INVESTIGATION OF THE ACOUSTIC ACTUATORS CREATION POSSIBILITY FOR CONTROLLING FLOW IN SWIRLING JET

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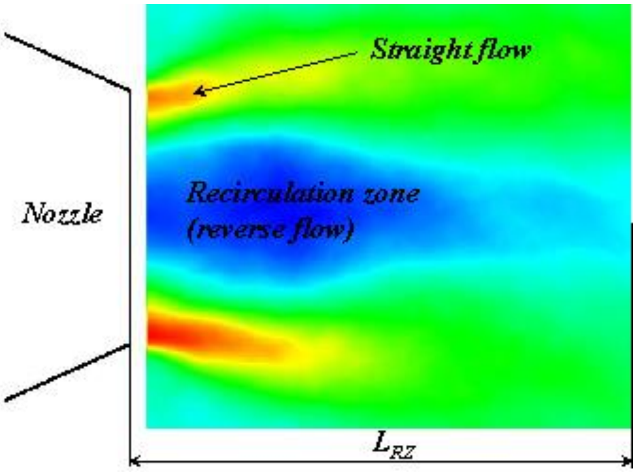
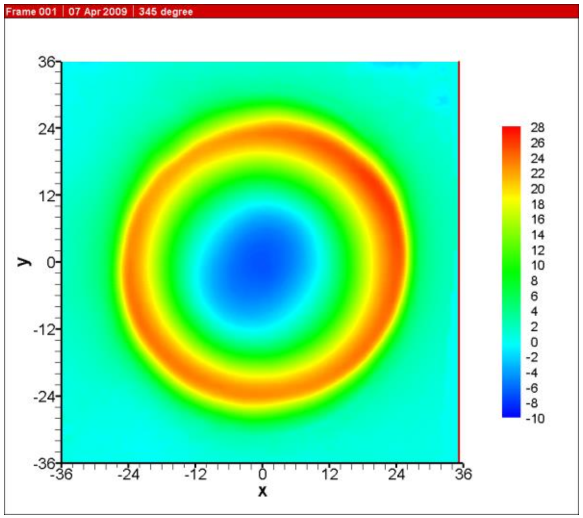
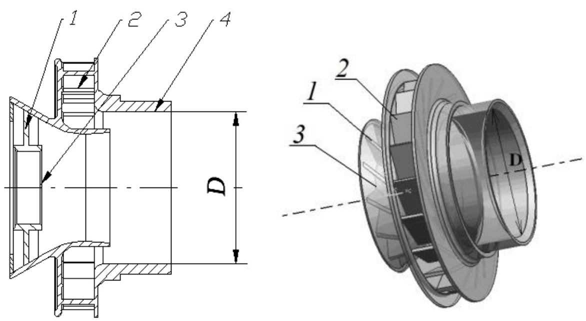




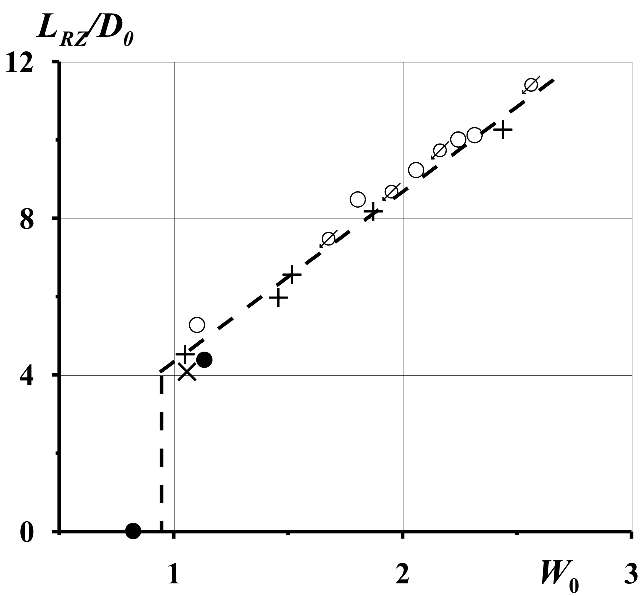
Possibility of acoustic control of the flow in swirling jet

Swirling jets are used in the vast majority of combustion chambers of the gas turbine engines for mixing intensification and combustion stabilization. The main feature of high swirled jets is the presence of precessing central recirculation zone (CRZ).



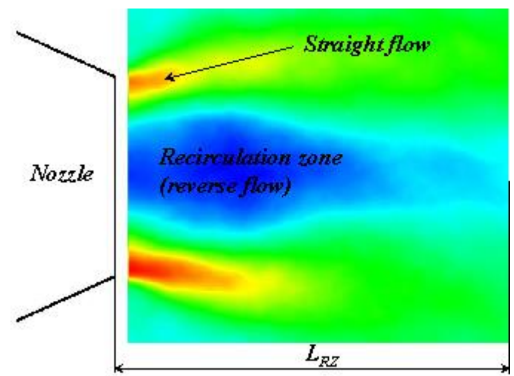
The intensity of swirling (swirling number) is defined as:

$$W_0 = \frac{1}{R_0}\left(\int_0^{R_0} ruwr^2 dr\right) \Big/ \left(\int_0^{R_0} u^2 r dr\right) \qquad W_0 = \frac{w_{\max}}{U_a}$$

