THE COANDA EFFECT AND LIFT

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SECTION 1.

This explanation contains no math. It is a thorough but non-technical explanation for non-engineers.

Conclusions:

1. Lift is not caused by the Bernoulli Effect.
2. Lift is a result of Vorticity.
3. The Coanda Effect does not occur on wings unless applied.
4. When applied, the Coanda Effect can increase lift by a factor of 3.
5. The Coanda Effect can increase efficiency of wind turbines and electricity production.
6. The myth of the Bernoulli Effect causing lift must be eliminated before decision makers can make real progress in many important areas.
7. It is time to abandon the “simplifying notions” that prevent full understanding.

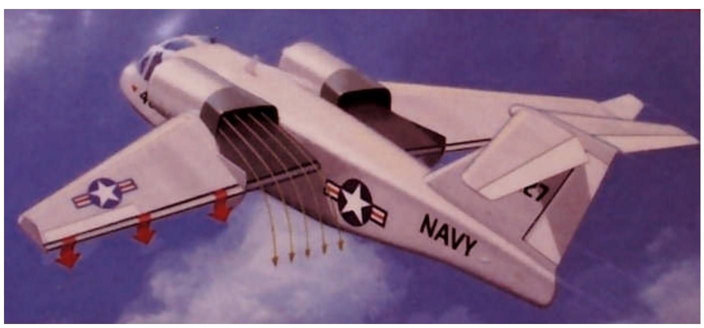


Fig 1. The proposed Navy Short Takeoff and Landing aircraft (STOL) employing the Coanda Effect.

The Coanda Effect will be a household name in the near future as it becomes utilized in appliances in our homes, automotive, industrial and aeronautical applications and renewable energy. New Fluid is a leader in developing many of these commercial applications.

There is much confusion about the Coanda Effect and lift theory. We explain here the lift mechanism accepted by Aeronautical Engineers. Many erroneous explanations are posted on the internet and elsewhere. To eliminate confusion a thorough but non mathematical explanation is here given employing simple demonstrations, pictures and diagrams. Intelligent decision makers cannot be expected to follow the math employed by Aeronautical Engineers. However they do deserve the facts if it affects their business.

The Bernoulli Effect and Coanda Effect do not naturally occur on aircraft wings. They play no part in generating conventional lift. It is emphasized that the Coanda Effect has to be applied.

Fig 2. below, shows the intervention required to apply the Coanda Effect to a wing. Air is compressed by a pump and forced from a slot. The resultant high speed jet follows the curved surface over to the wing underside generating a strong suction over the bluff trailing edge. See Fig 1 and Fig 2.

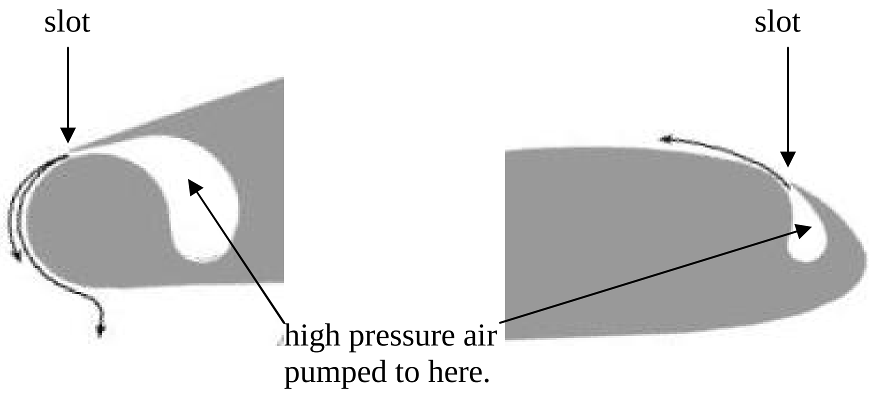


Fig 2. Trailing edge blowing. Air exits slot and flows around bluff trailing edge.

Leading edge blowing. Air exits slot and flows up and along wing.

The Coanda Effect increases lift by a factor of 3 to wings and wind turbine blades. In some cases air is blown from near the leading edge as well. The jet in each case is called a “Wall Jet” because it adheres to a wall.

Coanda Effect rarely occurs naturally.

Rare examples are where flowing water adheres to the undersurface of a gently sloping rainwater gutter and also under the curved undersurface of the roof of our stomach thus preventing excess liquid diluting the food/digestive acid mix as it passes above the food and out through the pyloric sphincter into the duodenum. In these natural cases, gravity accelerates the water and it becomes a thin wall jet. The speed of the wall jet decreases pressure between it and the surface and causes it to stick to and flow along an undersurface. The above demonstrates there is no possible way it can occur naturally on wings.

COANDA EFFECT AND BERNOULLI EXPLANATION IRRECONSILABLE

The Coanda Effect is man made and increases lift three times. It is impossible to understand how it does this unless the real cause of lift is understood.

SECTION 2.

HOW CONVENTIONAL LIFT IS GENERATED

Wing lift is not due to the Bernoulli Effect, despite many flight manuals and science museums claiming it is. The Bernoulli Effect is where a high speed fluid flowing over a surface reduces pressure. The Bernoulli Effect is a real phenomenon occurring elsewhere but not on wings. (The confusion may be in a few cases because the Bernoulli equation is often employed to calculate lift).

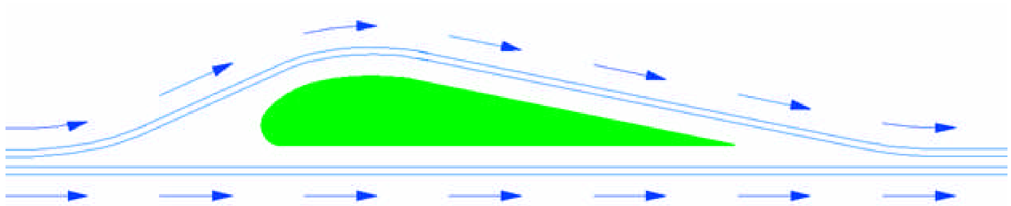


Fig 3. The “Bernoulli Effect” explanation states that because the distance over the top of the wing is further than the underside, the air over the top goes faster than the underside air to rejoin at the trailing edge and thus the increased speed reduces pressure above causing lift. Fig 3 depicts separated flow re-joining at the trailing edge. These notions are incorrect.

The following commonly accepted facts are fatal to the Bernoulli explanation of lift:

- Planes with conventional topside cambered wings can fly upside down.
- “Barn doors” or flat plates can fly.
- Symmetrical cross section wings fly very well. (Same distance over top and bottom). Aerobatic planes have symmetrical cross section wings.
- A wing moves through generally still air; i.e. the wing moves, not the air.
- Air atoms separated at the wing leading edge do not neatly re-join at the trailing edge.
- There is no accelerated “sheet” of air of any thickness flowing over the wing.

The above facts signal that the Bernoulli Effect is not involved in generating wing lift.

Lately the notion that the Coanda Effect naturally operates on the top of wings has been suggested as maintaining flow attachment. This also is incorrect.

Please forget the Bernoulli Effect explanation until the following explanation is completed. The mechanism for lift, practiced by all aeronautical engineers in the calculations for and design of, airfoils will be given.

The problem has long been that because lift is complex, “simplifying notions” have been provided without the explanation that that is only what they are. The belief that the Bernoulli Effect generates lift on wings is one of them.

SECTION 2.1

The following explanation is simplified and non – mathematical.

