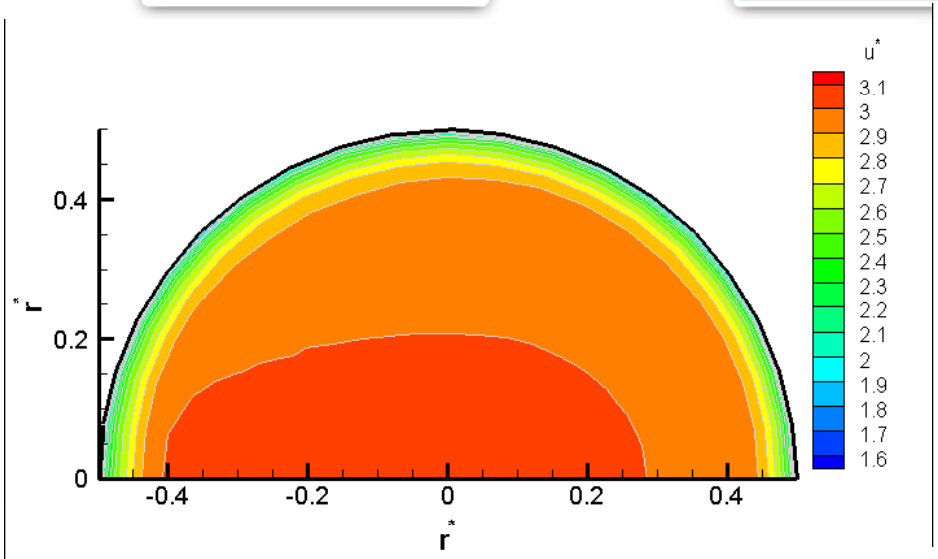

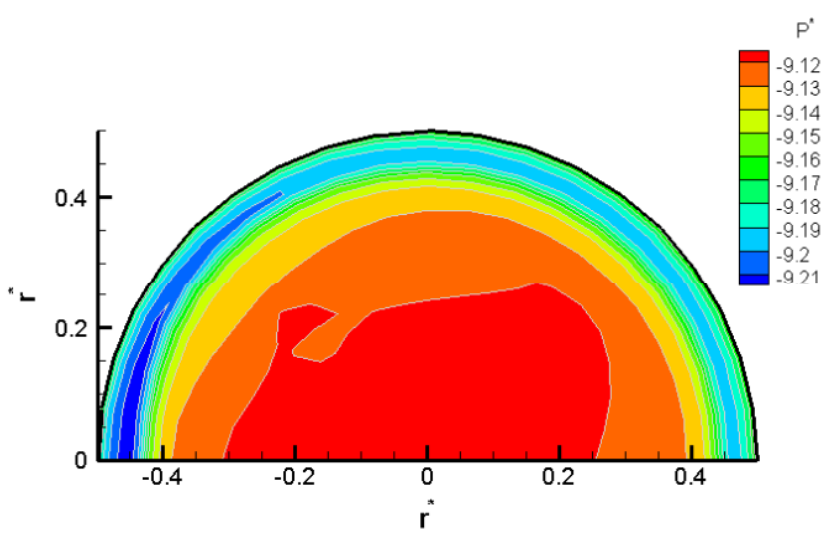

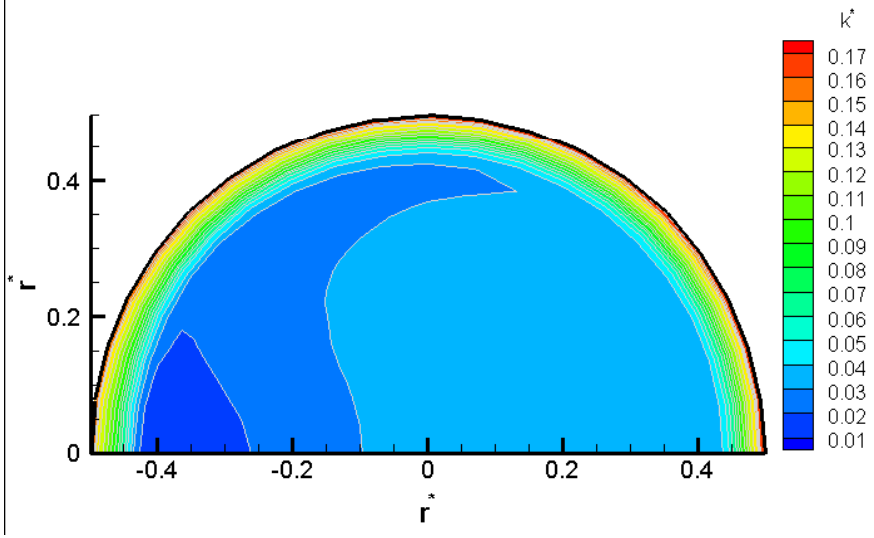

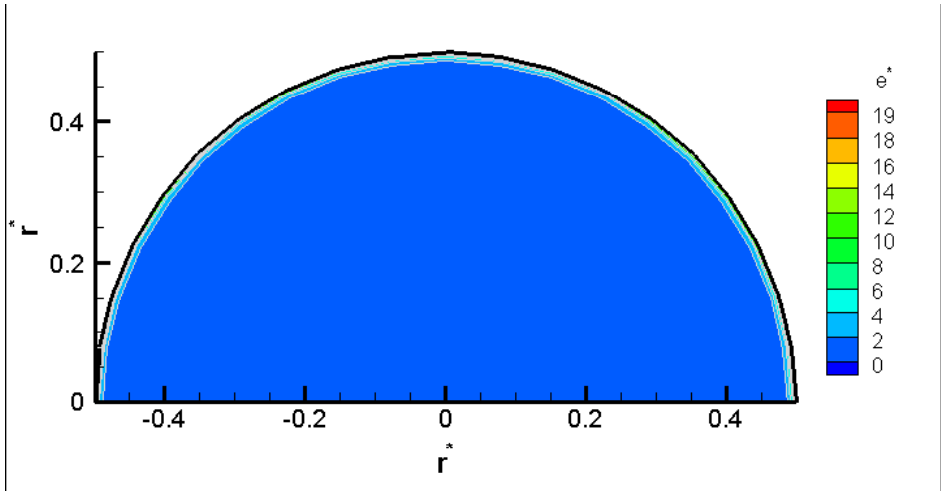

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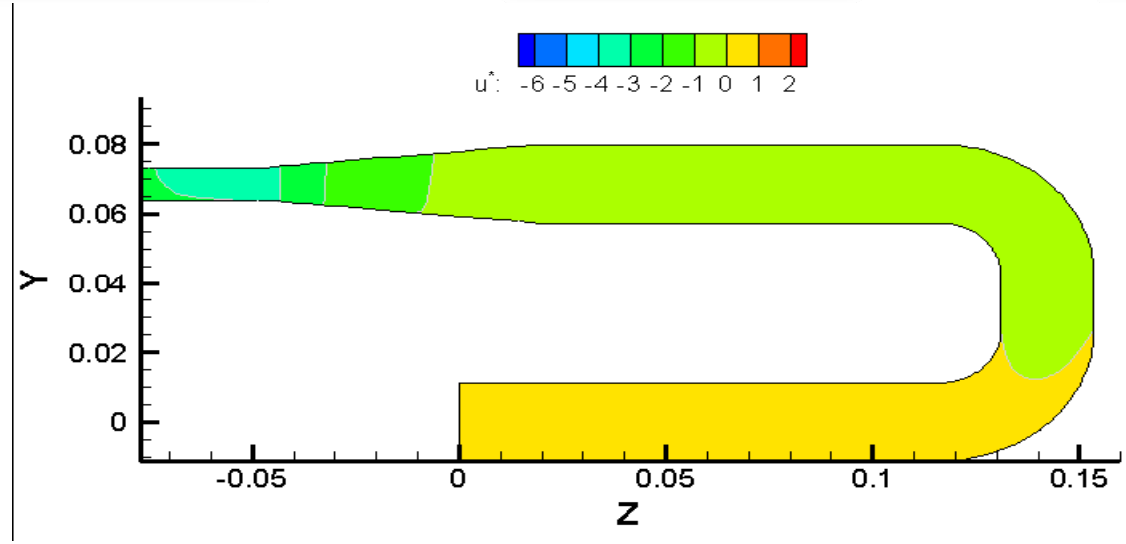