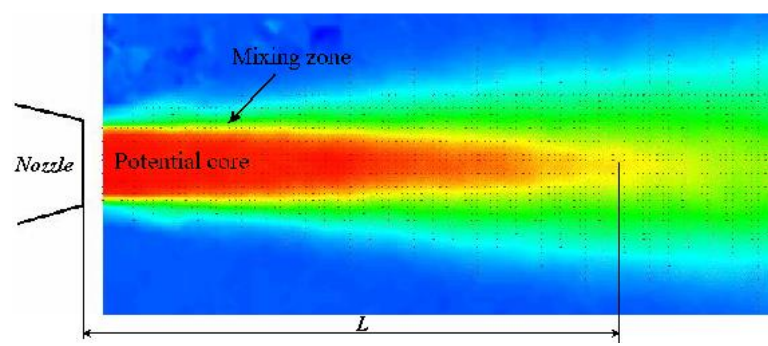


The influence of swirled number on length of CRZ

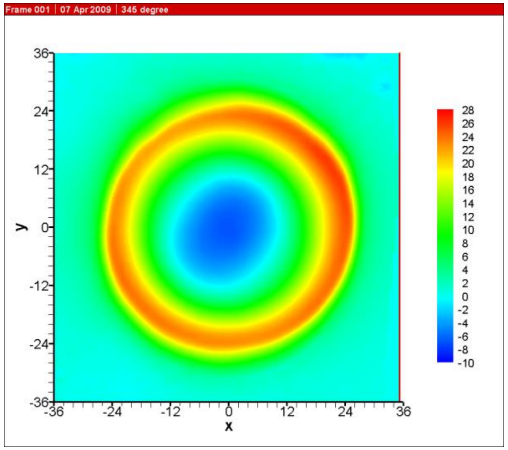
Swirled jet



"Usual" submerged jet

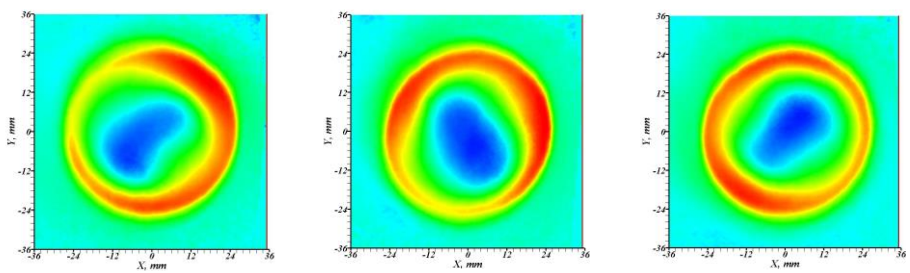


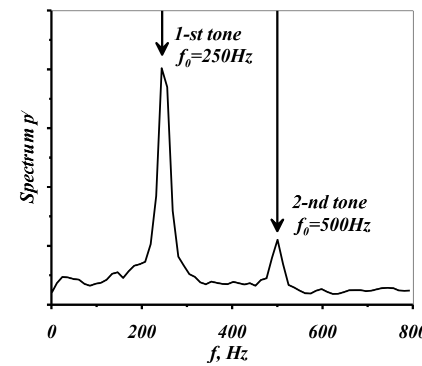
Possibility of acoustic control of the flow in swirling jet



A distinctive feature of the flow in strongly swirling jets with an axial reverse-flow zone is the observable rotation of the jet flowfield averaged over a small time interval; it is conventionally named precession
Thus, the on-average-axisymmetric flow structure has a periodic component observable in specially visualizing the flow.

$$Sh = f_0 D / U_a \approx 0.7 * W_0$$





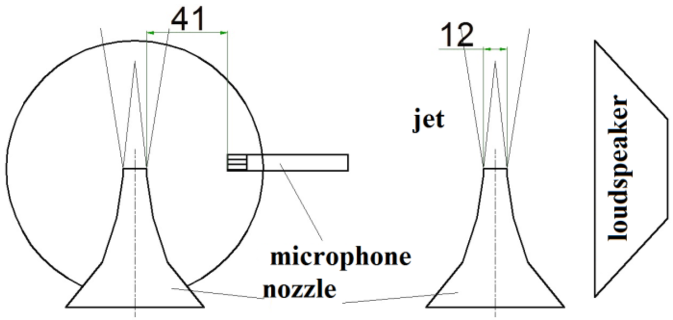
Articles on precessing vortex core [PVC]

1. Gupta AK, Lilley DG, Syred N (1984) Swirl flows. Abacus Press, Tunbridge Wells, UK
2. C. E. Cala, E. C. Fernandes M. V. Heitor, S. I. Shtork. Coherent structures in unsteady swirling jet flow. Experiments in Fluids (2006) 40: 267–276.
3. D. L. Zakharov, S. Yu. Krasheninnikov, V. P. Maslov, A.K.Mironov, and P. D. Toktaliev.Investigation of Unsteady Processes, Flow Properties, and Tonal Acoustic Radiation of a Swirling Jet. Fluid Dynamics, 2014, Vol. 49, No. 1, pp. 51–62.

And many many more……

Background for the presented work

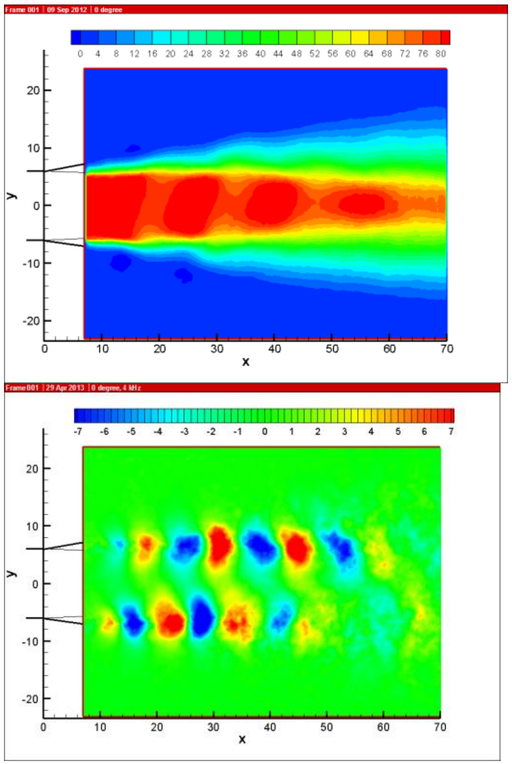
Possibility of acoustic control of the flow in swirling jet