Everything in the universe is a Vortex or otherwise possesses Vorticity!
"…every movement in a finite, closed space must obviously lead to a rotation". Hans Lugt, "Vortex Flow in Nature and Technology". Page 20

This includes generation of wing lift.

Electrons are said to possess spin, contributing vorticity to atoms and molecules. These in turn form part of larger vortices such as ocean and atmospheric currents. The planets spin (possess vorticity) as do the galaxies, being giant vortices.

A wing generates and remains embedded within a vortex.

Every modern plane has been designed by aeronautical engineers who rely on this phenomenon.

Don't be confused by the term boundary layer. It is not involved in lift, however must be understood by aeronautical engineers as it can be involved in stall which causes loss of lift.

The vortex the wing generates and is within, is bound to the wing and is called the "Bound Vortex" by aeronautical engineers.

Air possesses heat, humidity, pressure, density and the ability to transmit 2 kinds of pressure impulses. One is sound (acoustic) waves which propagate at the speed of sound *with, across* or *against* an air current flow direction. i.e. we can be heard upwind.

The second kind of pressure impulse is the type involved in lift. It also propagates within air that is flowing or still. Its speed is also exactly the speed of sound no matter how much force goes into its generation.

Sound waves are composed of many gas atoms in each wave or pressure peak. The pressure peaks may be different distances apart (different frequency past a fixed point) which determines the "pitch" of the sound.

The second type of pressure impulse is at the atom level and therefore has no frequency or pitch in the sense of the acoustic case. But it has direction and is termed Diffusion. An analogy: heat one end of an iron bar. The heat travels by diffusion along the bar. The atoms do not actually change their position but pass on their increased energetic state to the next atoms and so on. Similarly when air is disturbed, diffusion is also generated. The air atoms move at the speed of sound but only an infinitesimal distance to jostle the adjacent atoms. Diffusion therefore is a kind of relay from atom to atom.

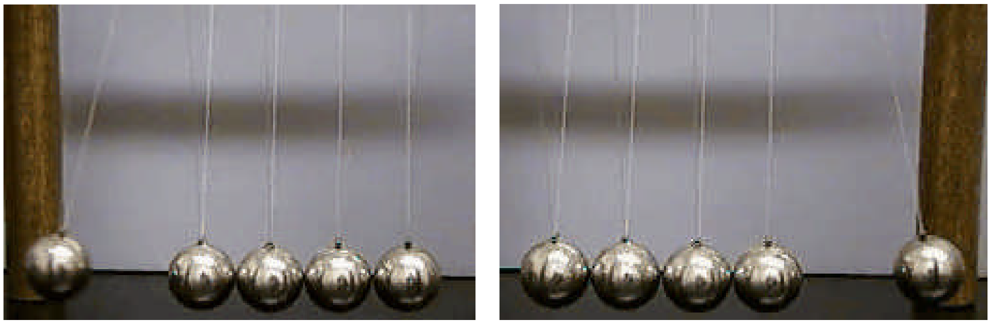


Fig 4. Central 3 balls seemingly do not move. This is analogous of diffusion.

The swinging ball novelty indicates how diffusion transfers the momentum of the released ball through the central balls, which seemingly do not move, to the far ball. However, unlike the solid iron bar or the swinging balls, diffusion spreading through fluids such as air, is vortical (rotational). At everyday conditions we cannot detect this diffusion with our senses. It can however be detected with scientific instruments which measure the air's local density variation.

<u>Diffusion spreads vorticity</u>.

It is by diffusion (the pressure impulse) that vorticity spreads from the point of generation. The pressure impulse does not radiate in all directions like acoustic waves, (acoustic waves however do possess vorticity, but it's another subject) but instead rotates around a centre. "Nature prefers rolling over gliding" Osborne Reynolds. This is an energy conservation law as important as the other more well known energy conservation laws.

The moving wing generates the bound vortex and its imaginary centre of rotation is found within the wing. This centre is termed a Vortex Filament.

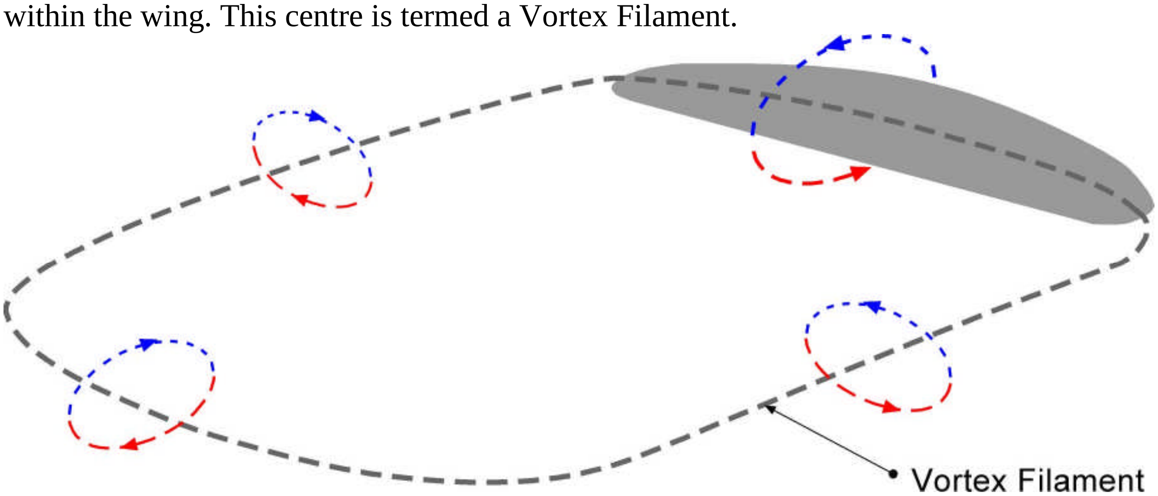


Fig 5. Vortex filament. *Diagram strictly schematic*.

When air actually flows as a breeze or fan generated airflow it is called Convection. *"In contrast to diffusion, the transport of physical quantities by the moving fluid itself is called "convection"*. Hans Lugt P 45.

It is emphasized here that the vorticity in this case of the bound vortex is not convection. There are two ways vorticity manifests 1; diffusion as described above and 2; fluids such as air may literally flow in a circle; this is convection in the same sense that a breeze is convection.

The smokers ring is where the smoke merely makes visible rotating air that has formed into a ring. Although the air in the smokers ring is convection, it is analogous only of the ring shape of the vortex filament of Fig 5. Because the air is invisible this is not at first apparent or intuitively grasped.

A ring vortex is a hoop shaped tube called a Vortex Tube. The wing remains embedded within only a section of the hoop.

The 2 types of vorticity follow a set of laws common to both. Before stating them, it is repeated and emphasized that wing lift generates a diffusion vortex, not a convection vortex.

***Lift involves a ring vortex*.**

The SAE: The Standard Handbook for Aeronautical and Astronautical Engineers, Section 10, 10.28 states*: "A vortex tube is defined as a bundle of vortex filaments". " The behavior of a vortex tube is governed by Helmholtz's laws of vorticity, which states that:*

1. *The strength of a vortex filament is constant along its length.*
2. *A vortex filament must form a closed path, extend to infinity, or terminate on a solid boundary. This is a consequence of the first law, which effectively states that the product of vorticity and the filament cross sectional area must remain constant.*
3. *A vortex filament always consists of the same fluid elements.*
4. *The strength of a vortex filament remains constant as it moves throughout the flow field."*

Law 2 above, states that the vortex tube that the wing is embedded within (the bound vortex) cannot have loose ends. It obviously cannot extend to infinity and there is no solid boundary nearby. Therefore it must form into a ring.