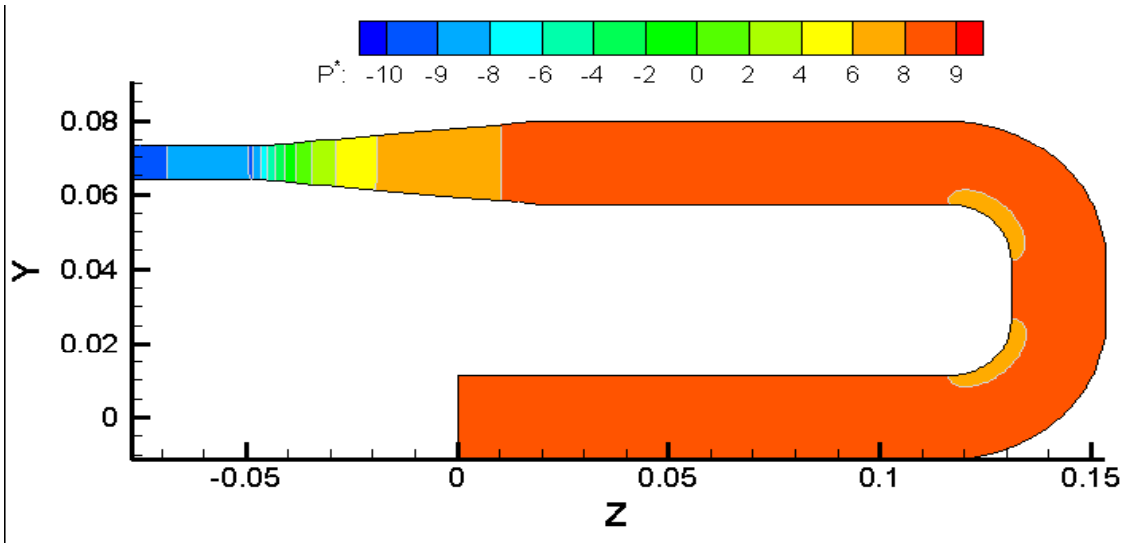

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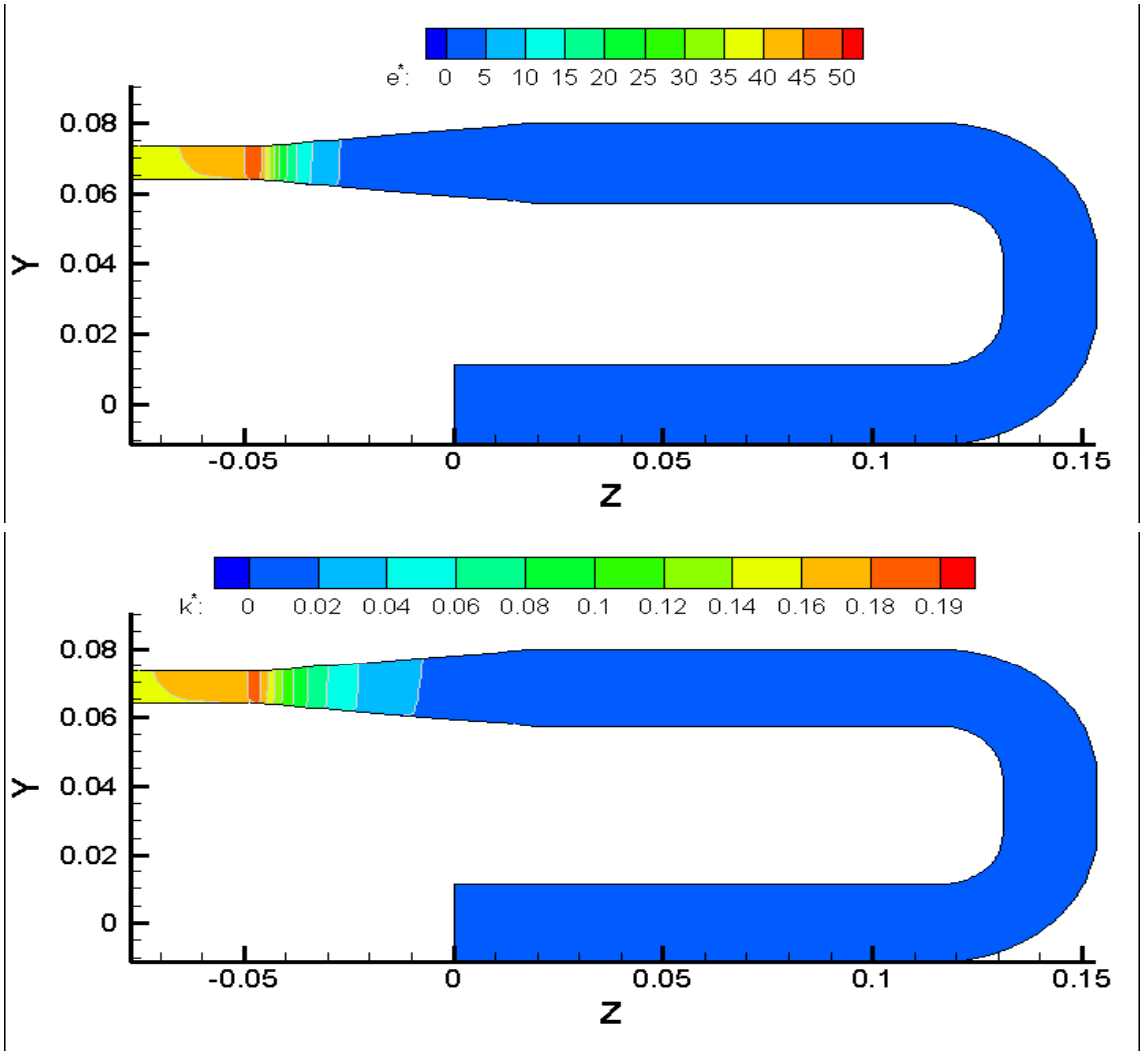