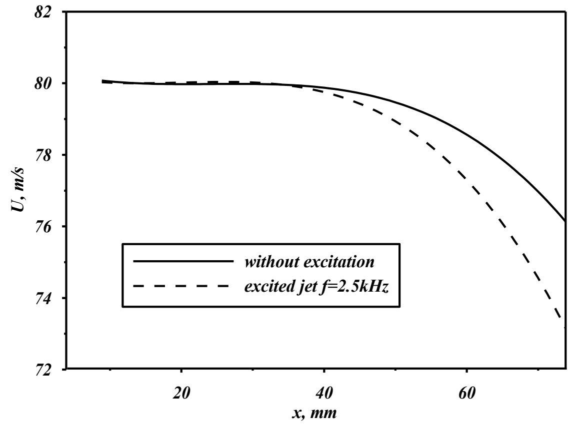
$p'_{ac}/(\rho U^2/2) \approx 5\%$

$Re \approx 10^5$

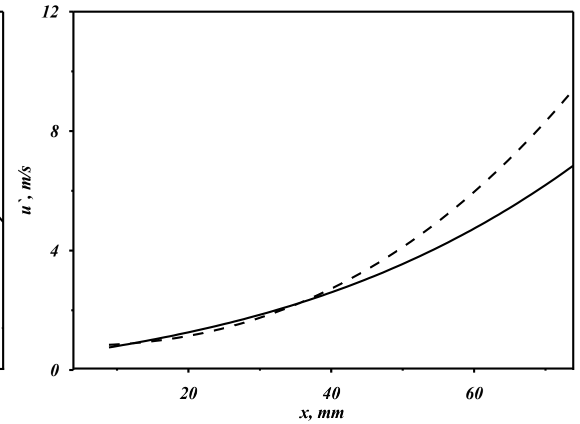
$\mathrm{Sh} = fD/U = 0.375\text{-}0.6$



Phase averaged flow-field



mean velocity



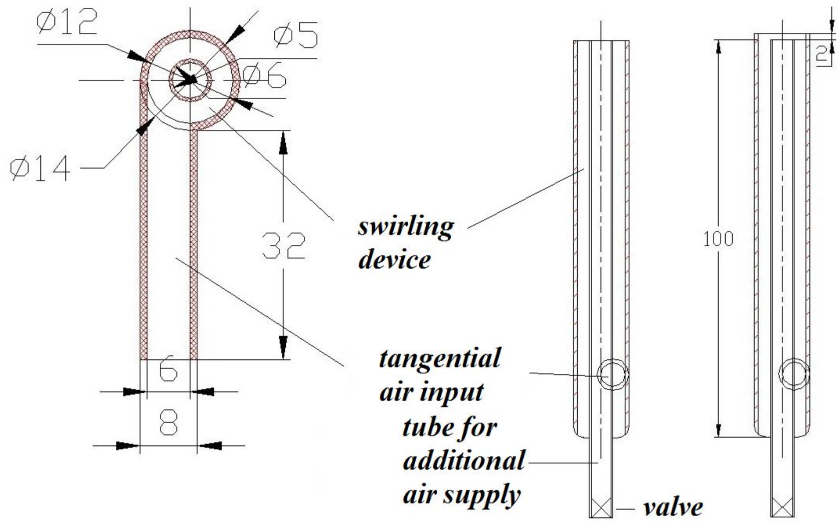
pulsation intensity

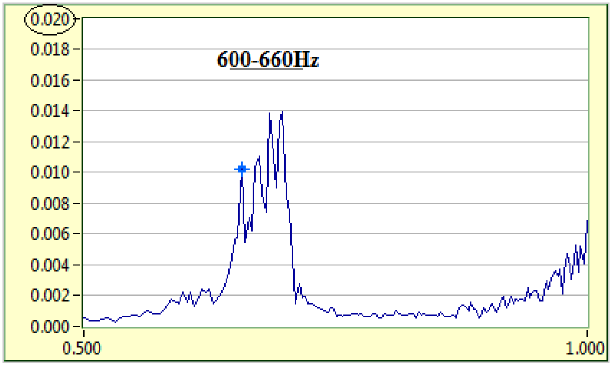
Axial distributions of longitudinal averaged velocity

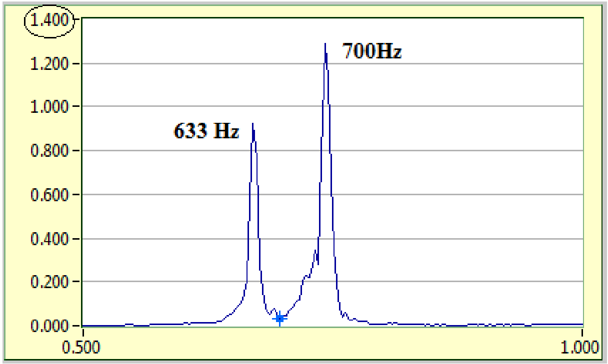
A. K. Mironov, et al. An Investigation of Dynamic of Ordered Structure in Axisymmetric Turbulent Jet under Transversal Acoustic Excitation. Acoustical Physics, 2016, Vol. 62, No. 4.

V. F. Kop'ev et al, Acoust. Phys. 59 (1), 16 (2013)

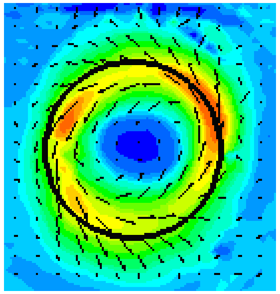
Possibility of acoustic control of the flow in swirling jet



