FUSELAGE AIRSTREAM SIMULATION FOR A COANDĂ UAV

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Abstract: *The objective of this paper is a study regarding the design of an unmanned aerial vehicle to ensure security by monitoring and collecting data from the atmosphere. Flight autonomy is realized using a propeller and additional for sustentation, thrust and orientation it uses the well Coandă effect. Atmospheric parameters are monitored by special gadgets, maintained by the ground operated vehicle. Flow dynamics study on the vehicle's cap during the auto-sustainable process is realized using Fluent 6.3 software.*

Keywords*: UAV, self propelled, aerial surveillance, Coandă effect.*

1. AIMS AND BACKGROUND

Aerial surveillance of the environment, especially of the protected areas, is done to ensure their preservation. This surveillance is a part of the structural and functional bio and ecological diversity dynamics studies. Thus can monitored – without human presence – different ecosystems, under, sometimes, hostile weather conditions and in locations hard to reach by human observers.

UAVs as solution will offer to the researchers interested in monitoring the ecosystems, a possibility of aerial surveillance with a vehicle with self-sustentation and an alternative propulsion method. Also the aerial surveillance will increase the ability to detect polluters better than ever, over land or wet areas and even over oceans, with smaller expenses and without endangering the human observers.

In this paper will be presented a new UAV type, designed for environmental surveillance, so called Coandă UAV.

A limitative condition for this new UAV type, condition that define it among others, is to use not for thrust an internal combustion engine – which is pollutant and noisy.

The same importance has the condition that the vehicle should be compliant with other several requirements considered normal for the observer. Thus, the vehicle has to have the ability to hover and to maintain its position and altitude over the area that needs monitoring.

The thrust and vertical movement system uses a ducted propeller, driven by an electric motor, and in order to improve the thrust and sustentation efficiency, as well as the horizontal maneuverability the well-known, but not so widely spread, Coandă effect is used.

This UAV type uses the propeller not only in the classic way, for sustentation, but also for creating air jets, vertically redirected by the upper vehicle fuselage surface, with the help of Coandă effect.

A study regarding the dynamic behavior of such new vehicle requires, at first, an analysis on a scale model.

The model simulation may determine and predict the contribution of the Coandă effect when modifying the flow parameters over the vehicle' cap surface.

For the wind tunnel tests, at first, the contribution of the ducted propeller was done using air with an adjustable flow. Air is to be supplied through a central vent and then guided by a round nozzle over the curved surface of the models, where the Coandă effect creates additional lift and increases the sustentation capability as in Fig. 1.

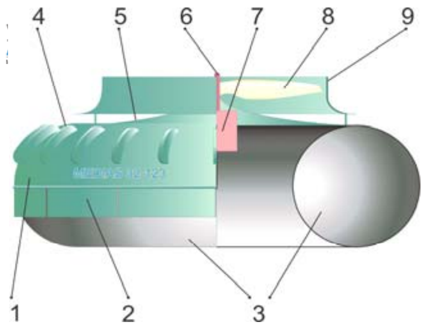


Fig. 1 UAV components, [1]
1 - curved upper cap; 2 - steering flaps; 3 - toroidal He chamber; 4 - counter-rotating fins; 5 - inner exhaust profiled cap; 6 - propeller's shaft; 7 - electrical motor and batteries; 8 - propeller; 9 – nozzle

2. AIR FLOW SIMULATION OVER THE UAV'S CURVED UPPER SURFACE

To realize a complete study on the flow over the curved upper surface of the fuselage, three vertical adjustable conic nozzles were fitted, with different diameters (respectively 90, 130 and 170 mm), in order to create jets with different dynamic characteristics, Fig. 2, Fig. 3, and Fig. 4. Also, as seen in Fig. 5, was tested a Laval adjustable nozzle, with 90 mm diameter.

