C2PoE-01： CFD simulation of the gas flow in a pulse tube cryocooler with two pulse tubes

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Background

In order to realize larger and heavier mass supporting without additional supporting components, a new structural pulse tube cryocooler(DPTC) with one regenerator and two parallel pulse tubes had been machined and experimented in previous works. In this paper, in order to help characterize the gas flow in the DPTC, a two-dimension Computational Fluid Dynamics (CFD) model is also developed to simulate temperature distribution and velocity distribution of oscillating fluid in the DPTC by individual phase-shifting.

Objectives

- ❖ simulate temperature distribution and velocity distribution of oscillating fluid in the DPTC by individual phase-shifting.

Conclusion

➢The use of the CFD method to simulate the temperature distribution and velocity distribution of oscillating fluid in the DPTC by individual phase-shifting is built.

➢The axial temperature distribution of regenerator is generally uniform, but there is a temperature difference about 3K between near wall and center at the middle cross-section of regenerator.

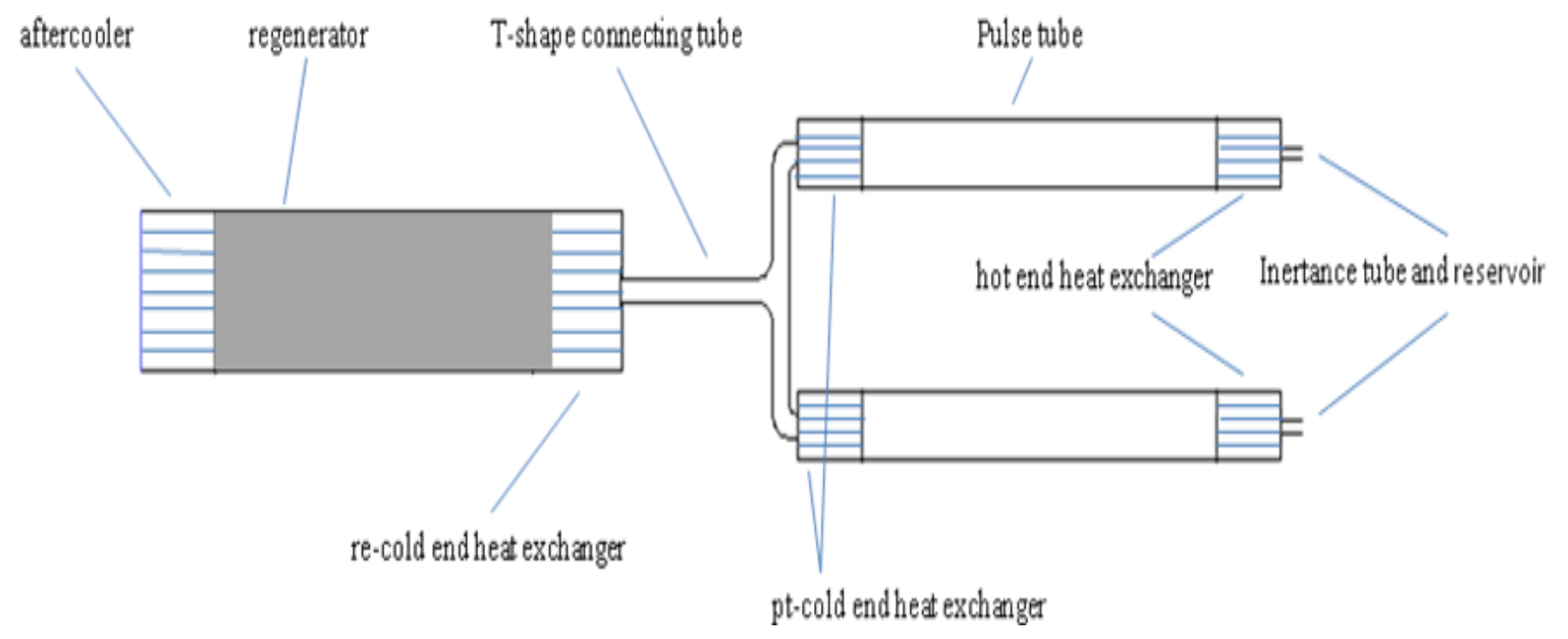
➢The temperature of two pulse tubes presents a uneven distribution and the wall temperature difference of 5-7K exists between the two pulse tubes.

➢The velocity distribution near the center of the regenerator is uniform and there is obvious injection stream coming form the hot end near the center of the pulse tubes.