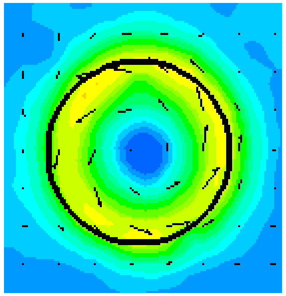


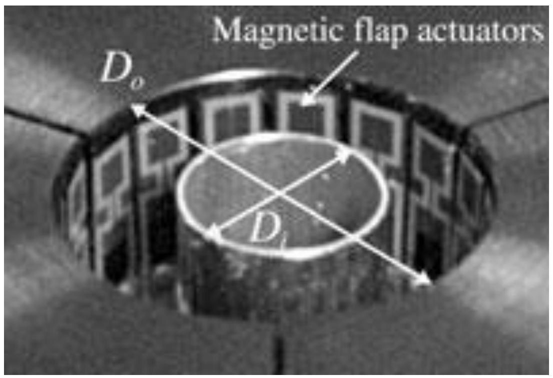


Without precession



With precession



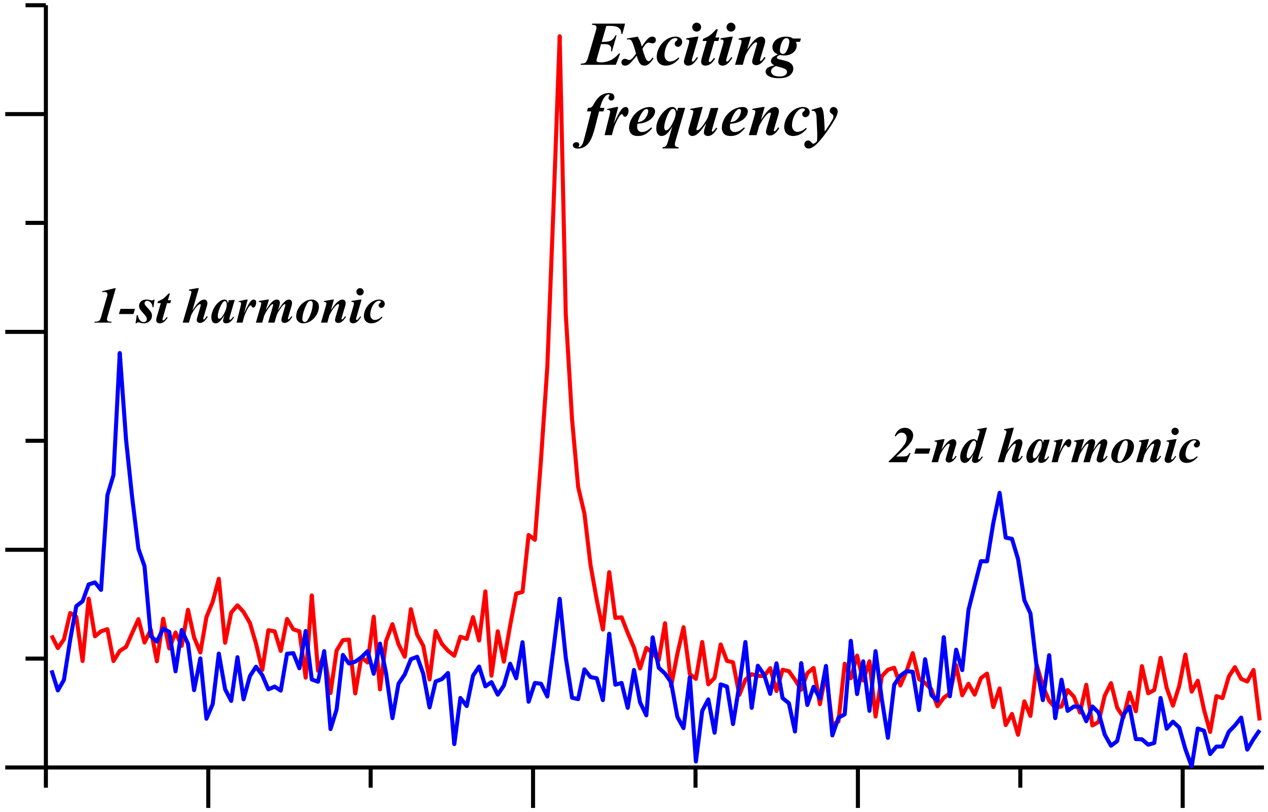


$$W_0 = 0.2 \quad and \quad 0.4$$

$$\mathrm{Re} = 2.4 * 10^3$$

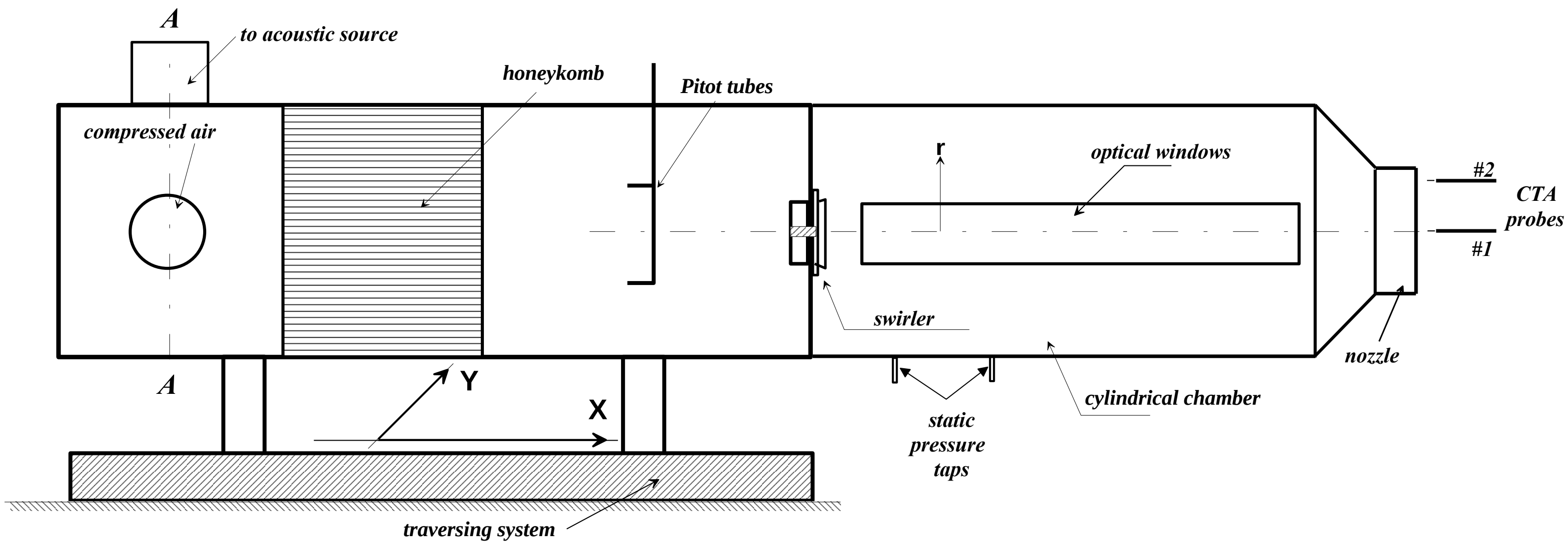
Yu Saiki · Yuji Suzuki · Nobuhide Kasagi.
"Active Control of Swirling Coaxial Jet Mixing with Manipulation of Large-Scale Vortical Structures."
Flow Turbulence Combust DOI 10.1007/s10494-010-9274-3

