COANDA EFFECT UAV – A NEW BORN BABY IN THE UNMANNED AERIAL VEHICLES FAMILY

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Abstract: *Most of the (UAVs) accomplishing their specific missions are designed to have propulsion according to one of the following two schemes. First, some of them have a fixed wing design, which resembles the one of a traditional plane. However, they offer a limited maneuverability and payload capacity. They also require a runway to take off and land, since the lift force is created by the plane's wings only as they move through the air. Others are employing rotors just as helicopters, thus achieving better results as far as hovering is concerned. This is important because the Vertical Take Off and Landing (VTOL) capability plays also a key part for an UAV. Nevertheless, their autonomy is highly diminished, the vehicles being dependent on the fuel amount or the energy accumulators carried on board. If we analyze the above mentioned demands for an efficient UAV, we may come to the idea of searching for a new design. Fluid mechanics is still offering interesting solutions which could overcome the differences between these two distinct heavier-than-air flying machines categories. During the past decade a new class of VTOL vehicles in the UAVs field, using the Coandă Effect has appeared. These have evolved to generate lift and maneuverability forces in a more efficient manner. Just as the first Coandă Aerodyne, more than 50 years ago, these flying machines use a central rotor fan to create the air movement over their fuselage. In the last decade, inspired by Coandă legacy, aroused in Europe a wave of new UAVs.*

Keywords: *UAV, classification, Coandă Effect, propulsion, VTOL, aerodyne.*

1. AIMS AND BACKGROUND

In the last years, no more than a decade, we were the eyewitnesses of the development of a new family of UAVs, having new propulsion and lift systems, as a synergy to the requests of the main two methods widely used to create lift and propulsion.

It is known that a fixed wing design similar with that of a traditional plane, even it is the most and widely used among the large or small aerial vehicles, even it has many advantages, is also marked by some disadvantages.

For example, the fixed wing design offers limited manoeuvrability for the platform and require a runway to take-off and land and.

Besides, they are unable to hover, or, for a UAV, to be VTOL (Vertical Take-Off and Landing) is a must, and also to be able to hover around the target is a very important aspect. So far, VTOL UAVs get around these problems, usually by employing rotors like a helicopter.

This paper aims to presents the evolution of the characteristics of this new class of aerial vehicles, with a close look on the main advantages and strengths and of the most adequate missions.

Apparently lifted by the propeller, as mini-choppers are, the lift forces of the new-born member of aerial vehicles family comes – mainly – from deflecting and streamlining the generated air flow along the outside upper curved surface, even the device is at rest.

This is because all this vehicles use a phenomenon known as the Coandă effect to create lift.

The upper propeller (it may be also a rotor or a fan) creates an airstream, adherent to the upper curved surface, where the Coandă Effect applies also and gets more air from above.

In the same time, the Coandă effect speeds up the air over the upper surface, and so lowers the air pressure next to it, which in turn generates more lift in this region, creating the necessary lift forces.

The Coandă UAV is compensating in this way its own weight and hovers along the direction of the resultant lift forces generated on the upper surface of the fuselage. In this way, the aerial vehicle generates buoyancy, and is able to take off or land vertically.

Coandă Effect is a classic phenomenon in fluid mechanics and one of the fundamental discoveries of the Romanian inventor Henri-Marie Coandă (1886-1972).

Henri Coandă was a Romanian inventor, aerodynamics pioneer and the designer and the builder of the world's first jet powered aircraft, the *Coandă-1910* a revolutionary plane of the 20th century beginning.

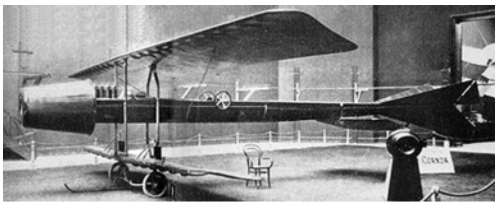

Fig. 1 In 1910, Henri Coandă built and flew the world's first jet aircraft

The Coandă effect became an obvious effect exactly 100 years ago, in 1910; at that time, Henri Coandă tested in a short flight an early type of jet engine aircraft, near Paris, France. The effect presently named after Coandă Henri Coandă described 20 years later, when he made public his discoveries.

In aeronautics, this effect is used today primarily in helicopters that have no tail rotors.

The first design of a Coandă UAV was created in 1932 [3], by the Romanian inventor Henri Marie Coandă.

In his first patents related to Coandă effect applications, in order to generate the jet of fluid over the upper surface of the fuselage, he was using mainly other means than a rotor, i.e. a burner or a combustion chamber.

