National Conference with International Participation
ENGINEERING MECHANICS 2003
Svratka, Czech Republic, May 12 – 15, 2003
paper no. 232

CONTINUOUS VISUALIZATION OF FLOW IN POWER FLUIDIC ELEMENTS AND BASIC ANALYSIS

K. Peszyński[1], **S. Wawrzyniak**[2]

Summary: *So far* v*isualization of the flow, [1] has involved heating the wire with paraffin oil placed across the horizontal axis of the nozzle. The point of the idea of a continuous visualization is to change a hot wire for a thin pipe with holes for steam of paraffin. The digital camcorder was used. For improvement of visibility, optical arrangement was used. The air stream is illuminated by a bundle of light with a defined thickness. The quantity of paraffin steam depends on tension of alternating current.*

1. Introduction

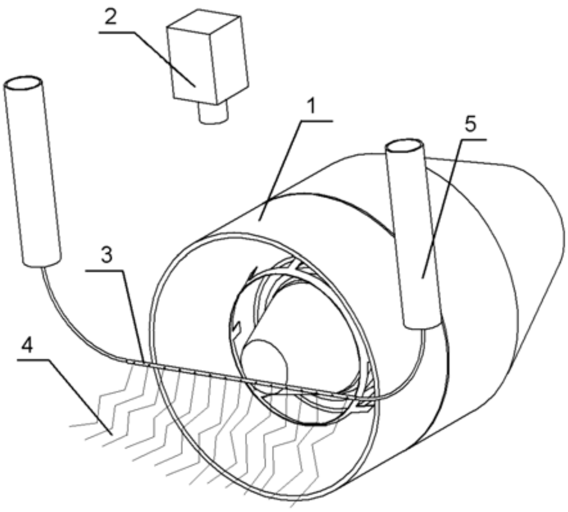

Fig. 1. Diagram of continuous visualization of flow: 1 – nozzle, 2 – camcorder, 3 – heating pipe, 4 – steam of paraffin, 5 – tank of paraffin oil.

So far the solution of visualization of flow in fluidic involves consists in placing a thin wire with put on paraffin oil perpendicularly to the nozzle axis, heating it up, and taking photographs of the phenomenon created by paraffin smog. This solution gives only a short-

University of Technology and Agriculture in Bydgoszcz, Faculty of Mechanical Engineering, Department of Control and Machinery Design 85-791 Bydgoszcz, Prof. S. Kaliskiego 7, Poland
[1] Dr ing. Kazimierz Peszyński e-mail: peszyn@mail.atr.bydgoszcz.pl
[2] Ing. Sylwester Wawrzyniak, e-mail: sylas@mail.atr.bydgoszcz.pl

time visualization effect. Little amount of paraffin which is located on the wire doesn’t allow observation of the phenomena for long time. Additional disadvantage of this method is the problem with synchronization between turning on the heating and taking the photograph. The aim of carrying out the research was to design a stand for continuous flow visualization and performance of an initial research of flow. Under investigation was flow from an axi-symmetric nozzle which was designed in Department of Control and Machinery Design [2].

The presented in Fig 1 stand enables continuous visualization of the jet and registration of occurring phenomena by using a camcorder. The wire was substituted by a thin tube. In the tube there were made small holes for the paraffin oil vapor to flow out. The tube is resistance heated. The camcorder was placed over the exit of the investigated nozzle and makes it possible to register the flow with paraffin oil vapor.

