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EXPERIMENTS WITH SYNTHETIC JET FOR DETECTING POTENTIAL TERRORISTS

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Abstract

Authors performed hot-wire anemometer investigations of the aerodynamics of an actuator designed to generate annular synthetic jets reaching to very large distances. The actuator is to be used for detecting illegal substances – and thus identifying terrorists and criminals who recently came into contact with explosives or drugs. It is designed to generate the synthetic jet with an annular cross section, thus creating between the nozzle exit and the cloth surface a space that is separated from the surrounding atmosphere in which in the present air-jet designs in detector the substance traces become diluted. The main problem encountered, because of the variability of the examined persons, is the need to reach to very large distances.

Keywords: *synthetic jets, annular jets, terrorism, hot-wire anemometry*

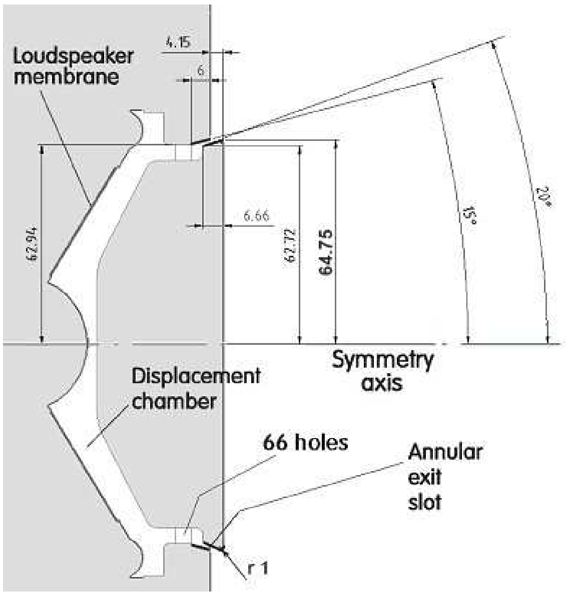
1. Introduction

In their previous paper [3], the authors describe the reasons why it may be useful to use an annular, low-frequency synthetic jet in the detectors used as an effective preventive measure for detecting traces of explosives and other dangerous substances left on clothes of those people who recently handled them. This detection is currently mostly done by trained dogs, which is rather expensive and cannot be made at the necessary very large scale in railway stations, airports, and public buildings. Also described in that paper is the layout of the proposed actuator combined with the collectors leading the examined substance traces into an analyser – and the laboratory model of the actuator used in the investigations. The main problem encountered, because of the variability of the examined persons, is the need to reach to very large distances.

As described by Tesař, Peszynski [3], the alternating flow in the annular nozzle was generated by standard woofer loudspeaker ARN-165-01/4 – Fig.1. In Fig. 2 photograph of the experimental setup is presented. The model actuator is at left, at right is the hot-wire anemometer probe moved in the meridian plane by the two mutually orthogonal traversing gears, the vertical one controlled directly by the data acquisition computer. The laboratory measurements, performed in the setup shown in Fig. 2, concentrated on measurement of air flow velocity in the generated synthetic jet.

The used instrumentation was the hot-wire anemometer system CTA 54T30 (DANTEC Dynamics) with standard single-wire probe type 55P16.

Actual program of experiments was rather extensive. In the present contribution, the discussion will be limited to the results of two experimental series, in both of which the evaluated quantity was the time-mean velocity magnitude, computed as the mean value of the velocity magnitudes acquired (and stored in the oscilloscope) at a particular location of the probe in the flowfield.