The 3 pictures below are of convection vortices.

Fig 6. On stage tornado terminates at solid boundary (floor) and top fan. (suction pump).

Tornado (a vortex) terminates on ground and a suction pump above. (which is often the Jet Stream).

200 meter vortex ejected from Mt Etna forms ring because no solid boundary is nearby.

The bound vortex, generated by the wing, also attempts to form into a ring.

The “tip vortices” form due to ambient air being spun by the bound vortex near the tip.

“The Standard Handbook for Aeronautical and Astronautical Engineers” further states; *“For more information on vortex flows and proofs of Helmholtz’s laws, see Lugt (1995)”* Section 10, 10, 28.

Lugt then in “Vortex Flow in Nature and Technology” states; *“At the ends of the plate two vortices must occur because the pressure above the plate is smaller than below”. The tip vortices cause a drag, the so called “induced drag”. With the Bound Vortex they form a “horseshoe vortex”. This vortex must be closed, according to Helmholtz’s first theorem* (law 2 above) *since a vortex filament cannot end within a fluid”*.P 57.

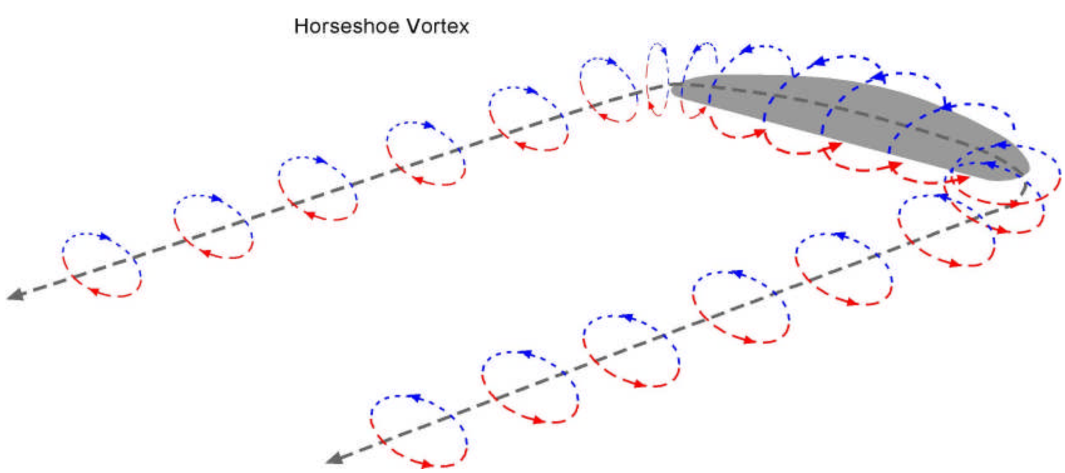


Fig 7. Bound Vortex and the tip vortices comprise the horseshoe vortex. *Diagram strictly schematic.*

Fig 8. Cloud pattern merely makes visible the trailing tip vortices depicted schematically in Fig 7 and 9.

We now have a horseshoe shaped vortex but we need a closed ring. *"The missing vortex is the "starting vortex" which is generated when the plate* (the wing) *begins to move"* Lugt .P57.

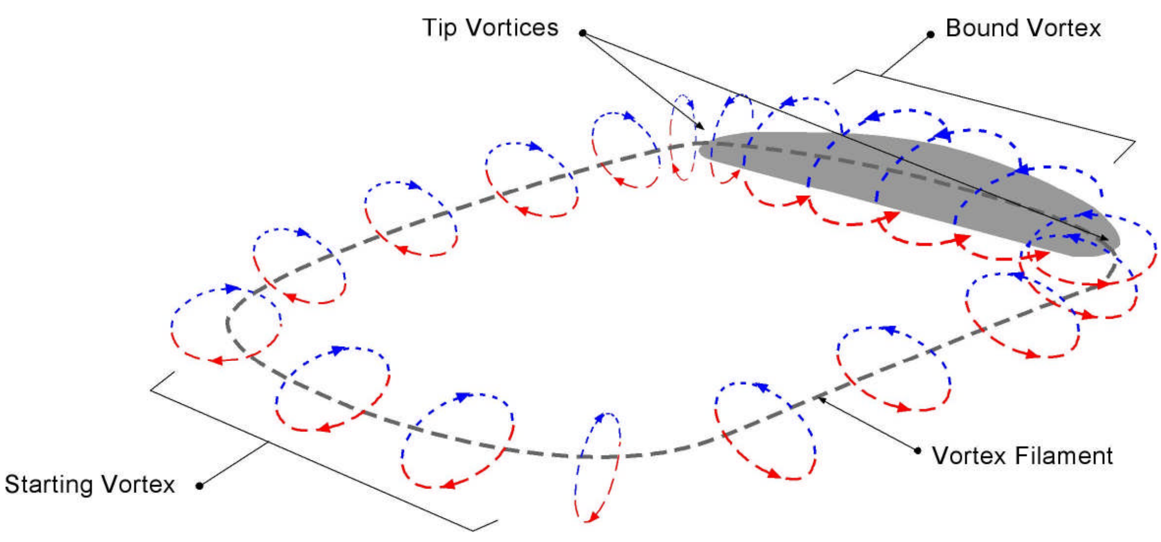


Fig 9. The vortex tube with a "vortex filament" as the imaginary centre. Arrowed lines show the direction of rotation only, not the diameter of the vortex tube. The bound vortex envelopes the whole wing extending a large distance above and below the wing. *Diagram strictly schematic.*

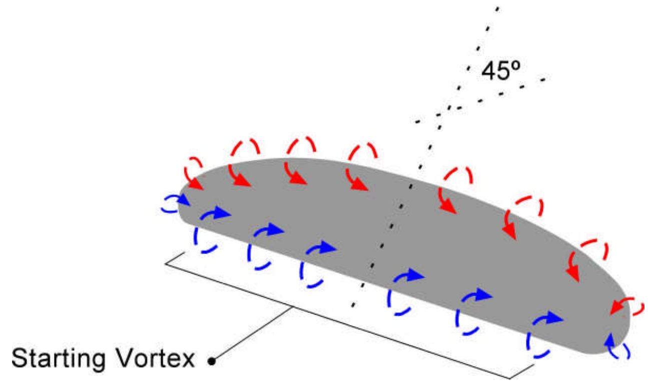


Fig 10. The natural convection of air around a plate at extremely high attack angle and low speeds cannot be sustained at high speeds and lower “flying” attack angles. At high speeds the starting vortex is shed and the wing becomes embedded within the leading vortex (red arrows). Then, according to natural law, that convection vortex transforms into diffusion as air cannot accelerate quickly. Red arrows indicate why circulation in the bound vortex is in direction indicated in Fig 7 and 9.

The starting vortex which attempts to roll up over the wing trailing edge during the takeoff ground roll is “shed” before takeoff.

The bound vortex, the 2 Tip Vortices and the starting vortex form the closed ring required by Helmholtz’s law (law 2 above).

However because the action of the wing is a dynamic process the full ring cannot remain intact. The shed or starting vortex is theoretically back at the airport leaving only the horseshoe shaped vortex consisting of the bound vortex and the tip vortices.

A very brief, forceful impulse may generate a convection ring vortex which swims through the air until it dissipates through frictional forces and mixing (such as the one ejected from Mt Etna).

