

Databases of flow and near pressure field signals obtained for compressible round jets using large-eddy simulations

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Databases of signals obtained in the flow and near pressure fields of compressible turbulent round jets computed by highly-resolved large-eddy simulations (LES) using cylindrical coordinates (r, θ, z) have been built up. **They are available upon request by email.** A brief description of the jet exit conditions, grid parameters and recorded signals is given below.

1 Jet exit conditions

1.1 Reference, Mach number 0.9 jets at low and high Reynolds numbers

At the beginning, two isothermal jets at a Mach number of 0.9 at diameter-based Reynolds numbers $\text{Re}_D = 3125$ and $\text{Re}_D = 10^5$ [1], represented by a red diamond and a red bullet in figure 1, have been simulated. Their initial conditions are given in table 1. The parameters of the simulations and the flow and noise properties of the jets are presented in recent papers [2, 3, 4, 5, 6]. The grid used are referred to as CGz75a and FGz40, see in section 3. The set of files recorded are D2 and D0, see in section 4. The recording times Tu_j/r_0 are slightly greater than 2500. The simulations are, however, ongoing to reach $Tu_j/r_0 = 4000$.

jet	M	Re_D	T_j/T_a	BL	δ_{BL}/r_0	u'_e/u_j	grid	n_θ	Tu_j/r_0	data
M09Re3125TaLd0420v1	0.9	3,125	1	L	0.42	1%	CGz75	512	3,000	D2
M09Re1e5TaLd0150v9	0.9	100,000	1	L	0.15	9%	FGz40	1,024	2,500	D0

Table 1: Mach and Reynolds numbers M and Re_D , jet temperature T_j , shape (L: laminar Blasius, T: transitional or turbulent) and thickness δ_{BL} of the boundary-layer profile imposed at the pipe nozzle inlet, peak turbulence intensity u'_e/u_j at the nozzle exit, grid used, number of points n_θ in the azimuthal direction, simulation time T after the transient period and recording files.

1.2 Low-Reynolds-number jets

On the basis of the simulation of the jet **M09Re3125TaLd0420v1** at $M = 0.9$ and $\text{Re}_D = 3,125$, jets also at $\text{Re}_D = 3125$ but at $M = 0.3, 0.45, 0.6, 1.3$ and 2 , with peak turbulence intensity $u'_e/u_j \simeq 0.01$ at the nozzle exit, have been computed. They are collected in table 2, and represented by diamonds in figure 1. The simulations are ongoing for all jets.

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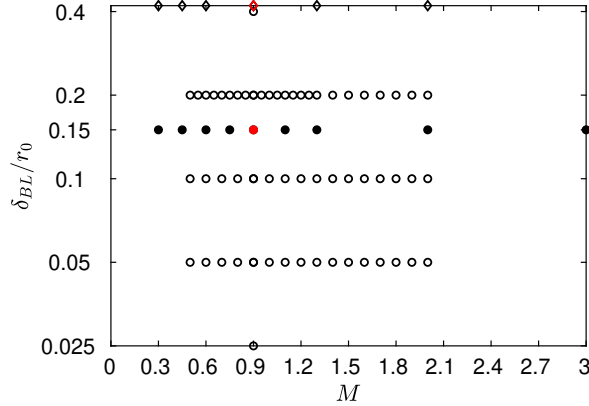


Figure 1: Jets at $Re_D = 10^5$ with \bullet tripped and \circ untripped boundary layers, and \diamond at $Re_D = 3125$: Mach number M and thickness δ_{BL} of the Blasius profiles at the pipe-nozzle inlet; \diamond M09Re3125TaLd0420v1 and \bullet M09Re1e5TaLd0150v9.

jet	M	Re_D	T_j/T_a	BL	δ_{BL}/r_0	u'_e/u_j	grid	n_θ	Tu_j/r_0	data
M03Re3125TaLd0420v1	0.3	3,125	1	L	0.42	1%	CGz75a	512	1,000	D2
M045Re3125TaLd0420v1	0.45	3,125	1	L	0.42	1%	CGz75a	512	1,500	D2
M06Re3125TaLd0420v1	0.6	3,125	1	L	0.42	1%	CGz75a	512	1,500	D2
M09Re3125TaLd0420v1	0.9	3,125	1	L	0.42	1%	CGz75a	512	3,000	D2
M13Re3125TaLd0420v1	1.3	3,125	1	L	0.42	1%	CGz75b	512	1,500	D2
M2Re3125TaLd0420v2.5	2	3,125	1	L	0.42	2.5%	CGz90	512	1,000	D2

Table 2: See caption of table 1.

