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POD INVESTIGATION INTO THE DYNAMICS OF THE TURBULENT JET USING HOT-WIRES

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1 Introduction

Recently, Gamard *et al.* [3] discovered that the energy distribution of the far field region of the turbulent axisymmetric jet at high Reynolds numbers is dominated by azimuthal mode-2. This result is contrary to both theoretical studies (mostly based on linear stability theory) and earlier experimental studies. Due to the importance and potentially controversial nature of those results, we decided to repeat them with a different experimental device.

The earlier investigation used an unique experimental apparatus with 139 hot-wires simultaneously in conjunction with 'slice' Proper Orthogonal Decomposition (POD) techniques to resolve the instantaneous streamwise velocity field at all locations. The POD was applied to a double Fourier transform in time and azimuthal direction of the two-point velocity correlation tensor. The present experiment uses a simplified array of 15 hot-wires placed in two rakes, one moveable with respect to the other fixed one, similar in design and implementation to that used by Glauser and George [4] and Delville *et al.* [2] in mixing layers. The POD was applied in a similar way, but using different computational codes.

2 Experimental Procedure

Measurements were done from 3 to 46 diameters downstream at Reynolds numbers from 33,300 to 117,600 based on the exit velocity and diameter. Only the results from 15 to 35 diameters at a Reynolds number of 84,700 are presented here.

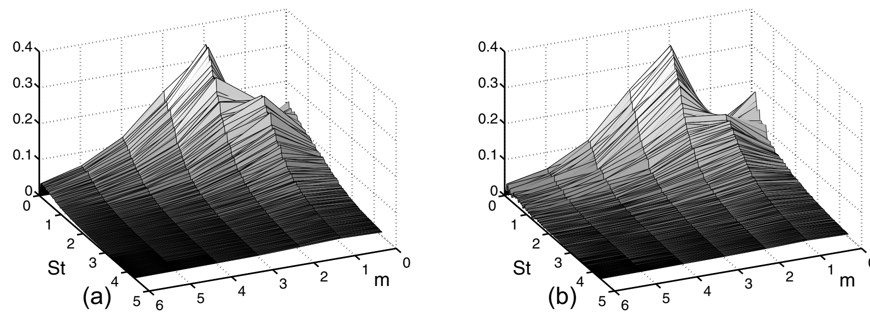

Figure 1: The first POD-mode, λ_1 (normalized intensity), function of Strouhal number, fx/U_c, and azimuthal mode number, m, at 20 diameters downstream, $U_0 = 50\text{m/s}$: (a) Gamard *et al.* [3], (b) Present experiment

The flow field was created by the same axisymmetric turbulent jet used by Gamard *et al.* [3]. The downstream component of the velocity was measured using a rake of 15 single hot-wires mounted on two wings, one moveable azimuthally around the other in 15° increments. The wires measured the downstream velocity, and were aligned along concentric circles to minimize the cross-flow errors. The hot wires were 2 mm. long, made of $5\mu m$ unplated tungsten and connected to DANTEC miniature-CTA 54T30 anemometers.

Individual velocity signals for each probe were Fourier transformed in time. For each azimuthal displacement, we computed the cross-correlation tensor between the different probes, which was then Fourier transformed in the azimuthal direction. The POD was then used in the radial direction to obtain the eigenspectrum, $\lambda(m, f)$.

3 Results

For the far jet, the earlier results from Gamard *et al.* [3] showed that the lowest order POD eigenspectrum, $\lambda_1(m, f)$, contained more than 60% of the measured kinetic energy. It was concentrated in very few azimuthal modes, and actually presented two peaks: one at near-zero frequency for azimuthal mode-2, and a lower secondary peak for azimuthal mode-1 at a local Strouhal number (fx/U_c) of approximately one. Our new results mainly confirm the above features as compared in Figures 1 for one downstream position. The eigenspectrum overall shape did not evolve with downstream distance, as seen in Figure 2. When integrated over frequency to highlight the azimuthal dependence only and normalized to reflect the partition of energy present, Figure 3, the azimuthal eigenspectrum peaks at mode-2. The difference in intensity between the two profiles comes from the fact that the wires used in the two experiments were radically different. In particular, the wires in this experiment are much shorter, and therefore pick up more of the energy in the flow, hence the smaller fraction of energies.