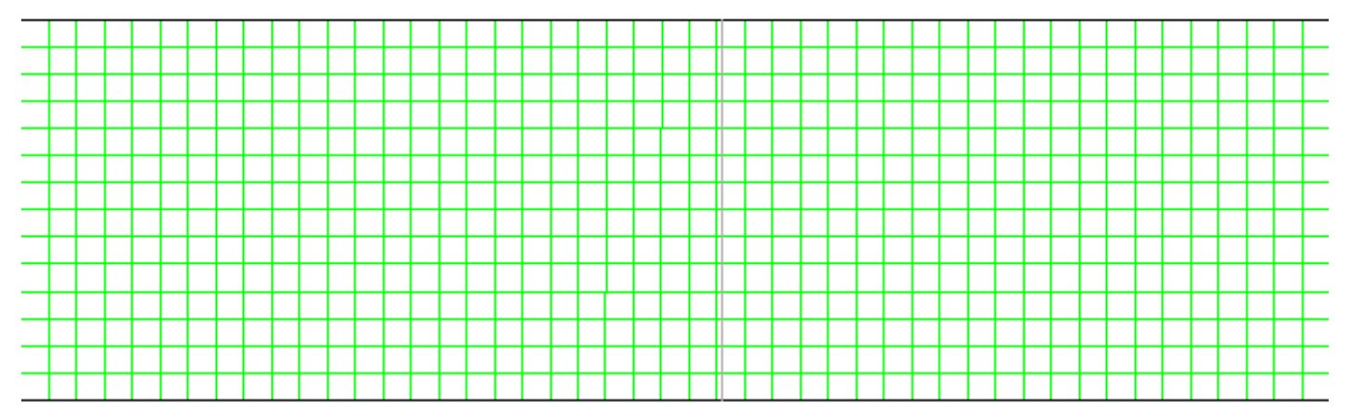
Method

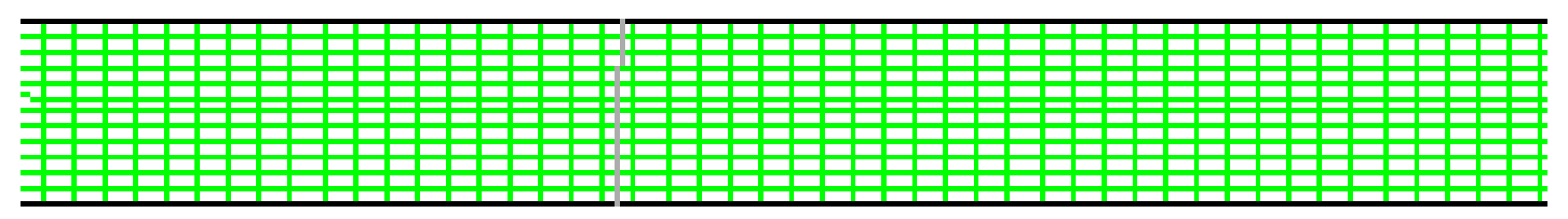
Physical model

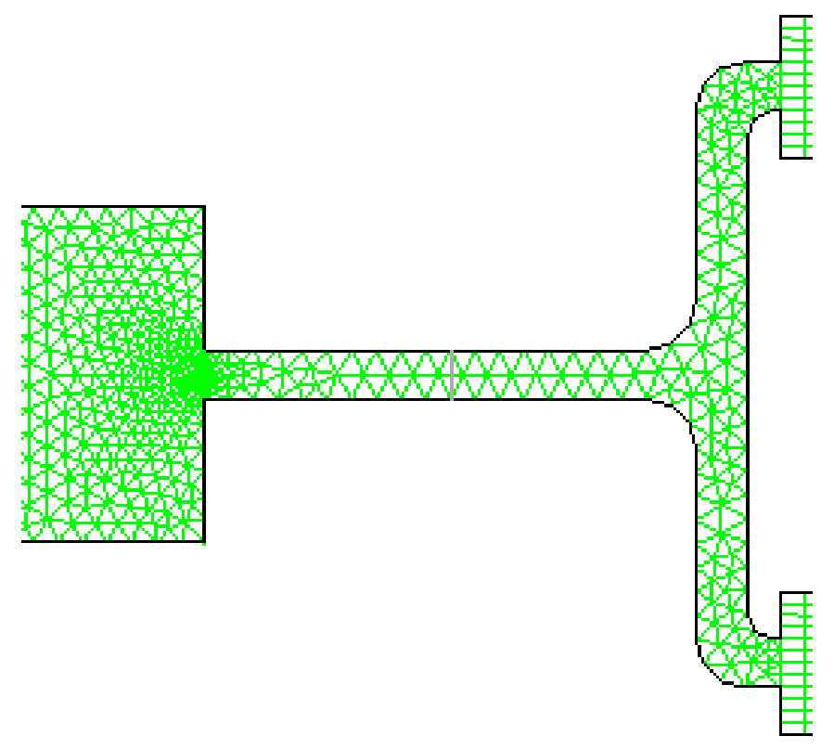
The 2D physical geometry simplified for the DPTC with same components as the experimental system beside the compressor is depicted.