1.3 High-Reynolds-number jets with untripped boundary-layers

Jets at $Re_D = 10^5$ with untripped boundary-layers have been considered in order to investigate the flow and sound fields of initially fully laminar jets. They are represented by circles in figure 1. The cost of the simulations of such jets is also much cheaper than that of jets with tripped boundary-layers.

1.3.1 Jets at a Mach number of 0.9

Jets at $M = 0.9$ with untripped boundary-layers of different thickness [7] have been computed. They are defined in table 3. Some results of the simulations are presented in recent papers [2, 5]. The simulations are ongoing for M09Re1e5TaLd0200v0 and M09Re1e5TaLd0025v0.

jet	M	Re_D	T_j/T_a	L	δ_{BL}/r_0	u'_e/u_j	grid	n_θ	Tu_j/r_0	data
M09Re1e5TaLd0400v0	0.9	100,000	1	L	0.4	0%	FGz40	256	500	D1
M09Re1e5TaLd0200v0	0.9	100,000	1	L	0.2	0%	FGz40	256	2,000	D1
M09Re1e5TaLd0100v0	0.9	100,000	1	L	0.1	0%	FGz40	512	500	D1
M09Re1e5TaLd0050v0	0.9	100,000	1	L	0.05	0%	FGz40	512	500	D1
M09Re1e5TaLd0025v0	0.9	100,000	1	L	0.025	0%	FGz40	512	1,000	D1

Table 3: See caption of table 1.

1.3.2 Jets at Mach numbers between 0.5 and 2

Jets with untripped boundary-layers of different thickness at Mach numbers varying between 0.5 and 2 in increments of 0.05 or 0.1 have been computed. They are defined in table 4. Some results of the simulations are presented in a recent paper [5].

jet	M	Re _D	T _j /T _a	L	δ _{BL} /r ₀	u' _e /u _j	grid	n _θ	Tu _j /r ₀	data
MxxxRe1e5TaLd0200v0	0.5 → 2	100,000	1	L	0.2	0%	FGz40	256	500	D3
MxxxRe1e5TaLd0100v0	0.5 → 2	100,000	1	L	0.1	0%	FGz40	256	500	D3
MxxxRe1e5TaLd0050v0	0.5 → 2	100,000	1	L	0.05	0%	FGz40	256	500	D3

Table 4: See caption of table 1.

1.4 High-Reynolds-number jets with tripped boundary-layers

Jets at Re_D = 10⁵ with tripped boundary-layers have been considered in order to investigate the flow and sound fields of initially highly disturbed jets. They are characterized by peak turbulence intensity u'_e/u_j typically of 9% at the nozzle exit.

1.4.1 Jets with nozzle-exit turbulence levels between 0 and 15%

Jets at M = 0.9 and Re_D = 10⁵ with peak turbulence intensity at the nozzle exit u'_e/u_j = 0, 3%, 6%, 9%, 12% and 15% [1, 8, 9] have been computed. They are defined in table 5.

jet	M	Re _D	T _j /T _a	BL	δ _{BL} /r ₀	u' _e /u _j	grid	n _θ	Tu _j /r ₀	data
M09Re1e5TaLd0150v0	0.9	100,000	1	L	0.15	0%	FGz40	512	500	D1
M09Re1e5TaLd0150v3	0.9	100,000	1	L	0.15	3%	FGz40	1,024	500	D1
M09Re1e5TaLd0150v6	0.9	100,000	1	L	0.15	6%	FGz40	1,024	500	D1
M09Re1e5TaLd0150v9	0.9	100,000	1	L	0.15	9%	FGz40	1,024	2,500	D0
M09Re1e5TaLd0150v12	0.9	100,000	1	L	0.15	12%	FGz40	1,024	500	D1
M09Re1e5TaLd0150v15	0.9	100,000	1	L	0.15	15%	FGz40	1,024	500	D1

Table 5: See caption of table 1.

