The flow field inside a Ranque-Hilsch vortex tube part I: Experimental analysis using planar filtered Rayleigh scattering

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The flow field of a Ranque-Hilsch vortex tube (RHVT) (Ranque, 1933; Hilsch, 1947) is characterized experimentally. Firstly conventional probe based technology is used in order to measure inlet and outlet temperatures as well as to acquire temporally resolved wall pressure data over a wide range of operating conditions. Secondly the filtered Rayleigh scattering technique is employed in order to gather detailed temporally averaged planar information on the vortex tube's flow topology. These measurements form the basis of a detailed numerical study in part II of this contribution.

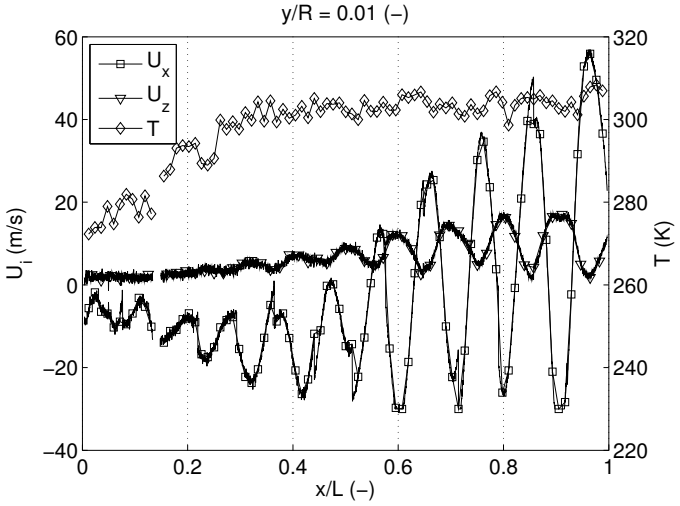

Figure 1. Profiles of U_x (□), U_z (▽) and T (◇) for $y/R = 0.01$.

The underlying mechanisms of the temperature separation process inside the RHVT are still controversially discussed in the literature. In their review article, Eiamsa-ard & Promvonge (2008) give a detailed overview on the different hypotheses used to explain the energy separation effect, including adiabatic expansion, internal friction, static temperature gradients and acoustic streaming. In Xue *et al.* (2010), present theories are summarized and subjected to a critical review. The authors point out that, due to the high complexity of the RHVT's flow field, several studies found in the literature come to contradictory conclusions. In this respect, the authors aim at the identification of existing knowledge gaps.

In order to get insight into the complex three dimensional flow topology and to confirm or abandon existing theories describing the temperature separation inside the tube, information on pressure, temperature and velocity are needed (Gao *et al.*, 2005). In this respect, the filtered Rayleigh scattering (FRS) technique (Miles & Lempert, 1990), extended by the method of frequency scanning (Forkey *et al.*, 1996; Doll *et al.*, 2014) was chosen, as it is capable to provide time averaged planar information on the relevant flow quantities simultaneously.

In Fig. 1, measured profiles at $y/R = 0.01$ extracted from the 2D results of axial, and circumferential velocities U_x and U_z as well as of the temperature T are plotted against x/L. U_x as well as U_z velocity curves bear reminiscence to a driven oscillation, with growing amplitudes towards the hot exit. The bulk temperature increase happens until $x/L = 0.3$. Up to $x/L = 0.9$ there is only a slight growth, intensifying again towards the hot exit. Data gathered by conventional probe based technology as well as FRS results suggest a strong relationship between acoustic phenomena and the time-averaged flow field.

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