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SYNTHETIC JET APPLIED TO DETECT POTENTIAL TERRORISTS

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Abstract

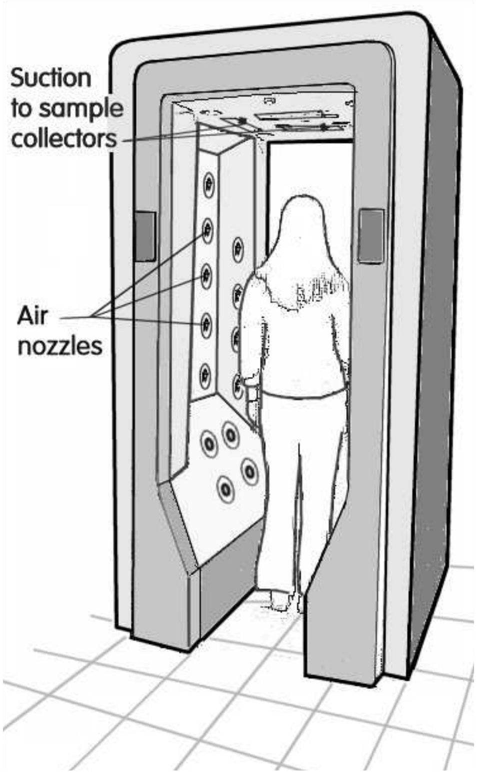
As an alternative to impinging steady flow jets used in detectors of illegal substance traces on clothings of people who recently came into contact with explosives or drugs, authors investigated synthetic jets with zero time-mean nozzle flow rate. The actuator designed to generate the synthetic jet has an unusual annular nozzle, creating between the nozzle exit and the cloth surface a space separated from the surrounding atmosphere. The detected traces are carried through this space to the detector inlet. The 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, detection of illegal material*

1. Introduction

Terrorism became one of the fundamental problems at the beginning of 21st century. The critical factor behind the relative success of terrorists is economy favouring the terrorist's activity [1]. It is much cheaper to perform the attack than to prevent it. The crude explosive devices terrorists use are inexpensive while securing safety requires deploying, maintaining, and manning costly systems and organisations. Essential is early warning which, to be an efficient deterrent, calls for large numbers of detectors deployed at many locations. The most effective preventive measure is 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. These are almost always in short supply, and their long-term training and the need for dedicated supervisor persons are very expensive.

Technology replacing the detection by dogs has been gradually developing, in its most effective form consisting of the detectors arranged in into portal units (Fig. 1) through which persons have to pass one by one [3]. Their operation actually, to a certain degree, mimics the detection as performed by dogs, which is done in two phases. To release the detected substances from the surface on which they are immobilised, in the first phase dog generates jets of air exhaled from lungs. In the subsequent second phase this alternates with inhaling by which the air with released substances is moved towards the olfactory sensing organs. The problem is the required extreme sensitivity of the analyser. In the current portal units this problem is aggravated by the acting air jets (Fig. 2) that inevitable disperse the released, already very small traces, into the surrounding atmosphere. The collectors taking the sample into the analyzer are usually positioned in the top part of the portal (using the thermal air convection currents produced by the person). Obviously, the traces reaching the collectors are very much diluted.



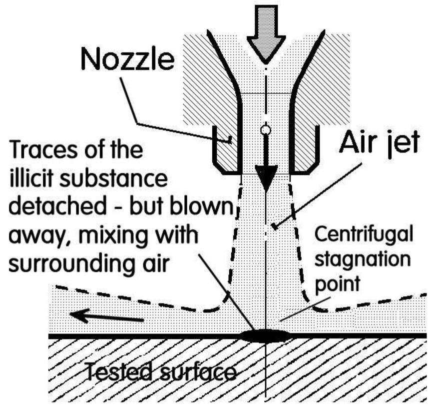


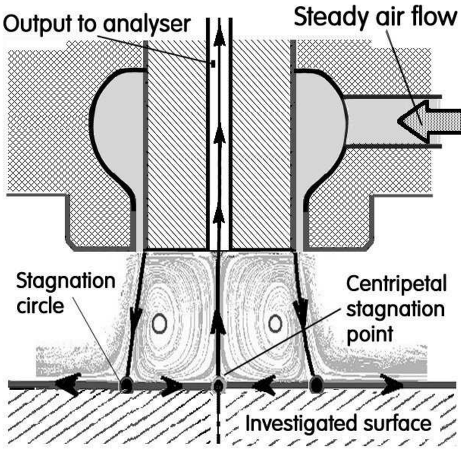
Fig. 1. (Left) A typical present-day portal detector with air-jet actuators unit for releasing traces of dangerous and illegal substances from clothes of persons passing through them

Fig. 2. (Right) The air jets used in present detectors mix the critically small amounts of detectable traces uncontrollably with surrounding atmospheric air

This dilution will be decreased, according to Fig. 3, if the nozzles that generate the air jet are provided with an annular exit - and are combined with the collector, leading to the analyser. The jet surrounds the space in which the detected substances move away from the investigated surface. The generated annular jet provides a protection of this space, preventing an uncontrollable mixing of the sample with the atmospheric air. Nevertheless, the annular jet is also formed by bringing into the detection space a relatively large amount of additional air (supplied from a compressor) and the sample is inevitable mixed with some of this air. A solution is proposed [20] in using the annular synthetic jet, according to Fig. 4. This is formed by means of the aerodynamic rectification phenomenon [9, 15], which was investigated by the present principal author for uses in fluidic systems [5, 6, 7, 8, 9, 10, 12,13] before it received its present name by prof. Glezer [4].