The grid models of main components are shown, which include regenerator, a T-shape connecting tube, two same pulse tubes.







Method

mathematical model

$$\varepsilon\frac{\partial\rho_f}{\partial \mathrm{t}}+\nabla\cdot(\varepsilon\rho_f\overrightarrow{\upsilon})=0$$

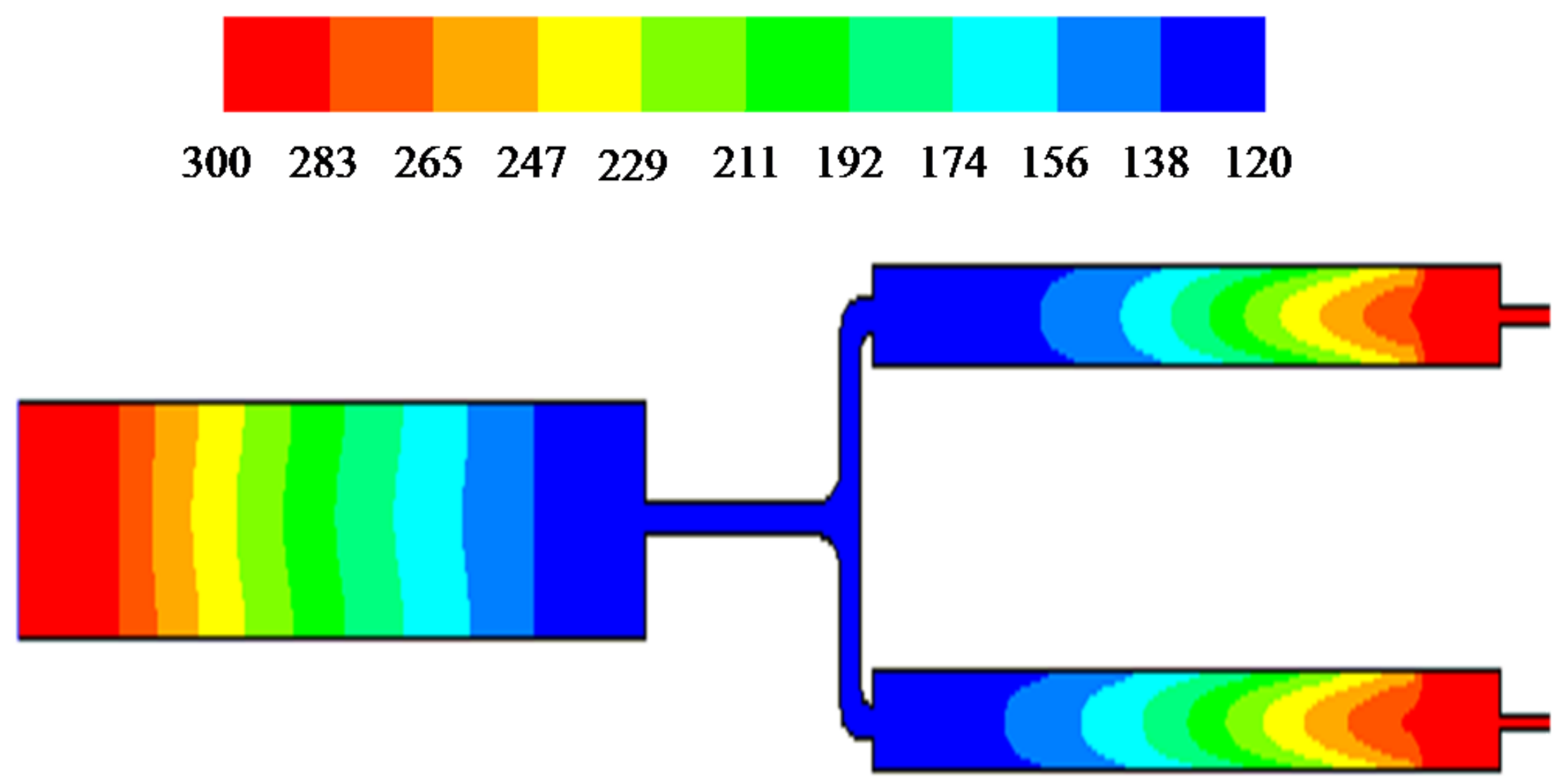
$$\frac{\partial(\varepsilon\rho_f\overrightarrow{\upsilon})}{\partial \mathrm{t}}+\nabla\cdot(\varepsilon\rho_f\overrightarrow{\upsilon}\overrightarrow{\upsilon})=-\varepsilon\nabla p+\varepsilon\nabla\cdot(\overline{\overline{\tau}})+\vec{f}$$

