The use of COANDA EFFECT in air circulation for acquiring lifting force of an UAV model

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Abstract. Based on the COANDA EFFECT, the model of an unmanned aerial vehicle (UAV) can be built that has the ability to rise from the ground as a result of the airflow that follows the fuselage design. The virtual three-dimensional model of the flight device is built and analysed from the point of view of external airflow stream so that high or low pressure zones can be set, as well as velocity values that have an influence on the ground lifting conditions. The possibilities of airflow optimization are analysed so that the device can perform easy take off from the ground. The numerical flow analysis is performed on the virtual model using the ANSYS CFX program. The results obtained in terms of flow velocity, static and total pressure, as well as turbulence values in the fluid area are presented.

1. Introduction

The phenomenon of circulating air strong adhesion to a contact surface is known as Coanda effect.

This airflow effect was first noticed on the basis of the research activities of the Romanian scientist Henry Coanda, while he made the world's first jet-flight in 1910. Although the flight was terminated with airplane total damage because of Coanda's precarious skills as a pilot, he noticed the strong adherence of the fired gas to the aircraft fuselage.

This phenomenon had a strong concern for Coanda after realizing the flight accomplishing multiple laboratory experiments by which he elucidated the phenomenon and was then established as the Coanda effect.

The Roman scientist was the first to recognize the practical application of the phenomenon in the development of the aircraft manufacturing industry.

In the case of a propeller or turbine, it has the possibility to take up the nearby air particles and trap them inside an enclosure whereby the fluid particles have a circulation along the convex geometry model, the flow with the strong tendency of adhesion to the device body.[2]

Henri Coanda in various patents described the phenomenon as "the tendency of a fluid jet coming out of an orifice to follow an adjacent plane or curved surface, being able to train the surrounding fluid so as to result in a more reduced pressure fluid region". This fluid region with lower pressure values allows a flight deck to have a lifting tendency when the pressure values are reduced to the top and higher at the bottom of the hull.

The pressure effect, which is usually not indicated, is fundamental to understanding the Coanda effect. [3]
2. Theoretical bases of forced circulation of airflow

Theoretical aspects of the air flow through a nozzle between two cross sections of different diameter are presented.

For the case of considerable air velocity, the air passage through a system enclosure where there is pressure loss and circulation flow limitation is considered.

Both the pressure losses and the air flow rate values are important parameters in the calculation of an air circulation system based on Coanda effect. [4]

It is assumed that during airflow, part of the airflow mechanical work is consumed to overcome the friction forces. This consumption results as energy dissipation in the form of heat transmitted to the outside environment or absorbed by the moving mass of air. [5]

The total heat amount regarding air flow rate circulation is assumed as the following equation: [1]

$$Q = Q_s + A \cdot L_f$$

where:

$Q_s$ - the amount of air exchange heat with the external environment;

$L_f$ - mechanical work.

For two sections considered to be covered by the fluid flow, the energy conservation equation for a circulating air mass ($G$) can be written as follows: [1]

$$E_2 - E_1 = Q - A\left(p_2V_2 - p_1V_1\right) - \frac{AG}{2g}\left(\omega_2^2 - \omega_1^2\right) - AL_f - L_e$$

or function of enthalpy: [1]

$$I_2 - I_1 = Q - \frac{AG}{2g}\left(\omega_2^2 - \omega_1^2\right) - AL_f - AL_e$$

where:

$E_1, E_2$ - the internal energy of the circulated air through sections 1 and 2;

$I_1, I_2$ - enthalpy of fluid in sections 1 and 2;

$\omega_1, \omega_2$ - fluid velocity medium values for section 1 and 2;

$L_e$ - mechanical work produced by air kinetic energy.

The relation describing the circulation of an air mass becomes: [1]

$$dE = dQ - Ad\left(pV\right) - Ad\left(\frac{\omega^2}{2g}\right) - AL_f$$

Considering the specific air weight ($\gamma$): [1]

$$d\left(\frac{\omega^2}{2g}\right) + \frac{dp}{\gamma} + dL_f$$
This relationship highlights the variation of the kinetic energy of the air circulated and the mechanical workload to achieve the resistance overcome due to the friction forces based on the pressure values.

3. Unmanned aerial vehicle model
A three-dimensional model is created that has the potential to highlight the Coanda effect on the forced airflow across the fuselage.

Figure 1 shows the schematically representation model for the unmanned aerial vehicle (UAV) as aircraft type.

It consists of a fuselage which has a special profile geometry whose construction principle enable the easily air flow from the upper part through the interior of the enclosure by means of the turbine rotor and further down vertically down along the fuselage wall.

The turbine represents the energy source needed to power the device, being mounted at the top of the fuselage, within the enclosure, able to take over the air flow rate from the upper fluid region and to drive it vertically down along the wall, creating in this manner a continuum airflow stream.

The continuous turbine operation is generating high values of air velocity alongside the fuselage of the apparatus and also lower pressure values in the respective fluid region.

The enclosure is of open type being installed at the turbine level in order to protect the air flow rate taken over by the turbine from the outside environment and to direct the air to the convex wall of the fuselage.