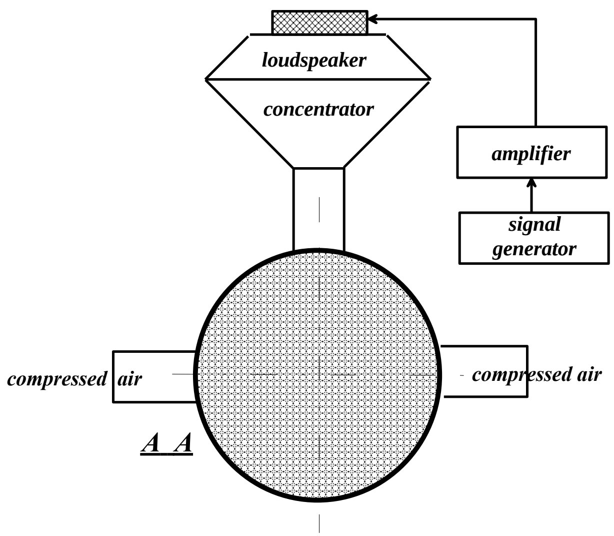
Possibility of acoustic control of the flow in swirling jet



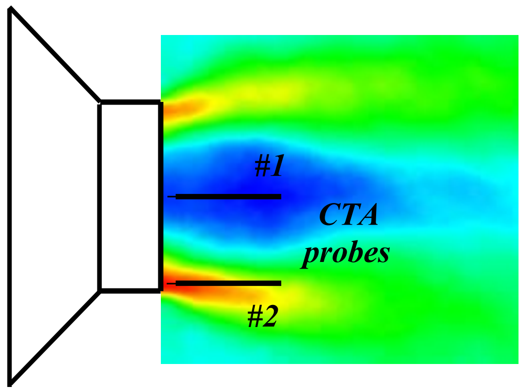
$$p'_{ac}/(\rho U^2/2) \approx 120\%$$

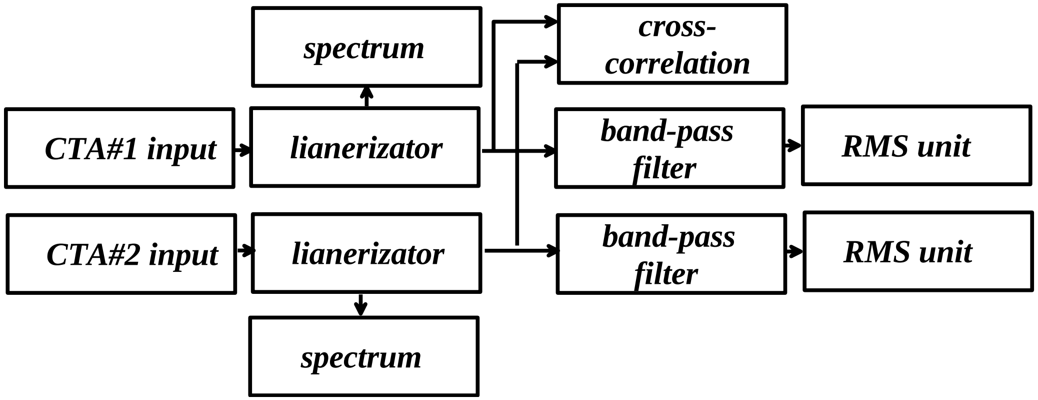
Possibility of acoustic control of the flow in swirling jet

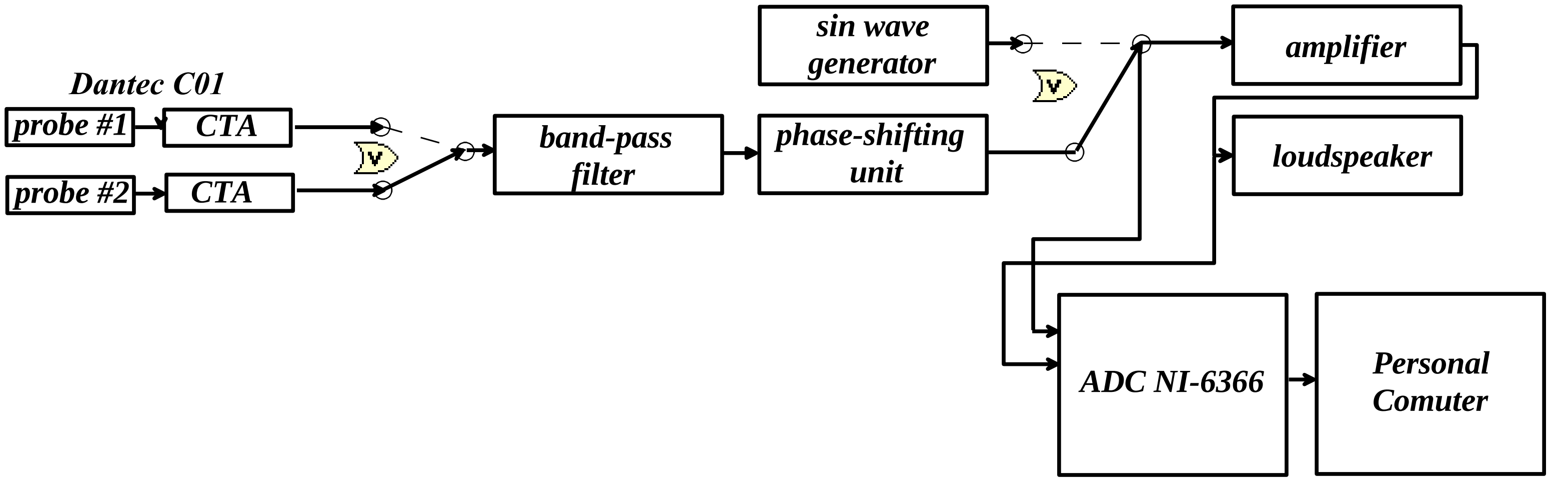




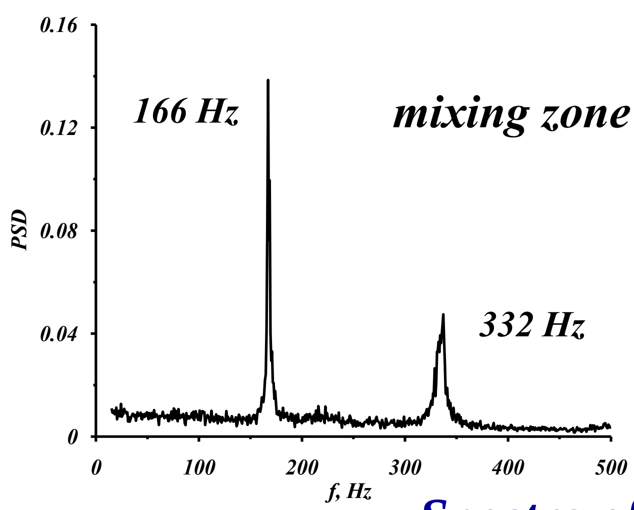
Possibility of acoustic control of the flow in swirling jet

