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Coandă effect

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1 Introduction

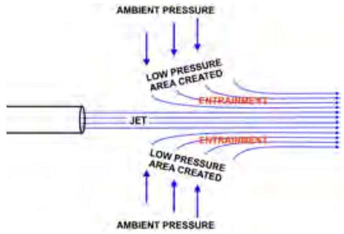
The Coandă effect is a phenomenon used in several applications such as health care, robotics and aeronautics [1, 2]. However, this effect is often interpreted incorrectly. The aim of this paper is to explain the Coandă effect and elaborate on the working principle behind it. In section 3 the common definition is given and additions are made to replenish it. It is explained when the Coandă effect is applicable for airfoils and finally, in section 4, some applications in modern-day aeronautics are presented, for example V/STOL, ACHEON and NOTAR.

2 Background

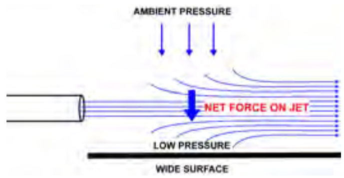
Henri Coandă (1886-1972) was an inventor and engineer born in Romania. In 1910 Coandă build arguably the first jet plane, the Coandă-1910 [3]. However, this plane caught fire and Coandă noticed that the flames followed the surface of the fuselage [3, 4]. Thomas Young also noticed this phenomenon with a candle in 1800 [5, 6]. But the crash of the plane caused Coandă to do extensive research which resulted in several patents and getting the Coandă effect officially recognized by Theodore von Kármán in 1934 [7, 8, 9].

3 Description

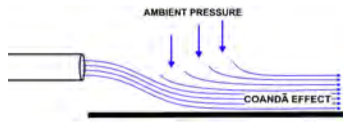
The most common explanation for the Coandă effect is the tendency of a fluid jet to attach to an adjoining surface [4, 6, 10, 11, 12]. Yet, certain additions should be made to this explanation to make it complete. First of all, the Coandă effect will still occur when the surface is removed. A free jet in a stationary fluid, so without a surface in the vicinity, drags along some of that stationary fluid. This results in an increase of the fluid's velocity around it. Since momentum is conserved, the jet will slow down as it moves through the stationary fluid. The surrounding particles that are dragged along with the jet will result in a decrease in pressure around the jet. This creates an inward suction of the particles nearby [4, 6, 10, 11, 12]. More and more particles are dragged along as the fluid moves through the stationary fluid, which is called entrainment, see Figure 1a. The suction of surrounding fluid along with the jet causes the Coandă effect [11]. In case the jet is in the vicinity of a surface, a wall jet, this entrainment is restricted. As a consequence, the fall in pressure cannot be compensated with surrounding particles, causing the jet to deflect towards the surface and eventually attach to it, see Figure 1b and Figure 1c [6, 10, 12]. The second addition to the earlier mentioned general explanation is the shape of the surface, which can either be straight or convex [4, 11].



(a) Entrainment of stationary fluid with free jet [13].



(b) Entrainment of stationary fluid with wall jet [14].



(c) Jet flow profile as a result of Coandă effect [15].

Fig. 1 : Diagrams illustrating the Coandă effect

However, it is of great importance not to confuse the Coandă effect with the flow following a curved surface on a regular aircraft airfoil. The air around an airfoil is all moving, so there is no stagnant fluid in which a jet mixes. Hence, there is no suction of fluid replacing the entrained fluid [11, 16].
Thus, the Coandă effect rarely occurs naturally on a wing, but can be produced when a part of the exhaust gasses is deflected over the wing, which could result in an increase of the lift by a factor of 3 [16]. These

fast exhaust gasses create entrainment of the air causing a regional pressure drop and delaying separation [17]. This could be applied in the future on controlled surfaces of an aircraft. These surfaces are mainly dimensionalized for high-lift situations and when the lift can be increased significantly in these situations, these surfaces can be reduced in size while still being able to deliver the required lift in normal operations.

4 Applications

In the aeronautic field, new technologies should be designed to meet the changing demands in terms of reducing environmental impact and cost while still increasing the overall performance [18, 19]. As described in section 3, the Coandă effect can be utilized for increasing the lift of an aircraft, but can be used in more applications. Applications discussed in this paper are: the V/STOL aircraft, the ACHEON nozzle and the NOTAR system.

