Acheon Project: A Novel Vectoring Jet Concept

Conference Paper · November 2012

DOI: 10.1115/IMECE2012-87638

6 authors, including:

Antonio Dumas
Università degli Studi di Modena e Reggio Emilia
113 PUBLICATIONS **679** CITATIONS

José Páscoa
Universidade da Beira Interior
162 PUBLICATIONS **646** CITATIONS

-Michele Trancossi-
Sheffield Hallam University
139 PUBLICATIONS **684** CITATIONS

Alessandro Tacchini
Università degli Studi di Modena e Reggio Emilia
16 PUBLICATIONS **35** CITATIONS

Proceedings of the ASME 2012 International Mechanical Engineering Congress & Exposition
IMECE2012
November 9-15, 2012, Houston, Texas, USA

IMECE2012-87638

ACHEON PROJECT: A NOVEL VECTORING JET CONCEPT

Prof. Antonio Dumas
Università di Modena e Reggio Emilia
Di.S.M.I, Reggio Emilia, 42100 Italy
antonio.dumas@unimore.it

Prof. Josè Pascoa
Universidade da Beira Interior
D.E.E. - 6201-001 Covilhã
pascoa@ubi.pt

Dr. Michele Trancossi Phd.
Università di Modena e Reggio Emilia
Di.S.M.I, Reggio Emilia, 42100 Italy
michele.trancossi@unimore.it

Dr. Alessandro Tacchini
Reggio Emilia Innovazione scrl,
Reggio Emilia, 42100, Italy
tacchini@reinnova.it

Dr. Galina Ilieva
Universidade da Beira Interior
D.E.E. - 6201-001 Covilhã
galinaili@yahoo.com

Dr. Mauro Madonia
Università di Modena e Reggio Emilia
Reggio Emilia, 42100, Italy
mauro.madonia@unimore.it

ABSTRACT
This paper presents a general overview of the ACHEON Project (EU FP7 Level 0 - Transport including Aeronautic).
This project presents a novel dynamically controllable Coanda jet using two fluid streams to produce the angular deflection of the jet as a function of their momentum. A control system with electrostatic plasma is used to produce an effective and more precise control of the system.
This paper presents the general guidelines of the project which is going to start and presents expected results.

NOMENCLATURE

a	radius of curved surface;
A_c	area of control exit slot;
A_p	area of primary exit slot;
B	secondary jet exit slot width; exit slot width of systems involving one Coanda jet;
CSM	Coanda-assisted spray manipulation;
d	distance between slots in parallel jets;
D	primary jet diameter at slot exit;
h	height of jet on plane perpendicular to the vector angle of the jet;
J	distance from the exit of the Coanda jet to the tangential centre of the curved surface (location of jet impingement);
J*	momentum ratio Jc/Jp;
$\dot{m}$	mass flow rate;
P	supply pressure;
p_∞	ambient pressure;
p_s	supply pressure;
Re	Reynolds number;
s	step height;
u	velocity;
λ	control slot circumference / primary slot circumference;
ν	kinematic viscosity;
Φ	vector angle;
ρ	fluid density;
Θ	rotation direction of vectored jet; angle downstream on curved surface;
θ_{sep}	separation angle in previous studies

INTRODUCTION

The importance of Air Transport
Free movement of people and goods is one of the fundamental freedoms of the EU. Europe's transport policy

continues to suffer from an imbalance in the utilization of the different modes of transport and of the absence of efficient European coordination platforms and of systemic vectors.

Air transport is the main activity which has transformed our society in the last 100 years by “shrinking the planet” with large economic and social benefits through the world.

Air traffic has definitely recovered after the temporary slowdown following the terrorist attacks on 11 September 2001 and the downturn of the world economy in general. It is estimated that air traffic will have a progressive increase over the next 10 years. The traffic increase and the reduction of costs for tickets require a permanent emphasis on safety, efficiency and environmental issues.

European Aeronautics Industry Overview

Aeronautics and Air Transport sector is a key strategic economic domain in Europe. The European aeronautics industry is currently a fundamental player in the global market, with high competition levels on a global scale (USA, Brazil, Russia, India, and China).