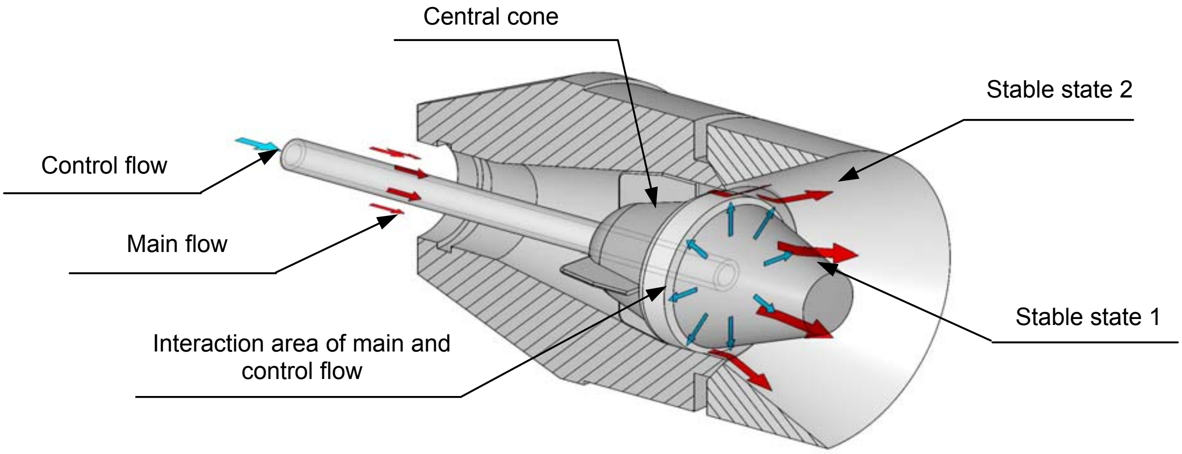

Fig. 2. The axi-symmetric nozzle

The nozzle operation is based upon the Coanda effect of attachment of a jet to a wall - in an axisymmetric geometry, with two attachment walls. Both walls are conical - the outer one is a concave, hollow cone, the inner one is a convex. cone, formed by the end of the central body. generates a narrow fluid jet. Small control flow is admitted into the cavity in the central body if the jet is to be changed into a wide slow one. The annular nozzle exit was made by fixing the central body to the end of the pipe. The outer diameter of the exit is 88 mm, inner diameter is 65 mm. The end of the central body is formed as a 80 mm long, 55 mm base diameter cone with truncated tip. This conical surface forms the inner attachment wall to which the flow leaving the annular nozzle adheres by the action of the Coanda effect.

2. Measurement parameters

The basic investigations were carried out for jets impinging on the wall placed opposite to the nozzle. Topology of output jet for all different distances between the wall and the nozzle was investigated. Furthermore the influence of changes of the arrangement of the angle between the axis of the nozzle and the normal to the wall on the shape of the output jet was examined. Investigations carried out for jets impinging on the wall require modification of the existing stand. The introduced modification involves in using transparent material for the wall. From behind this wall the beam of light was sent for the jet lighting. It enabled direct and even lighting of the whole width of the investigated cross-section.

Investigations were carried out for following parameters: input velocity of flow $v = 3\,\mathrm{m/s}$, flow rate for this velocity was $Q_V = 0{,}004985\,\mathrm{m^3/s}$, control flow rate was $Q_c = 0{,}000833\,\mathrm{m^3/s}$. Measurements for following angles between the nozzle axis and normal to the wall were $\alpha = 0°, 15°, 30°$. Variable was the distance between the end of the nozzle and the wall, measured along the nozzle axis. Following measurement distances from $x = 25\,\mathrm{mm}$ to $x = 225\,\mathrm{mm}$, step $\Delta x = 25\,\mathrm{mm}$ were chosen. Rhe given values of variables were presented in table 1.

Table 1. Setting-up of angle parameters and distances of wall from the nozzle.

		Distance form the wall x [mm]									
		25	50	75	100	125	150	175	200	225	250
Angle α[°]	0	X	X	X	X	X	X	X	X	X	X
	15			X	X	X	X	X	X	X	X
	30					X	X	X	X	X	X

The above table shows for which parameters of angle and distances of wall from the nozzle the measurements were performed. Cells filled with X inform about possibility of carrying out measurements. The area marked by thick line can't be a subject of measurements for technical reasons connected with difficulties of the wall arrangement to the nozzle.

After measurements were carried out, the results taken by camcorder were copied to personal computer PC. Behavior of jet flow with respect to angle parameters and distances of the wall from the nozzle were analyzed.

3. Measurement results

Because restrains connected with the size of files in the this paper only chosen frames from the registered films will be presented.

