CFD study on the effects of viscous shear in a hot cascade Ranque-Hilsch vortex tube

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Outline

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- Hot cascade RHVT model description
- Geometrical domain
- Boundary conditions
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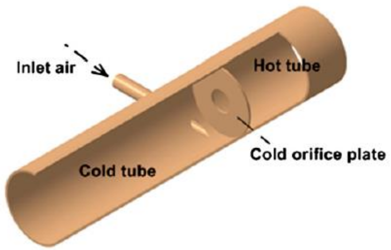
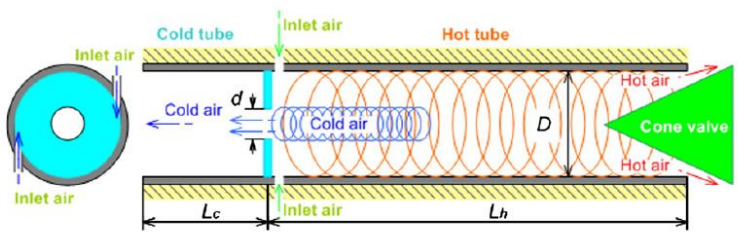
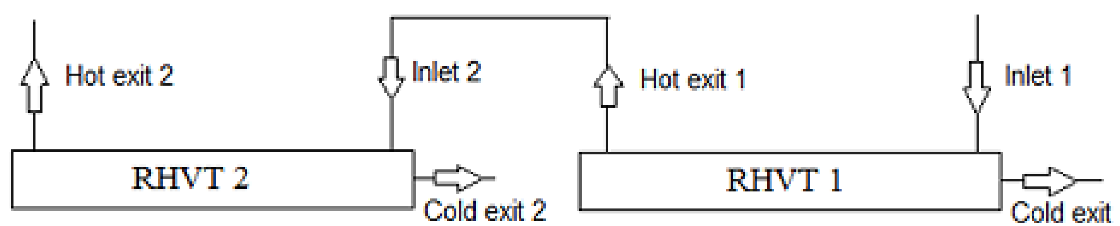
Introduction



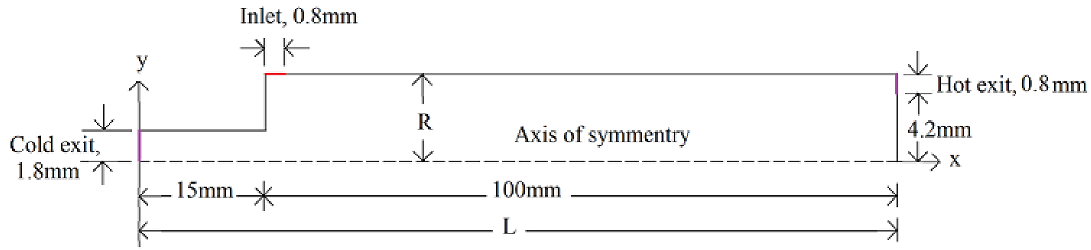


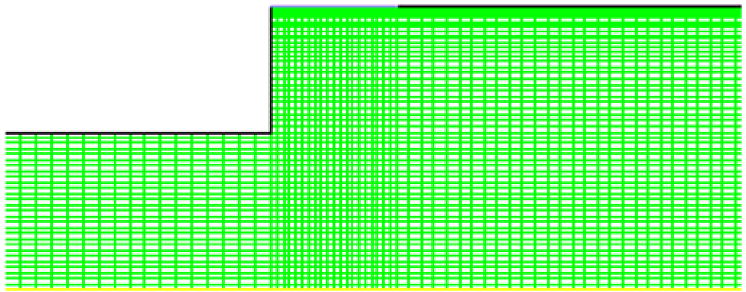
Working principle of Ranque-Hilsch vortex tube (RHVT)