2. Investigated laboratory model 85

For verification of the idea, present authors investigated a laboratory model of the detector combined with the synthetic-jet actuator, based on the idea presented in Fig. 5. To reach the necessary large distances, the annular nozzle is of a very large 130 mm diameter. For generation of the alternating flow the actuator uses a standard loudspeaker, as shown in section view in Fig. 6. To minimise the problems associated with the acoustic noise, the actuator was operated at an infrasonic frequency 0 – 20 Hz. The loudspeaker was therefore a low-frequency woofer ARN-165-01/4 of rated short-term maximum power 100 W; actually operated throughout the tests by harmonic driving signal at much lower electric input power 4 W.



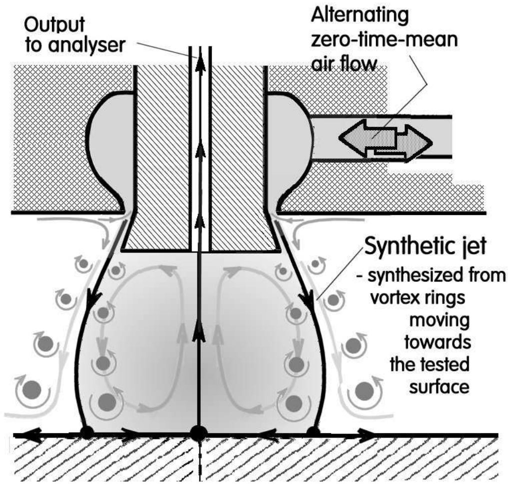


Fig. 3. (Left) An annular jet can surround the space between the collector leading to the analyser and the source of the detected substances - so that the latter are prevented from moving away into the atmosphere. However, the large amounts of supplied air still mix with the small amounts of the substances and this places extreme requirements on analyser sensitivity

Fig. 4 (Right) The proposed alternative: synthetic annular jet with zero time-mean supplied air flow. The pulsatile character also helps in releasing the detected traces from the surface

The basic question to be answered by the performed laboratory tests was how large action distance between the annular nozzle exit and the investigated surface (the textile on the clothing surface of the person) may be achieved. The problem with the recirculation regions formed by annular nozzles, both for steady (Fig. 2) and synthetic (Fig. 3) jets, is they tend to be decreased by the radial pressure forces generated by the entrainment of the surrounding air into the jet. The generated annular jet removes the air from the internal protected space and carries it away. This generates low pressure in this space and this effect leads to convergence of the outer boundaries.

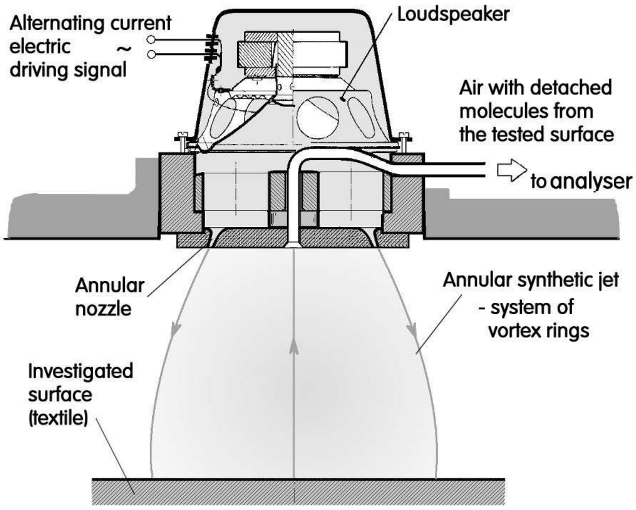


Fig. 5. The basic idea of the detector sensor combined with an actuator generating an annular synthetic jet [20]

To counter the convergence of the time-mean pathlines of the issuing flow, the nozzle was designed with significant radial outward diverging orientation of the exit velocity vector. This makes the recirculating region wider: the apex half-angles of the inner and outer cones are 20° and 15°, respectively. Moreover, also to direct the issuing jet more into the outward direction, the nozzle orifice was designed with the 4.15 mm stagger of the exit lips (the internal core is longer than the outer frame). The (nominal) width of the nozzle slot is b = 1 mm. The inner diameter of the exit is defined by the exchangeable centrebody plate, which also contains the 9 collector orifices through which the suction is to be applied to remove the sample and send it into the analyser. In the present investigations these orifices were closed off and the centrebody plate was not changed. Earlier experience with pulsating flow through orifices [17] have shown that the efficiency of generating the alternating output flow may be significantly decreased by the capacitance [14] of the cavities upstream from the exit. Instead of forming the jet, the pulsating supply tends just to compress and expand the air inside the cavities. To suppress this effect, the volume inside the conical membrane of the loudspeaker was decreased by the inserted solid centrebody.