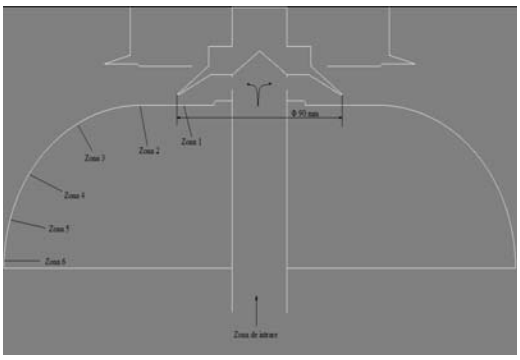


Fig. 2 Positions for the flow parameters (diameter D = 90 mm)

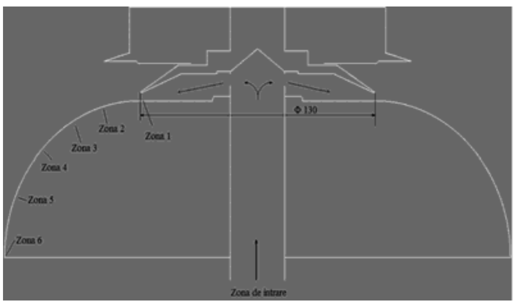


Fig. 3 Positions for the flow parameters (diameter D = 130 mm)

The flow simulation was realized using the Fluent 6.3 software.

We were tracking the parameter values in the flow direction for six representative positions, from the nozzle exit area to the exit off the curved upper surface.

Various values for the static pressure on the flow surface, for dynamic pressure and for flow speeds were taken, using as input the air flow through the central section.

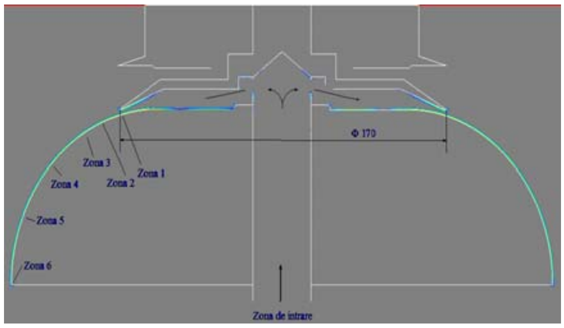


Fig. 4 Positions for the flow parameters (for diameter D = 170 mm)

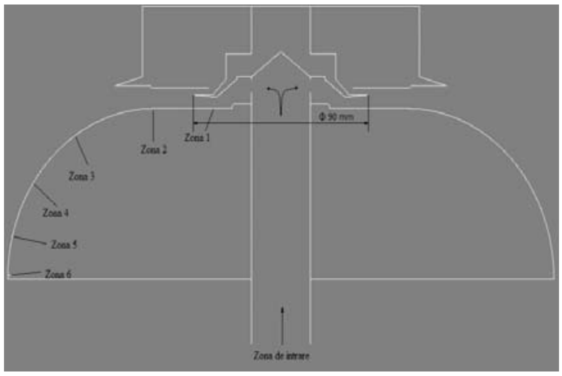


Fig. 5 Positions for the flow parameters at the Laval adjustable nozzle (diameter D = 90 mm)

Static pressure and air flow speed for the three values of the nozzle diameter and for the three values required for the flow through the nozzle are plotted in 6 and 7 for Laval nozzle, and 8 and 9 for conic nozzles.

Tab. 1 presents all this data for Laval nozzle, taking into consideration that air density at 20ºC is 1.2 kg/m^3.

Tab. 2, Tab. 3 and Tab. 4 present the same data for conic nozzles.

Fig. 6 and Fig. 7 present, respectively, the air jet speed variation and the static pressure variation for Laval nozzle.