The European Air Transport sector, made up of civil Aeronautics and Air Transport, generates a turnover in excess of 94 billion € and employs almost half a million highly skilled people directly plus high levels of spin-out technology and employment in other sectors. Indirect jobs attributed to air transport related activities can thus be considered much higher and produce a contribution of about 240 billion € to gross domestic product.

Present Air Transport Scenario

The evolution of the most diffused aeronautic concepts (defined during and after World War II) has now reached maturity. Air vehicles with enhanced performance, increased cargo capacity, reduced consumption of energy resources and lowered environmental impacts could be possible by further evolution of traditional concepts, but expected gains appear reduced if compared to the associated costs.

Even if Kondratieff and Schumpeter Cyclic theory [1-5] is not universally accepted, the actual macroeconomic scenario can be identified with the depressive part of a technological wave. Maturity is leading to a competition based on prices, causing an economic slowdown in rich countries, shifting the industrial production to emerging countries with lower cost and increasing unemployment and concentration of richness.

These symptoms can be clearly identified with a depressive moment of a long term technological wave of a Kondratieff cycle, leading to economical, social and political instability due to the reduction of wellness.

In this scenario novel technologies are needed to start a future expansive economic cycle. E.C. through 7 F.P. 2012 has introduced the novel level 0 projects, which aims to encourage the research about the radical step change required for air transport in the second half of this century and beyond.

History of European Air Transport Policy

EU direction was defined through a novel green European scenario in 1992 [6-16]. This direction leads to the communication “Air Transport and the Environment” (1999). The Lisbon Strategy (2000) aims to make Europe the “most competitive and the most dynamic knowledge-based economy in the world”. It generates the “Vision 2020” report and the EU’s Transport White Paper “Environmental certification of aircraft, their parts and appliances” (2003), which defines the rules for the airworthiness and environmental certification of aircraft and establishes a new certification system under the authority of the EASA.

The communication “Aviation and Climate Change” (2005) analyses the available options for reducing the impact of air transport on climate change, encourages innovation and includes air transport in the Greenhouse Gas Emissions Trading Scheme. This direction has been reinforced by “Reducing climate change impact of aviation” (December 2005).

"Europe 2020: a European strategy for smart, sustainable and inclusive growth" (2010) aims to enhance the EU's growth potential and deliver high levels of employment, productivity and social cohesion, influencing also aerospace policies.

PROBLEM STATEMENT

H.O.M.E.R.: The Idea Originating the ACHEON Project

H.O.M.E.R. nozzle concept [17-22] produces a fully controllable flux, with the ability to maintain a predefined direction and to change this direction arbitrarily as a function of momentum (or velocity) of two primitive streams and of the geometric configuration of the nozzle itself.

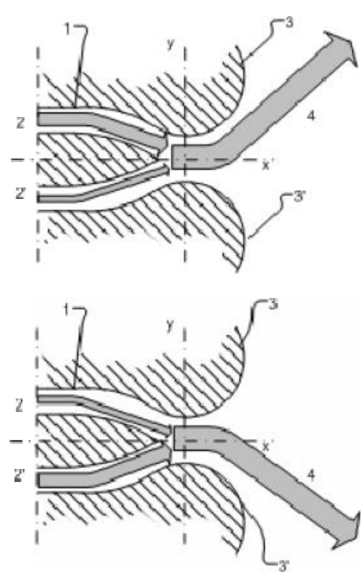


Figure 1 - Representation of the nozzle and its behaviour

Figure 1 shows the architecture of the nozzle. It can have any arbitrary geometry as long as it is constituted by a duct (1) eventually bipartite into two channels by a central septum. The two channels converge into the nozzle outlet, connected to two Coanda surfaces (3) and (3’).

This nozzle is different, more rational and simple than any other jet vector system ever conceived before. It has the ability to permit the stabilization of a synthetic jet with an arbitrary predefined direction and to modify this direction dynamically without any moving mechanical part. It generates a vector and controllable jet by the combined action of two different physical phenomena: the mixing of two primitive jets (2) and (2') and the angular deviation of the resulting synthetic jet by adhering to the Coanda surfaces (3) and (3’).