1.4.2 Jets at Reynolds numbers between 12,500 and 400,000

Jets with highly disturbed boundary layers at M = 0.9 and Re_D varying between 12,500 and 400,000 [10] have been computed. They are presented in table 6.

jet	M	Re _D	T _j /T _a	BL	δ _{BL} /r ₀	u' _e /u _j	grid	n _θ	Tu _j /r ₀	data
M09Re1.25e4TaLd0150v7.5	0.9	12,500	1	L	0.15	7.5%	FGz40	1,024	500	D1
M09Re2.5e4TaLd0150v9	0.9	25,000	1	L	0.15	9%	FGz40	1,024	500	D1
M09Re5e4TaLd0150v9	0.9	50,000	1	L	0.15	9%	FGz40	1,024	500	D1
M09Re1e5TaLd0150v9	0.9	100,000	1	L	0.15	9%	FGz40	1,024	2,500	D0
M09Re2e5TaLd0150v9	0.9	200,000	1	L	0.15	9%	FGz40	1,024	500	D1
M09Re4e5TaLd0150v9	0.9	400,000	1	L	0.15	9%	FGz40	1,024	500	D1

Table 6: See caption of table 1.

1.4.3 Jets with different boundary-layer thicknesses

Jets at $M = 0.9$ with highly disturbed boundary layers of different thickness [11] have been computed. They are reported in table 7. Results are available in [12].

jet	M	Re_D	T_j/T_a	L	δ_{BL}/r_0	u'_e/u_j	grid	n_θ	Tu_j/r_0	data
M09Re5e4TaLd0150v9	0.9	50,000	1	L	0.15	9%	FGz40	1,024	500	D1
M09Re5e4TaLd0090v9	0.9	50,000	1	L	0.09	9%	FGz40	1,024	500	D1
M09Re5e4TaLd0250v9	0.9	50,000	1	L	0.25	9%	FGz40	1,024	500	D1
M09Re5e4TaLd0420v9	0.9	50,000	1	L	0.42	9%	FGz40	1,024	500	D1
M09Re8.3e4TaLd0250v9	0.9	83,333	1	L	0.09	9%	FGz40	1,024	500	D1
M09Re3e4TaLd0250v9	0.9	30,000	1	L	0.25	9%	FGz40	1,024	500	D1
M09Re1.8e4TaLd0250v9	0.9	18,000	1	L	0.42	9%	FGz40	1,024	500	D1

Table 7: See caption of table 1.

1.4.4 Jets at Mach numbers between 0.3 and 3

On the basis of the simulation of the jet **M09Re1e5TaLd0150v9** at $M = 0.9$ and $Re_D = 100,000$, jets also at $Re_D = 100,000$ but at $M = 0.3, 0.45, 0.6, 0.75, 1.1, 1.3, 2$ and 3 have been computed. They are collected in table 8, and are represented by bullets in figure 1. The parameters of the simulations and the flow and noise properties of the jets are presented in a recent paper [5]. The simulations are ongoing for all jets.

jet	M	Re_D	T_j/T_a	BL	δ_{BL}/r_0	u'_e/u_j	grid	n_θ	Tu_j/r_0	data
M03Re1e5TaLd0150v9	0.3	100,000	1	L	0.15	9%	FGz40	1,024	450	D1
M045Re1e5TaLd0150v9	0.45	100,000	1	L	0.15	9%	FGz40	1,024	700	D1
M06Re1e5TaLd0150v9	0.6	100,000	1	L	0.15	9%	FGz40	1,024	1,000	D1
M075Re1e5TaLd0150v9	0.75	100,000	1	L	0.15	9%	FGz40	1,024	1,000	D1
M09Re1e5TaLd0150v9	0.9	100,000	1	L	0.15	9%	FGz40	1,024	2,500	D0
M11Re1e5TaLd0150v9	1.1	100,000	1	L	0.15	9%	FGz40	1,024	1,000	D1
M13Re1e5TaLd0150v9	1.3	100,000	1	L	0.15	9%	FGz50	1,024	1,000	D1
M2Re1e5TaLd0150v9	2	100,000	1	L	0.15	9%	FGz60	1,024	1,500	D1
M3Re1e5TaLd0150v9	3	100,000	1	L	0.15	9%	FGz70	1,024	150	D1

Table 8: See caption of table 1.