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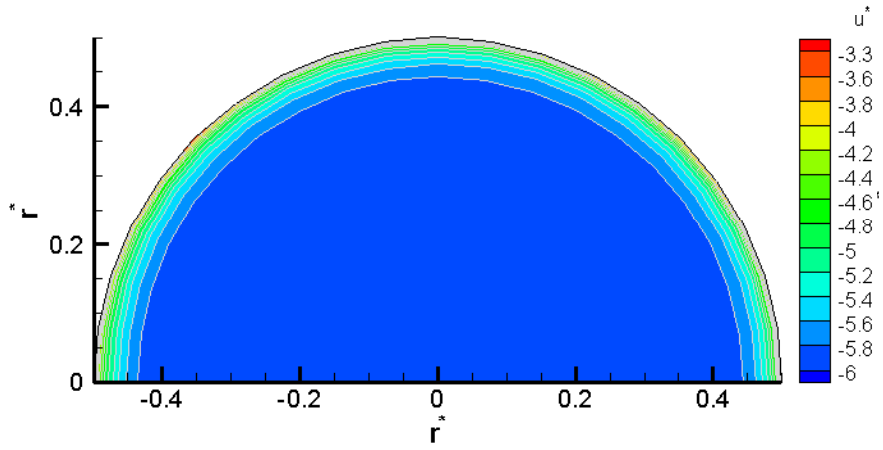
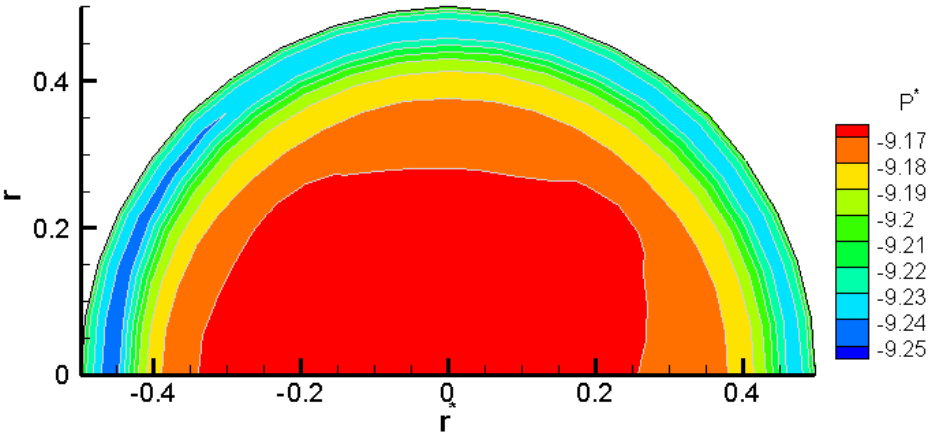
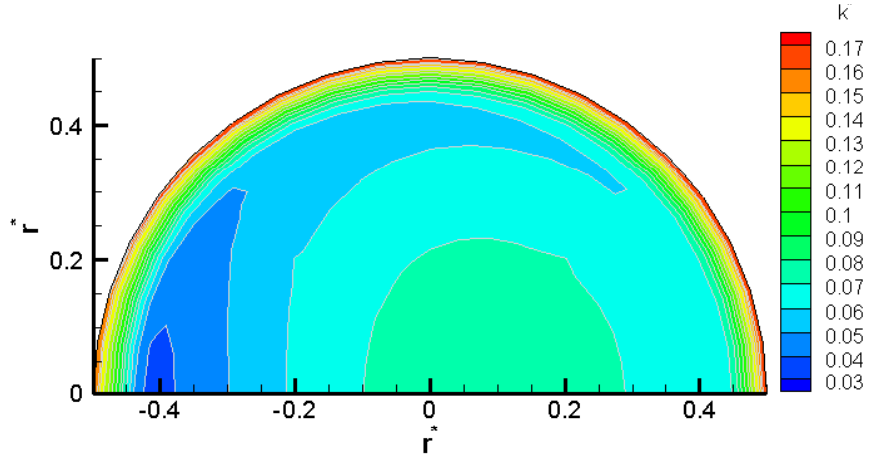
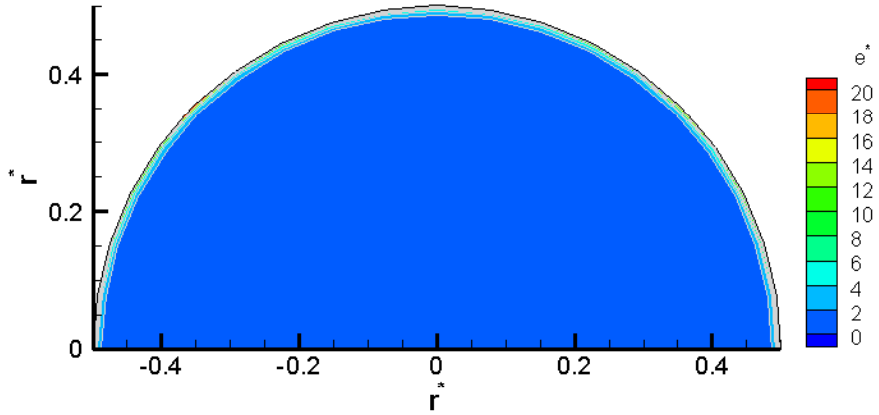