But in a patent he obtained in 1935 [1], he was enumerating the possibility to use also a centrifugal fan for supplying the necessary air flow.

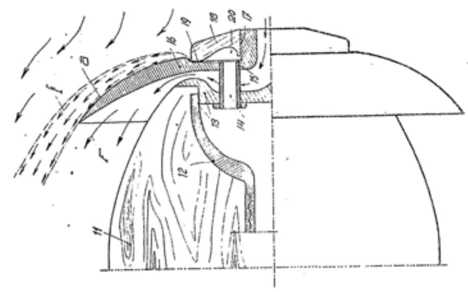

Fig. 2 Coandă patent "Perfectionnement aux propulseurs" [1]

Dans son brevet n° 762.688 du 23 novembre 1932, le demandeur a décrit un propulseur dont la caractéristique essentielle réside en ce qu'il crée, par détente d'un fluide qui s'échappe d'un élément de forme approprié le long d'un guidage de profil également approprié, une zone de dépression en avant du mobile sur lequel est monté le propulseur, ladite dépression étant telle que le mobile s'y précipite, et ainsi de suite.

Fig. 3 Extract from a later Coandă patent with reference to his first Coandă effect patent [3]

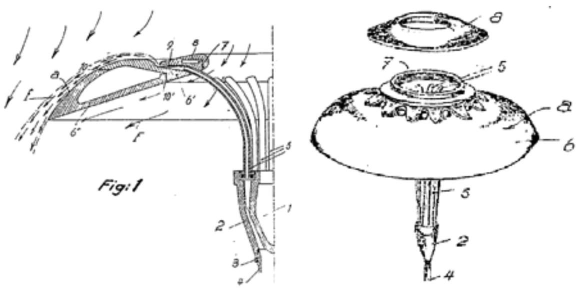

Fig. 4 Perfectionnement aux propulseurs [3]

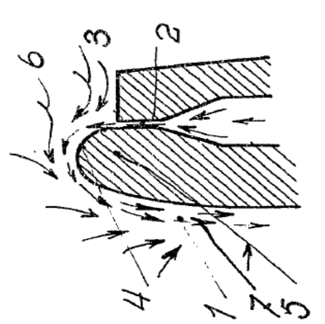

Fig. 5 Procédé et dispositif pour faire dévier une veine de fluide pénétrant dans un autre fluide [2]

In UK, 50 years later, Robert Collins valued Coandă effect capabilities in one of his inventions, which obtained a GB patent no. 2387158, granted in 2003.

This new Coandă application was already presented in his paper „Coandă - A New Airspace Platform for UAVs" at the Bristol International UAV Conference, in April 2002 [4].

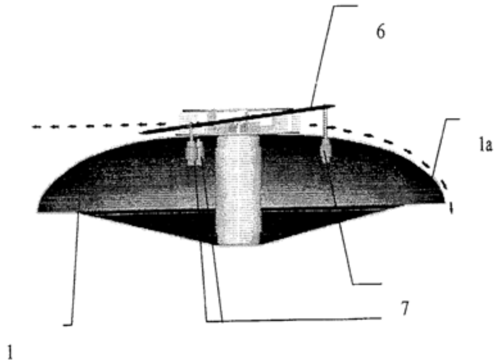

Fig. 6 Robert Collin's Aerial Flying Device [4]

In the design of a Coandă UAV the rotor at the center of the hollow fuselage canopy pulls air in from above the craft and blows it out radially, over the top of the curved body. Because of the Coandă effect, the airstream remains 'stuck' to the canopy and follows the curved surface, leaving the body at its base. This, along with the downwards thrust of the fan, pulls the aircraft upwards.

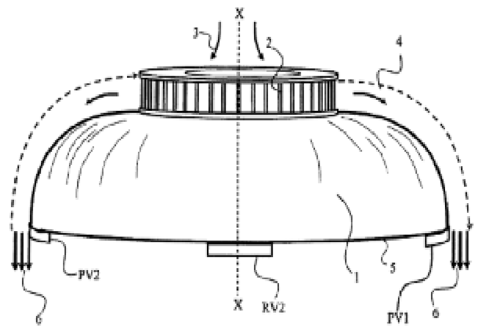

Fig. 7 Geoff Hatton's first Coandă UAV (2005)

Also in the 90's, another inventor from UK, Geoffrey Hutton, together with the GFS projects team, promoted also an aerial Coandă device, with a circular shape canopy.