Schematic representation of hot cascade RHVT

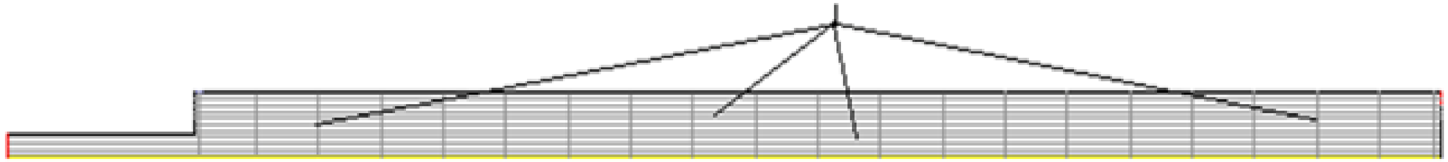


Geometrical and computational domain





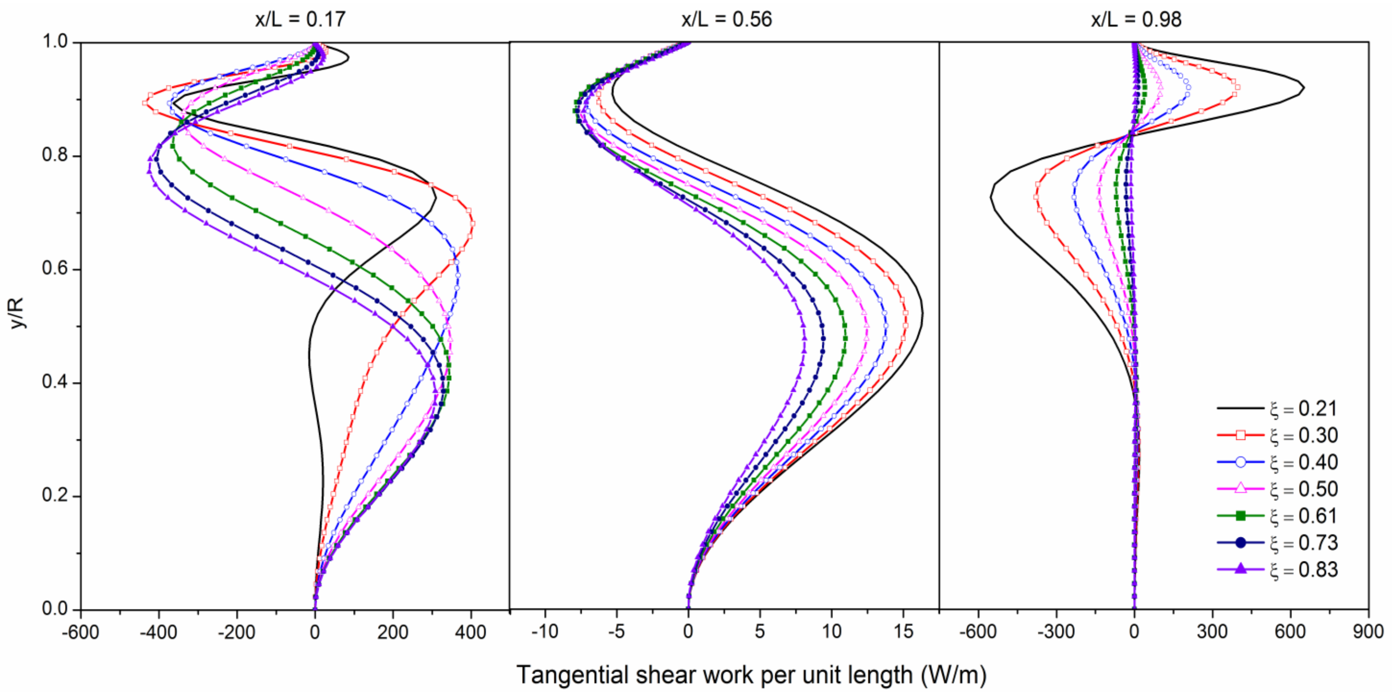
Control surfaces along the axial and radial locations



Boundary conditions

- The numerical simulation is carried out for the second stage RHVT keeping the cold fraction of the first RHVT at 0.5
- Pressure boundary condition applied at the inlet
- Pressure at cold exit = 100kPa(abs)
- Hot exit pressure varies to obtain different values of cold fractions
- Zero temperature gradient is applied at both the hot and cold exit
- Adiabatic conditions and no slip are set at all the solid bounds

