OBSERVATIONS OF PARTICLE DISPERSION EXTRACTED FROM THE UVP SIGNAL

G.P. King*, N. Furuichi **, Y. Takeda***

*Fluid Dynamics Research Centre, School of Engineering, University of Warwick, Coventry, UK CV4 7AL,
E-mail: greg.king@warwick.ac.uk,
**National Institute of Advanced Industrial Science and Technology
Center 3, Umezono1-1-1, Tsukuba 305-8563, Japan, E-mail: furuichi.noriyuki@aist.go.jp
***Laboratory for Flow Control, Hokkaido University, E-mail: yft@eng.hokudai.ac.jpT

ABSTRACT

An idea how to obtain qualitative information about particle dispersion by a flow from the UVP signal without further investment in instrumentation is described and illustrated in flow through an axisymmetric sudden expansion.

Keywords: Turbulent flow, Backward Facing Step, Vortex, Wake, and Separation

INTRODUCTION

In many fluid mechanical applications one desires to know not only the velocity field, but also how a tracer is stirred and dispersed by the flow. In work reported at the last ISUD meeting, Cellino described the development and application of an ultrasound system to measure the velocity and concentration fields simultaneously [1]. However, at the present time it is very expensive to implement their techniques. On the other hand if one is satisfied with less detailed knowledge, then the owners of a standard commercial ultrasound velocity profiler (UVP) can obtain some information about tracer dispersal at no additional cost.

The key to the idea is straightforward. Recall that in order to measure a velocity, particles capable of backscattering the incident ultrasound radiation must be present in the measurement volume. The UVP signal processing software counts the number of valid velocities measured during the profile sampling period. The number of valid velocities during the sampling period is called the success rate and here will be denoted by σ and is suitably normalized so that $0 \le \sigma \le 1$. Since the UVP carries out the measurement for a number of spatial positions in parallel, and as a function of time, we obtain $\sigma(x,t)$ where x denotes the US beam direction. Thus $\sigma(x,t)$ is a measure of the presence of tracer as a function of space and time along the beam direction. Clearly if one has more US transducers, more information about the space-time evolution of the tracers could be obtained. Also, the velocities at the positions where the success rate is large enough could be recorded and suitable averages of the particle flux could be obtained.

In this note we describe our idea (arrived at independently a few months before the last ISUD) and illustrate it with some experiments on the flow in an axisysmmetric sudden expansion.

EXPERIMENTAL METHOD

We use the experimental configuration and apparatus previously used by Furuichi, Takeda and Kumada [2] who investigated the flow transition in an axisymmetric sudden expansion using an ultrasound velocity profiler [3]. The flow configuration and coordinate system is shown in Figure 1. The flow emerging into the expansion section forms a separation bubble, and it is well known that the time averaged reattachment length varies as a function of Reynolds number, $Re_d = V_b d/\nu$, where V_b is a bulk velocity estimated from the flow rate, d is the pipe diameter upstream of the step and ν is the kinematic viscosity. The transitional scheme is classified as laminar flow for Re_d <1000, transitional regime for 1000< Re_d <4000, and turbulent regime for Re_d <4000. Two large changes in the flow structure were observed in the transitional regime: the first at $Re_d \approx 1500$ caused by a change in the spatial structure of the flow, and the second at $Re_d \approx 2000$ where a change in the upstream flow occurred.

Air particles were produced by hydrolysis and used as scatterers/tracers, just as in the work by Furuichi et al [2]. The electrode was in the shape of a semi-circle and was positioned near the corner of the step in the lower half of the expansion section, as indicated in Figure 1. The transducer was aligned in the cross-stream direction at four different streamwise positions: z/z_R=0.67, 1.0, 1.33 and 1.67, where z_R is the position of the time-averaged reattachment point.

The experimental protocol was as follows. First the flow rate was set to yield a pre-selected Reynolds number, and the US transducer was positioned at one of the pre-determined streamwise positions. Then a short duration current was sent through the electrode, thereby causing a pulse of small air bubbles to be released into the flow. A short time after the current was turned off the UVP data collection began, and the success rate $\sigma_k(r,t)$ was collected and stored as a function of radial position and time at a fixed streamwise position z_k. Next, the position of the transducer was moved to a new streamwise position and the experiment repeated.

RESULTS AND DISCUSSION

Results of these experiments are shown in Figure 2 (space-time plots of $\sigma_k(r,t)$) and Figure 3 ($\overline{\sigma_k}(t) = \int \sigma_k(r,t)dr$).

Figure 2 is a measure of the residence time at different radial positions as a function of time. The figures require some care to interpret properly and this will be described in the presentation.