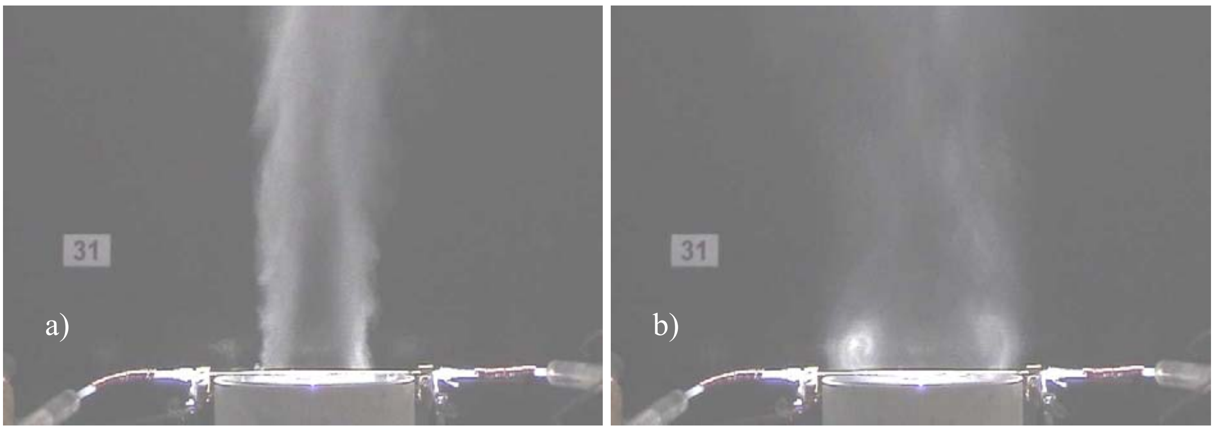

Fig. 3. Frames from film without the wall: a) first stable state, b) second stable state.

Performed research permits to make an initial analysis of jet behavior which flows out from the nozzle impinging the wall placed in front of the nozzle. Especially behavior of toroidal vortex, arising in the second stable state, is of very interest to us. The presented bellow figures show chosen film frames.

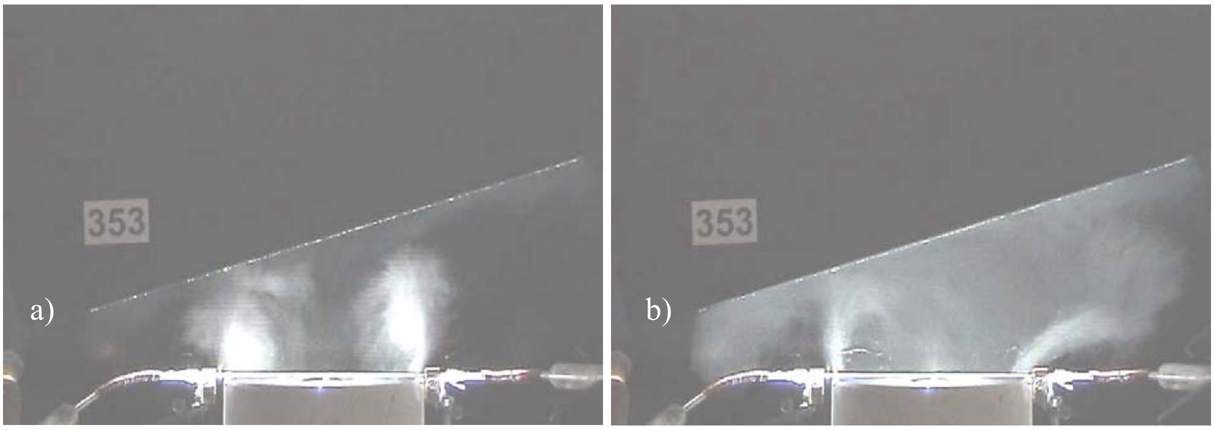

Fig. 4. Frames from film with the wall. The distance of the wall from the nozzle is $x = 100\,\text{mm}$, $\alpha = 15°$ a) the beginning of rising second stable state b) second stable for continuous contact with the wall.