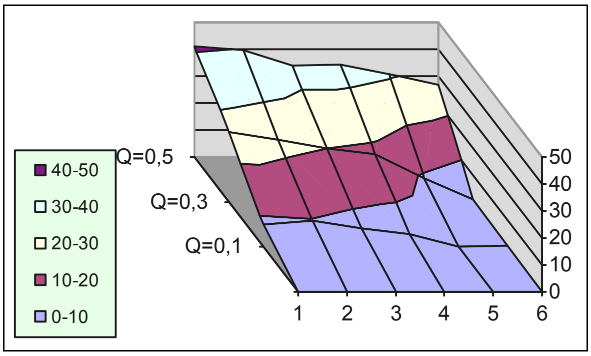


Fig. 6 Air jet speed variation for Laval nozzle with a diameter D = 90 mm

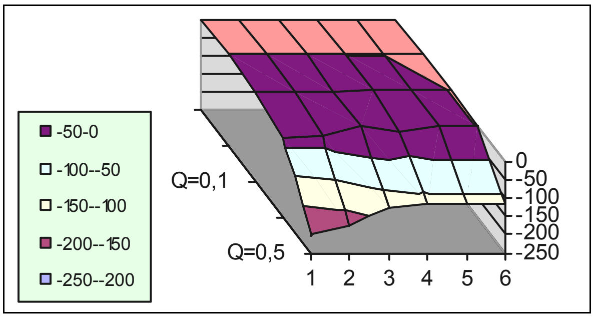


Fig. 7 Static pressure variation for Laval nozzle with: D = 90 mm

Tab. 1 Static pressure, dynamic pressure and air jet speed for Laval nozzle (diameter D = 90 mm)

D	**Q = 0,1** m^3/s		
mm	**Ps**	**Pd**	**v**
90	Pa	Pa	m/s
Z 1	-4.0	42.7	8.3
Z 2	-3.9	37.0	9.7
Z 3	-3.8	27.0	6.8
Z 4	-1.2	15.0	4.7
Z 5	-0.1	0.0	0.3
Z 6	0.0	0.0	0.5
D	**Q = 0,3** m^3/s		
mm	**Ps**	**Pd**	**v**
90	Pa	Pa	m/s
Z 1	-35.0	508.0	26.1
Z 2	-30.0	410.0	23.0
Z 3	0.0	254.0	20.0
Z 4	-15.0	400.0	17.8
Z 5	-1.0	244.0	9.0
Z 6	0.0	0.0	1.0
D	**Q = 0,5** m^3/s		
mm	**Ps**	**Pd**	**v**
90	Pa	Pa	m/s
Z 1	-201.0	961.0	41.0
Z 2	-175.0	850.0	39.7
Z 3	-126.0	750.0	34.0
Z 4	-115.0	700.0	34.3
Z 5	-114.0	414.0	30.7
Z 6	-114.0	380.0	27.0

Tab. 2 Static pressure, dynamic pressure and air jet speed for conic nozzles (diameter D = 90 mm)

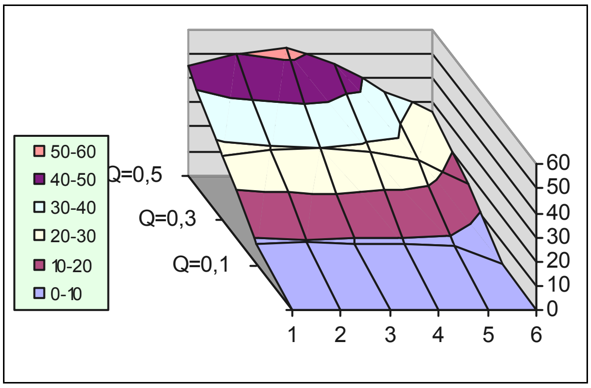
D	**Q = 0,1** m^3/s		
mm	**Ps**	**Pd**	**v**
90	Pa	Pa	m/s
Z 1	110.0	4.0	9.1
Z 2	-1.5	57.0	9.7
Z 3	-3.0	58.0	9.0
Z 4	-7.2	55.0	8.7
Z 5	0.0	40.0	8.2
Z 6	0.0	0.0	0.5
D	**Q = 0,3** m^3/s		
mm	**Ps**	**Pd**	**v**
90	Pa	Pa	m/s
Z 1	70.0	450.0	26.9
Z 2	-30.0	510.0	29.0
Z 3	-37.2	582.0	30.0
Z 4	-15.0	400.0	27.8
Z 5	-50.0	244.0	25.0
Z 6	0.0	130.0	15.0
D	**Q = 0,5** m^3/s		
mm	**Ps**	**Pd**	**v**
90	Pa	Pa	m/s
Z 1	248.0	128.0	45.0
Z 2	-175.0	150.0	49.7
Z 3	-100.0	134.0	52.9
Z 4	-150.0	900.0	46.3
Z 5	-150.0	614.0	34.7
Z 6	0.0	400.0	26.5

Tab. 3 Static pressure, dynamic pressure and air jet speed for conic nozzles (diameter D =130 mm)