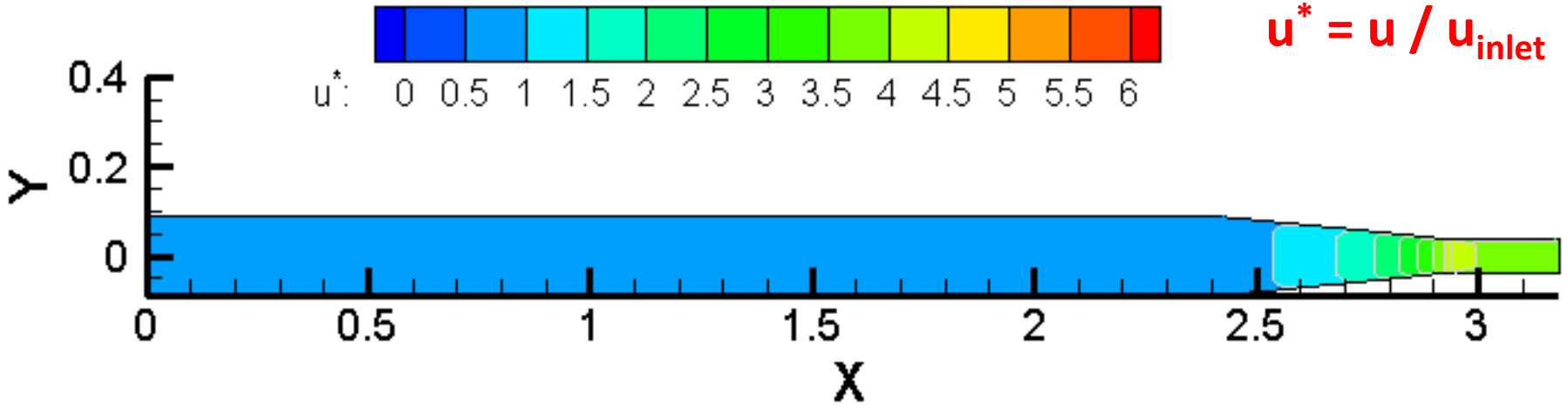






Water Flow

0 Deg | **60 Deg** | **180 Deg**



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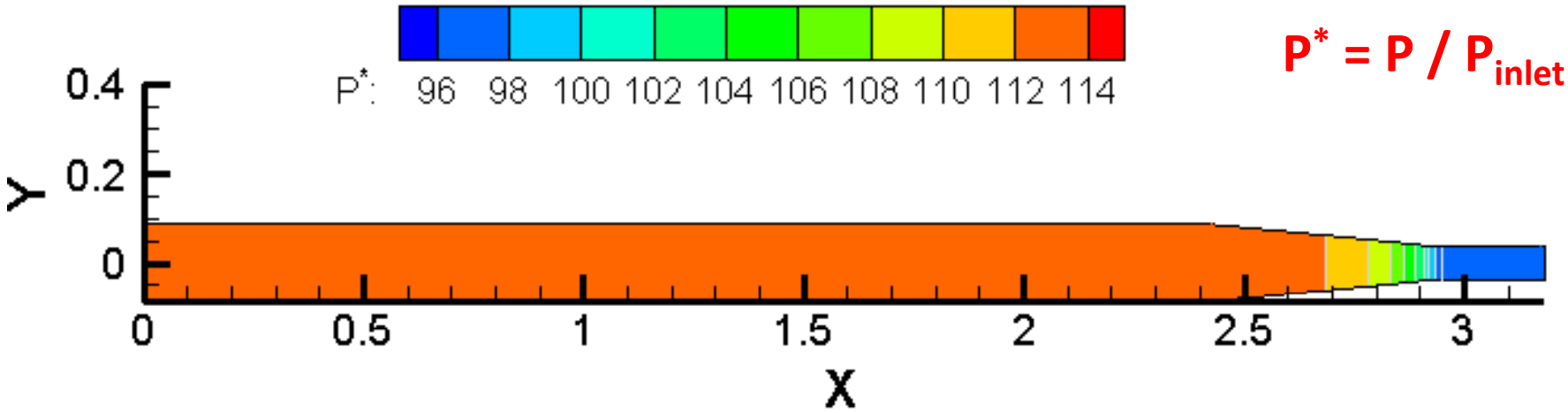

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Water Flow

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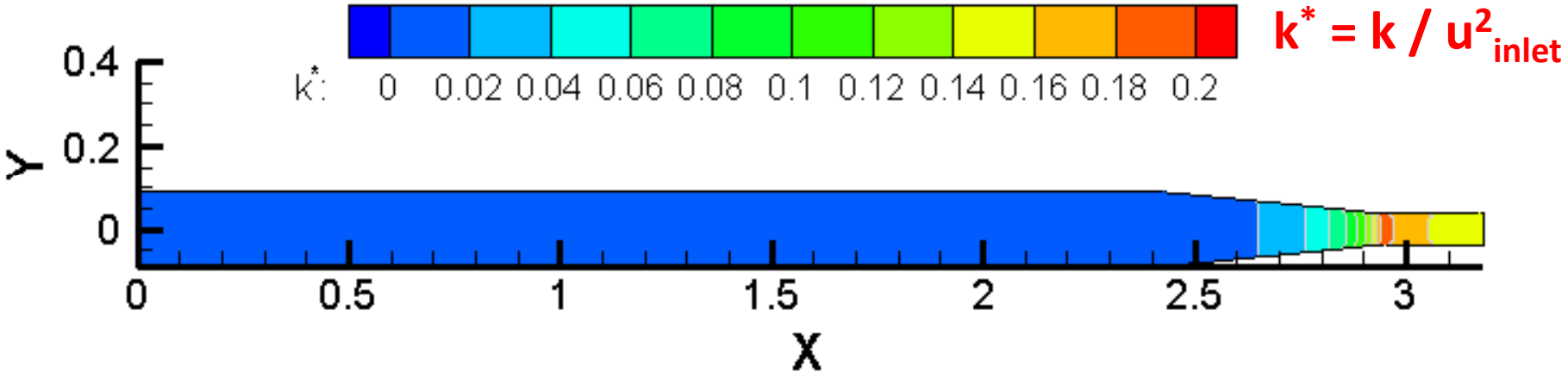

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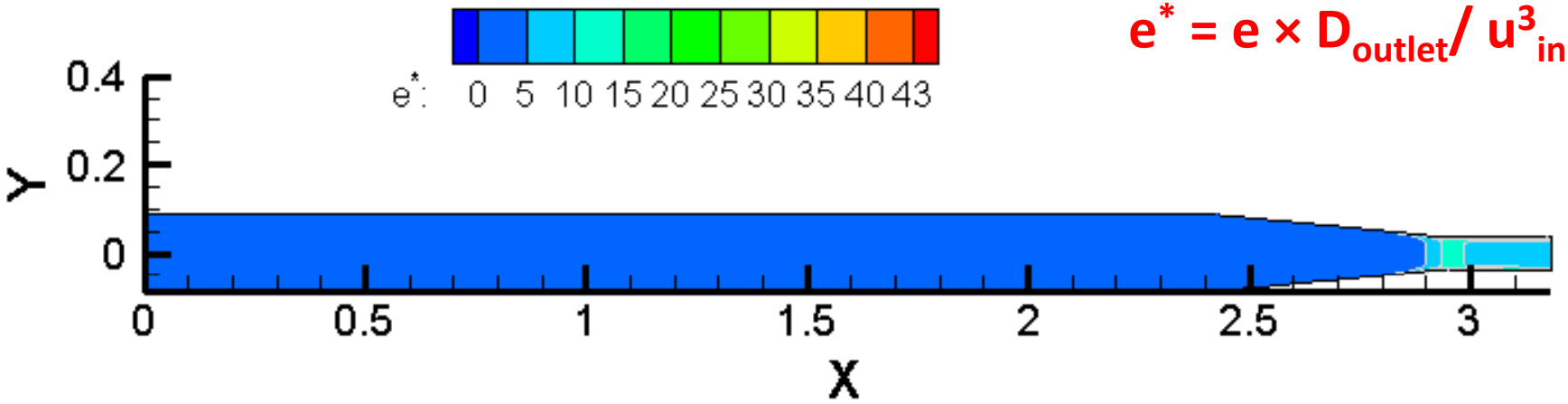

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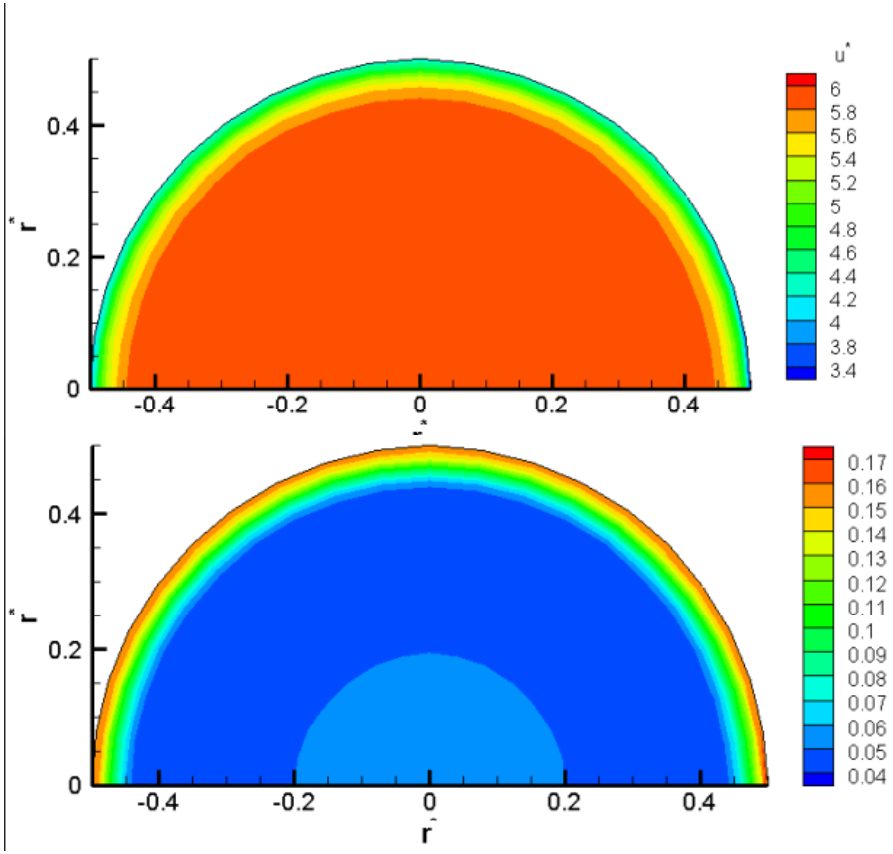