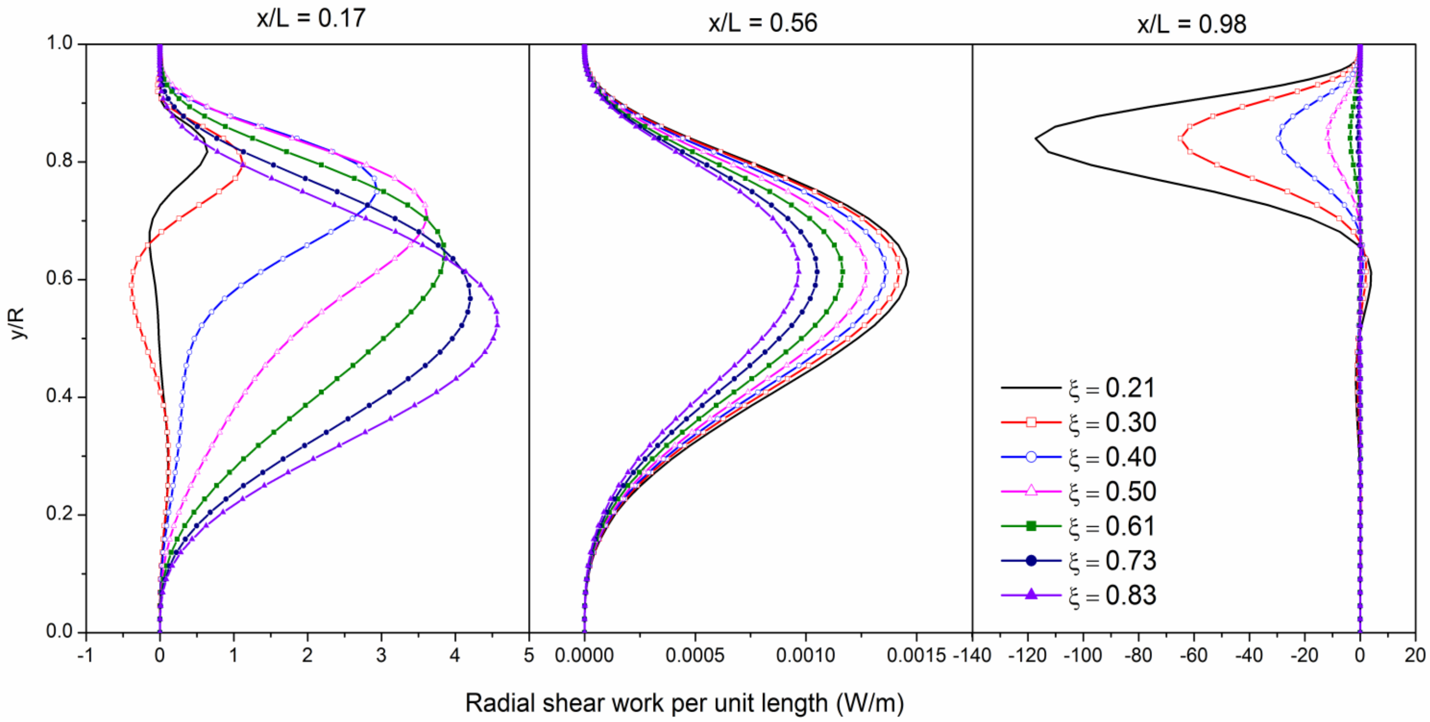
Radial distribution of tangential viscous shear work transfer