4.1 V/STOL

Vertical and/or Short-Take-Off and Landing (V/STOL) aircraft can introduce new and greener technologies in aeronautics and can be very useful in specific mission profiles. However, helicopters are limited in the maximum horizontal speed and airplanes with V/STOL have problems with the large weight, as a result of the mechanisms needed for tilting the engines [18]. Besides, V/STOL has been introduced in the field of UAVs, being dependent on the amount of energy on board. Due to the limitations for these specific classes, a new class of V/STOL was introduced using the Coandă Effect. The vertical and horizontal thrust in these Coandă V/STOL aircraft is generated by a central rotor fan to create a controlled airflow that is vented over the fuselage. Consequently, low pressure around the fuselage will occur and the aircraft is lifted [20, 21]. These aircraft can produce maneuverability forces and lift more effective than the earlier described V/STOL aircraft [21].

4.2 ACHEON

The Aerial Coandă High Efficiency Orienting-jet Nozzle (ACHEON) project investigates a new propulsive system for aircraft with the main advantage being able to deflect the trust only by fluid-dynamic effects without any part in movement [18, 19, 22]. This trust vectoring is largely realized by making use of the Coandă effect. The ACHEON concept is based on two technologies: the HOMER (High-speed Orienting Momentum with Enhanced Reversibility) nozzle and the PEACE (Plasma Enhanced Actuator for Coandă Effect) concept. The HOMER nozzle is a thrust vectoring propulsive nozzle producing a controllable deflection of a synthetic jet and the PEACE concept extends the angle of operation of the nozzle. The integration of a HOMER nozzle with the PEACE concept can lead to a system that is applicable in new aerial vehicles and creating new possibilities with directionally controllable fluid jets focusing on more sustainable and all-electric propulsion systems [18, 23].
The original patented nozzle architecture (1), shown in Figure 2, is capable of mixing two primitive fluid jets (2) and (2') and subsequently creating an adjustable synthetic jet (7), by changing the mass flow of both jets independently.

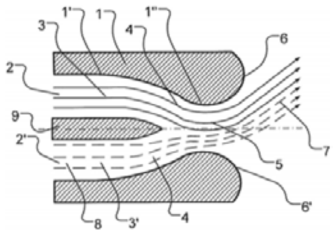


Fig. 2 : ACHEON configuration defined by the patent [24].

The study performed by Trancossi et al. [19], demonstrated the benefits of an ACHEON based civil aircraft and ensuring better performance. However, this is still a relatively new technology and should be further investigated before being implemented in commercial civil aircraft.

4.3 NOTAR system

The Coandă effect is also applied in helicopters without tail rotors. NOTAR (NO TAil Rotor), developed by McDonnell Douglas Helicopter Systems, is a system which replaces the tail rotor and thereby eliminating its mechanical disadvantage, such as noise and vibrations while also increasing safety [25].

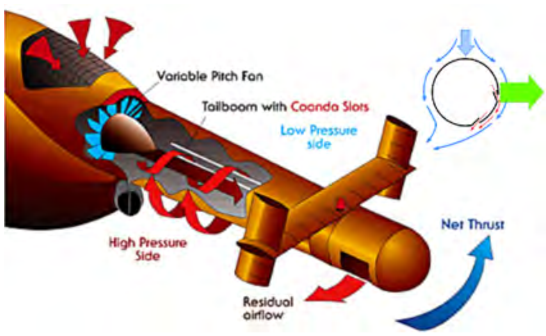


Fig. 3 : Configuration of a NOTAR tailboom [25, 26].

NOTAR, as shown in Figure 3, uses a fan inside the tail boom forcing an airflow to exit through two longitudinal slots, creating a boundary layer flow and utilizing the Coandă effect. This effect changes the direction of the airflow around the tail boom, creating an anti-torque to the torque effect impaired by the main rotor. However, directional control is still accomplished by a rotating direct jet thruster and the thrust created by the Coandă effect acts mainly as a stabilizer [27].

5 Conclusion

The Coandă effect is a phenomenon which can be used in a widespread of applications. It is commonly known for creating extra lift over the airfoils of airplanes. Besides this application, the effect can also have other uses within aeronautics. Such as: V/STOL, where the Coandă effect is used in a new type of aircraft to generate lift in an effective way; ACHEON, which is a new propulsion system where the direction of the thrust can be regulated creating possibilities for electric propulsion systems in aerial vehicles and the NOTAR system, a system in helicopters where the tail rotor has become redundant while increasing the performance. In conclusion, the Coandă effect applied within aeronautics gives rise to better aircraft performances and new opportunities for more sustainable aircraft.

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