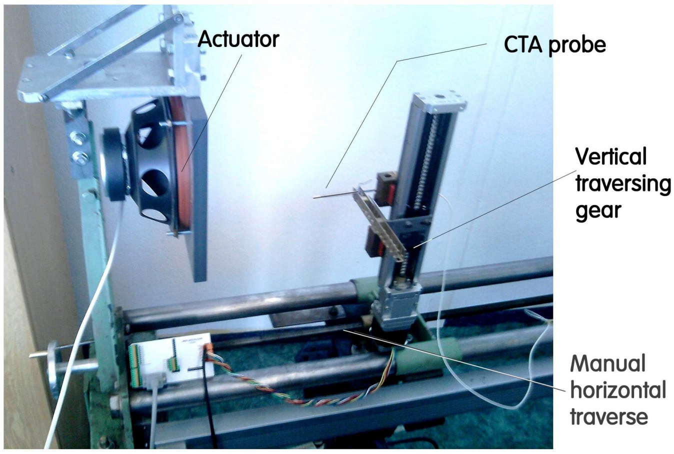


Fig. 1. (Left) Geometry and dimensions of the cavities of the actuator model

Fig. 2. (Right) The actuator model with the hot-wire probe traversing gear during the laboratory tests

2. Size of the recirculation region

In this first test series, the measurements were made in each location of the matrix of 20 x 14 measuring points separated by 5 mm steps: the upper 20 x 5 points of this matrix are visible in Fig. 4, which also shows typical character of the oscilloscope traces as they were observed in two locations near to the nozzle exit. The matrix points in this experiment nearest to the nozzle exit were at the 8.4 mm streamwise axial distance. This separation from the actuator components was chosen for avoiding any possibility of probe collision with them.

Over most of the matrix points, the measured time-mean velocity magnitudes were very small, indeed negligible. Thus of interest were only those locations near to the path of the annular jet issuing from the nozzle slit, as they are seen in Fig. 4. In this diagram, it was possible to identify, by interpolating between the matrix points at the same axial distance from the nozzle, the position of the velocity maxima. These are marked by the black data points in Fig. 4, where these points are connected by the continuous dark line. These points define the extent of the recirculation bubble.

Of course, as the jet width increases in the downstream direction due to the entrainment of the outer air, the precision of determining the maxima decreases. The velocity profiles became very flat and wide. Nevertheless, the maxima could be determined and in Fig. 5, only these maximum points defining the outer boundary of the recirculation bubble are shown. Even though it was not possible to perform the measurements at larger distances from the nozzle, it is obvious that the measured recirculation bubble is quite large – it extends to as far as ~120 mm downstream from the nozzle exit.

This value agrees comfortably with the requirement of the active distance for the proposed anti-terrorist application in the detection portals. Thus these measurements document the applicability of the actuator for this particular use. It should be noted that the experiment was performed with driving frequency f = 10 Hz, well below the audible range, which is a signify.