The synthetic jet is generated and governed by two primitive jets (2) and (2’) by varying their momentums. Physical quantities which guarantee the controllability of the deflection angle of the synthetic jets are the momentum - or speed, for homogeneous jets - and geometric dimensions and design of the nozzle. Minimal operating conditions are related to the Reynolds number (Re > 5000) of the synthetic jet (4) in correspondence to the nozzle outlet. In case of lower Reynolds numbers the system behaviour is unpredictable.

It has been verified that this nozzle can produce an angular deviation of a synthetic jet with no moving mechanical parts, and change the direction of the synthetic jet dynamically. It has been also verified that the synthetic jet always deflects on the side of the primitive stream with the maximum momentum. Referring to Figure 1 the following conditions can be identified:

1. if the momentum of the primitive jet (2) is greater than the one of (2’) the synthetic jet (4) adheres to the Coanda surface designated as (3);
2. if the momentum of the primitive jet (2’) is greater than the one of (2) the synthetic jet (4) adheres to the Coanda surface designated as (3’);
3. if momentums are equal the synthetic jet is straight aligned with the nozzle axis.

The angle formed by the synthetic jet (4) and the geometrical axis of the nozzle can be controlled by the momentums of the primitive jets (2) and (2’). It can be increased when the difference between the moments of the two primitive jets (2) and (2') increases, can be decreased when it decreases and becomes null when it is zero.

PEACE the second idea originating the project

The second IDEA originating the ACHEON project is in the PEACE system which is in a very preliminary stage of development. It is the PEACE project started at Universidade da Beira Interior. PEACE is the acronym of Plasma Enhanced Actuator for Coanda Effect. PEACE aims to produce an active control of the Coanda adhesion to a surface by means of the BSD technology (Dielectric Barrier Discharge) which can enhance and control adhesion of the synthetic by an active control system.

A plasma actuator consists of two offset thin electrodes that are separated by a layer of dielectric insulator material (Figure 2). One electrode is exposed to the air. The other is fully covered by a dielectric material.

The electrode exposed to air is assumed to be loaded by a high voltage, whereas an electrode buried under the dielectric is expected to be grounded. A high voltage AC potential (high-amplitude (several kV) and high-frequency (typically several kHz) AC voltage) is supplied to the electrodes. This effect permits a partial ionization in the region of the largest electric potential, which usually begins at the edge of the electrode that is exposed to the air, and spreads out over the area projected by the covered electrode.

The ionized air (plasma) in the presence of the electric field produces an attraction/repulsion on the surrounding air. Ionized particles are accelerated and transmit their momentum, through collision, to the neutral air particles in the plasma region over the covered electrode. The result is an acceleration of the air in proximity of the surface of the dielectric.

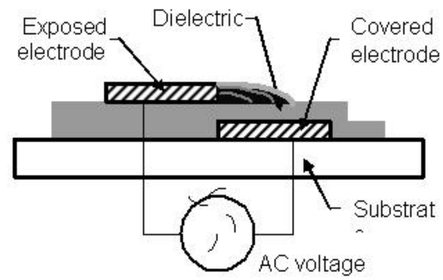


Figure 2 - Schematic of Plasma actuator method

This technology permits an active control on the Coanda effect by means of a very simple system with very high advantages against Coanda adhesion control by control jets.

DBD plasma actuators have a large number of advantages over other active flow control devices:

- very simple, fully electronic, no moving parts
- operated in either steady (continuous) and unsteady (pulsed or duty cycle) modes;
- low power consumption (0,0067-0,0134 Watts per mm for unsteady operation);
- simple integration, maintenance and operating costs;
- it does not affect surfaces and their aerodynamic performances,
- conformability to any surface curvature;
- high mechanical resistance, affordability and durability;,
- fast response for feedback control due to high bandwidth and possibility of closed-loop feedback control;
- possible modulation in terms of frequency and of power variations.