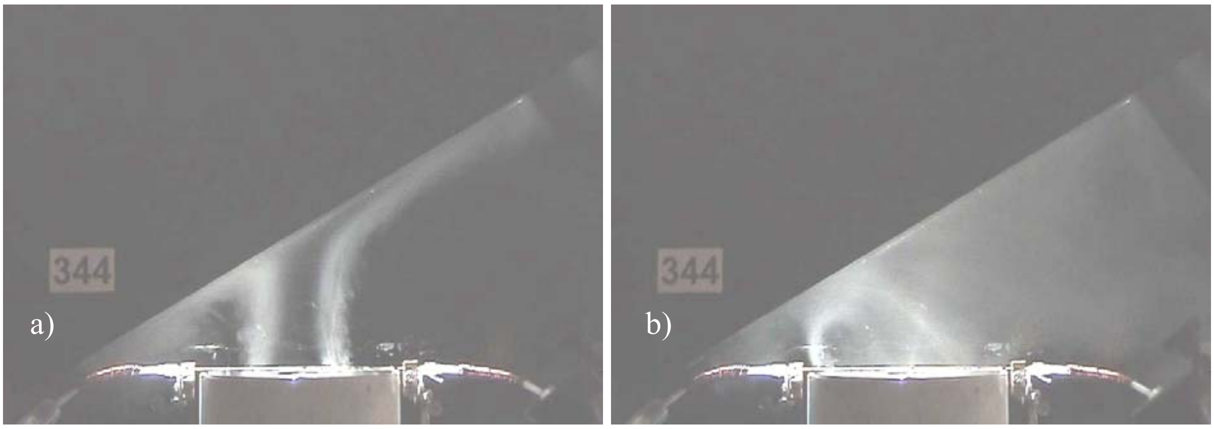

Fig. 5. Frames from film with the wall. The distance of the wall from the nozzle is $x = 125\,\text{mm}$, $\alpha = 30°$ a) first stable state, b) second stable state.

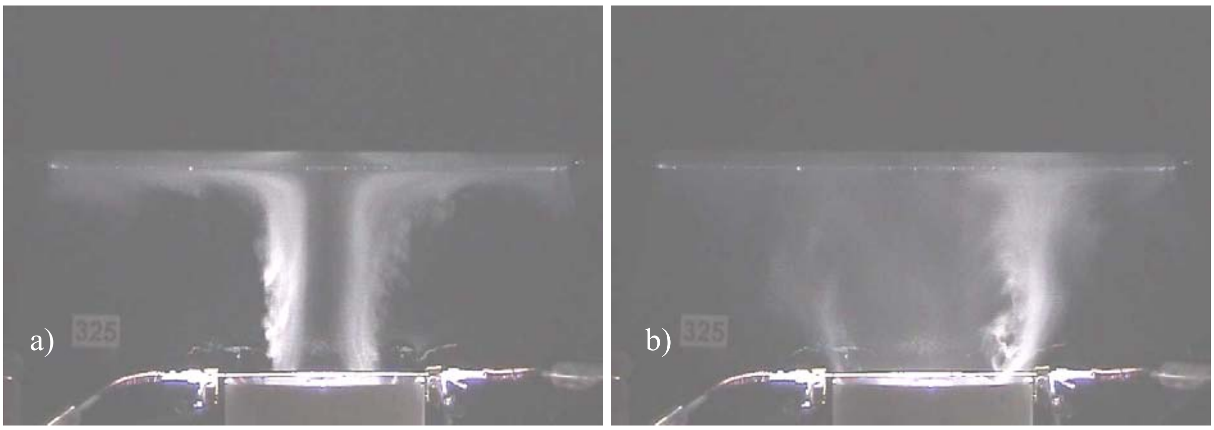

Fig. 6. Frames from film with the wall. The distance of the wall from the nozzle is $x = 150\,\text{mm}$, $\alpha = 0°$ a) first stable state, b) second stable state.