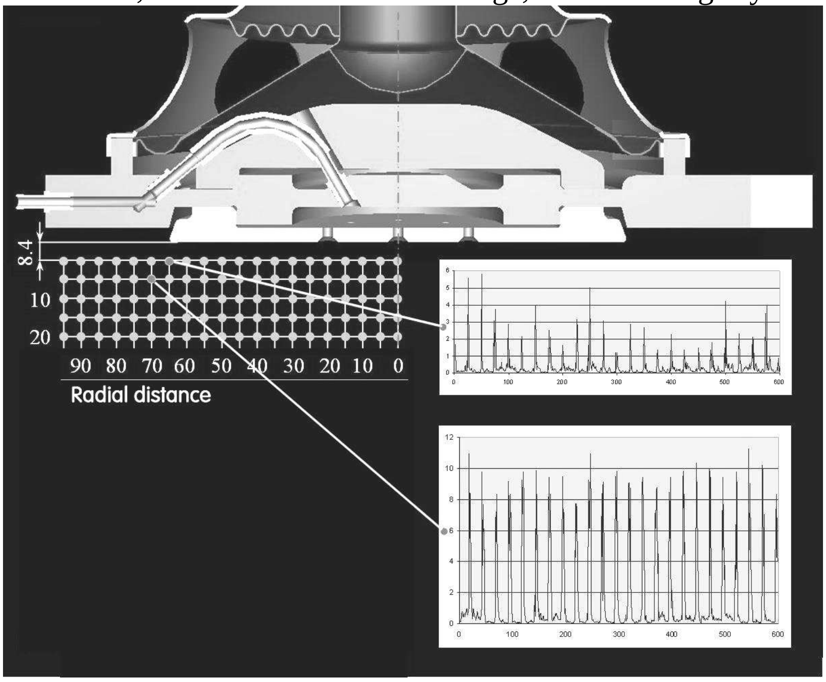


Fig. 3. Typical character of the oscilloscope traces obtained by the measurements near the nozzle exit.

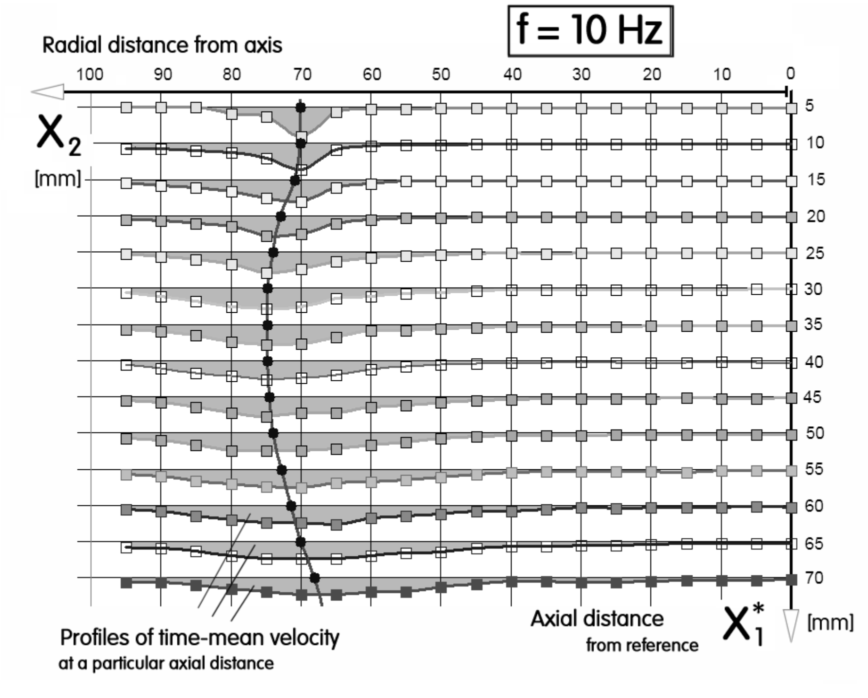


Fig. 4. Velocity measurements in the 5 mm x 5 mm step matrix of location points downstream from the actuator nozzle identified the positions of velocity maxima in individual streamwise profiles

cant factor for the applicability – and audible noisy device is not likely to be accepted by the general public

3. Details of velocity profiles and the effect of frequency

This second series of experiments concentrated on the conditions very near to the nozzle. The region in which the velocity magnitude measurements were made is presented in Fig. 3. Safe course of the experiments with the hot wire probe traversed near to the actuator component overcame the initial fears and the hot wire was now positioned as near as 2.4 mm streamwise from inner the core lip (extended from the outer frame). The transverse steps at which the probe was moved were decreased to 1 mm. The profiles were measured at driving frequencies gradually increased in 5 Hz steps from 5 Hz minimum to 65 Hz maximum value.

Typical examples of the velocity profiles obtained in this measurement series are presented in Fig. 8. They all exhibit a steep maximum roughly in the middle of the traversing range. Immediately apparent is the continuous increase of the velocity with the increasing driving frequency. Also apparent fact is the asymmetry: the velocities away from the maximum are visibly higher on the outer side (i.e. at radii larger than the radius of the nozzle slit measured from the jet axis). At first sight this asymmetry is somewhat strange. The diameter of the nozzle slit is so much larger than the nominal 1 mm slit width that an effect of radial divergence might be expected to be negligible. The explanation of this asymmetry effect we have at this moment is the omnidirectional sensitivity of the hot-wire probe (in the meridian plane) in association with the entrainment flow from outside. The higher velocities the probe found on the outer side are due to the inflow of the outer air from the atmosphere. No doubt another factor that may be responsible is also the already mentioned 4.15 mm stagger of the exit lips: the velocities on the inner side (at smaller radii) are measured at a smaller distance from the wall.