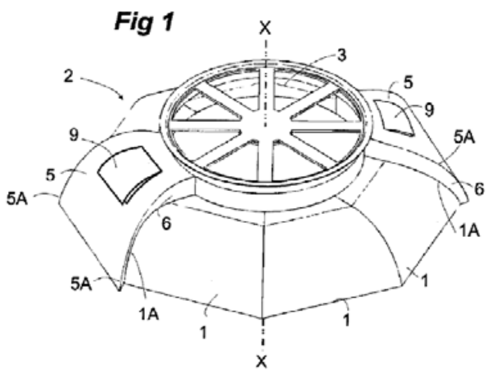

Fig. 8 Geoff Hatton's 2007-UAV model

GFS Projects is the final chosen name for Geoff's Flying Saucers - a new company created in 2002 with a £43,000 grant obtained from the UK Department of Trade and Industry.

When GFS projects built their first model, the circular shape turned to be octagonal, with flat flaps on four opposite sides of the trailing edge.

In 2006, Jean-Louis Naudin made and tested his first UAV (GFS-UAV model N-01A). This one, propelled by an electric engine, was using the Coandă effect to take off vertically, fly, hover and land vertically (VTOL).

Fig. 9 J.-L. Naudin's first GFS-UAV (N-01A)

The design of the GFS-UAV N-01A was based on the Geoff Hatton' flying saucer from GFS Project limited.

In the next year, Jean-Louis Naudin freely published the full plan of the GFS-UAV N-01A and a detailed tutorial to help UAV fans to replicate his GFS UAV [7].

Fig. 10 Geoff Hatton's GFS-02

In 2007 Geoffrey Hatton presented an optimized control for his family of Coandă UAVs, this time improving the airflow over the outer surface, especially in open air, when it may be disturbed by a lateral wind [8].

In 2008, in Romania, an academic consortium, with researchers from Galați, Iași and Bacău universities, coordinated by the author, obtained, for the researches on Coandă effect, a national grant from CNMP, for the surveillance and protection of the natural environment, using a Coandă UAV.

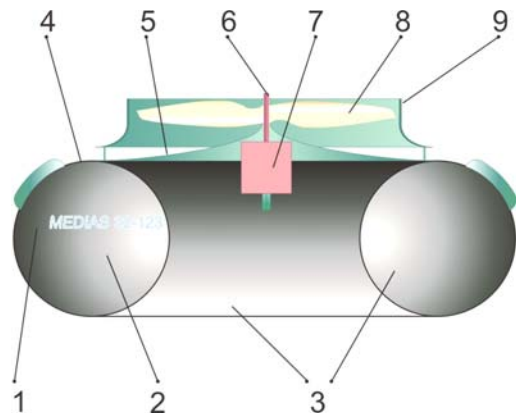

Fig. 11 MEDIAS components [10]
1 - curved upper surface; 2 - steering flaps;
3 - toroidal He chamber; 4 - counter-rotating fins;
5 - inner exhaust profiled cap; 6 - propeller's shaft;
7 - electrical motor and batteries; 8 - propeller; 9 - propeller duct

According the contract, this new UAV, named MEDIAS, had to be in the same time a modern and a nonpolluting aerial vehicle, easy to maneuver and safe to the environment and people.

As a main characteristic, MEDIAS with his adequate shape, uses the Coandă Effect (I) for lift and maneuverability. An air flow created by an electrically driven propeller (II) flows over the upper surfaces of a curved radial canopy and changes the pressure field above and under the vehicle, creating more lift and improving the stability of the flight.

A toroidal Helium optionally added inflatable chamber (III) is increasing the buoyancy and functionality of the MEDIAS VTOL UAV design and is increasing also the UAV's mission autonomy.

This high propulsion efficiency will be obtained because, besides using Coandă effect, the vehicle has an innovative design, MEDIAS being a hybrid between the following:

1. An aerial vehicle - propelled and steered by Coandă effect and vertical air jets,
2. An aerial platform - which ensures its sustentation by using a propeller, preferably ducted, for a greater efficiency,
3. An aerostat - preferably filled with Helium - which improves some of the flight parameters.

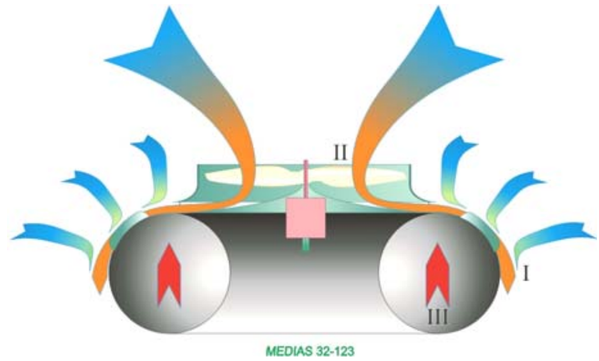

Fig. 12 The sustentation and propulsion components of MEDIAS UAV

However, the Coandă effect, as physical phenomenon used for sustentation, should allow it to lift and carry a significant weight compared to its estimated energetic consumption.