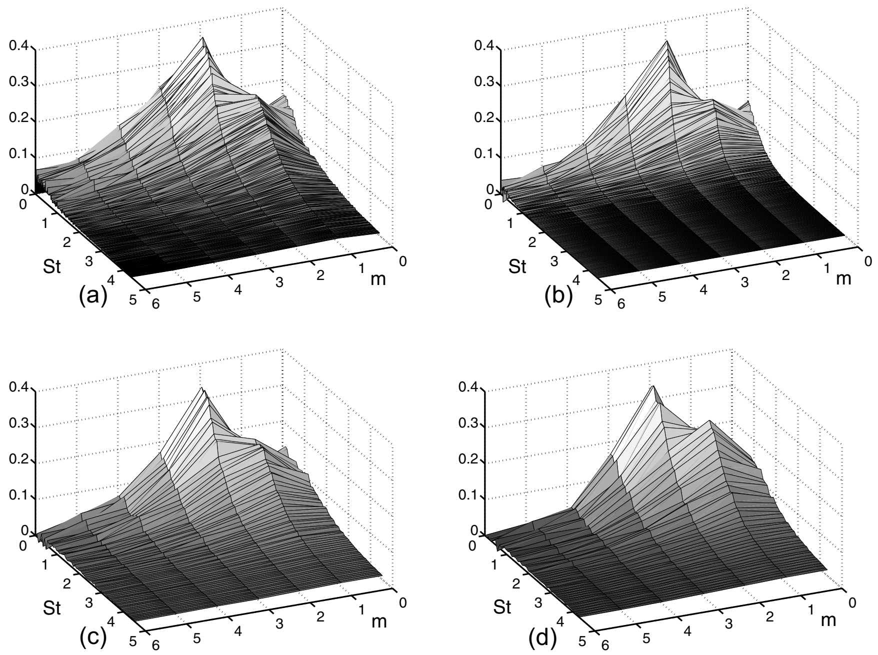

Figure 2: $\lambda_1(m, fx/U_c)$ at $U_0 = 50$m/s (normalized intensity): (a) 15 D, (b) 25 D, (c) 30 D, 35 D

4 Conclusions

A new set of experimental data, using a rake of 15 hot-wires mounted in two moveable wings, is presented for the far field region of an axisymmetric turbulent jet at high Reynolds numbers. The 'slice' POD technique was applied to the acquired two-point correlation. The resulting eigenspectra confirm earlier measurements made by Jung *et al.* [5] and Gamard *et al.* [3], mainly that the eigenspectra evolves earlier than expected towards a far field shape where most of the energy is concentrated on two peaks at azimuthal mode-2 and near-zero frequency, and mode-1 at a local Strouhal number of 1. Moreover, mode-2 has the most energy, consistent with the earlier findings.

This new data confirm that the previously used 139 hot-wire array was not influencing the results. The earlier findings have also been confirmed by the recent DNS computations at a much lower Reynolds number (3,600) and higher

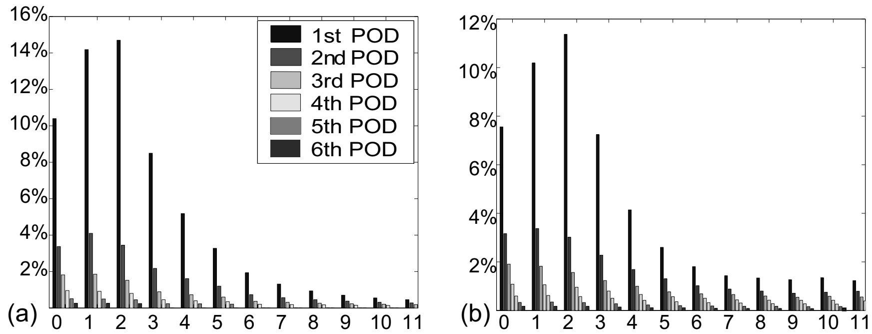

Figure 3: Energy repartition per azimuthal mode number, m, for all POD modes at 20 diameters downstream, $U_0 = 50\text{m/s}$: (a) Gamard *et al.* [3], (b) Present experiment

Mach number by Freund and Colonius [1]. Moreover, they are consistent with the trends observed by Ukeiley *et al.* [7] and the radiated noise measurements of Kopiev [6] at the Central Aerohydrodynamic Institute (TsAGI) in Moscow.

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