CONCLUDING REMARKS

In conclusion, the results are to be interpreted qualitatively, not quantitatively. The idea is highly suggestive that interesting information about how the flow disperses tracer particles in the flow can be obtained from the UVP signal, complementing the measured velocity field.

REFERENCES

1. M. Cellino, Ultrasonic measurements of instantaneous velocity and suspended concentration in open channel, ISUD3, 23-29, (2002), Lausanne.
2. N. Furuichi, Y. Takeda and M. Kumada, Spatial structure of the flow in an axisymmetric sudden expansion, Experiments in Fluids, **34**, 643-650, (2003) .
3. Y. Takeda, Development of ultrasound velocity profile monitor, Nuc. Eng. Des., **126,** 177, (1990).

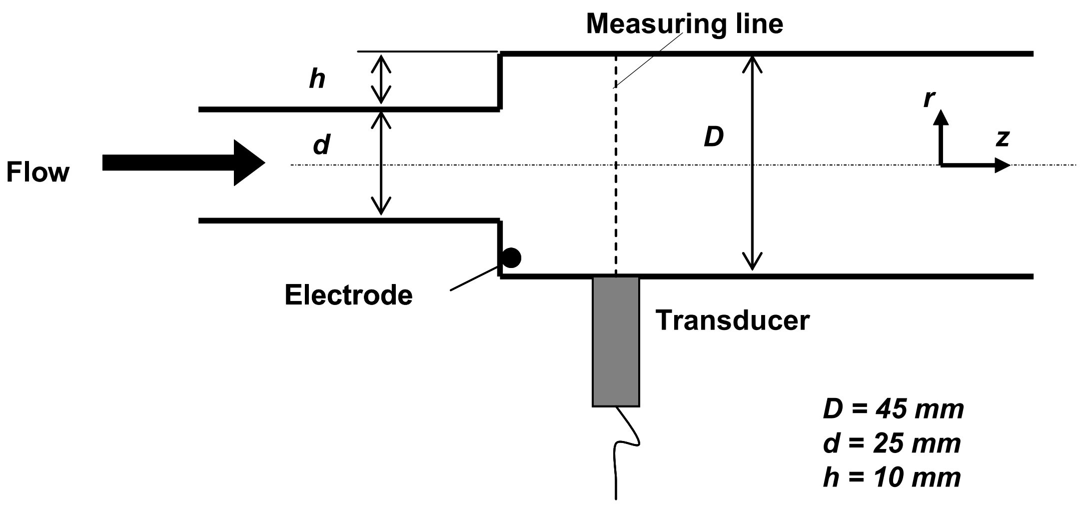

Figure 1: Experimental configuration of the axisymmetry sudden expansion.