$$\frac{\partial}{\partial t}(\varepsilon\rho_f E_f+(1-\varepsilon)\rho_s E_s)+\nabla\cdot(\vec{\upsilon}(\rho_f E_f+p))=\nabla\cdot((\varepsilon k_f+(1-\varepsilon))k_s\nabla T)+\Phi+S_f^h$$

$$\vec{f}=-(\frac{\mu}{\alpha}\upsilon+\frac{1}{2}C\rho_f|\upsilon|\upsilon)$$

Results and Analysis

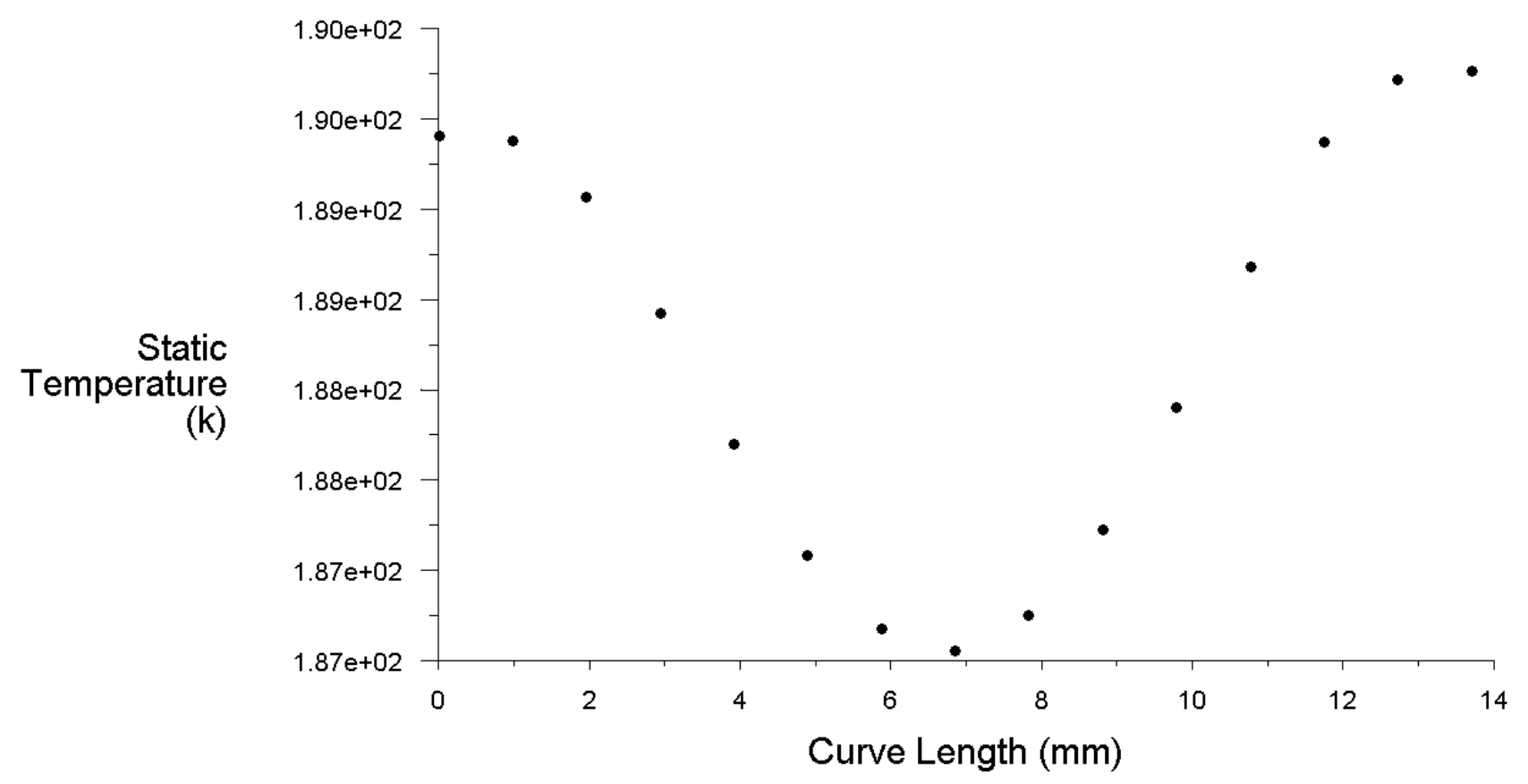
Temperature distribution