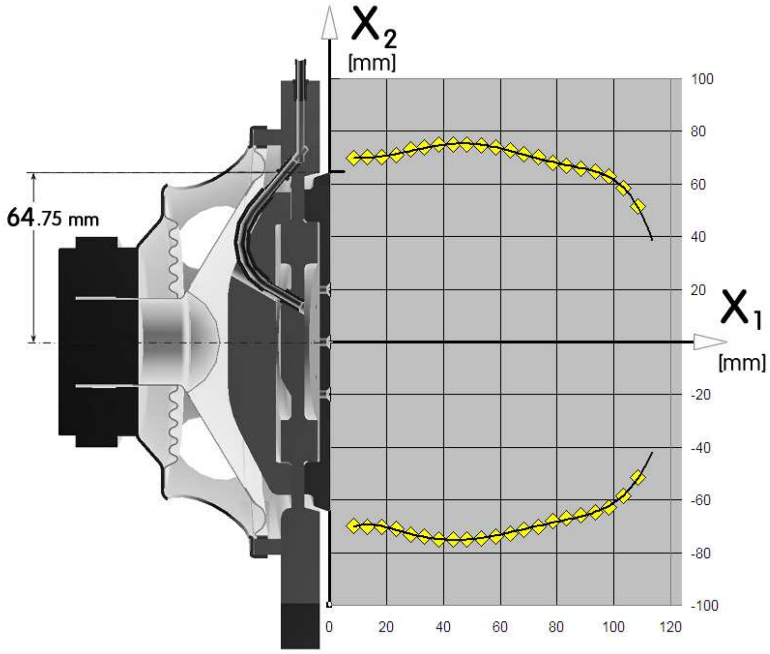


Fig. 5. The extent of the separation bubble identified from the velocity measurements as shown in Fig. 4. The annular synthetic jet was demonstrated to reach to a streamwise distance roughly comparable to the diameter of the nozzle slit.

