Int. J. Multiphase Flow Vol. 9, No. 6, pp. 751–754, 1983
Printed in Great Britain.

0301-9322/83 $3.00 + .00
Pergamon/Elsevier

BRIEF COMMUNICATION

LASER DOPPLER VELOCIMETER MEASUREMENTS OF AEROSOLS IN TURBULENT PIPE FLOW

J. L. STEIMKE† and A. E. DUKLER
Department of Chemical Engineering, University of Houston, Houston, TX 77004, U.S.A.

(*Received* 16 *May* 1982; *in revised form* 20 *March* 1983)

INTRODUCTION

Laser Doppler Velocimeters (LDV's) are being applied increasingly to two-phase flow. Velocity measurements of large particles suspended in air have been made by Carlson & Peskin (1975), Arundel *et al.* (1974), Semiat & Dukler (1981), Lesinski *et al.* (1981) and Lee & Durst (1982).

This communication gives the results of LDV measurements of axial and radial components of velocity of 60 μm glass beads suspended in air in horizontal pipe flow. The beads exhibited strong inertial effects because the time constant for acceleration was roughly ten times the Lagrangian time scale of turbulence. Velocity measurements were also made for 20 μm dioctylphthalate (DOP) droplets. The time constant for the droplets was about half as large as the Lagrangian time scale.

EXPERIMENTAL APPARATUS

The LDV system, described by Steimke (1978), consisted of two independent sets of fringe mode optics whose sampling volumes intersected at the point of measurement. The optical channels measured the axial velocity and a velocity component oriented at 45° to the pipe axis. The radial velocity was calculated from the two measured components of velocity.

The flow channel was a horizontal pipe with a 50.8-mm i.d. and a 3.048-m length. To form windows at the measurement location, flat surfaces were milled on both sides of the pipe just deep enough to create slots on the inner surfaces. Optically flat glass was placed over the slots.

The glass beads that were suspended in the flow had a mean diameter of 60 μm and a standard deviation of 6 μm. The beads were fed into the upstream end of the flow channel with a screw type conveyor at the rate of about one gram per second. The 20 μm DOP droplets were generated by a spinning disk generator. In a third series of experiments a tracer aerosol of DOP was used which had a median droplet diameter of 3 μm.

The Doppler frequencies of the LDV signals were measured using commercial LDV trackers. The output of the trackers was tape recorded and later processed to give mean and RMS fluctuating velocities. The autocorrelation coefficient was calculated using the algorithm of Smith & Meadows (1974) which was developed for low sample rate data.

The accuracy of the LDV system was verified by the good agreement of LDV measurements of tracer aerosol with hot wire anemometer measurements in the absence of aerosol but at the same flow. The comparisons were made for mean and RMS, axial and radial velocities.

RESULTS AND DISCUSSION

Instantaneous axial and radial components of bead velocity were measured at a flow Reynolds number of 84,000 and compared with measurements at the same Reynolds number for

†Present address: E. I. Du Pont de Nemours & Co., Inc., Savannah River Laboratory, Aiken, SC 29808, U.S.A.

the DOP tracer aerosol which followed air turbulence. The mean and RMS velocities differed markedly. The mean axial velocity profiles of figure 1 ($\bar{U}$, vs r/R) indicates the existence of significant relative velocity for the glass beads and negligible relative velocity for the 20 μm DOP drops. The RMS fluctuating axial velocity for the beads was higher than that for the continuous phase as shown in figure 2. Axial velocity autocorrelation coefficients, $R(t)$, are shown in figures 3 and 4 for two radial positions. The correlation of velocities of successive beads passing through a sample volume located at the pipe centerline was only about 0.2 as shown at zero time delay.

The observed high value of axial RMS velocity and low autocorrelation for the glass beads can be explained by their inability to adjust quickly to changes in the local air velocity. As beads move down the pipe, they move randomly to various radial positions. During any sampling period the sample mean includes successive beads originating near the pipe wall with low velocity and near the center with higher velocity. The number-averaged velocity measured in the center will thus be lower as a result of the fact that the beads originating near the wall have insufficient time to respond to the local air velocity in the center of the pipe.

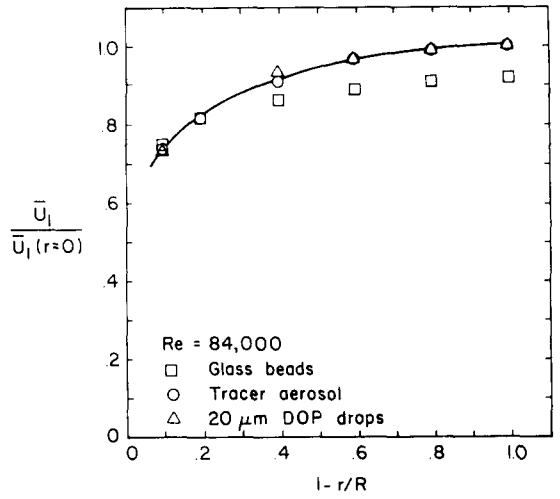

Figure 1. Mean axial velocity.