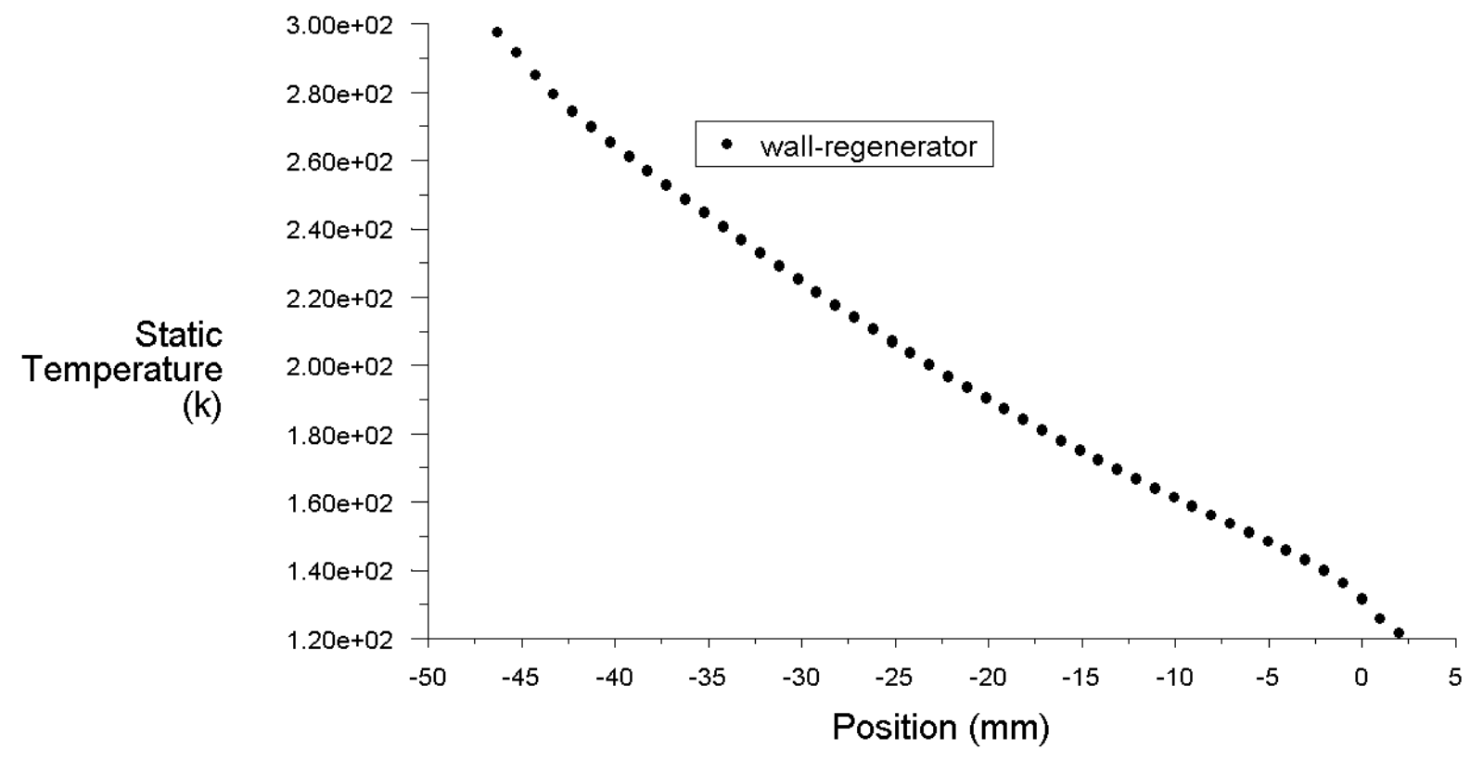


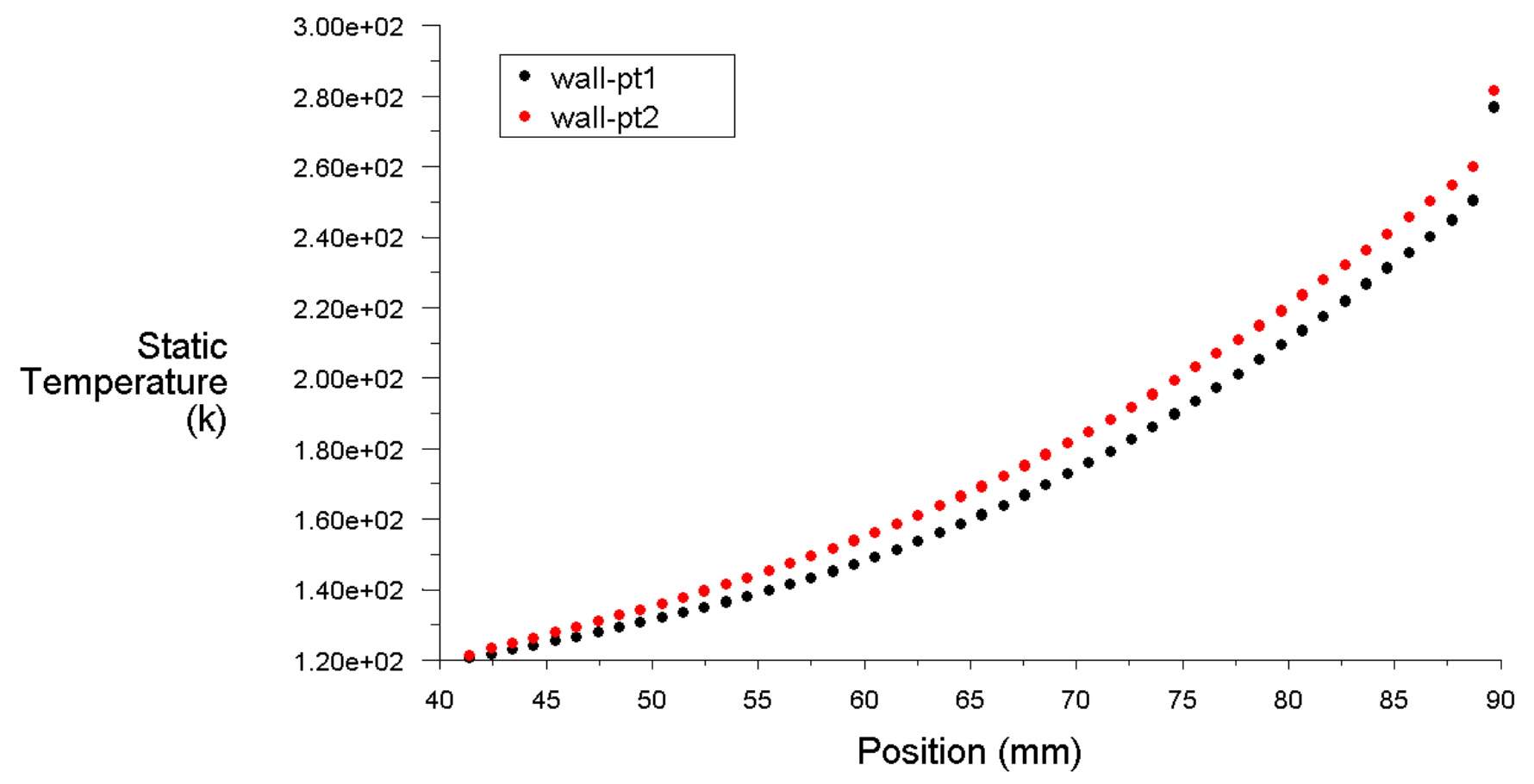
The axial temperature distribution of regenerator is generally uniform. The temperature of two pulse tubes presents a uneven distribution that the temperature near the center of pulse tube is higher than near wall.

A temperature difference about 3K between near wall and center at the middle cross-section of regenerator.

The temperature difference of 5-7K exists between the two pulse tubes because of unsymmetry of the T-shape connecting tube.







Velocity distribution

The velocity distribution nearthe center of the regenerator is uniform and there is obvious injection stream near the center of the pulse tubes coming form the hot end.