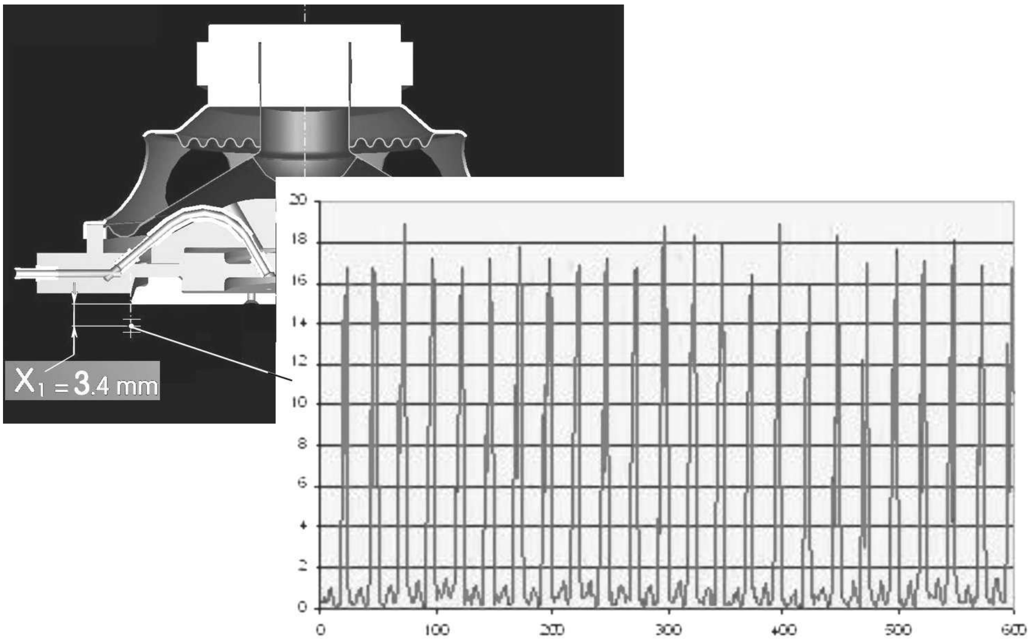


Fig. 6. Characteristic oscilloscope signal trace with the small secondary peak between the large velocity pulses, found in the locations immediately downstream from the nozzle generating the annular synthetic jet

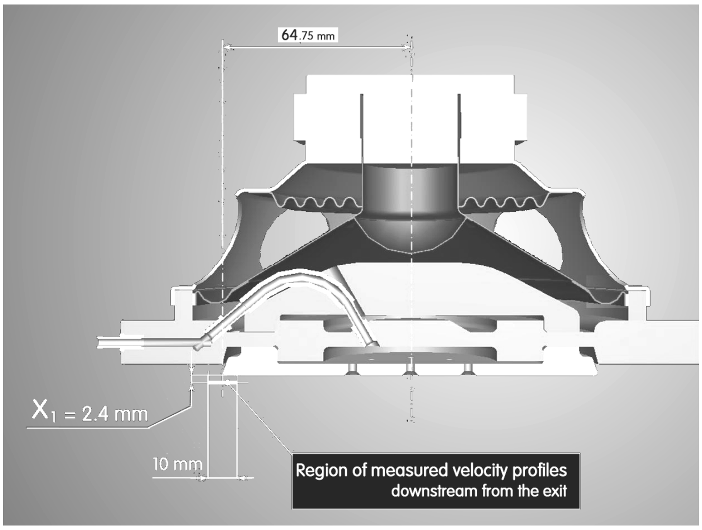


Fig. 7. Location of the region immediately downstream from the nozzle. The velocity profiles with the small, 1mm transverse step across the 10 mm wide range were investigated to reveal the influence of the excitation frequency

Another presentation of essemntially the same data is in Fig. 18. In this diagram, the velocity magnitudes at selected radial positions are plotted as a function of the driving frequency. All data pints presented there indicate a continuous growth of the velocity with increasing frequency. Initial slope of the growth is significantly larger. It slows at the frequency about ~25 Hz, but remains positive. Obviously, the 10 Hz driving applied in the experiments the result of which is shown in Fig. 4 is way below of what could be generated with the same actuator. Of course, the associated increase of the audible noise may make this simple way towards a higher effectiveness not acceptable from the practical point of view.