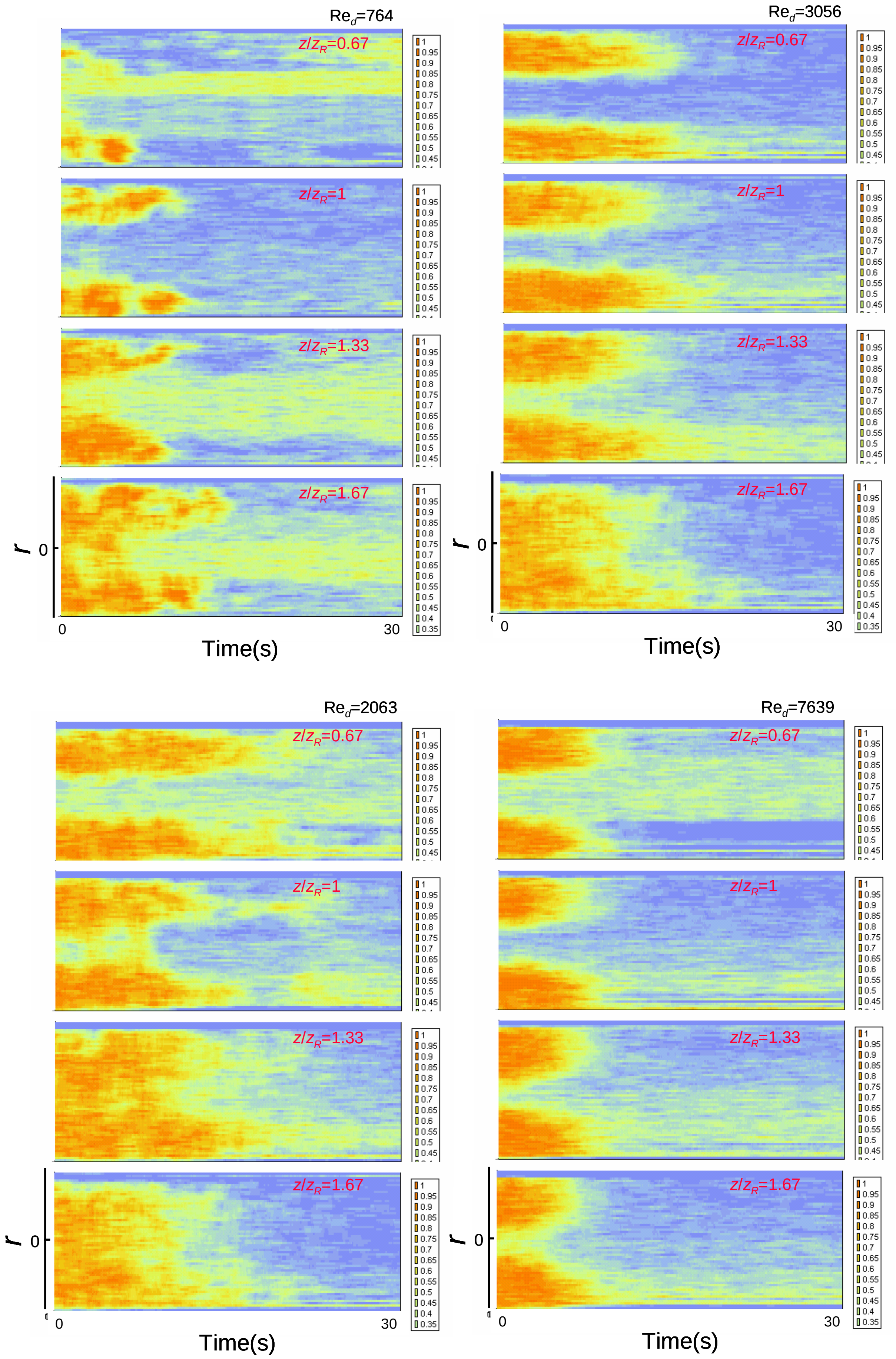

Figure 2: Space – time color density plots of the success rate $\sigma_k(r,t)$

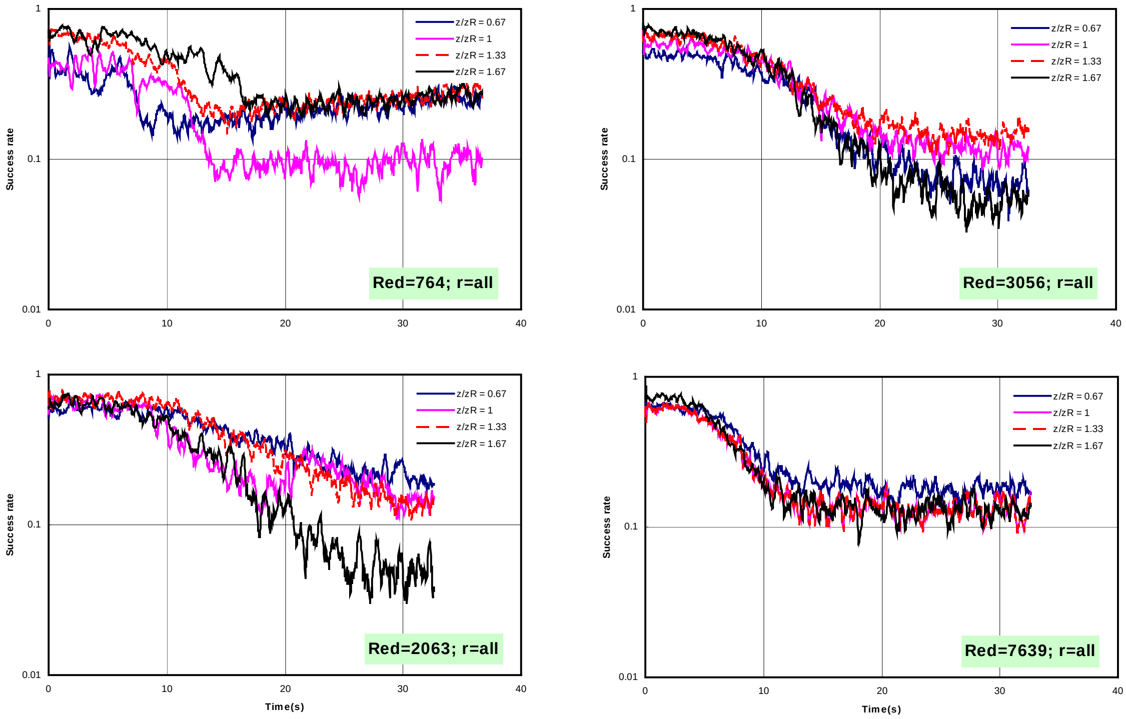

Figure 3: Plots of the radially integrated success rate, $\overline{\sigma_k}(t) = \int \sigma_k(r,t)dr$.