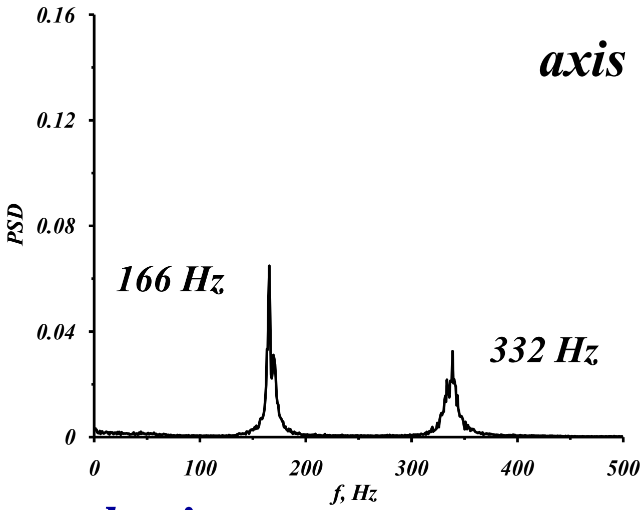






Possibility of acoustic control of the flow in swirling jet





Spectra of velocity pulsation

<u>Main regime:</u>

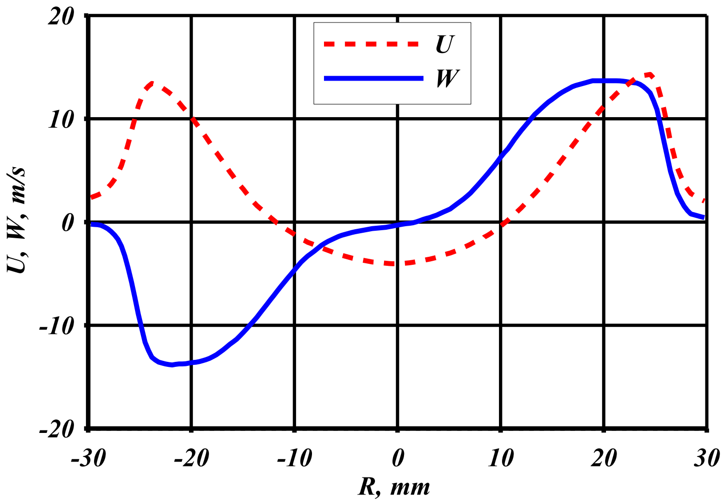
NPR=0.01 (Δ*P*=100 mm H_2O)

Swirling Number: W_0=1.76

First harmonic: *f*=166Hz

Excitation level: 0-130dB

(0-10% ΔP)

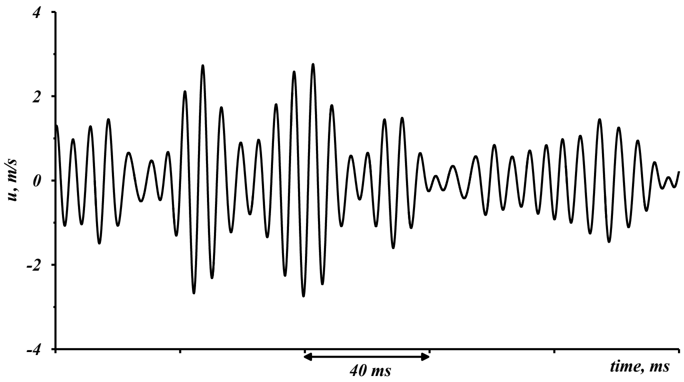


Profiles of velocity at the nozzle exit

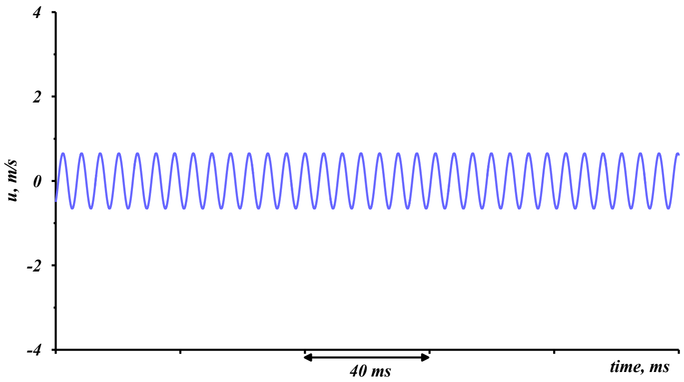
PIV measurements from previous work

Possibility of acoustic control of the flow in swirling jet

What did we expect to observe ?



Time history of filtered signal without sound excitation



Oscillogram of induced velocity

For example, if $A_1 = A_2$,

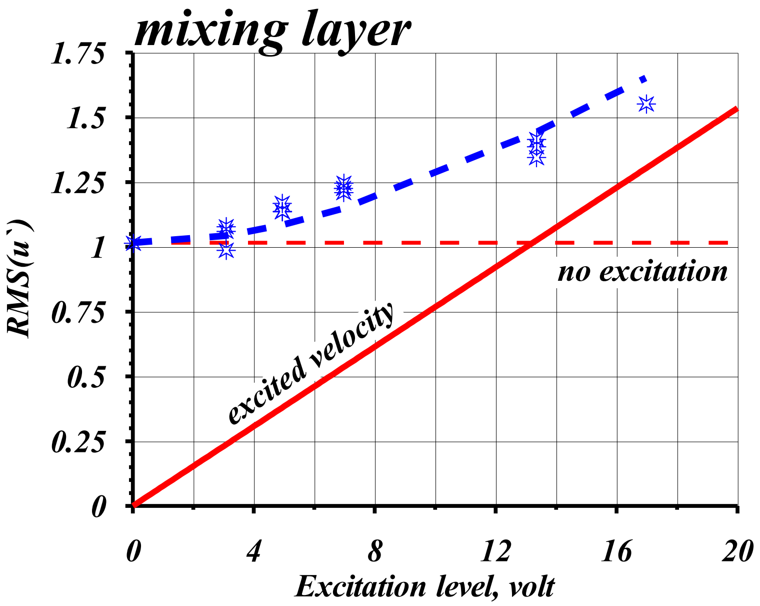
$$A_\Sigma = \sqrt{2}\, A_1 = \sqrt{2}\, A_2$$