Conversely, a wing generates a continuous force (a dynamic process) on the stationary air. Therefore the bound vortex, being a diffusion vortex, cannot impart convection vorticity to the ambient air between the two wingtips. But it can past each wingtip as underside air bleeds around the tip to the top and so spins, becoming the tip vortex.

The bound vortex is carried along with the wing, the phenomenon according to the law; *“…every movement in a finite, closed space must obviously lead to a rotation”*. Hans Lugt, P20 i.e. nature generates vorticity!

<u>Circulation.</u>

The pressure impulse circulating around the wing, (the bound vortex), is therefore termed “Circulation” by aeronautical engineers.

Aeronautical Engineers also describe this as ‘Superposition”, i.e., the circulation is superposed over the seemingly simple separating by the wing of the ambient air.

This "superposed" circulation around the wing is the front section of the vortex tube mentioned above.

Fig 11. Standing wave. The wave is stationary. Standing waves are found around the world.

The standing wave above demonstrates how a fluid can flow through an area of increased (or decreased) pressure. Pressure (pressure impulse) within the wave lifts water against gravity. River flow comes from the right, slows through the wave, resumes speed and continues left. *By eliminating the spectators and beach it could be equally true that it is the wave that is advancing through still water and not the other way around!*

The pressure impulse within the wave is analogous to the pressure impulse under a wing. If a model of the plane is placed in a wind tunnel and the air is moving past its wings the pressure impulse is there the same as if it is the plane that is moving and the air is still.

Fig 12. Jet flying at less than sonic speed. Note the front of the disturbance of water precedes the plane. It is not downwash. The "pressure impulse", "circulation" or "bound vortex" extends from wings to water surface. It also extends a similar distance above wing but above the pressure is less than ambient.

***Conservation of vorticity*.**

Some well known laws are the "Conservation of Matter", the "Conservation of Energy" the "Conservation of Angular Momentum". A less known law but of equal significance is the "Conservation of Vorticity".

Helmholtz's laws of vorticity, 1 and 4 above, show that the strength of a vortex tube or filament must remain constant along its length and cross sectional area.

Because the dynamic action of the traveling wing on each small section of stationary air encountered is such a fleeting episode, the full development of the required ring vortex is not completed. It is aborted by the required speed of the wing needed to generate the pressure impulse and the wing has long passed before convection can catch up with the vortical diffusion. *"However, vorticity is transported much more slowly in the fluid than the pressure impulse"* Hans Lugt. P45

Diffusion or circulation (the pressure impulse) travels at the speed of sound but the local (ambient air) cannot travel that fast and certainly cannot accelerate (down) instantly.

The constancy of strength of vorticity of the cross section of the bound vortex (a vortex tube) must be maintained (laws 1 and 4). The wing exerts a force by its underside (the body surface) which raises the air pressure above ambient. *"Vorticity generated at the body surface spreads from there into the fluid through diffusion and convection."* Hans Lugt P45. Within the bound vortex convection cannot catch up with the diffusion.

Fig 12 demonstrates the extent of the vorticity field below the wing. To satisfy Helmholtz's laws 1 and 4 above, the vorticity must also extend an equal distance above the wing. However the pressure above the wing must be below ambient. This does not mean less energy above the wing.

Close the outlet of a bicycle pump or syringe and pull or push. It takes the same force (applying the same amount of work) to reduce pressure as it does to raise pressure by the same amount. Therefore the reduced pressure above the wing has the same cross sectional strength of vorticity as the underside, i.e. negative pressure does not mean less energy. The air atoms above are stretched away from each other while under the wing they are forced closer. Surprisingly, vorticity can involve negative pressure.

Stagnation points.

Because the pressure above the wing is less than below it, it requires that there be a "Stagnation Point" that is at local or ambient pressure, near the leading and trailing edges.

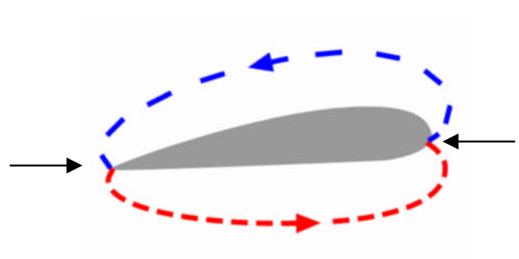


Fig 13. Forward and rear "stagnation points" present in normal flight. *This diagram is strictly schematic.*

Thus the strength of the vorticity above and below the wing is the same but with opposite pressures. Helmholtz law 2 is satisfied.

The low pressure "Flowfield" above the wing, a result of vorticity, accelerates the local (ambient) air down because the ambient air tries to find a speed corresponding to the pressure. It can now be seen that it is the low pressure "field" above the wing that accelerates the air and not a sheet of accelerated air over the wing surface that lowers the pressure. The Bernoulli Effect is not required.

Because a vortex tube will assume a natural circular cross sectional shape if it can, the vorticity "field" (circulation) must extend far above and below the wing.

Fig 14. These pictures show the extent of the vorticity field which depresses the water and also depicts passing through the sound barrier. First picture shows that the front of the water depression, due to circulation, precedes the plane. Last picture shows abrupt cessation of circulation as plane speed exceeds sonic. (The plane can be seen above bow of ship)

The disturbance and depression of the water surface in the above pictures is not due to the downwash. As stated the ambient air cannot travel that fast and cannot be accelerated down instantly.

Sound Barrier.

Because the circulation is limited to the speed of sound, the wing must be driven quickly through this barrier or severe buffeting occurs. A shock wave is generated and heard on the ground as a sonic boom.

Top camber does not generate Coanda Effect.

The cambered top of the wing is shaped as it is to optimize the rotational circulation around the wing and to not interfere too much with the descending downwash. The camber is not there to give a greater distance over the top. The small distance increase topside compared to bottomside is incidental and has an insignificant effect on lift.

While the pressure impulse “circulates” around the wing and the gently cambered top of the leading 25 % of the chord accommodates it, that camber is more to minimise the possibility of leading edge stall caused by leading edge boundary layer breakaway. The boundary layer, remember, is attached to the wing.

The wing performs work; lift requires power.

The drawn down air must pass aft of the trailing edge ahead of the underside air or no work will have been done on the air and no lift results. The time rate of doing work is called Power. Lift requires power.

Forgetting the Bernoulli Effect explanation, we quote instead Newton’s third law: “For every action there is an equal and opposite reaction”. A very large amount of air is accelerated down. Work has been performed on the air. The reaction is lift.

According to David Anderson and Scott Eberhardt in “A Physical Description of Flight”, ***http://newfluidtechnology.com/FLIGHT_DESCRIPTION.pdf*** a plane the size of a Cessna 172 draws down 5 or more tons of air per second to maintain level flight. That requires all the air for 7.3 meters (18 feet) above the wing to be accelerated down. Faster or larger planes accelerate much more air down.

Anderson and Eberhardt’s publication, which is an abstract from their book: ***"Understanding Flight", McGraw-Hill, 2001, ISBN: 0-07-136377-7*** is recommended to gain an insight into many aspects of lift.

We only disagree with their contention that the Coanda Effect is responsible for preventing flow breakaway over the top of the leading edge. As has been explained, the Coanda Effect is not naturally found on wings, it is applied by the forceful ejection of a high speed jet from a slot to reduce pressure over the wing surface. Conversely, the bound vortex includes a generally low pressure field that extends a large distance above the wing.

The Coanda Effect is one type of Active Flowfield Control. There is no naturally occurring wall jet of any thickness generating low pressure close to the wing, which would constitute the Coanda Effect.