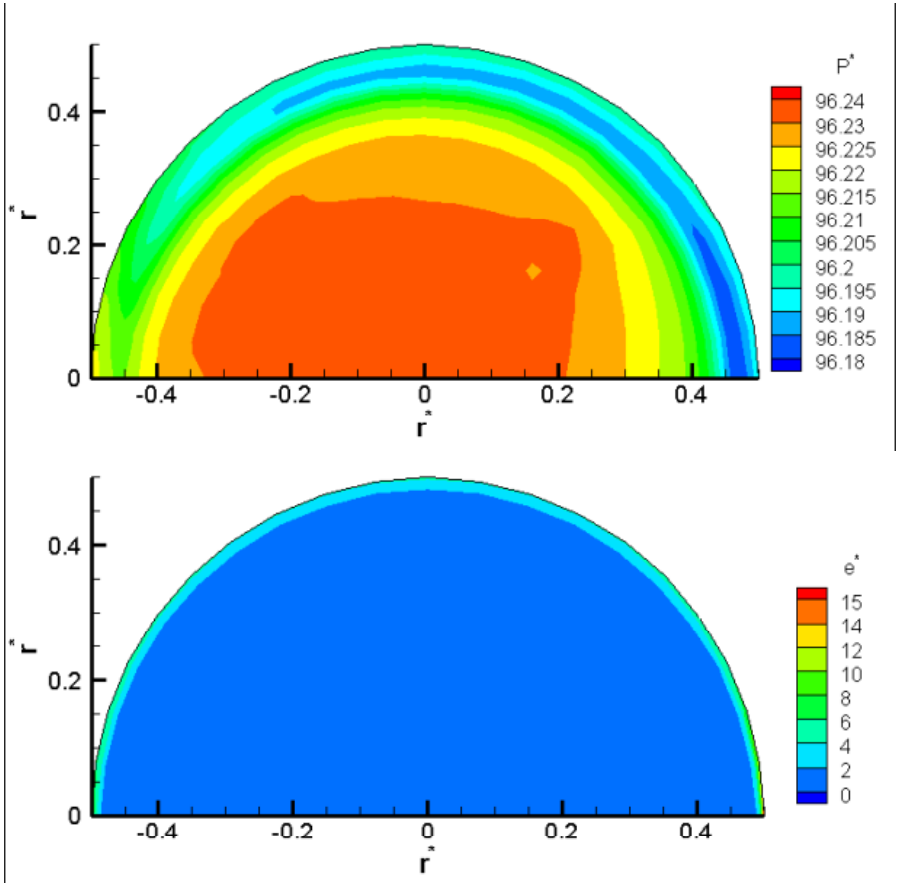

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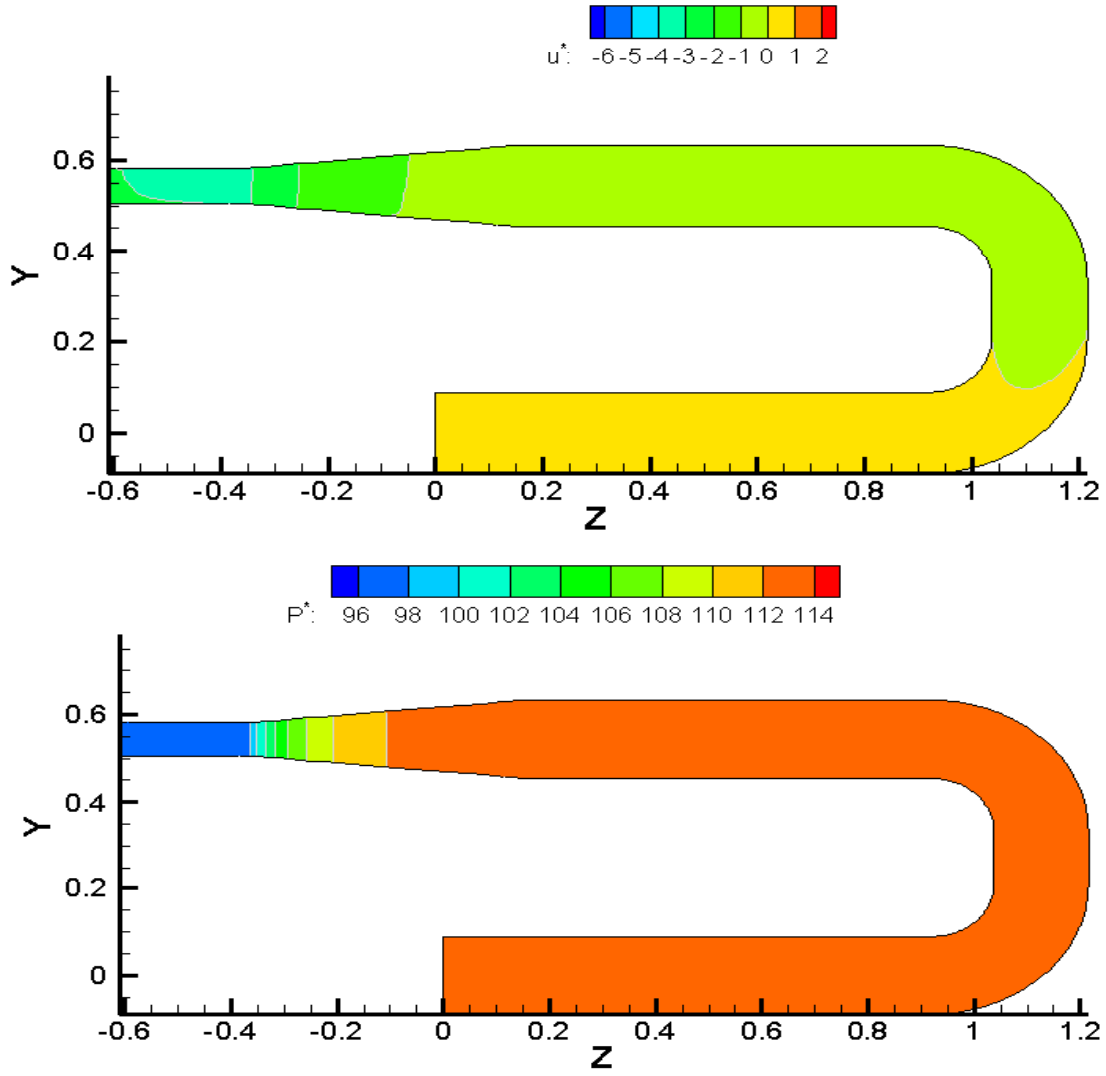