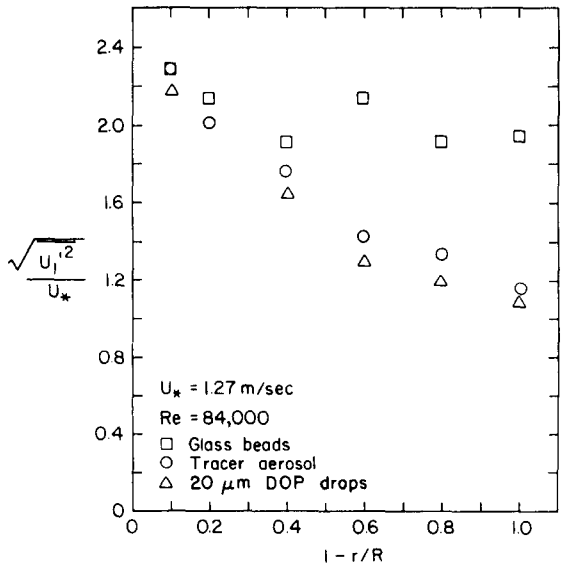

Figure 2. RMS axial velocity.

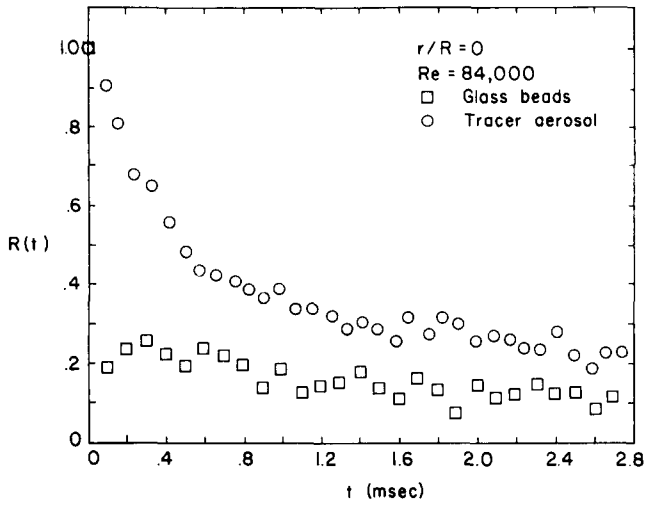

Figure 3. Autocorrelation coefficient for glass beads.

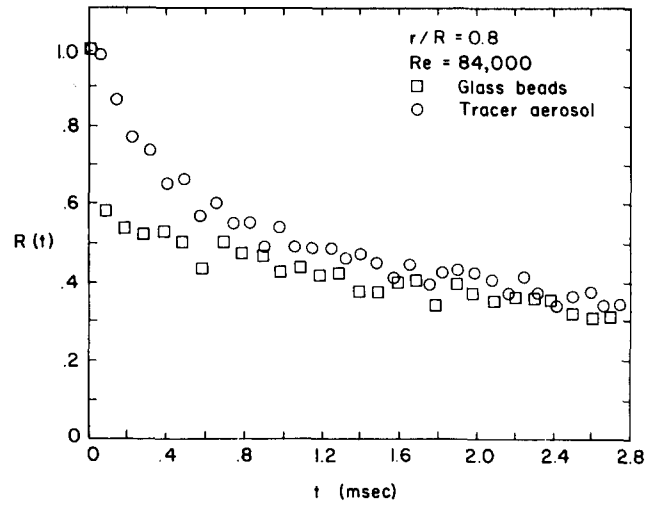

Figure 4. Autocorrelation coefficient for glass beads.

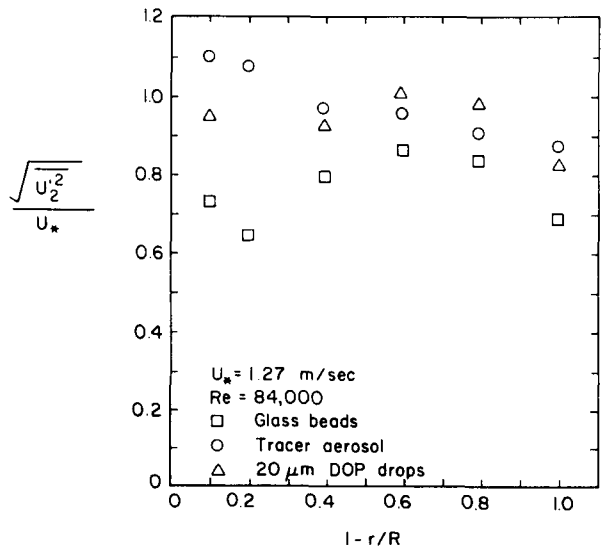

Figure 5. RMS radial velocity.

The same inability to adjust to the local air velocities accounts for the fact that the RMS fluctuating axial velocity for the glass beads is higher than for the air. Those particles with long residence time at the position of measurement adjust their axial velocity. Those with short residence time do not and the result is a larger spread or variance in the axial velocity.

The RMS radial velocities for the beads are given in figure 5. At most positions, the root mean square radial velocity for the beads was significantly less than the corresponding RMS velocity for the tracer aerosol because the inertia of the beads tended to damp the radial velocity fluctuations.

The mean and fluctuating velocities for the DOP drops appear to follow that of the continuous phase as shown in figures 1, 2 and 5. This result is consistent with prediction using the theory of Chao (1964).

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