![Figure 1. Schematically representation of unmanned aerial vehicle (UAV).](image1)

The three-dimensional assembly is shown in Figure 2 where you can see the constructive details of the component parts of the apparatus.

![Figure 2. UAV three-dimensional assembly model.](image2)
The assembly model contains the UAV fuselage with the enclosure and turbine with blades. The basis diameter of the fuselage is of 923 mm with a height of 222 mm and the enclosure internal diameter is 623 mm. Also, the radius for the fuselage is of 267 mm. The enclosure height is of 70 mm being mounted at 25 mm distance from the device fuselage body.

The diameter for the turbine is of 467 mm and the number of blades is 24. The minimum blade height is of 34.5 mm and the maximum blade height is 56 mm.

The turbine rotor is attached to the device body having the possibility of performing the rotational motion necessary for the air entrainment on the vertical direction.

4. Air flow numerical analysis on virtual model

In order to highlight the air circulation on the exterior of the aircraft's fuselage, a flow analysis was performed on the overall virtual model of the device.

The analysis is carried out with the Ansys CFX program and aims at obtaining results that provide information on the current air path-lines and the specific pressure and velocity values if the turbine has a rotating motion forcing the air to cross the enclosure and forming a continuous current of movement along the device fuselage body.

Due to the Coanda effect, it is expected that the air will adhere to the device body and then be discharged to the bottom of the device, creating specific turbulence so as to create the premises for the emergence of the ground lifting force of the device.

The lifting force can be achieved due to the pressure difference that is created as a result of high air velocity values near the fuselage wall area compared to the higher pressure registered at the inferior part of the analyzed fluid region.

![Flow analysis](image)

**Figure 3.** Fluid flow analysis main domains and mesh network.
It is highlighted the fluid domain contained inside the enclosure that surrounds the overall UAV assembly model considered as immersed solid within the fluid region.

A mesh network is realized on the overall analysis model containing the fluid region of air and the solid model represented by the UAV model assembly. It is a triangle surface mesh network containing 159160 nodes and 839476 elements.

The air volume inside the fluid region is $1.1613 \ m^3$.

Three values for rotational velocity are declared for the turbine rotor model involved in the air flow analysis starting from 3000 rev/min, 6000 rev/min and finally 10000 rev/min.

The results from the air flow analysis are presented in figure 4 in terms of fluid velocity and total pressure registered inside the fluid region.

Figure 4. Fluid flow analysis results on virtual model.
The result values are presented on the XZ cutting plane emphasizing the effective values obtained at the turbine and fuselage model.

It is shown the air flow path lines along the fuselage body with the corresponding values for velocity and total pressure.

Due to turbine rotational motion with the above mentioned values the air is involved in motion from the upper part of the enclosure and forced to circulate along the fuselage body with specific velocity values. For each rotational velocity used in flow analysis the total pressure values are presented. At the fuselage body level where the fluid velocity values are high the pressure is of lower values.

Because of the pressure and air velocity differences based on the turbine rotor motion it can be achieved the lifting force of the unmanned aerial vehicle from the ground.

5. Conclusion
Based on the air flow around a body, the strong tendency to adhere the airflow to the wall with which it comes into contact was observed. This phenomenon is described as the Coanda effect after the name of the great Romanian scientist who accidentally discovered this phenomenon while performing the first world jet flight in 1910 at Paris.

Based on this effect, multiple attempts have been made to put this flow phenomenon in relation to the adjacent surface.

A flight apparatus with a specific shape of the fuselage that can highlight the Coanda effect was described by Henry Coanda himself, being the first to initiate this prototype of a flight instrument with which he also carried out tests, being called “lenticular aerodyne”.

Starting from this idea of a flight instrument operating on the Coanda effect, a virtual unmanned aerial vehicle model (UAV) was developed in order to be analyzed from the airflow point of view on the outside of the body.

The results are presented in this paper in terms of air velocity and total pressure in the analyzed fluid area.

Higher air velocity values at the fuselage wall level are observed while pressure values are lower in this area, meaning that the device’s lifting conditions are met based on the pressure difference between the upper and lower base areas unit.

References
[1] Axinti G and Axinti A S 2008 Actionari hidraulice si pneumatice – Componente si sisteme functii si caracteristici, Editura Tehnica-Info Chisinau ISBN 978-9975-63-112-9
[2] Vasilescu Al A 1979 Mecanica Fluidelor Ministerul Educatiei si Invatamantului, Universitatea din Galati, Galati
[3] Olivotto C 2010 Fluidic elements based on Coanda Effect Incas Bulletin No 4 Volume 2 pp 163-172
[4] Hong CC Choi JW Ahn C H 2001 A Novel In-Plane Passive Micromixer Using Coanda Effect In Ramsey J.M., van den Berg A. (eds) Micro Total Analysis Systems 2001 Springer Dordrecht
[5] Trancossi M 2011 An Overview of Scientific and Technical Literature on Coanda Effect Applied to Nozzles SAE Technical Paper 2011-01-2591 available at https://doi.org/10.4271/2011-01-2591