Tangential viscous shear work per unit length,

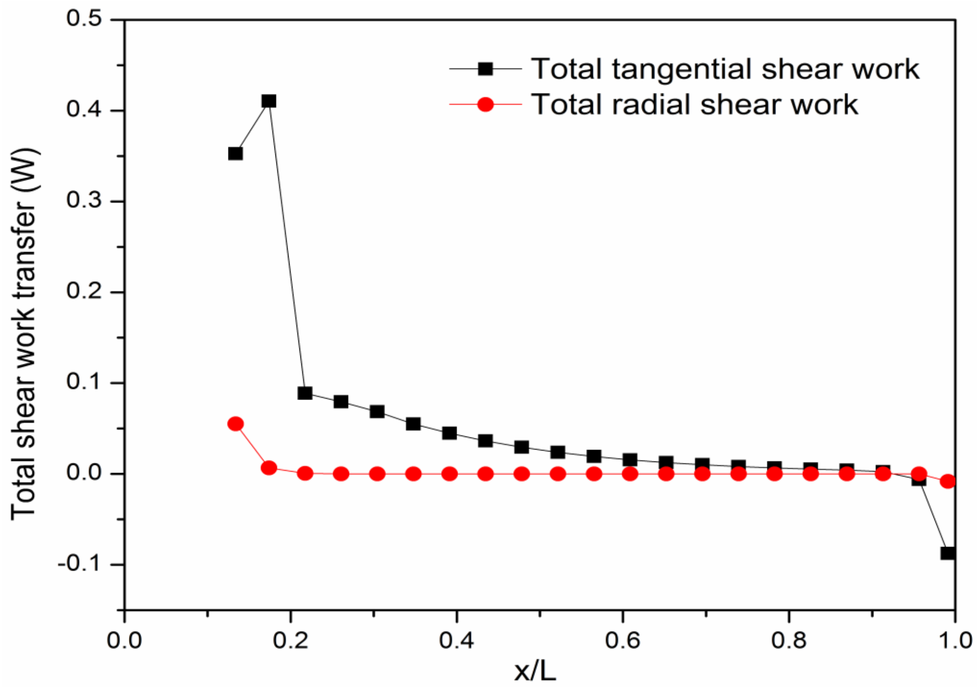
$$\frac{\delta \dot{W}_\theta}{dr} = -2\pi r \mu_{eff} w \frac{\partial w}{\partial x}$$

Radial distribution of radial viscous shear work transfer



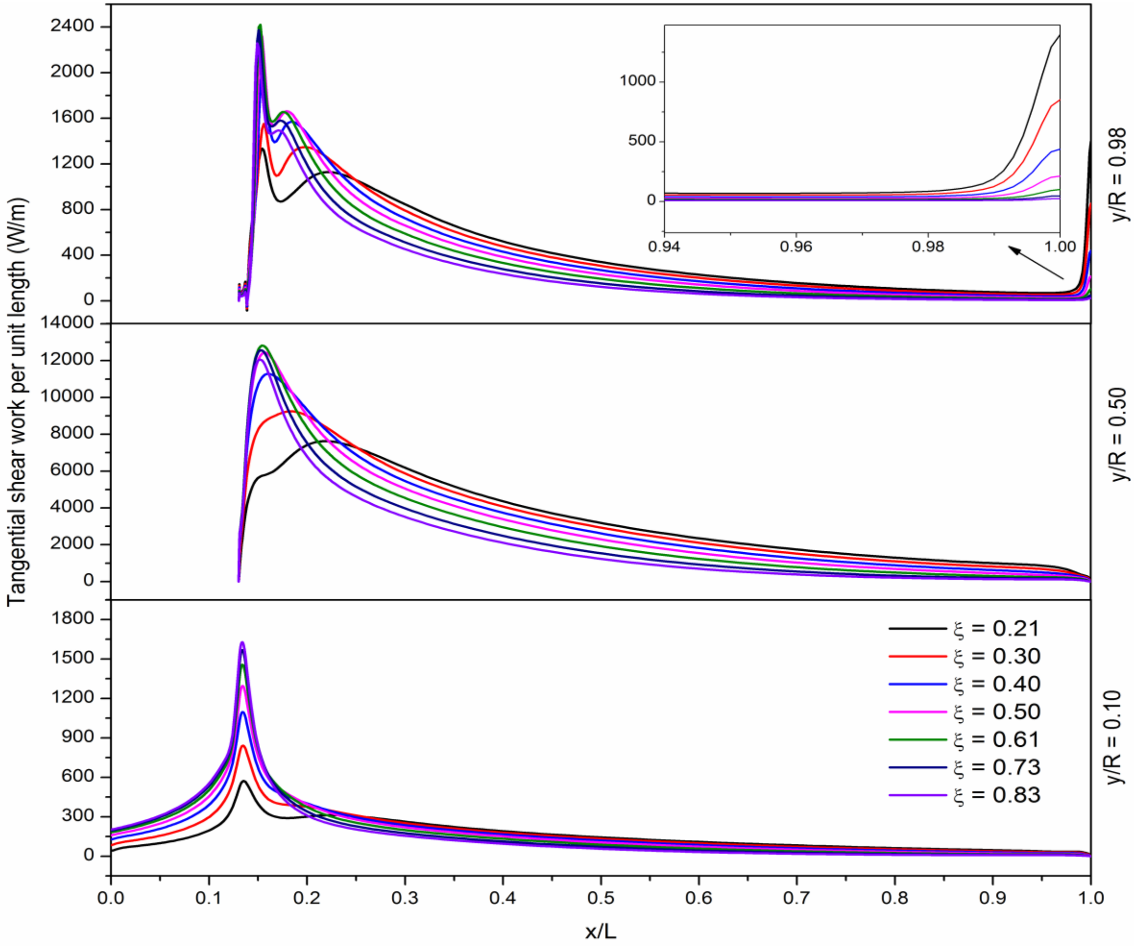
Radial viscous shear work per unit length, $$\frac{\delta \dot{W}_r}{dr} = -2\pi r \mu_{eff} v \frac{\partial v}{\partial x}$$