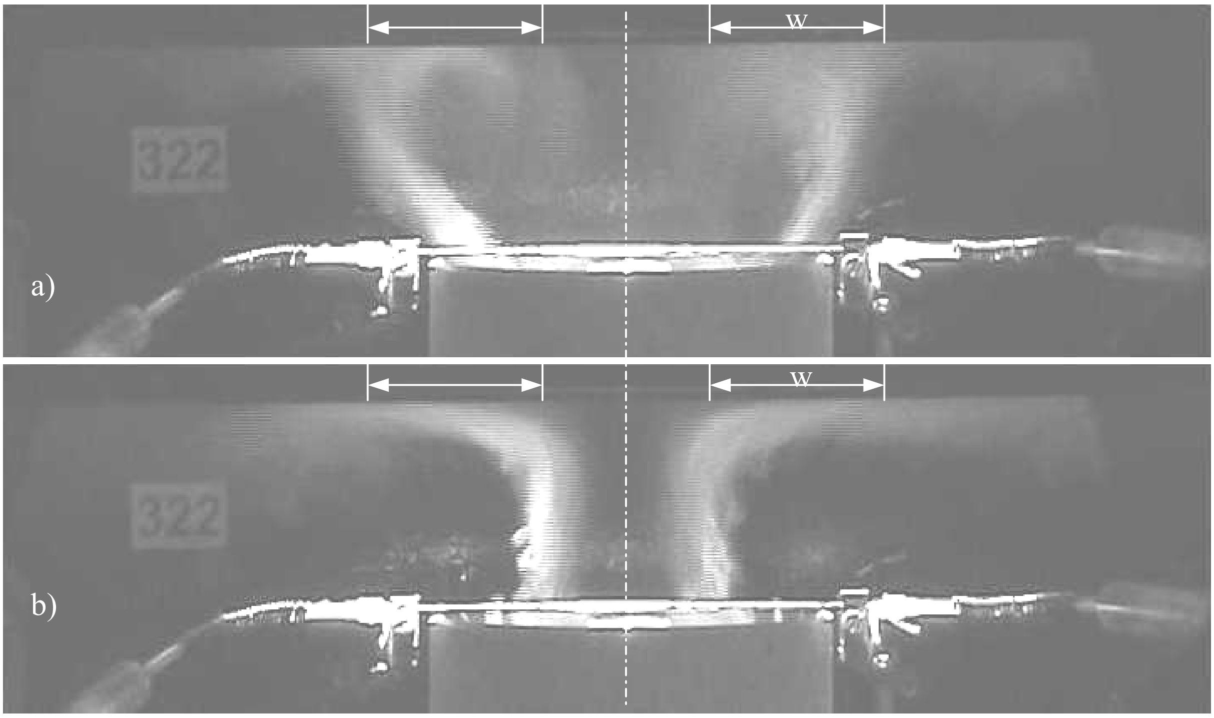

Fig. 7. Frames from film with the wall. The wall is in distance $x = 75\,\mathrm{mm}$, $\alpha = 0°$ a) first stable state, b) second stable state, w - area of changing velocity vector of wall jet impinging

The presented above Figures show chosen frames from films. Frames presented in Fig. 3 show the behavior in two stable states. The vortex visible in Fig. 2 is a toroidal vortex rising in the second state, whose behavior is the subject of the present investigations. Fig. 4 and Fig. 5 show the air jet during impinging the wall situated at an angle different from zero. For the wall situation angle $\alpha = 15°$ a toroidal vortex in the second stable state was created only for the wall distances $x = 175\,\mathrm{mm}$, $x = 200\,\mathrm{mm}$, $x = 225\,\mathrm{mm}$, and $x = 250\,\mathrm{mm}$. For the wall situated at the angle $\alpha = 30°$ the jet was stable only for the distances $x = 200\,\mathrm{mm}$, $x = 225\,\mathrm{mm}$, and $x = 250\,\mathrm{mm}$. For the distance $x = 175\,\mathrm{mm}$ the first signs of lack of stability appeared.