For an increase in efficiency, the electrical driven propeller itself was mounted in a central duct. In this particular arrangement, also the air volumes entrained by the Coandă effect became several times multiplied.

Meanwhile, on January 28th 2009, AESIR Ltd, a privately owned company, established to develop a family of Coandă effect VTOL UAVs, inherited GFS Projects Ltd legacy.

Fig. 13 GFS/AESIR Coandă-effect UAV

With a military support, this time, AESIR Ltd presented in September 2009, at Defence & Security Equipment International, London, a new VTOL-UAV, (named ODIN, after the chief god in the Viking mythology, in accordance with the company's name AESIR, considered to be the Pantheon of the Viking gods).

Fig. 14 ODIN – The AESIR's demonstrator for a military Coandă UAV

This new-born Coandă UAV was a 1...1.5 meter diameter octagonal craft, fitted with a Wankel Rotary internal combustion engine. It weighs up to 10kg and can carry a maximum of 10kg payload for up to an hour.

Fitted with an autonomous flight control system and managed through a simple to operate ground control system, ODIN has been primarily designed to operate as an Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR) platform, a logistics craft or as an aerial communications re-broadcast station.

Fig. 15 AESIR's VIDAR UAV

Also, due its versatility, it may participate in missions of electronic warfare, asset protection, IED detection, or even being used as a weapon or loitering munitions.

In the same exhibition stand at London DSEi, AESIR presented VIDAR, a 300 mm, man portable craft designed to provide surveillance and situational awareness inside buildings and in-close-confined spaces.

It has an electric engine powered by Lithium Polymer batteries to provide up to 15 minutes of flight time. It weighs 400g and is capable of carrying a 100g payload.

The next project of VTOL UAVs that AESIR Ltd. was developing were EMBLA, a 600mm diameter electric engine craft which has been developed to show the militaries the capabilities of a Coandă effect VTOL UAV.

Fig. 16 EMBLA, an emblematic Coandă UAV

Fig. 17 EMBLA - in its counter IED role on top of a Northrop Grumman Remotec Mk 8 EOD Wheelbarrow

HODER is the larger UAV from AESIR family, but it is a heavy lift craft, with two or more engines, with a mass of 1500 kg and is capable of carrying a 1000 kg as a payload, for up to eight hours.

Fig. 18 HODER – A cargo transport VTOL-UAV

As the main mission, HODER it is intended for cargo transport and resupply vehicle for front line forces, but can be adapted to become a long endurance craft by reducing the payload and increasing the fuel.

(As an anecdotic aspect, Hoder is the name of the strongest of all the Norse gods).

All these VTOL UAVs are using the Coandă effect in order to generate lift and have an excellent stability in their role as a surveillance platform.

2. STRENGTHS AND ADVANTAGES

All these VTOL UAVs are using the Coandă effect in order to generate lift and gain an excellent stability in their role as a surveillance platform.

Missions that a Coandă UAV will be capable to accomplish will diversify in the time to come, both in civil and in the military field.

The design of the Coandă UAV's has many strengths and advantages and that’s why, in the next years, we could be the witnesses of a fast spreading of new models from this new class of vehicles.

Their strengths and advantages are:

1. First, a Coandă UAV it is not as vulnerable to impacts against walls, ceilings etc., as a more conventional unmanned plane or helicopter, so it may bump into horizontal or vertical walls, or other kind of obstacles, without losing altitude or being damaged
2. A Coandă UAV has no external rotating parts, so the vehicles could survive to low speed impact with the ground, buildings and other fixed objects.
3. Due to the elasticity of the toroidal He chamber, located at the inferior part of vehicle, the MEDIAS UAV has a better approach in landing on ground, with the payload unaltered, in very different weather conditions or locations, even if the approaching manoeuvres are not well conducted.
4. The optional added / filled He chamber improves the autonomy of the MEDIAS UAV because the MEDIAS design has a better ratio payload vs. total weight.
5. The air masses entrained by the Coandă effect flow over the upper surfaces are changing the both pressure fields, of above and under the vehicle, thus creating more lift and improving the stability of the flight.
6. Coandă effect amplifies and even multiplies the lift forces due the increased air volume entrained.
7. The payload is not located directly in the stream of air responsible for creating lift forces.
8. The airflow necessary to create lift forces is not as dependent of the altitude or the angle of attack as fixed-wing UAVs are, so the vehicles are more stable during the flight.