1.4.5 Jets with non-laminar boundary-layer shape

Jets at $M = 0.9$ and $Re_D = 50,000$ with highly disturbed boundary layers of different shapes [13] (laminar L and non-laminar T1, T2 and T3) have been computed. They are defined in table 9. The parameters of the simulations and the flow and noise properties of the jets are presented in recent papers [14, 12].

1.4.6 Hot jets

Finally, hot jets at $M = 0.9$ and Re_D between 25,000 and 200,000 with highly disturbed boundary layers [15, 16] have been computed. Their nozzle-exit static temperatures are $T_j = 1.5T_a$ or $T_j =$

jet	M	Re _D	T _j /T _a	BL	δ _{BL} /r ₀	u' _e /u _j	grid	n _θ	Tu _j /r ₀	data
M09Re5e4TaLd0250v0	0.9	50,000	1	L	0.25	0%	FGz40	1,024	500	D1
M09Re5e4TaT1d0250v0	0.9	50,000	1	T1	0.25	0%	FGz40	1,024	500	D1
M09Re5e4TaT2d0250v0	0.9	50,000	1	T2	0.25	0%	FGz40	1,024	500	D1
M09Re5e4TaT3d0250v0	0.9	50,000	1	T3	0.25	0%	FGz40	1,024	500	D1
M09Re5e4TaLd0250v6	0.9	50,000	1	L	0.25	6%	FGz40	1,024	500	D1
M09Re5e4TaT1d0250v6	0.9	50,000	1	T1	0.25	6%	FGz40	1,024	500	D1
M09Re5e4TaT2d0250v6	0.9	50,000	1	T2	0.25	6%	FGz40	1,024	500	D1

Table 9: See caption of table 1.

2.25T_a. They are defined in table 10. The simulations are ongoing for M09Re1e5Ta1.5Ld0150v9 and M09Re1e5Ta2.25Ld0150v9.

jet	M	Re _D	T _j /T _a	BL	δ _{BL} /r ₀	u' _e /u _j	grid	n _θ	Tu _j /r ₀	data
M09Re1e5TaLd0150v9	0.9	100,000	1	L	0.15	9%	FGz40	1,024	2,500	D0
M09Re5e4Ta1.5Ld0150v9	0.9	50,000	1.5	L	0.15	3%	FGz40	1,024	500	D1
M09Re1e5Ta1.5Ld0150v9	0.9	100,000	1.5	L	0.15	3%	FGz40	1,024	1,000	D1
M09Re2e5Ta1.5Ld0150v9	0.9	200,000	1.5	L	0.15	3%	FGz40	1,024	500	D1
M09Re2.5e4Ta2.25Ld0150v9	0.9	25,000	2.25	L	0.15	0%	FGz40	1,024	500	D1
M09Re1e5Ta2.25Ld0150v9	0.9	100,000	2.25	L	0.15	0%	FGz40	1,024	1,000	D1

Table 10: See caption of table 1.

2 Grid parameters

Some characteristics of the mesh grids used for the simulations in the radial and axial directions are provided in table 11. The CG (coarse) and FG (fine) grids are employed for the jets at Re_D = 3, 125 and Re_D ≥ 12, 500, respectively; zXX indicates that the grid extends down to z = L_z = XXr₀ in the axial direction, excluding the outflow sponge zone. The grids are detailed in recent papers [2, 3, 5]. The numbers of points n_θ in the azimuthal direction (256, 512 or 1024) in the different simulations are given in tables 1-10. For illustration purposes, the variations of the radial and axial mesh spacings in FGz40, FGz50 and FGz60 are shown in figure 2.