Radial distribution of net shear work transfer



- Very small total work transfer due to the tangential and radial viscous shear between different fluid layers in radial direction

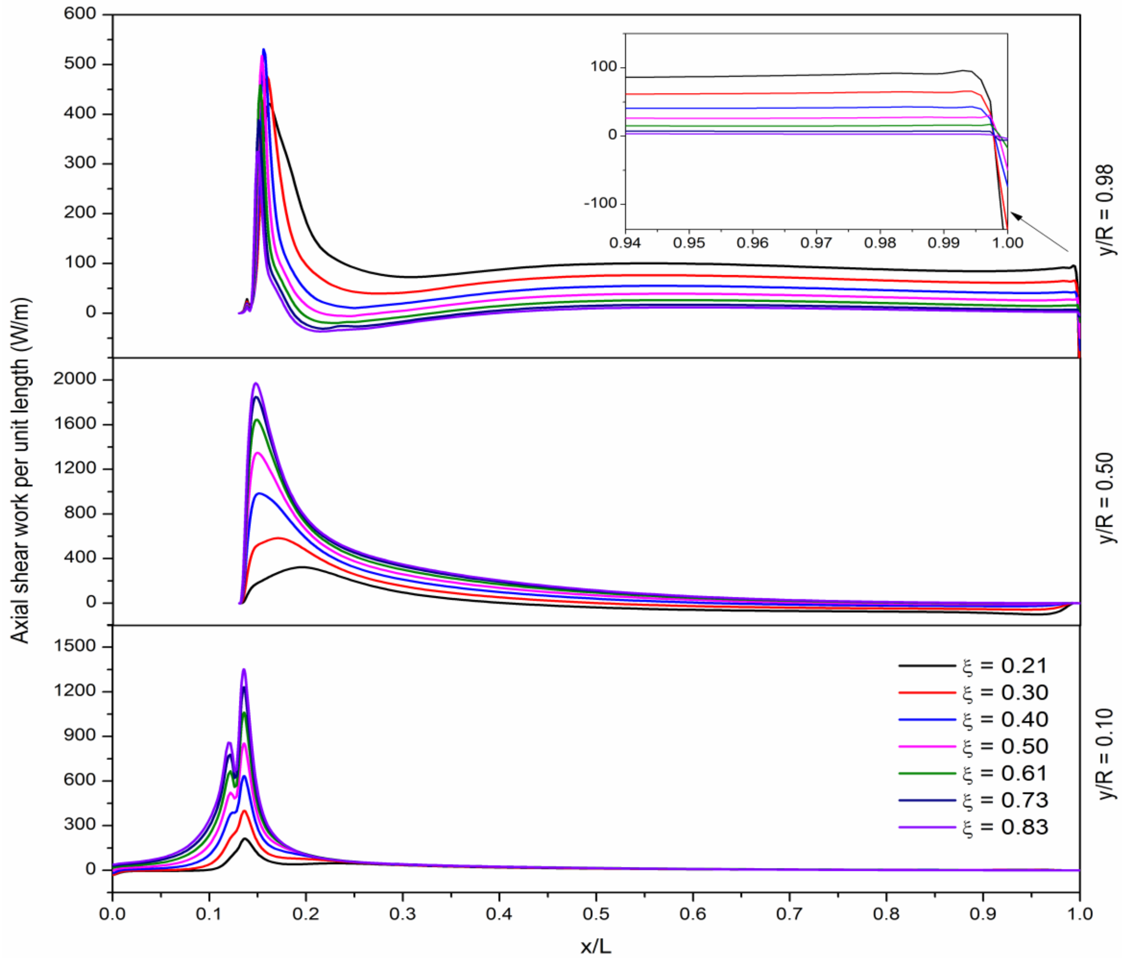
Axial distribution of tangential viscous shear work transfer:



Tangential shear work per unit length,

$$\frac{\delta \dot{W}_\theta}{dx} = -2\pi r \mu_{eff} w \left(\frac{\partial w}{\partial r} - \frac{w}{r} \right)$$

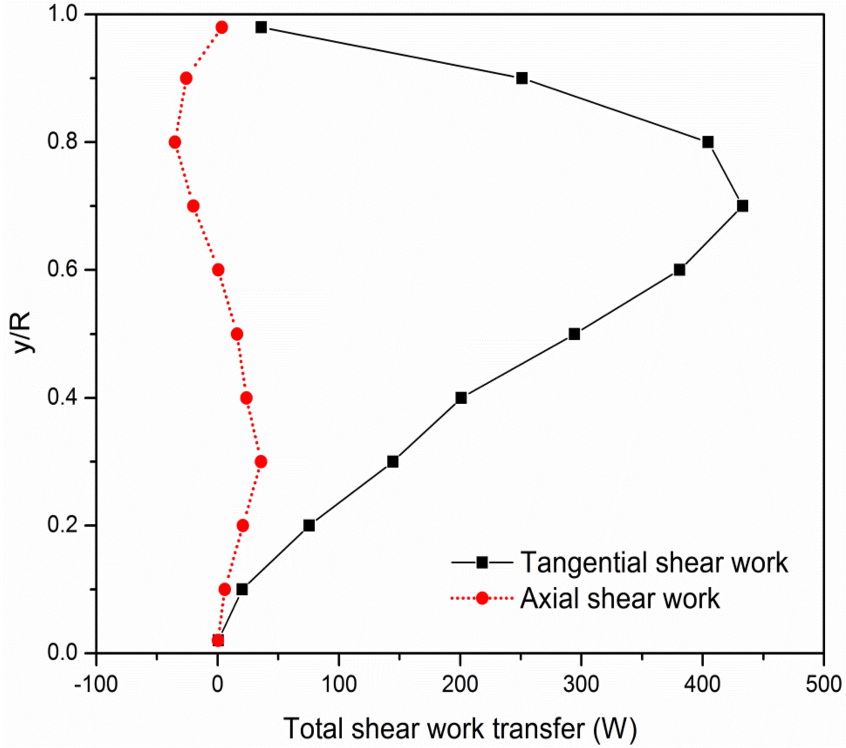
Axial distribution of axial viscous shear work transfer:



Axial shear work per unit length,

$$\frac{\delta \dot{W}_x}{dx} = -2\pi r \mu_{eff} u \frac{\partial u}{\partial r}$$

Axial distribution of net shear work transfer



- tangential shear work plays the utmost role in the process of thermal separation

Conclusions

- Tangential shear work transfer is the predominant driving mechanism of thermal separation in vortex tube.
- The positive sign of tangential shear confirms the transfer of energy from cold fluid zone to hot fluid zone as a result of pressure drop.
- Maximum temperature separation occurs within an axial span of x/L = 0.17 to 0.50.
- It has been confirmed that the action of viscous shear on fluid layers promotes the conversion of kinetic energy into thermal energy.

References:

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THANK YOU