We also believe that Anderson and Eberhardt, while mentioning circulation, have minimized its importance by not elaborating on it. Circulation is not a notion for lift calculation purposes. The circulation within the bound vortex is a literal event resulting from a natural law first articulated by Helmholtz.

<u>Ground Effect.</u>

Ground effect is not due to rammed air being compressed under the wing. That is impossible. It is because the circulation that the bound vortex consists of is restricted by the reduced gap between the wing undersurface and the ground or water resulting in approximately 50% increase in lifting efficiency and which is why Wing in Ground Effect (WIG) ships (with some hybridization) could be considered for high speed transport across the oceans.

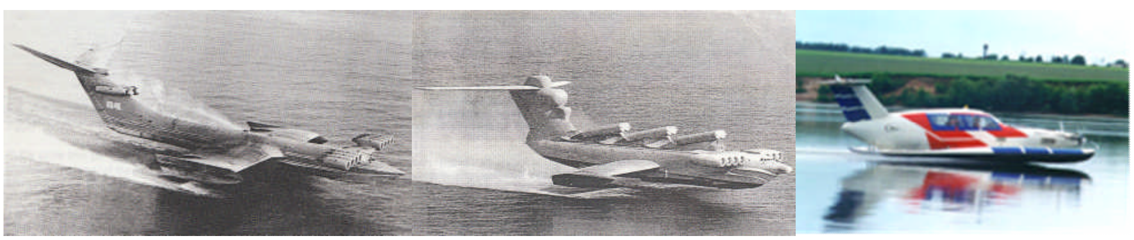


Fig 15. Ekranoplan 1000 passengers 1966. (WIG)   Rocket launcher “Lun” (WIG)   Amphistar (WIG)

<u>Coanda Effect is for sub sonic flight.</u>

Obviously flight exceeding the speed of sound involves a different means of lift than circulation. The Coanda Effect is applied to increase lift in sub-sonic situations.

SECTION 3.

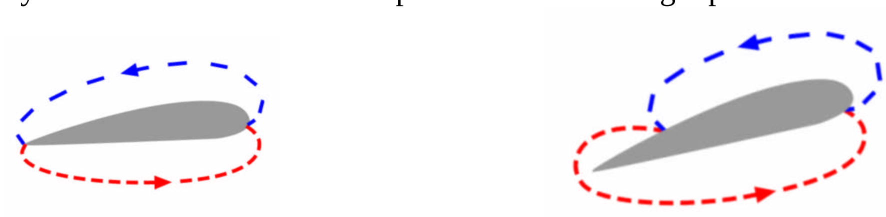
THE COANDA EFFECT

Now that lift is correctly understood it can be described exactly how the Coanda Effect greatly increases it.

The conventional way to increase lift is to increase the Pitch (increase nose up) while applying more power. This puts more force on the underside air and so increases the strength of the vorticity, i.e. the circulation around the wing becomes stronger but the speed of that circulation remains exactly sonic.

Stall.

Nose up or down is pitch. There is a limit to how much the pitch can be increased. Too much pitchup and the wing stalls because the rear stagnation point drifts up stream, the boundary layer destabilizes and the air separates from the wing top.



a **b**

Fig 16. *These are strictly schematic diagrams.* **a**, stagnation points in normal unstalled positions. For **b**; the rear stagnation point shifts upstream resulting in stall.

If the pitch could be significantly increased while applying more power without stall, the strength of the reduced pressure vorticity field above the wing can be increased to the point that a much greater amount of air is deflected down resulting in 3 or more times the lift. This is where the boundary layer is important because it can become unstable. The boundary layer is up to 2.5 inches thick and its many layers naturally shear relative to each other with the first layer traveling along with the wing. The boundary layer is not a flowing sheet of air. “The Standard Handbook for Aeronautical and Astronomical Engineers”, *Section 10. 10. 58* describes 5 types of stall.
It is not necessary to know more about stall than thus far to understand lift and the Coanda Effect. Leave that to the aeronautical engineers.

Coanda Effect postpones stall.

The 2 stagnation points are the divide between the top reduced pressure and the underside increased pressure. One stagnation point must be kept at the trailing edge. When it drifts upstream it nevertheless still remains the divide between the topside and underside pressures. In this case the underside high pressure air bleeds around the trailing edge and drifts upstream causing detachment of the air from the wing. No more air is drawn down: lift is lost.

A high speed Coanda jet blown from a slot above a rounded trailing edge follows the curvature because the jet speed generates a significant pressure reduction under its flow which cannot be relieved through the highly energetic air sheet. The resultant suction causes the jet to remain attached to the curving surface over to the underside of the trailing edge.

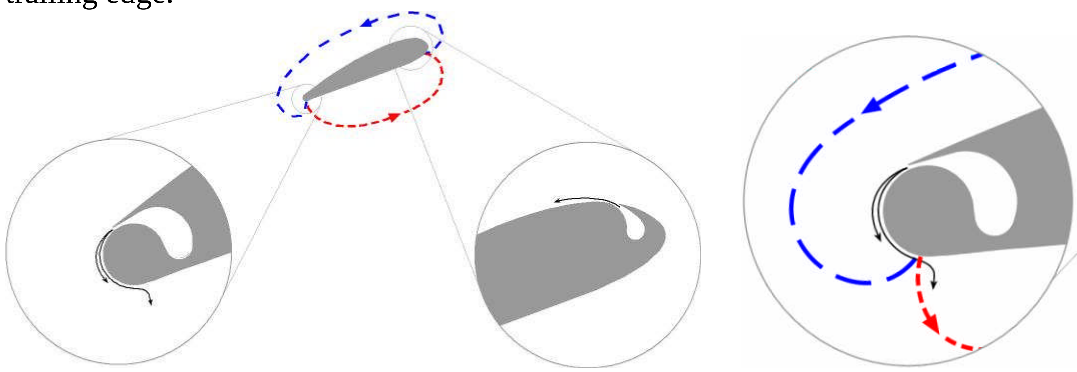


Fig 17. Coanda Jet suction shifts the rear stagnation point to the position where the Coanda jet separates from the underside. If employed, leading edge blowing is aimed at keeping the boundary layer over the leading edge attached at high angles of attack. Leading edge blowing is seldom used. Recent investigations indicate it may be very effective for preventing leading edge stall on wind turbine blades.

The Coanda jet's suction restores the topside low pressure and also shifts it further around to the underside of the trailing edge.

The topside camber refers not so much to the literal shape but the area and distance of the cambered surface on top. That is why the application of the Coanda Effect to wings is said to "increase the effective camber"

It also restores the wing back to within the Bound Vortex even at high angles of attack. The circulation is controlled. That is why applying the Coanda Effect in this way is usually referred to as "Circulation Control" or CC. The result is that the plane can fly with increased pitch without stall or can fly at normal pitch with increased lift. Employing the Coanda Effect results in lift being increased by a factor of 3.

Power Requirements.

Georgia Tech Research Institutes Bob Englar, reports that the Coanda slot blowing momentum input yields a return of 8,000%. "Applications of Circulation Control Technology", chapter 2: *Overview of Circulation Control Pneumatic Aerodynamics*, Page 25. This is simply stating that applying the power of the Coanda jet results in a lift increase that equals 80 times that energy input.