Potential Applications to Aerial Transport Systems

Jet deflection systems are an important enabling technology for novel of air vehicle concepts with enhanced performance, manoeuvrability, shorter takeoff and landing spaces: It permits the exploration of radical new aerial vehicle concepts, and gives a realization to some very advanced concepts which have been proposed during the history of aviation but couldn't be applied because of the absence of an effective and affordable jet vector system.

The main importance of an effective and affordable system to control the direction of a propulsive jet can be interesting because it could enable many directions of aeronautic design development:

1. improving performance, safety, efficiency and manoeuvrability of today's air vehicle concepts;
2. defining future air vehicle designs, which include innovative concepts such as control without vertical empennages and reduction of mobile ailerons, and innovative aerodynamic concepts which require directional control of propulsive jets;
3. analysis of the most efficient and environmental friendly aircraft models based on distributed propulsion systems and on novel propulsive concepts;
4. investigation of novel aerial vehicle concepts which are optimized to enhance and maximize the possibilities which are guaranteed by similar technologies;
5. exploration of novel aerial vehicle guidance models and, in particular, novel trajectories, novel manoeuvring enabling technologies such as vector flight and most efficient aerodynamic configurations;
6. delivery of novel propulsive which can reduce the emission greenhouse gasses such as electrical turbofan, which can be powered by renewable or photovoltaic electricity.

It has been demonstrated by the experiences gained in the last 4/5 decades, that control based on sophisticated mechanical systems can only be suitable for military combat planes and for very short operational periods (combat flight), because they lack in terms of affordability and safety.

Operative considerations

The key element to define a decisive breakthrough by using this propulsion system is related to the definition of novel aerial vehicle architectures which can take the maximum advantage from the H.O.M.E.R. nozzle concept. In particular different architectures with different operational models can be tested and verified both by CFD simulation (to identify best operative solutions) and by testing reduced scale radio-controlled (RC) models of the most promising architectures so to acquire the necessary operative experiences which can accelerate further investigations on the system.

In particular different architectures can be tested to verify if a similar propulsive concept with direction control of the propelling jet could be implemented on well tested air vehicle architectures and could gradually lead to effectively optimized future air vehicle concepts which can maximise the benefits of this kind of nozzle and the consequent jet directionality.

In particular the project aims to investigate different configurations and application of this propulsion system with thrust direction control capability. Different air vehicle architectures will be investigated both by CFD simulation and experimental tests. In particular this test activity will be performed on different architectures and design concepts which can have significant advantages by the proposed propulsive architecture.

In particular, this proposed propulsive technology will be evaluated for different aerial vehicle configurations with the aims of enhancing the overall system manoeuvrability and shortening take off and landing spaces:

- traditional wide-body airliner with wing mounted engines;
- traditional airship bodies;
- innovative concepts of aerial vehicles, with distributed or localized propulsion;
- novel concepts specifically designed to maximize advantages by this directional propulsion system.

EXPECTED RESULTS

The expected results of the project are:

- verification and tuning of the H.O.M.E.R. nozzle concept for aerial propulsion;
- definition of a design methodology for H.O.M.E.R. nozzle in different operative conditions, optimizing geometric parameters as a function of fluid-dynamic properties;
- analysis of feasibility of different application of the H.O.M.E.R. nozzle for aerial propulsion both on traditionally shaped air vehicles and unconventionally shaped ones;
- optimization of the H.O.M.E.R. nozzle system in the most promising configurations.

Design and low inertia, high power/weight optimization of novel high-speed permanent magnet AC motor and electrical drive system to power the fan/compressor stages for low/high altitude operation.

These results are expected by a scientific approach involving together CFD simulations and experimental verification and validation of numerical results aiming to demonstrate the feasibility of the system and to define the possible operative methodologies and the possible limitations connected to its application.

PROGRESS BEYOND THE STATE OF THE ART

Coanda Effect Essentials

The Coanda effect can be described by few main physical parameters [21]. Considering any two-dimensional Coanda flow and referring to Figure 1, the main geometric parameters are the angle of separation θ, the slot width b, radius of curvature a. Physical parameters are Reynolds number Re and the pressure differential $p_s - p_\infty$, (where p_s is the supply pressure).