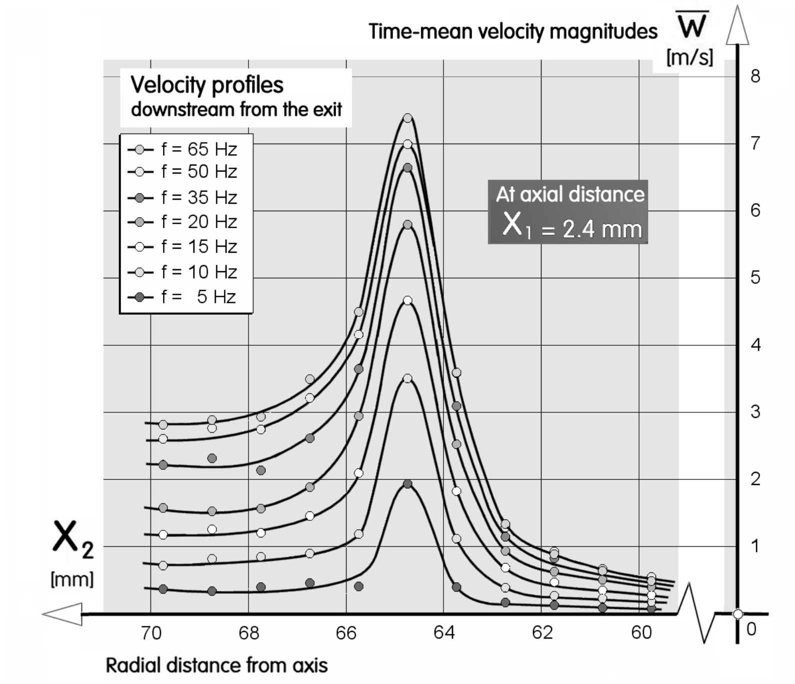


Fig. 8. The velocity magnitude profiles obtained by the measurements near the nozzle exit according to Fig. 7

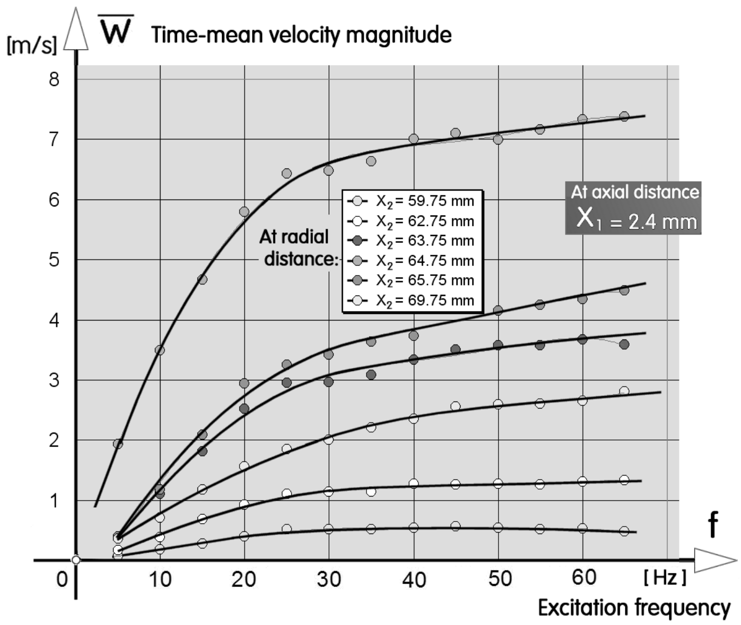


Fig. 9. The monotonous growths of the time-mean velocity with increasing excitation frequency in the profiles from Fig. 7

The response to the varied frequency of the investigated actuator was already investigated early – in particular it was the subject of the paper by Krejčí et al. [1]. These results were also presented in [24]. Rather surprisingly, the two sets investigation results disagree. In these previous experiments, the frequency dependence exhibited a clear maximum near to f = 40 Hz – evaluated not only in a series of experiments but also predicted theoretically by Dr. Trávníček. The explanation of this enigmatic fact is to be our next task in foreseeable future. One of the key factors to be considered is the circumstance of the frequency dependence measured by by Krejčí et al., [1], by means of a Pitot probe (of 0.8 mm i.d., positioned at a location 2 mm downstream from the annular nozzle exit). Another circumstance to be considered is the fact that in the Krejčí et al. measurements the electric driving power was closely watched and adjusted – in the present case, this was not done and the actual driving power could be influenced by the frequency characteristic of the driving source.

5. Conclusions

The experimental data support the basic idea of the infrasonic long-range annular synthetic jet detector and actuator. The data were also used in the concurrent numerical flowfield computations performed by doc. J. Vogel, see [6], with a complete success. Apart from the time-mean velocity distributions, reported in the present paper, we have also accumulated data on the spatial distributions of energy of fluctuation, evaluated by the same approach as described in Tesař and Kordík [7, 8]0. The data demonstrate applicability of the concept.

6. Acknowledgement

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