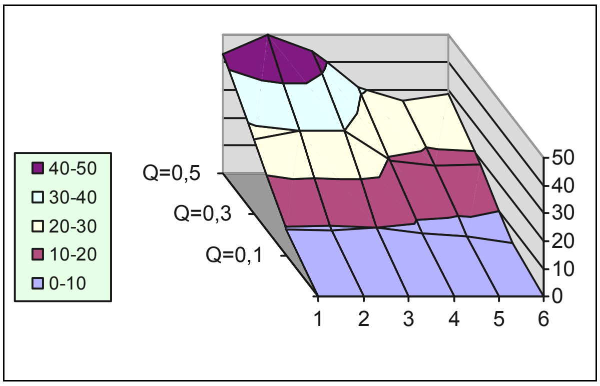
D	**Q = 0,1** m^3/s		
mm	**Ps**	**Pd**	**v**
130	Pa	Pa	m/s
Z 1	7.0	50.0	9.3
Z 2	-4.4	55.0	9.0
Z 3	0.0	35.0	10.0
Z 4	-3.0	27.0	7.8
Z 5	-5.0	30.0	7.0
Z 6	0.0	13.0	4.5
D	**Q = 0,3** m^3/s		
mm	**Ps**	**Pd**	**v**
130	Pa	Pa	m/s
Z 1	84.0	389.0	27.0
Z 2	-30.0	520.0	30.0
Z 3	-17.0	560.0	30.0
Z 4	0.0	210.0	19.5
Z 5	-17.0	150.0	17.5
Z 6	10.5	200.0	18.0
D	**Q = 0,5** m^3/s		
mm	**Ps**	**Pd**	**v**
130	Pa	Pa	m/s
Z 1	200.0	110.0	43.0
Z 2	120.0	140.0	50.0
Z 3	0.0	130.0	44.0
Z 4	-10.0	600.0	31.0
Z 5	0.0	430.0	26.0
Z 6	658.0	518.0	28.5

Tab. 4 Static pressure, dynamic pressure and air jet speed for conic nozzles (diameter D =170 mm)

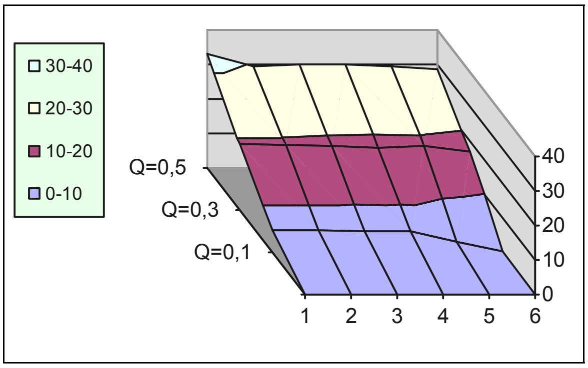
D mm	**Q= 0,1** m^3/s		
	Ps	**Pd**	**v**
170	Pa	Pa	m/s
Z 1	-15.0	24.7	6.3
Z 2	-20.0	23.0	6.3
Z 3	-25.0	23.0	6.1
Z 4	-29.0	23.0	6.3
Z 5	-0.3	3.0	3.1
Z 6	-0.3	0.0	0.3
D mm	**Q= 0,3** m^3/s		
	Ps	**Pd**	**v**
170	Pa	Pa	m/s
Z 1	-10.0	240.0	19.1
Z 2	-15.0	207.0	19.0
Z 3	-15.0	207.0	18.5
Z 4	-20.0	200.0	18.1
Z 5	-20.0	220.0	18.5
Z 6	-5.0	180.0	17.0
D mm	**Q= 0,5** m^3/s		
	Ps	**Pd**	**v**
170	Pa	Pa	m/s
Z 1	0.0	670.0	33.0
Z 2	-61.0	590.0	29.5
Z 3	-61.0	570.0	30.0
Z 4	-36.0	550.0	30.0
Z 5	-61.0	560.0	29.5
Z 6	-30.0	470.0	28.5