3. MISSIONS

The current main market for UAVs is in defence, with 57% of UAVs being classed as military according a 2009 study. [12].

They are often used to spy on hostile situations from a distance, to watch the area around a soldier or troops and have the potential to search for IEDs (Improvised Explosive Devices). This eliminates the need for the soldier to take any unnecessary risks.

A more desirable capability for a UAV in many of these situations is VTOL (Vertical Take Off and Landing) which gives the ability to hover and perch, and monitor an area from a fixed position, but this usually results in reduced flight times and Coandă UAVs are prepared to have a large autonomy.

A small UAV, as so far VIDAR is, with its 0.3 m diameter and 0.5kg of weight (payload included), could be flown into an unknown building in order to generate floor plans ahead of an infantry assault, for instance.

A larger Coandă UAV, as EMBLA or MEDIAS are, could be sent out for about an hour to scout out the territory, flying at an altitude from few meters to up to 1000m, and bring it back.

Because 71% of all UAVs are fixed-wing [12], they have to keep flying / moving to avoid landing. Unlike fixed wing UAVs, Coandă UAVs don’t have to keep flying, because they may land and take off whenever it will be needed.

As well as providing surveillance images, day or night, the UAV could also act as a communications relay, hovering to keep the communication for a strategic location or transmitting live information from troops onthe ground. It could also accomplish a logistics role, for example, by bringing ammunition or other small supplies/packages to forward operations posts.

In the civil field, the VTOL capability of the Coandă UAVs will offer them the possibility to accomplish missions with a great diversity. Besides the measurement of the environmental parameters and monitoring of the nature reserves as a non-polluting UAV (e.g. MEDIAS) could accomplish, the civil Coandă UAVs shall be able to carry out a large variety of missions such as:

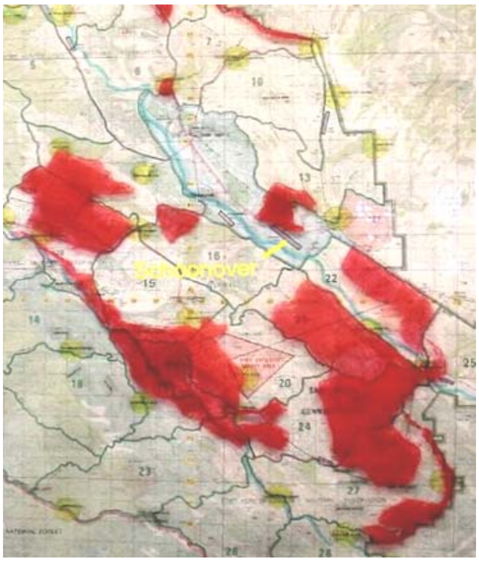

Fig. 19 Forest fire detection representation on a hybrid map (map + aerial IR image)

1. Fire and Rescue
    - Forest and crops fire detection and fire fighting management
    - Other major incidents
    - Emergency rescue (e.g. Mountain rescue)
2. Government
    - Law enforcement (Police, Civil Security)
    - Border security
3. Energy Sector
    - Oil and gas industry distribution infrastructure monitoring
    - Electricity grids / distribution network monitoring
    - Coastguard
4. Agriculture, Forestry and Fisheries
    - Environmental monitoring
    - Forest and crops disease management
    - Forestry or fishery protection and aerial inspection
    - Optimizing the use of water and soil resources

Fig. 20 Civil/Military Applications IR picture

5. Communications and Broadcasting
    - Camera aerial platforms (e.g. broadcasting, and film industry)
6. Earth Observation and Remote Sensing
    - Climate monitoring
    - Aerial photography, mapping and surveying
    - Natural disasters monitoring (water flows, avalanches, oil leak tracking, seismic events) etc.

4. CONCLUSIONS

1. As a recent application of 100 years old discovery, Coandă UAVs are in a position of winning terrain in front of other light UAVs (under 150kg).

2. There is a growing and stimulating competition for innovating and demanding patents, where for now, Europe is in pole position, but new signals of interest come from Middle East and US.

3. The early start was made by independent inventors and civil companies, but in the next ten years, maybe, the militaries will be those to keep going the engine of the R&D for Coandă UAVs.

4. As the UK and Romanian research teams showed, the hovercraft legacy could be valued again in this new field of research.

5. ACKNOWLEDGEMENTS

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