Figure 6 shows the jet impinging the wall situated perpendicularly to the nozzle axis, which is placed in the distance $x = 150\,\mathrm{mm}$, Fig. 6a) shows the stream in the first stable state, Fig. 6b) shows it in the second state. Jet interferences which do not allow rising a clear toroidal vortex which is formed for other distances of the wall from the nozzle are visible here.

For the wall situated at the angle $\alpha = 0°$ the vortex seen in Fig.. 3b was created for all distances of the wall from the nozzle with the exception of $x = 125\,\mathrm{mm}$ and $x = 150\,\mathrm{mm}$. For these distances there occurred jet interferences is characterized by lack of clear vortexes or creation of only one vortex. For distances smaller then the above ones as for example $x = 75\,\mathrm{mm}$ such vortexes were created, Fig. 7a is an example. In Fig. 7 a setting up of the first and the second states is presented. Jet vortexes rising near the wall are visible. This setting shows us an easily seen area with ring cross-section whose width is w, and on which during changing the jet state there can be noticed a clear change of the direction of the air jet flowing around the wall. For the distance $x = 25\,\mathrm{mm}$ these vortexes also occur however the area of clear change of the direction of flow near the wall is definitely smaller then the area which is created for longer distances.

The situation is similar to the results of observation of the jet near the wall placed at an angle to the nozzle symmetry axis. For the distances $x = 175\,\mathrm{mm}$, $x = 200\,\mathrm{mm}$, $x = 225\,\mathrm{mm}$, and $x = 250\,\mathrm{mm}$ for angles $\alpha = 15°$ and $\alpha = 30°$ the vortex occurring in the second stable state was clearly seen. For shorter distances interferences caused by the presence of the wall did not allow its rising. In the observed cross-section the whole jet changes its flow direction being somehow pushed away by the part of the jet impinging the part of the wall which is closer to the nozzle.

4. Results analysis and conclusions

The aim of the carried out laboratory investigations was to characterize the influence parameters of impinging wall arrangement on air jet flowing from the axi-symmetric nozzle with the central body. Under observation was jet in two stable sates, with particular attention paid on second stable state.

Presented results let us state, that the most important parameter which has a crucial influence on stable state is the distance between the impinging wall and the nozzle, marked as x. The wall position larger then $x = 150\,\mathrm{mm}$ makes it possible for the toroidal vortex to rise in second stable state. For position of the wall less than $x = 150\,\mathrm{mm}$ this vortex does not rise.

Unstable flow for distances $x = 125\,\mathrm{mm}$, $x = 150\,\mathrm{mm}$ of the wall situated at the angle is an very interested phenomenon. For smaller distances vortex creation was observed whose center was closer to the wall then in the case free flow observation without the wall.

Special attention should be paid to Figure 7 which shows the flow behavior at the wall situated in the distance $x = 75\,\mathrm{mm}$. The flow state change causes total change of the direction of the air flow, flowing round the wall in the ring shaped area with width w.

Because of the possibility to use the investigated nozzle for drying processes the distance of the dried element from the nozzle is the most important in this case. This distance should not however be too small so as to avoid problems connected with carrying away heat from the object which is being dried.

4. References

1. Wawrzyniak S.: Stanowisko do ciągłej wizualizacji przepływu w elementach strumieniowych, VI seminarium naukowe “Postępy w konstrukcji i sterowaniu”, Bydgoszcz – Duszniki 2002, p. 63 – 64. Set of abstracts. Full text on included CDR.
2. Trávníček Z., Peszyński K., Hošek J., Wawrzyniak S.: Aerodynamic and mass transfer characteristics of an annular bistable impinging jet with a fluidic flip–flop control, International Journal of Heat and Mass Transer 46 (2003), p. 1265-1278.
3. Peszyński K., Trávníček Z., Wawrzyniak S.: „Optyczna i numeryczna wizualizacja pola prędkości na wyjściu dyszy do urządzeń suszących” XI Konferencja Międzynarodowa Recyrkulacja w Budowie Maszyn 23-24 maja 2001 Bydgoszcz