The Coandă Effect

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1 Historical Background and Discovery

One of the first descriptions of the phenomenon now known as the Coandă effect was given by physicist Thomas Young in a lecture in 1800 [1]. Almost one hundred years later it was fully described by the eponymous Romanian Henri Coandă. Henri Coandă conducted several experiments as early as 1905 but he identified the effect with one of his creations: The Coandă–1910 aircraft which is shown in Fig. 1, an unconventional sesquiplane aircraft powered by a ducted fan. He discovered that when a fluid jet is passing over a curved surface, it tends to follow the geometrical root of the surface, entraining large amounts of air as it does so [2].
The first official documents in which we encounter the Coandă effect are two patents published by him in 1936. One with the title "Device for Deflecting a Stream of Elastic Fluid Projected into an Elastic Fluid" [3] and the other as "Lifting Device Coandă Effect" [4]. This name for the phenomenon was accepted by the leading aerodynamicist at the time, Theodore Von Kármán. The two of them had a long and strong scientific relationship in solving aerodynamic problems [5, p. 177].

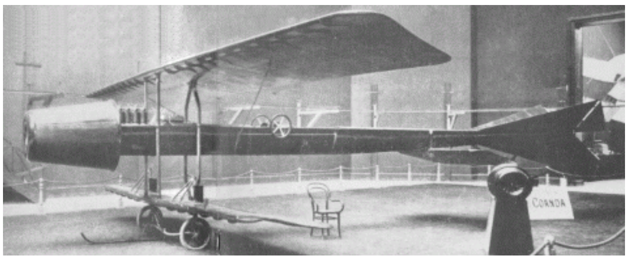

Fig. 1 . Coandă-1910 at the 1910 Paris Flight Salon.

2 Scientific Background

Fundamental to the understanding of the Coandă effect is the principle of entrainment. Entrainment is a phenomenon that occurs between two regions of differing velocities within a fluid. Of particular interest regarding the Coandă effect is the entrainment between a stream of high velocity air, such as a jet, and a stagnant, or otherwise of such low energy that it could be considered still in comparison to the jet, region of air. The high velocity, or high energy, region of the air moves past the stagnant region and imparts some of its energy to it, engaging some of the previously stationary air particles into the jet. These particles have been *entrained* in the jet [6].
The entrained particles are, in a sense, consumed by the jet, meaning that the concentration of particles in the surroundings suddenly diminishes. This is analogous to a pressure drop in the immediate surroundings of the jet which exerts a force on it. In the case of a free stream jet, the net force is zero. However, if a flat surface is introduced approximately parallel into the vicinity of the jet, the number of possible particles for entrainment decreases in the volume between them. This is due to the lower influx of particles as compared to the free side of the jet because of the obstruction caused by the surface [7]. This results in a pressure differential across the jet which forces it toward the surface to which it subsequently attaches [2].
Somewhat counterintuitively, the attachment can persist even if the surface curves away from the jet. The mechanism responsible for this is the same as for the initial attachment. The curvature must not be too severe, however.

3 Current Applications

Currently, the main application of the Coandă effect is in airfoils. The top of most of the modern airfoils is curved, and due to the effect, the airflow follows the surface of the airfoil. Since it has to travel a longer distance in the same time (higher velocity) compared to the bottom of the airfoil, application of the Bernoulli's equation shows that the pressure is decreased on the upper surface, and this pressure difference generates lift on the wing [8].
Another application of the Coandă effect that is underutilized at the moment, is using the exhaust

gases from vehicles to improve their grip and comfort levels while driving. This was first used in Formula One cars in the late 2000's, with the concept created by Adrian Newey. An exhaust would be placed in a groove, as shown in Fig. 2 [9], and the walls of it, alongside the downwash, would guide the gas towards the diffuser, where the low pressure gas would create additional downforce [10]. It has been deemed illegal since, but new developments in vehicles could allow this type of exhaust to improve the grip of the vehicle, thus ensuring smooth driving at low and high speeds.
Another good application in modern aerodynamics is the NOTAR (No Tail Rotor) technology. It utilizes the Coandă effect in the tailboom, where the low pressure air is brought in via a fan. The tailboom expels the air through two slots, which causes the Coandă effect, creating a boundary layer along the tailboom [11]. This airflow, combined with the downwash of the aircraft, creates an anti-torque force. In addition, the air that has been expelled from the tailboom creates additional lift forces [12]. Currently, the technology is relatively young, since only three helicopters utilize the NOTAR.

Fig. 2 . Red Bull RB8 Coandă exhaust.

4 Future Applications

The Coandă effect offers a lot of potential for future aircraft propulsion systems. One of the fields of research ongoing today includes the use of the Coandă effect in the so called ACHEON project (Aerial Coandă High Efficiency Orienting Nozzle) [13]. Basically, it is a new approach for the vector and thrust propulsion system used in aircraft today. The aim of the project is to increase performance and maneuverability of the aircraft using the Coandă effect. Furthermore, research is focused also on reducing aviation impact on nature, by making it available in all electric aircraft is as well.
As seen from Fig. 3, the ACHEON nozzle works by mixing two streams of flow with different velocities together. It directs the outgoing flow stream without having any mechanical parts in the nozzle. At the end, the nozzle has a curvature which makes the diameter of the outflow hole contract. A flow will follow this curvature after the nozzle as well, as can be seen from Fig. 3. This is possible due to the Coandă effect, which turns the outgoing flow from the usual horizontal position. By mixing two separate flows together, it is possible to achieve a variety of angles in the flow after the nozzle.
This concept is the basic principle of the ACHEON project, which is still only in the early stages of research. However, first analysis and CFD simulations were made, comparing the performance of the Cessna 402 with traditional propulsion and by implementing an ACHEON nozzle in it. The earliest analysis was made in three areas of operation: take-off, climbing and landing. The results showed an increase in maneuverability, as well as reduced take-off and landing distances.
The early analyses of a Coandă based ACHEON nozzle propulsion system showed potential performance enhancements in both conventional and all electric aircraft in the future. It also demonstrated possibility of renovation of old aircraft by installation of the ACHEON propulsion system. However, it is still not sufficient enough to be available for use within the industry, so further research is needed before implementing the ACHEON propulsion system in future aircraft.

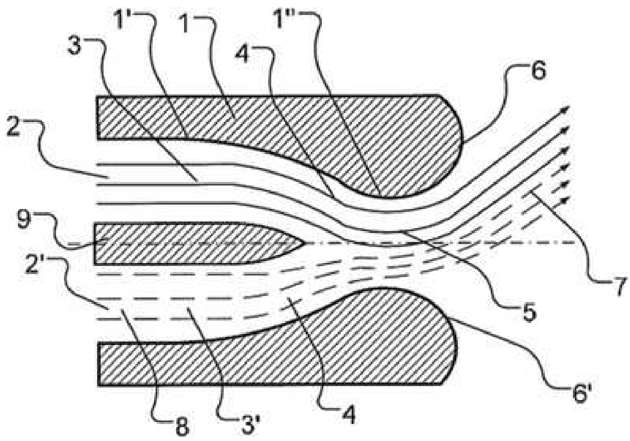

Fig. 3 . ACHEON nozzle architecture.

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