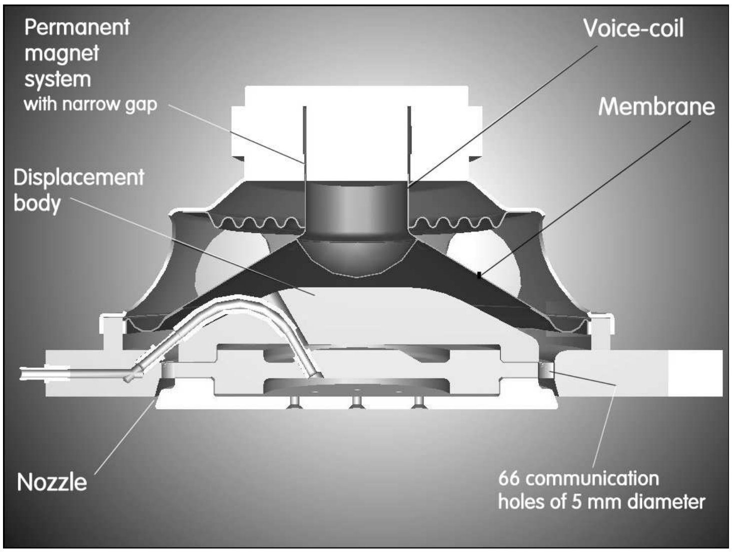


Fig. 6. The actuator model – shown in meridian section - used by the authors in their experiment. The key component is a standard loudspeaker ARN-165-01/4 .

3. Experiments

As described above, the alternating flow in the annular nozzle was generated by standard woofer loudspeaker ARN-165-01/4. The nominal diameter of the annular nozzle exit was 130 mm. The measurements performed by the authors concentrated on measuring 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. The probe was traversed in the radial direction by an automatic traversing gear, driven by a stepping motor. At each location the probe remained stationary for the duration of the data acquisition. The computer control of the traversing, as well as an elegant method of data acquisition using the data storage properties of the digital oscilloscope RIGOL DC 1042CD. Before the actual experiment, the anemometric system was calibrated by comparison with Pitot probe positioned into the same location in the potential core of an auxiliary air jet. The parameters of the adjustment – in particular the probe currents – were used as supplied by the probe and anemometer manufacturer. Since the measured velocities in the actual experiment were in most of the jet flow-field very low, the calibration procedure was set up so as to concentrate on the low-velocity end of the range. The calibration diagram and the quadratic law by which it was fitted are presented in Fig. 7.

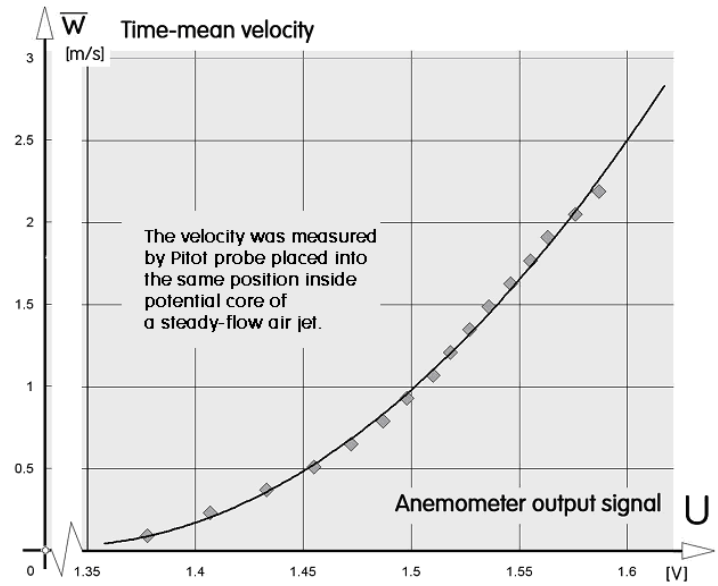


Fig. 7. Calibration curve of the hot-wire probe as used in the tests. The calibration procedure was specially set up so as to reach the range of very low velocities

It should be noted that because of the probe being of the single-wire type, it was sensitive not only to the axial component of the air flow velocity, but also to the radial component – since the heated wire was held oriented with its axis in the tangential direction relative to the nozzle axis. This is why – given the negligible tangential velocity component – the measured value is here described as velocity magnitude. Also, as usual with hot-wire probes, it was impossible to discriminate between positive and negative direction of the velocity.

3. Conclusions

The paper describes the purpose and the layout of the investigated laboratory model of an annular synthetic jet designed to reach to very large axial distances. The main reason for the measurements was accumulating data to be used in the concurrent numerical flowfield computations performed by doc. J. Vogel, see [21]. This was done with a complete success. Apart from the time-mean velocity distributions, to be reported in a forthcoming paper, we have also accumulated data on the spatial distributions of energy of fluctuation, evaluated by the same approach as described in [17, 18].

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