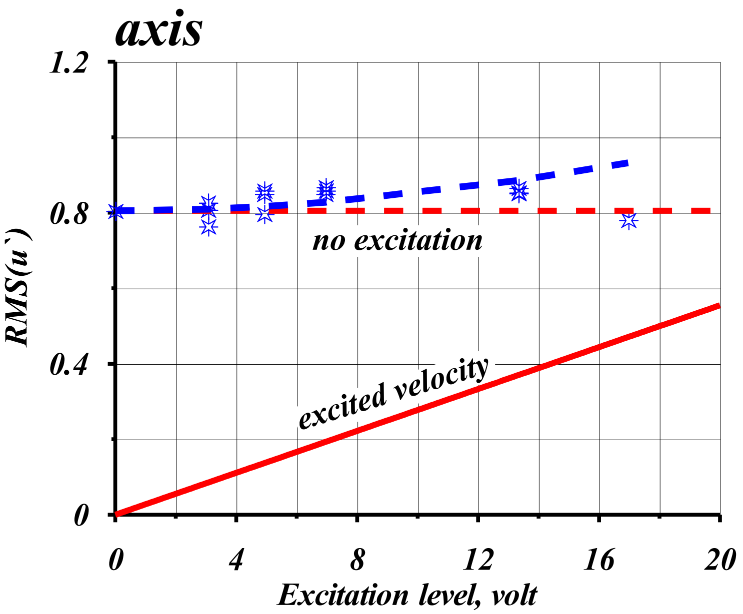
Independent signal (random phases)

$$A_\Sigma = A_1 + A_2 = 2A_1$$

Coherent signals

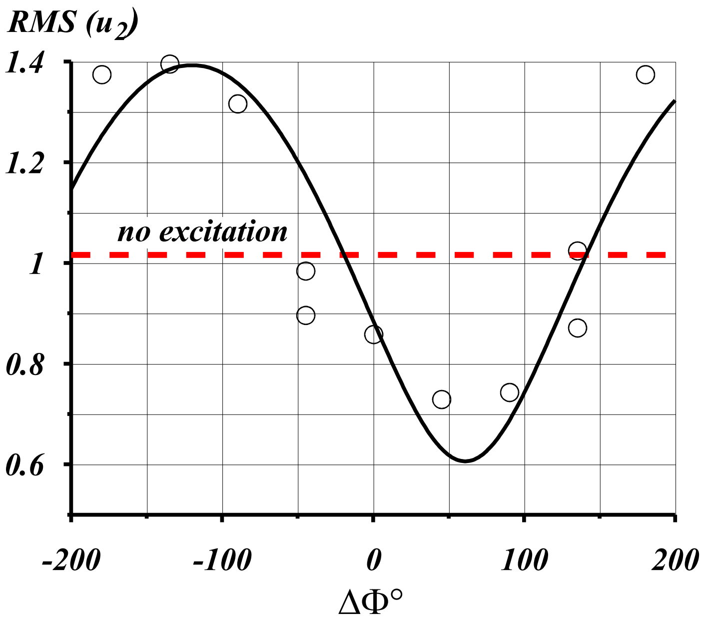
An influence of excitation on turbulent intensity (no signal synchronization)

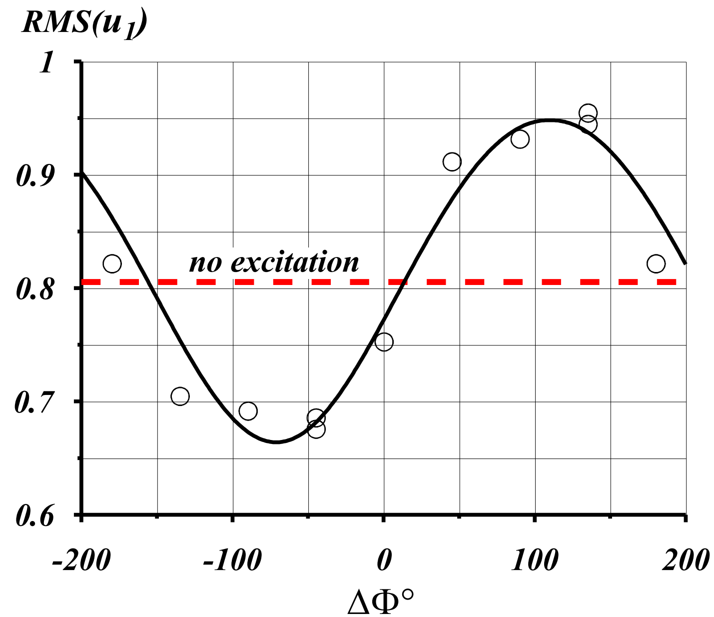


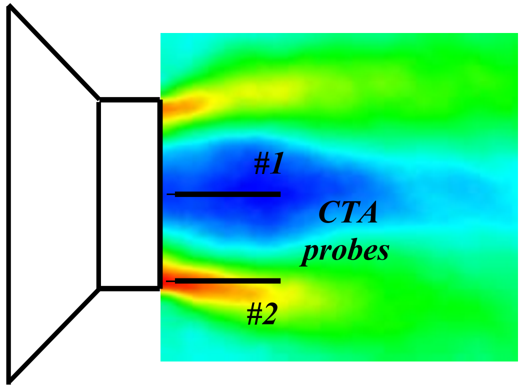


(No noticeable influence on mean velocity)

An influence of excitation on turbulent intensity (signal synchronization by CTA#1)