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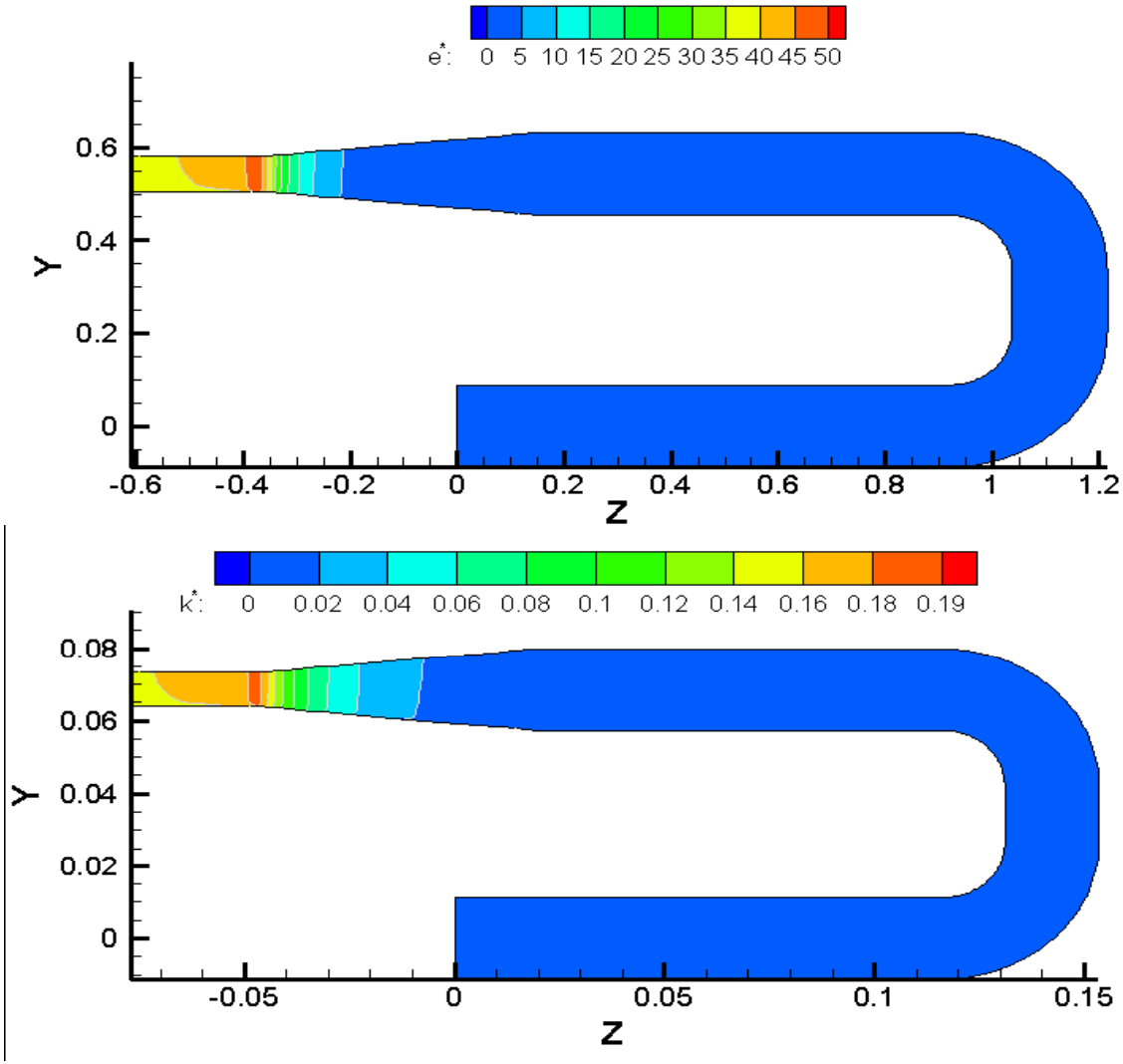

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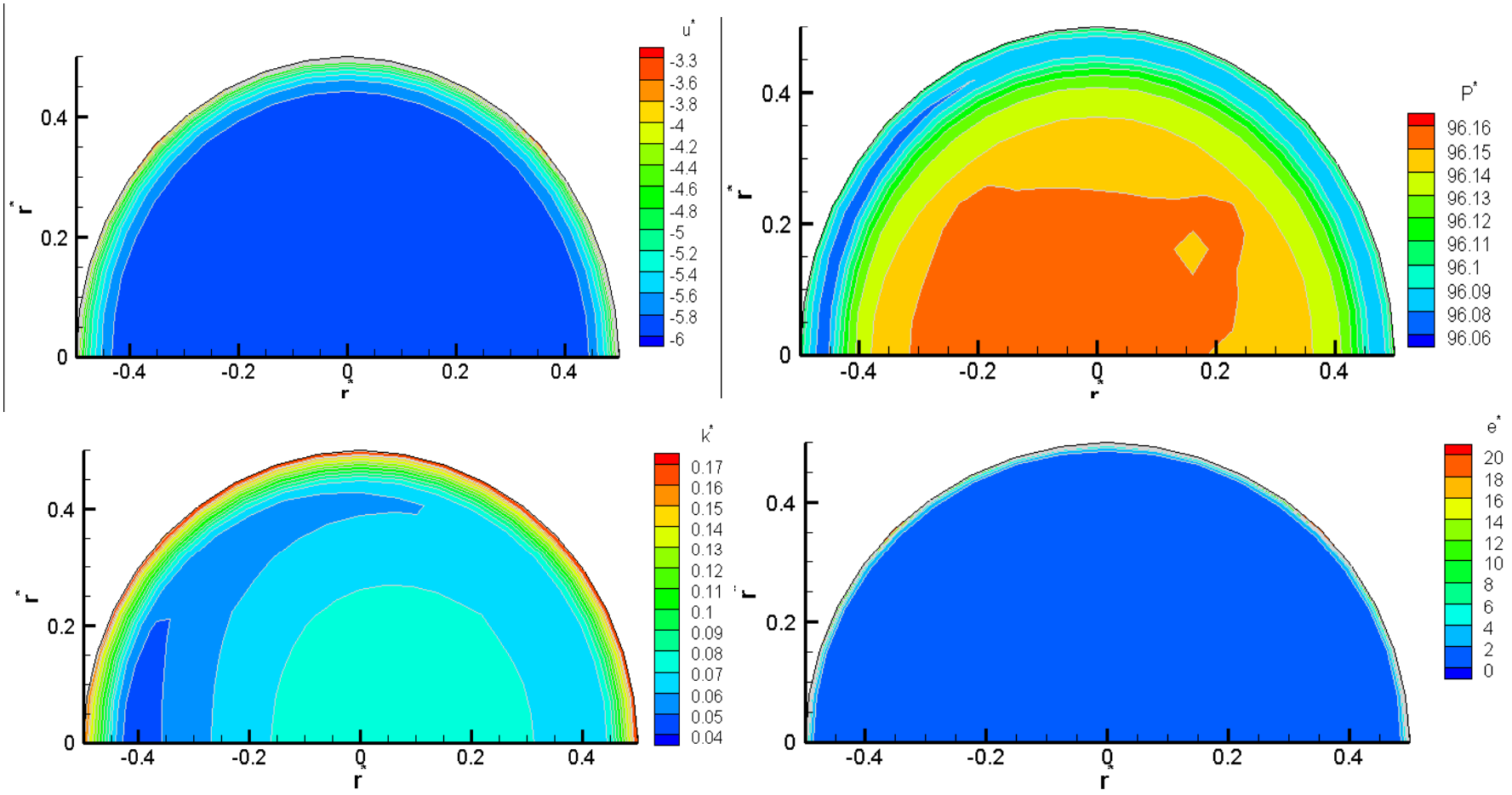
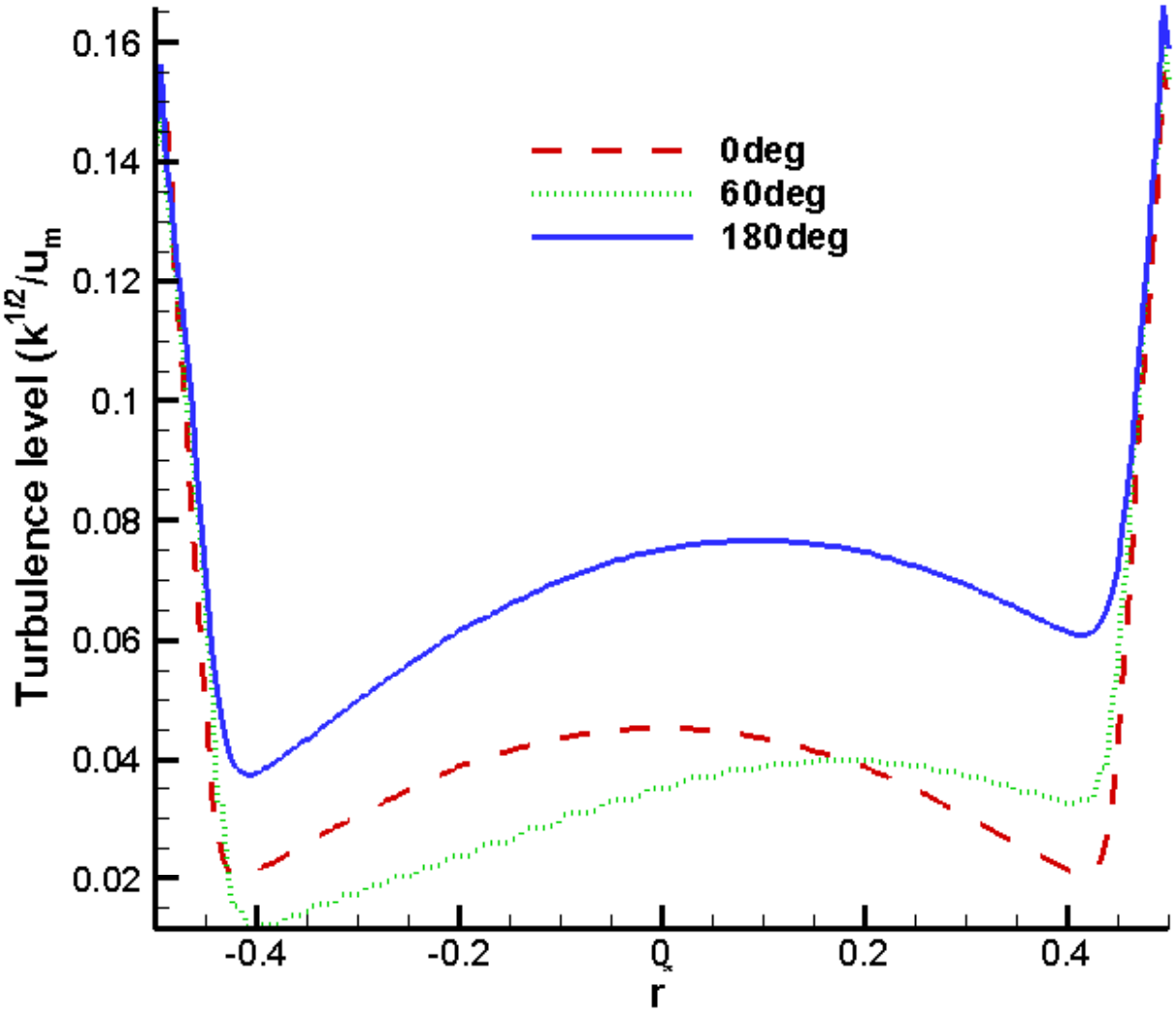