a) D = 90 mm

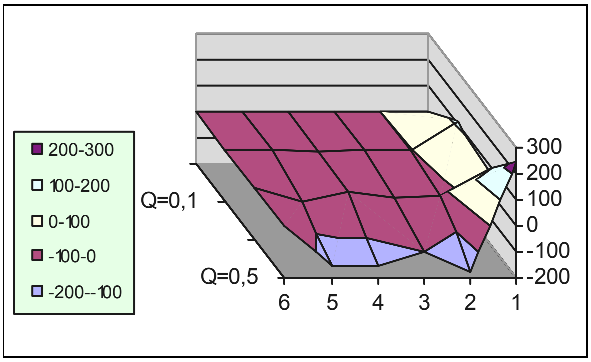


b) D = 130 mm

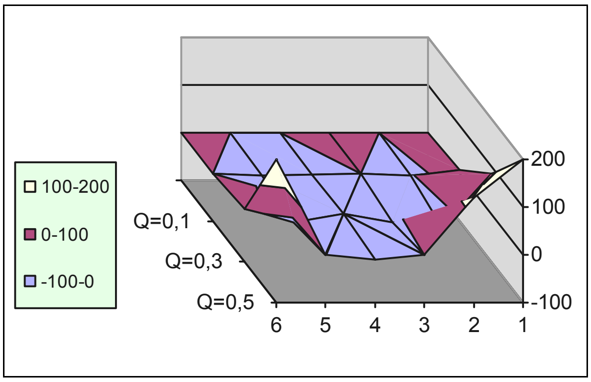


c) D = 170 mm

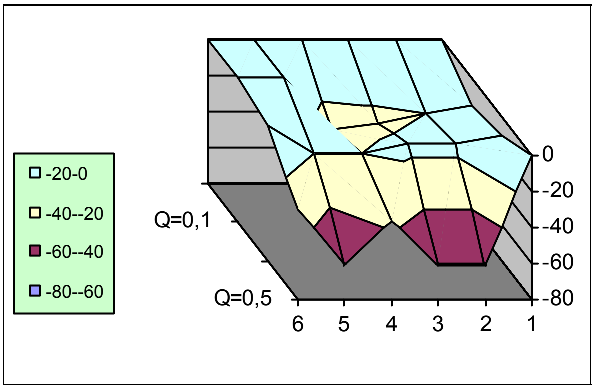
Fig. 6 Air jet speed variation for conic nozzles



a) D = 90 mm



b) D = 130 mm



c) D = 170 mm

Fig. 7 Static pressure variation for conic nozzles

3. DISCUSSIONS

Based on the values presented in Tab. 1 we can conclude:

- The static pressure under surface of the flow, for Laval nozzle, is smaller than static pressure for the conic nozzle. The observations are valuable only for 90 mm diameter;
- The air jet speeds for conic nozzles are higher than air speed for Laval nozzle;
- At the higher values of the air feed, the air jet speeds are approximate equals;
- The loss of energy at the changes of the directions of the flow of the nozzle's out generated the difference of the known values.
- The experimental testes will be confirmed or infirmed the differences between theoretical and experimental studies.

Based on the charts analysis and data presented in Tab. 2, Tab. 3 and Tab. 4 the following conclusions can be drawn:

- Along the six areas studied, along the motion direction, the flow is approximately even, while the increase of speed with the increase of current flow may be observed. The top speed of 53 m/s is obtained for a nozzle diameter of D = 90 mm while the minimum speed is obtained for a nozzle with a larger diameter (D = 170 mm).
- At higher flow values, it is noticed that the current lines reach the extremity of the surface (area 6), following its curvature. The turbulence motion generated by high values for the Reynolds number has areas with whirlwinds which go with the flow and produce irregularities in static pressure values.
- On the vehicle surface, static pressure is minimum for D = 90 mm diameter and maximum for D = 170 mm diameter.
- Static pressure values increase with the increase of air flow values, being connected with the rise of speed values, and dynamic pressure values respectively.
- Static pressure variation along the flow is relatively uniform for a flow value of $Q = 0{,}3\ m^3/s$ and it's less predictable for a flow value of $Q = 0{,}5\ m^3/s$. The software we used highlighted whirlwind variation, which create areas with static pressures lower than the medium values.
- Low static pressure values on the flow surface are also highlighted, which leads to the idea of reducing upper thrust, due to the vehicle's shape and the flow of the air jet on the vehicle.
- Laboratory tests will verify the predictions generated by the theoretical study of the flow on the vehicles' surface.

4. ACKNOWLEDGEMENTS

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