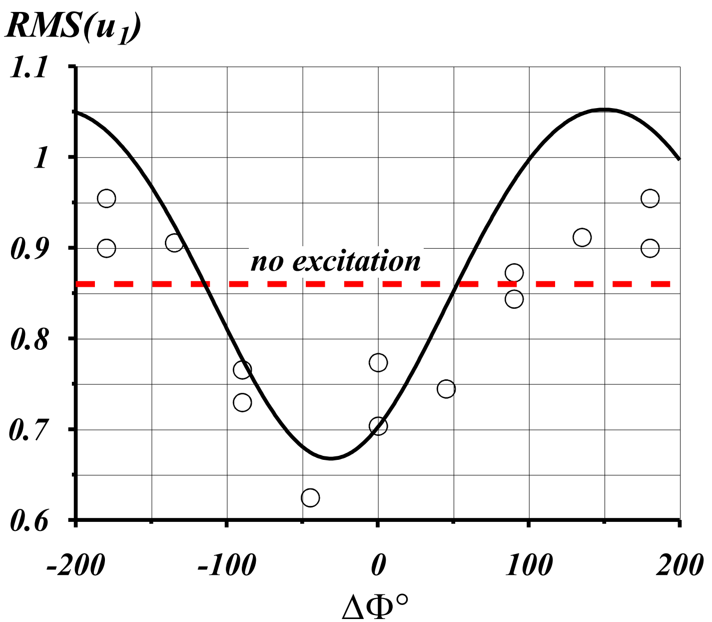


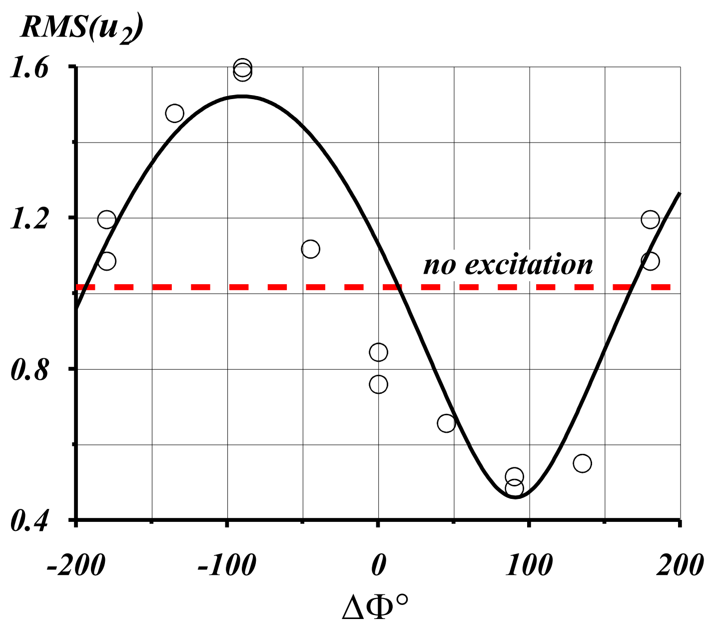


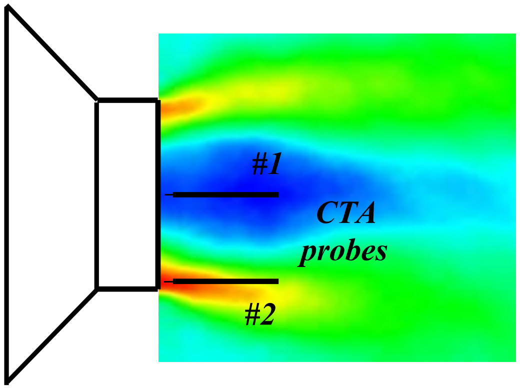


(No noticeable influence on mean velocity)

An influence of excitation on turbulent intensity (signal synchronization by CTA#2)







(No noticeable influence on mean velocity)

Conclusion

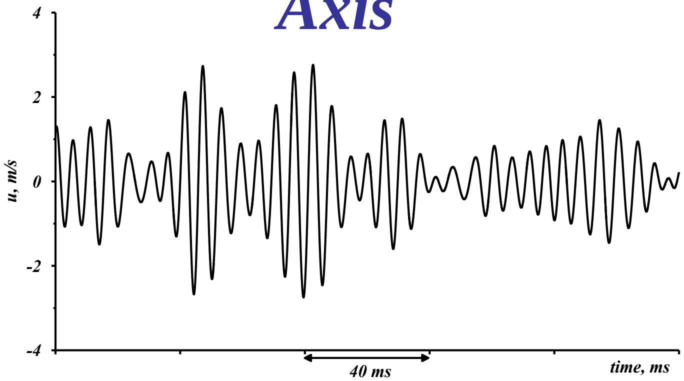
No remarkable influence of sound excitation on flow in swirling jet was found.

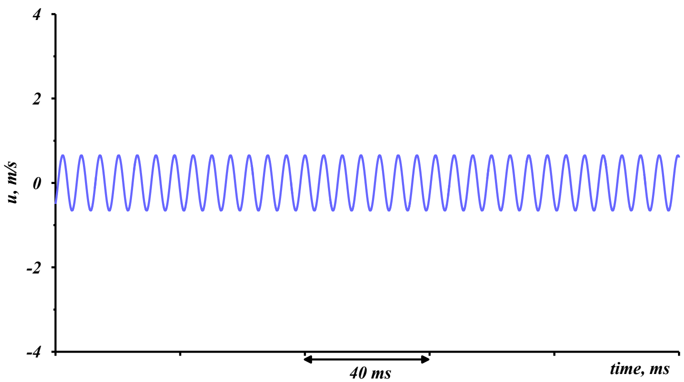
All observed effects are connected with simple energetic summing of turbulent pulsation and velocity in inducing sound wave.

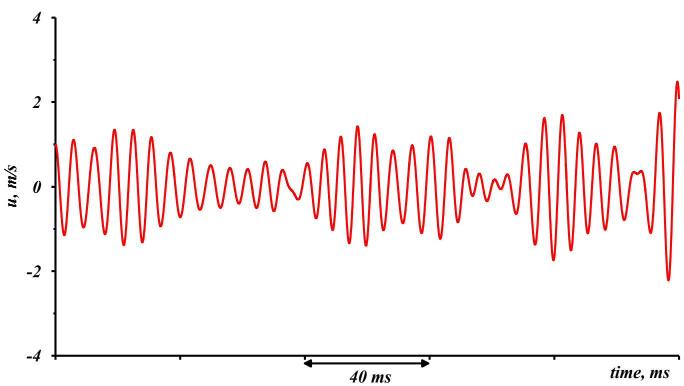
Спасибо за внимание!

Possibility of acoustic control of the flow in swirling jet

Axis







Mixing layer