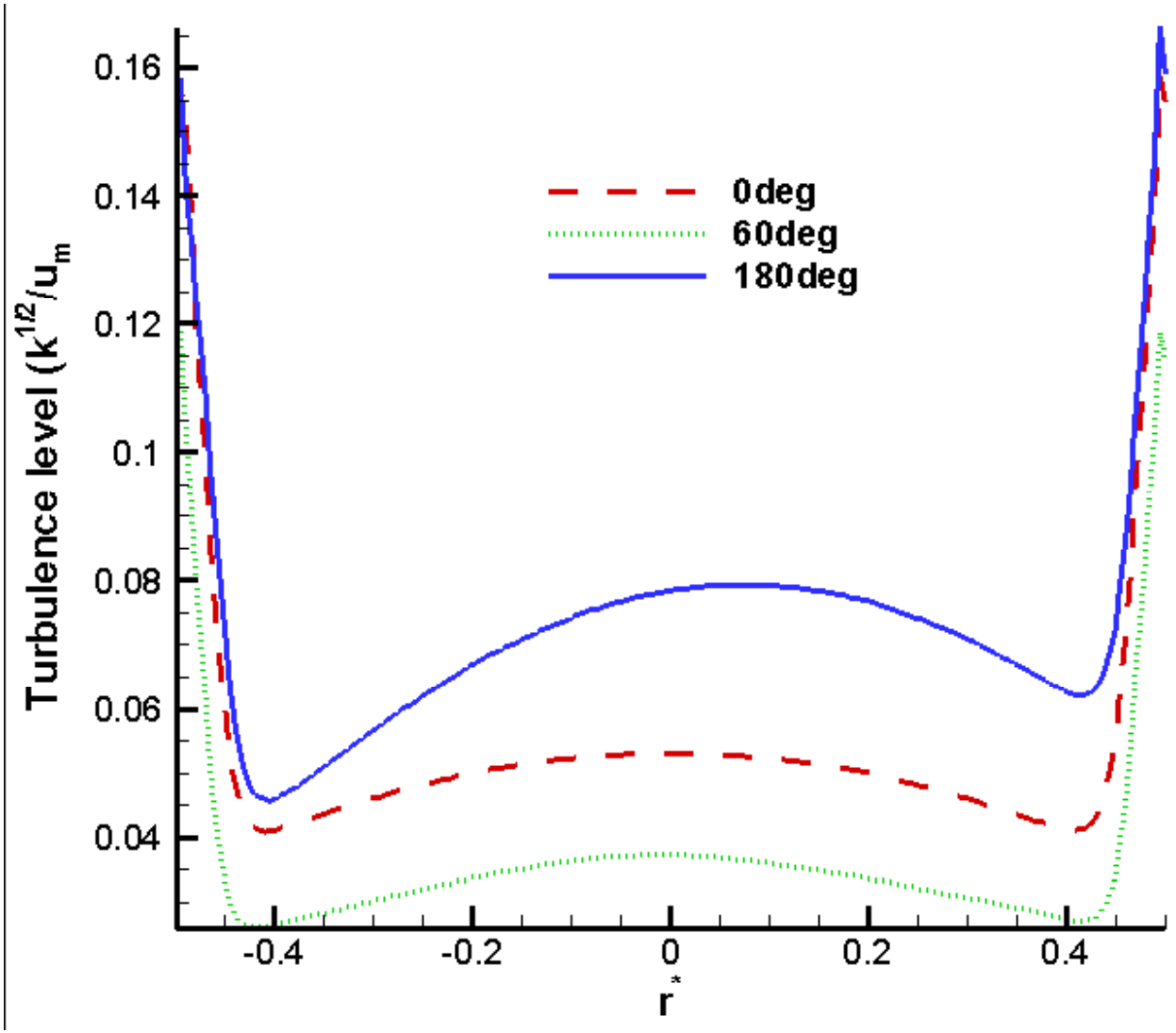
Turbulence level comparison

-Mercury flow



Turbulence level comparison

-Water flow



Concepts

Cavitation Number

$$\sigma = \frac{P_a - P_v}{0.5\rho_L V_m^2}$$

Where

Atmospheric pressure Pa = 101000 Pa

Vapor saturation pressure Pv = 0.22664 Pa (T=25^{o}C)