grid	n _r	n _z	L _r	L _z	Δr/r ₀ (%) at			Δz/r ₀ (%) at		
					r = 0	r = r ₀	r = L _r	z = 0	z = 15r ₀	z = L _z
CGz75a	427	2458	25r ₀	75r ₀	2.48	0.72	14.94	1.45	2.49	6.25
CGz75b	479	2458	25r ₀	75r ₀	2.48	0.72	10.03	1.45	2.49	6.25
CGz90	479	3058	25r ₀	90r ₀	2.48	0.72	10.03	1.45	2.49	6.25
FGz40	504	2085	15r ₀	40r ₀	1.41	0.36	7.55	0.72	2.30	4.88
FGz50	572	2412	15r ₀	50r ₀	1.41	0.36	5.03	0.72	2.12	5.31
FGz60	572	2947	15r ₀	60r ₀	1.41	0.36	5.03	0.72	1.82	4.95
FGz70	626	3822	15r ₀	70r ₀	1.41	0.36	4.02	0.72	1.47	4

Table 11: Numbers of points n_r and n_z and extents of the physical domain L_r and L_z in the radial and axial directions, and mesh spacings Δr and Δz at different positions.

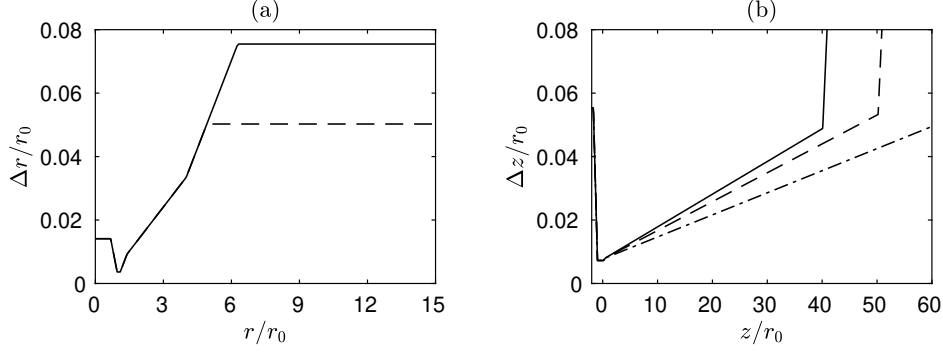


Figure 2: Variations (a) of radial mesh spacing Δr for — FGz40 and - - - FGz50 and FGz60 and (b) of axial mesh spacing Δz for — FGz40, - - - FGz50 and - · - · FGz60.

3 Database parameters

The recording files are defined in table 12: 3-D fields are stored in the 3Dxxx files, 2-D fields at constant radial, azimuthal and axial positions are stored in the Rxx, Txx and Zxx files, respectively. The maximum Strouhal number allowed by the sampling frequency is equal to 32 for T_{HF} and to 6.4 or 12.8 in the other cases.

The set of files recorded in each simulation, referred to as D0, D1, D2 and D3 in tables 1-10, are defined in table 13. For storage issues, all the files are saved (case D0) only for the reference, isothermal tripped jet at Mach 0.9 and Reynolds 100,000 (M09Re1e5TaLd0150v9). For most other jets at high Reynolds numbers, the 3-D fields and the 2-D fields at $\theta = \pi/4 \rightarrow 13\pi/4$ every $\pi/2$ are not stored (case D1). For the jets at Reynolds 3,125, in addition, the Fourier coefficients for $n_{\theta=5-8}$ are not recorded (case D2). Finally, case D3 applies to the untripped jets at $M \neq 0.9$.