<u>No free lunch.</u>

Non engineers may think this (a 3 fold increase in lift) is claiming something for free. Unfortunately there is still no" free lunch". It is just that the lifting efficiency of the wing has been enhanced especially at high angles of attack. Aeronautical engineers use a term Lift over Drag (L/D). Applying circulation control changes the L/D ratio. When lift is increased, unfortunately so is drag. The lifting efficiency is increased but the higher speed cruise ability is greatly reduced and so there is essentially no increase in overall efficiency, it's just that the increased drag is not a penalty at the low takeoff and landing speeds and can even be taken advantage of. Takeoff and landing is the only situation to apply CC as the wing has plenty of lift at normal cruise speeds and CC is not required. Wind turbines do not require cruise, but instead, lift, to increase shaft torque.

SECTION 4.

A BRIEF HISTORY OF THE COANDA EFFECT.

A number of cases where CC has been applied historically follow.

Fig 18. Boeing 387-80 prototype of the 707 airliner on the ramp at NASA Wallops Station, Virginia, in June **1964**. The "Dash 80" had been modified for very slow flight using wing flaps blown by Coanda Effect. Primary air for blowing the flaps came from compressor bleed of the Number One and Number Four engines. ***Aircraft could fly as slow as 70 knots.*** *<u>Caption by G. Harry Stine.</u>*
(70 knots = 80.6 mph = 129.85 kph which is about half its normal takeoff speed).

Fig 19. A 6 with bluff wing trailing edge; 1979.

CC applied to this aircraft enabled a 75% increase in payload.

Fig 20. Navy/Kaman Aerospace, Circulation Control (CC) helicopter.

Fig 21. Coanda blowing of flat backed trucks yields 11% to 12 % fuel saving. *The technology is owned by Georgia Tech Research Institute.* Download report from Georgia Tech at: http://newfluidtechnology.com.au/GTRI.pdf

Fig 22. V22 Tiltrotor has a Coanda, CC blown foil inside exhaust nozzle for jet exhaust deflection.

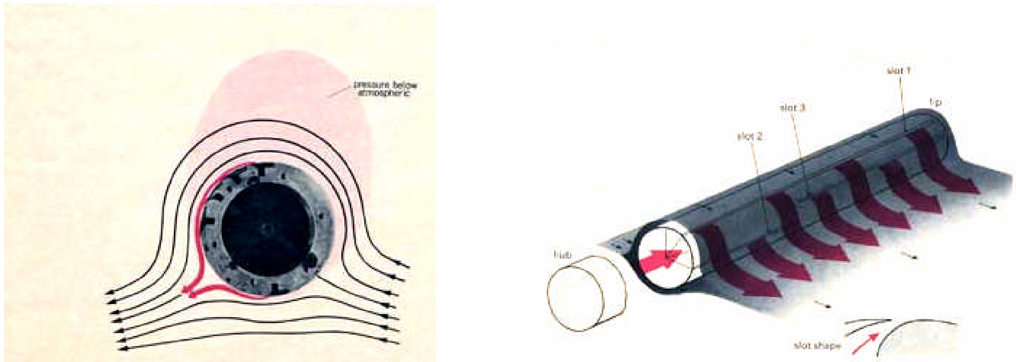


Fig 23. Mid 1960s; Dr Ian Cheeseman of British National Gas Turbine Establishment experimented with a Vertical Takeoff and Landing (VTOL) helicopter with Coanda slot blown cylindrical rotors. 3 slots eject air. 2 slots blow at one time. It demonstrated extreme lift but efficiency was too low. Rotors were meant to fold back for forward conventional flight.

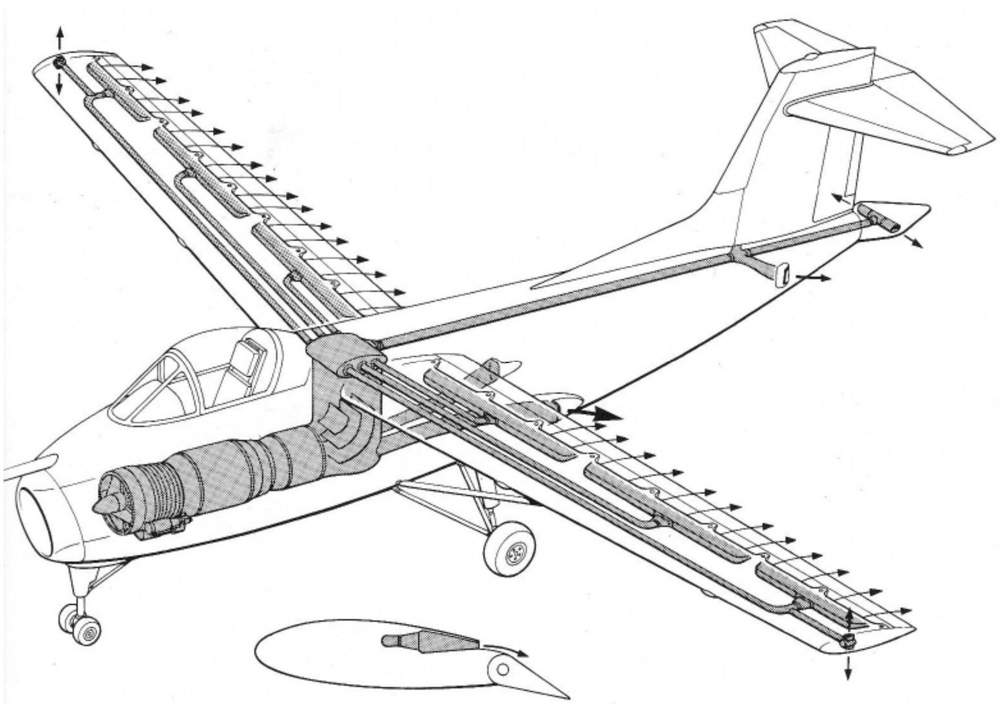


Fig 24. The Hunting, H.126 developed by the British National Gas Turbine Establishment had Coanda blowing over the wing flaps. *Source; The International Encyclopedia of Aviation.*