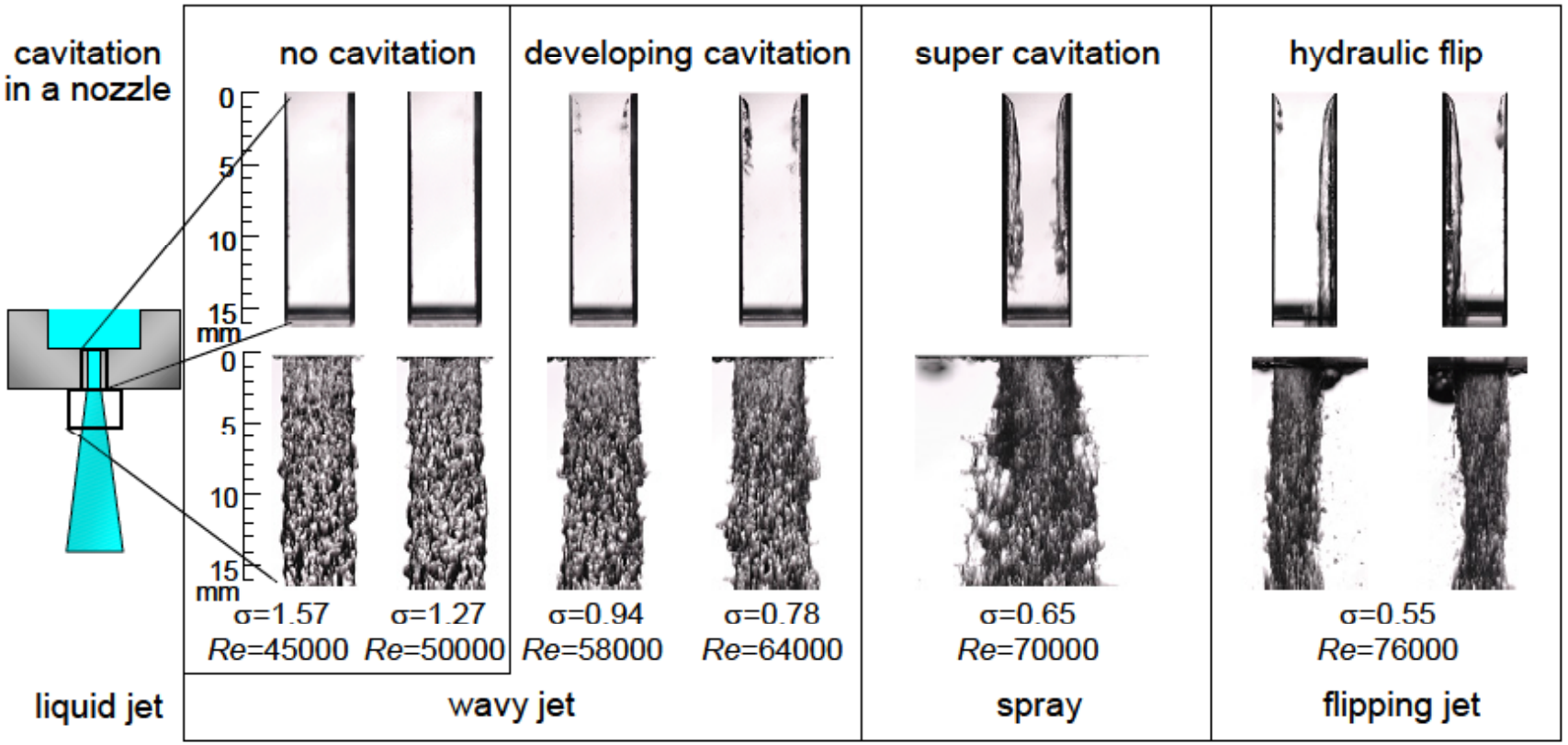
Liquid density of mercury ρ_L = 13526 kg/m3

Mean velocity in the nozzle V_m = 23.345 m/s

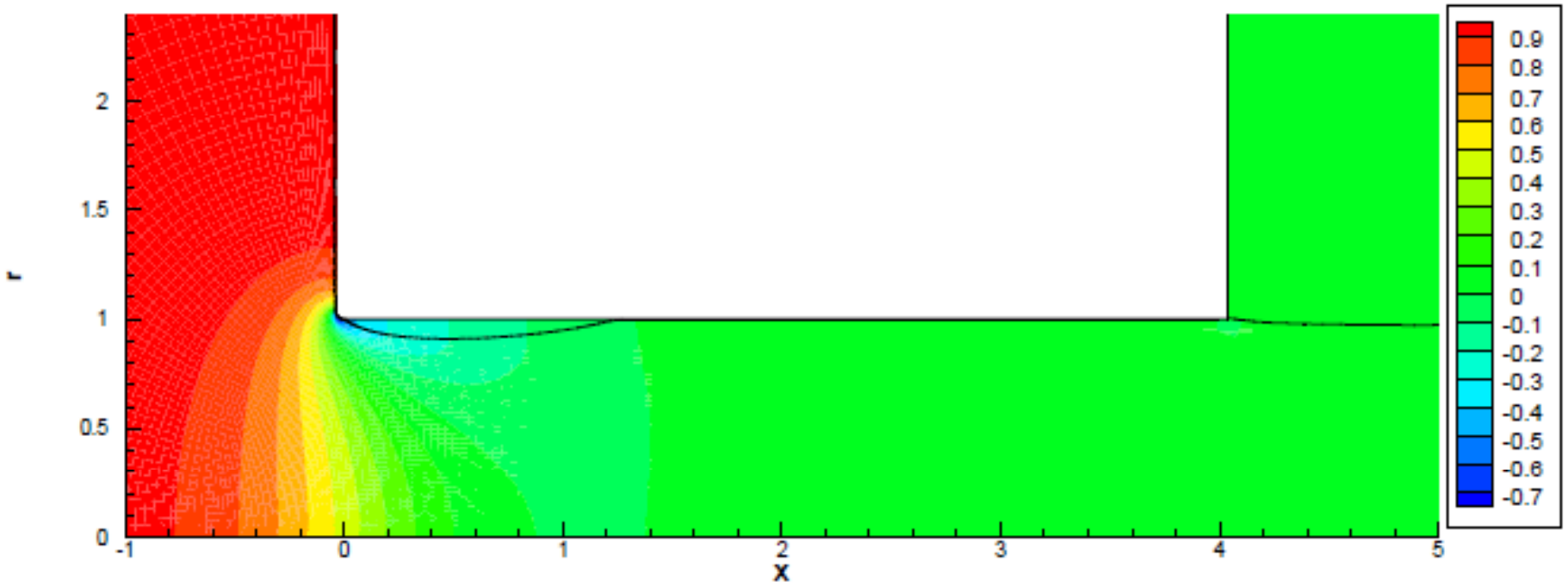
Therefore

$\sigma \approx 0.0274$

Cavitation in a Nozzle



Akira Sou, Shigeo Hosokawa, Akio Tomiyama, Effects of Caviation in a nozzle on Liquid Jet Atomization, Intl. Heat and Mass Transfer, Vol.50, Iss. 17-18, 2007, 3575-3582



Contours of $(P - Pd)/(1/2\rho u^2)$ for orifice flow with Re = 2000

Dabiri, S., Sirignano, W. A. & Joseph, D. D. 2007 Cavitation in an orifice flow. Phys. Fluids **19 (7),** 072112