References

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files	St_D	z	r	θ	variables
<i>3Daero</i>	6.4	$0 \rightarrow 30r_0$ every $2\Delta z$	$0 \rightarrow 6r_0$ every $2\Delta r$	$0 \rightarrow 2\pi - 2\pi/512$ every $2\pi/512$	ρ, u_i, p
<i>3Dac</i>	6.4	$0 \rightarrow L_z$ every $2\Delta z$	L_r	$0 \rightarrow 2\pi - 2\pi/512$ every $2\pi/512$	p
	6.4	$0 \rightarrow L_z$ every $2\Delta z$	$0 \rightarrow L_r$ every Δr	$0 \rightarrow 3\pi/2$ every $\pi/2$	p
	6.4	$0 \rightarrow L_z$ every $10r_0$	$0 \rightarrow L_r$ every Δr	$0 \rightarrow 2\pi - 2\pi/512$ every $2\pi/512$	p
<i>R₀</i>	12.8	$-1.25r_0 \rightarrow L_z$ every $2\Delta z$	0	$0 \rightarrow 2\pi - 2\pi/256$ every $2\pi/256$	$\rho, u_i, p, \omega , \Theta$
<i>R₁</i>	12.8	$-1.25r_0 \rightarrow L_z$ every $2\Delta z$	r_0	$0 \rightarrow 2\pi - 2\pi/256$ every $2\pi/256$	$\rho, u_i, p, \omega , \Theta$
<i>R_{WP}</i>	12.8	$-1.25r_0 \rightarrow L_z$ every $2\Delta z$	$1.4r_0$ at $z = 0$ 8° cone angle	$0 \rightarrow 2\pi - 2\pi/256$ every $2\pi/256$	$\rho, u_i, p, \omega , \Theta$
<i>R_{NF}</i>	12.8	$-1.25r_0 \rightarrow L_z$ every $2\Delta z$	L_r	$0 \rightarrow 2\pi - 2\pi/256$ every $2\pi/256$	ρ, u_i, p
<i>T_{axi}</i>	6.4	$-1.25r_0 \rightarrow L_z$ every Δz	$0 \rightarrow L_r$ every Δr		Fourier coef $n_{\theta=0}$ for ρ, u_i, p
<i>T₀₋₂₇₀</i>	6.4	$-1.25r_0 \rightarrow L_z$ every Δz	$0 \rightarrow L_r$ every Δr	$0 \rightarrow 3\pi/2$ every $\pi/2$	$\rho, u_i, p, \partial u_i / \partial \theta$
<i>T₄₅₋₃₁₅</i>	6.4	$-1.25r_0 \rightarrow L_z$ every Δz	$0 \rightarrow L_r$ every Δr	$\pi/4 \rightarrow 13\pi/4$ every $\pi/2$	$\rho, u_i, p, \partial u_i / \partial \theta$
<i>T_{nθ=0-4}</i>	6.4	$0 \rightarrow L_z$ every $2\Delta z$	$0 \rightarrow L_r$ every $2\Delta r$		Fourier coef $n_{\theta=0 \rightarrow 4}$ for $\rho, u_i, p, \omega , \Theta$
<i>T_{nθ=5-8}</i>	6.4	$0 \rightarrow L_z$ every $2\Delta z$	$0 \rightarrow L_r$ every $2\Delta r$		Fourier coef $n_{\theta=5 \rightarrow 8}$ for $\rho, u_i, p, \omega , \Theta$
<i>T_{HF}</i>	32	$0 \rightarrow 20r_0$ every $2\Delta z$	$0 \rightarrow 3.5r_0$ every $2\Delta r$	0	ρ, u_i, p
<i>Z_{0/start/end}</i>	12.8	$-1.25r_0, 0, L_z$	$0 \rightarrow L_r$ every Δr	$0 \rightarrow 2\pi - 2\pi/256$ every $2\pi/256$	ρ, u_i, p
<i>Z₅₋₃₅</i>	6.4	$5r_0 \rightarrow 35r_0$ every $5r_0$	$0 \rightarrow L_r$ every $2\Delta r$	$0 \rightarrow 2\pi - 2\pi/256$ every $2\pi/256$	ρ, u_i, p

Table 12: Recording files: Strouhal number given by the sampling frequency, recording positions, and variables recorded (density ρ , velocity components $u_i = (u_r, u_t, u_z)$, pressure p , vorticity norm $|\omega|$, dilatation Θ).

jets	case	files recorded
M09Re1e5TaLd0150v9	D0	all files
most jets at $Re_D \geq 12,500$	D1	all files except for <i>3Daero</i> , <i>3Dac</i> and <i>T₄₅₋₃₁₅</i>
jets at $Re_D = 3,125$	D2	all files except for <i>3Daero</i> , <i>3Dac</i> , <i>T₄₅₋₃₁₅</i> , <i>T_{nθ=5-8}</i> and <i>T_{HF}</i>
untripped jets at $M \neq 0.9$	D3	all files except for <i>3Daero</i> , <i>3Dac</i> , <i>T₄₅₋₃₁₅</i> , <i>T_{nθ=2-8}</i> , <i>T_{HF}</i> and <i>Z₅₋₃₅</i>

Table 13: Set of files recorded in each simulation.

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