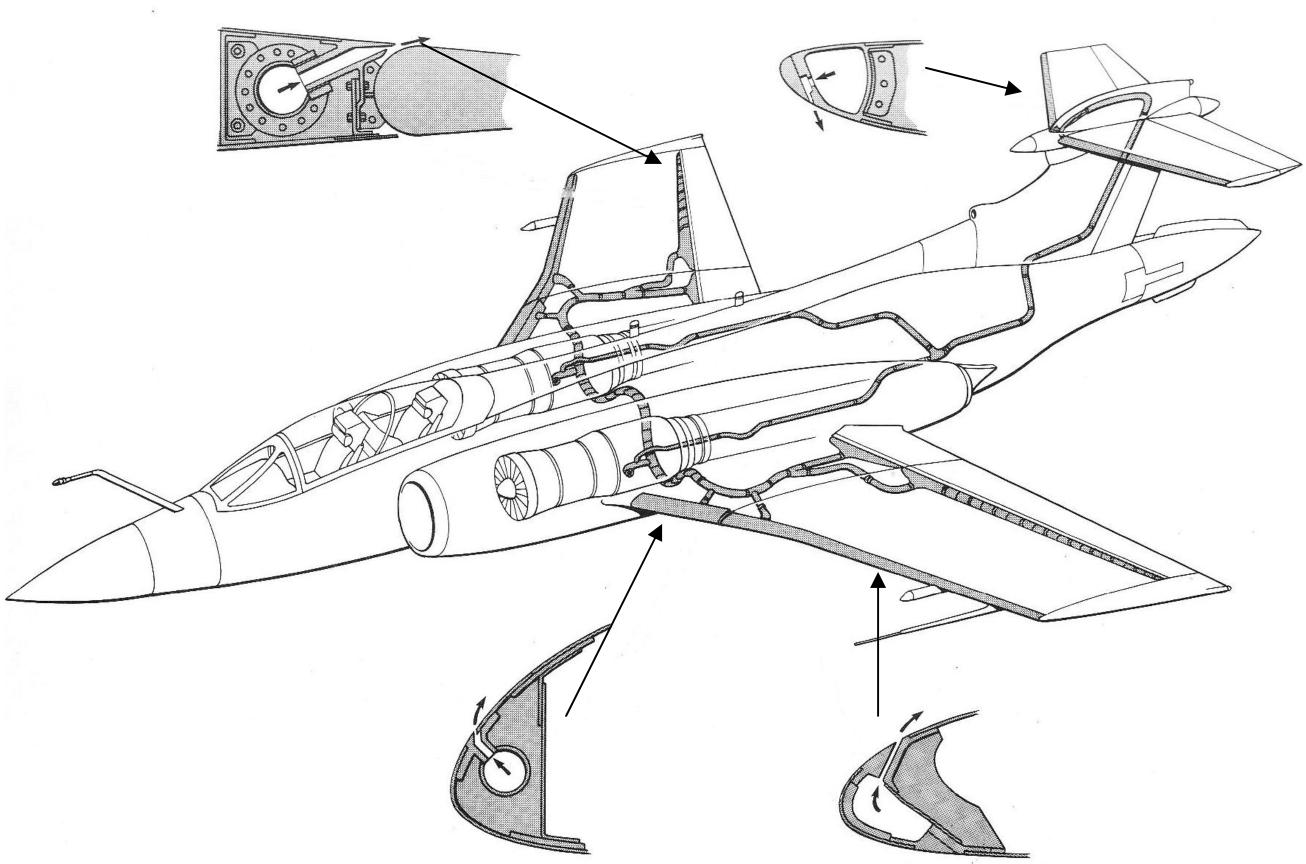


Fig 25. Hawker Siddeley "Buccaneer" July 1962. Had leading edge blowing as well as blown flaps. *Source; The International Encyclopedia of Aviation.*

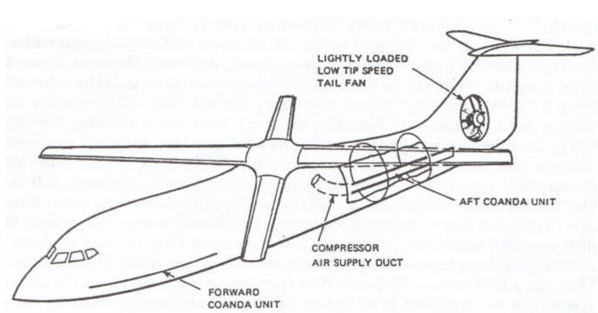


Fig 26. X-Wing; No pitch control mechanism is employed. Blades have Coanda slots.

There is no mechanism present for cyclic and collective pitch control on this later version.

In the late 60s to early 80s the X-Wing was developed with a stoppable rotor that locked into place after takeoff to become a wing for higher speed flight. The full size aircraft did liftoff in the NASA Ames 40x80 ft tunnel and successfully transitioned from hover to stopped rotor.

The 2 planes below are designed for Short Takeoff and Landing (STOL).

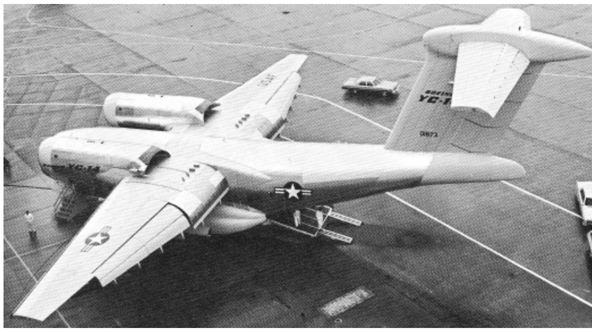


Fig 27. Boeing YC-14. Jet scrubs wing and is deflected down. Source ; The International Encyclopedia of Aviation.

Russian An-72 are Derivatives of this plane are still in production.

The YC-14 above, met all STOL expectations, but never went into production because of budget cuts. It had its engines mounted ahead and above the wing. The concept was called “upper surface blowing” (USB) and there is no question that it enhanced lift. The effect with flaps was dramatic. Douglas developed a similar experimental plane, the YC-15. It differed in that it blew the jet exhaust stream only over the flaps, which were made of heat-resistant titanium, rather than over most of the chord of the wing. The plane has been an outstanding success both as a military transport and as a short-haul airliner operating out of tiny, remote strips.

COANDA EFFECT BENEFITS

The foregoing is surely an indicator that the Coanda Effect form of circulation control should be developed as a matter of urgency due to the benefits it gives in aeronautical applications not the least one being the enhanced safety. CC blowing is “push button” and many times faster than worm drive actuated wing flap extension. Wind shear is an example of where CC could save lives.

Since 1974, numerous other applications for CC blowing over a rounded trailing edge have demonstrated the versatility of this technology.

For example:

1, Wake drag reduction behind cars, trucks, torpedoes etc.
2, Propeller downwash drag reduction on tilt rotors.
3, Improved performance of low drag horizontally mounted radiators in cars.
4, Lightweight hot exhaust gas deflectors on helicopter engines in ground effect.
5, Providing an alternative to a helicopter tail rotor, to cancel rotor torque.
6, Noise reduction by wake dissipation on helicopter rotors.
7, Improved effectiveness and control with upper surface blowing (USB).
8, Providing pneumatic control on fixed flight control surfaces.

These developments indicate that the future for new CC applications is bright. John L. Loth; "Advantages of Combining BLC Suction with Circulation Control High Lift Generation", Ch 1, Applications of Circulation Control Technology, *Progress in Astronautics and Aeronautics.*P3.

SECTION 4.1.

Wind Turbines.

CC is ideal for wind turbines because a wind turbine blade does not need the ability for cruise as with an airplane wing. More lift than cruise ability is desirable to give increased torque to the generator shaft. This means also that the trailing edge of the blades does not need to be altered during operation. The very high angle of attack of the blades may, in some cases, require leading edge blowing as well to prevent leading edge stall.

"Here, variations in blowing parameters through the individual blade slots could vary the output of the fan, or conversely, for a pneumatic windmill, vary the sensitivity of each individual blade to the incoming wind angle and strength, as well as the radial load distribution on the blades. For the windmill, blade pitch would not be required to change mechanically for maximum performance or avoidance of rotor overspeed", Robert J Englar, Applications of Circulation Control Technology: Ch 2, p 23 Overview of Circulation Control Pneumatic Aerodynamics.

The following 3 excerpts are from a PHD thesis by Chanin Tongchitpakdee, "In Partial Fulfillment of the Requirements for the Degree, Doctor of Philosophy in the School of Aerospace Engineering, Georgia Institute of Technology, May 2007."

"This analysis has been validated for the NREL Phase VI rotor tested at NASA Ames Research Center."
"3. For attached flow conditions, circulation control technology (using trailing edge blowing) and Gurney flap both are very effective at increasing circulation around the airfoil section leading to a net increase in generated power compared to the baseline rotor."
"It was found that leading edge blowing can be used to create large leading edge suction, which leads to increased torque and power generation."

Download Chanin's thesis at http://newfluidtechnology.com.au/Chanins_thesis.pdf

SECTION 5.

WHY IS THE COANDA EFFECT UNDERUTILIZED?

How is it then that the Coanda Effect (CC) is utilized in only 2 production aircraft shown below and neither for lift augmentation?

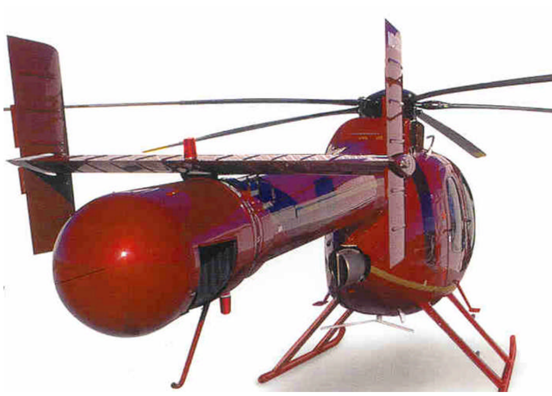


Fig 28. No Tail Rotor helicopter (NOTAR): Coanda jet lowers pressure over boom for directional control.

V22 Osprey: Coanda wing in exhaust duct deflects exhaust away from critical areas on Carrier decks.

SECTION 5.1

That question was asked at the first Circulation Control workshop in 1971 and then again at the next workshop held at the NASA, Ames Research Centre in 1986.

The last Circulation Control workshop conducted by NASA and Office of Naval Research (ONR) was in March, 2004, in Hampton, Virginia.

During the 2 full day workshop, attended by 110 scientists, engineers and managers, 30 papers and 4 posters were presented.

At the end of the presentations, which represented the latest “state of the art” in CC, the same question was again asked; why is Circulation Control underutilized? And further; what can be done about it?

Since that workshop the papers have been updated, peer reviewed and 24 of the 30 have been included in the book published by the American Institute of Aeronautics and Astronautics: Applications of Circulation Control Technology, *Progress in Astronautics and Aeronautics.* Edited by Ronald D. Joslin and Greg S. Jones. (ISBN 1-56347-789-0).

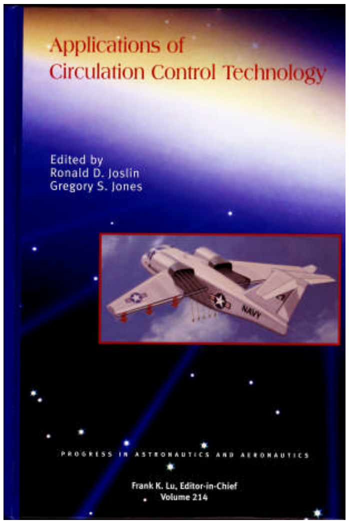


Fig 29. The book "State of the art" in circulation control technologies.

This author delivered the final paper to the 2 day NASA/ONR workshop and contributed the final chapter to the above CC book," Chapter 24, *Coanda Effect and Circulation control for Nonaeronautical Applications*". P 599.

The answer to the question is two fold. 1; a reliable, efficient source of slot blowing air had not been found and 2: a completely safe means of in flight switch from the sharp trailing edge, required for cruise, to the bluff shape required for CC had not been found. Both the above requirements have been successfully resolved technically.

New Fluid Technology has conducted extensive, practical research into the above two issues.

Fig 30. New Fluid Technology Coanda wind turbine blade section.
:Setting slot height.

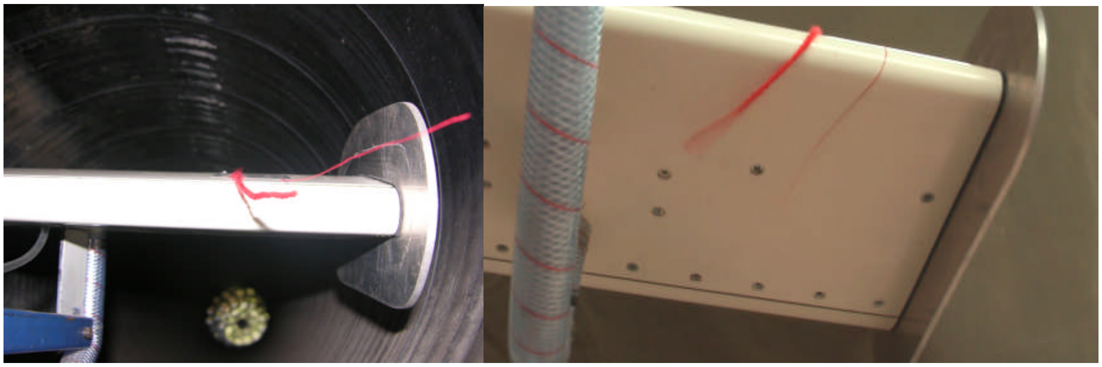


Fig 31. Blowing turned off. Wool and cotton in tunnel freestream. Blowing on. Wool and cotton entrained in Coanda jet to underside of trailing edge.

Numbers for the above blown blade:

- Attack angle 15 degrees.
- Tunnel air speed 9.55 meters/sec (2.652kph, 1.65 mph)
- Slot height .508 mm (20 x thousandths of an inch) span 433mm.
- Pre slot plenum pressure 1.75kpa (7 inches wg). (via digital manometer)
- Jet speed from slot 54 meters/sec (15kph, 9.32mph). (via Pitot tube)
- Mass flow 11.9 liters/sec
- Watts of air power; 20.8 watts.
- Mass flow to 3 blades 35.7 liters/sec.
- Watts of slot air power for 3 bladed wind turbine; 62.4 watts. (Georgia Tech Research Institute's Bob Englar, reports that the Coanda slot blowing momentum input yields a lift return of 8,000% or 80 times.
- If 40 % efficient air compressor is employed, electrical watts input; 156 w.
- Load cell reading without Coanda blowing ***713*** grams.
- Load cell reading with Coanda blowing on ***2170*** grams.
- Lift is increased ***300%.*** (measured by balance bar and load cell)

Newfluid is developing an <u>*innovative compact pump*</u> *to supply the blowing air to CC wind turbine blades.*

New Fluid Technology has also been conducting practical research into applications of the Coanda Effect in appliances for the home, industry and transportation. For more information view our website; www.newfluidtechnology.com

<u>Private Enterprise.</u>

With modern engineering and new materials any roadblocks will be resolved. It is likely that private enterprise will get involved as it appears that the profit motive can drive certain projects harder and quicker than academic motives as has been the case with the Burt Rutan, Richard Branson business for the privatization of space travel for profit.

Circulation Control and other applications of the Coanda Effect are mature technologies that have been investigated and proven by some of the world's best engineers and scientists employing the most rigorous methodology at the expense, in most cases, of governments through agencies such as NASA, Office of Naval Research and leading Universities such as WVU and Georgia Tech Research Institute among others. The question is; who will get the “Vision”?

Who will know when and how to act to put together sound business initiatives to develop renewable energy systems and energy saving appliances and make a profit as well.

We recommend that any serious decision makers download the 2 day NASA, ONR Circulation Control workshop proceedings; http://hdl.handle.net/2002/15755 and http://hdl.handle.net/2002/15756, and acquire the book, Applications of Circulation Control Technology, to get a full understanding of this important subject.

Key words& phrases for further research:

Active flow control
Circulation control
CC
Increasing effective camber.
Stall postponement.
Bernoulli Effect
Bound Vortex
Coanda Effect
Conservation of Vorticity
Diffusion

STOL
Wall Jet
Stagnation Point
Starting Vortex
Tip Vortices
Upper Surface Blowing
USB
Vorticity
Wing in Ground Effect
WIG