Different fluid dynamic effects concur to create the so-called "Coanda effect" which was defined by Coanda in 1910 although still in an embryonic formulation [22].

Further, it was completely formulated in 1936 [23] as the combination of three effects: the boundary layer effect, the tendency of a fluid jet approaching a curved surface to remain attached to the surface; the adhesion effect, the ability of a fluid jet to adhere to a nearby surface; the attraction effect, the tendency of jet flows over convex curved surfaces to attract surrounding fluid and increase more rapidly than that of plane wall jets.

The scientific studies about the Coanda effect are characterized by a fundamental landmark study by Newman [24]. He investigated a two-dimensional, incompressible, turbulent jet flowing around a circular cylinder (Figure 2-a). It can be demonstrated that Coanda adhesion to a curved surface is a consequence of the balance of the forces applied to the fluid. During adhesive motion on a curved wall, two forces are in equilibrium: centrifugal force and radial pressure.

The contact pressure with the Coanda surface is lower than ambient pressure because of the speed of the fluid and the viscous interaction between fluid and wall. This differential pressure is the main cause of the fluid movement in contact with curved wall surface.

The pressure along the curved wall rises and gradually equates the ambient pressure generated at the end a detachment of the jet from the curved wall.

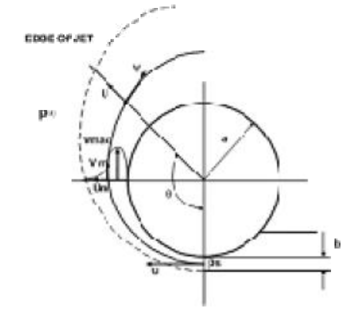
Newman using this setup obtained a relation among detachment angle θ and main geometric parameters of the flow and dynamic quantities involved in the system schematised in Figure 2-a.

Coanda effect applications classification

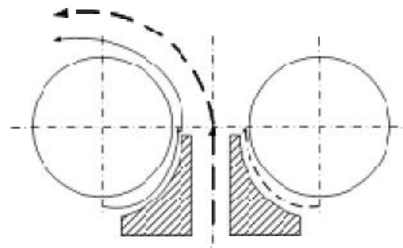
The main application of Coanda nozzles can be classified into the four main groups presented in Figure 2:

a. *Single jet Coanda nozzle*
   This configuration has been used by Newman, Bradshaw, Patankar and others [25-27] was fundamental for first studies about Coanda effect and its laws, it has been used especially for study reasons both in 2D and 3D mostly for experimental purposes and only some applications related to combustion and wings improvements are known;

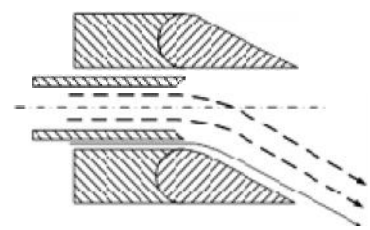
b. *Enhanced Coanda nozzles*
   this definition has been historically used by Smith, but is related to the research activity of Postma, Smith, Trent, and Juvet [28-32]; it is based on the testing architecture developed both by Juvet (Figure 2-b) and uses a mainstream with a great mass flow and one or more secondary jets with high speed, demonstrating that an axis symmetric apparatus is not influenced by the Coanda effect with no blowing through the secondary slot. The other important conclusion produced is that:



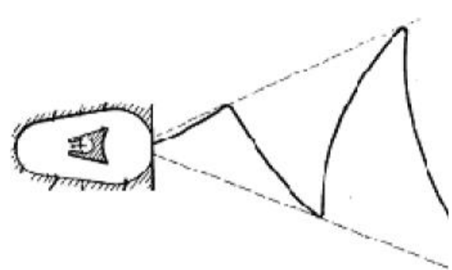
(a) Newman case study



(b) Juvet and Smith pilot jet architecture



(c) Wings and Mason architecture



(d) Bauer Fluidic Oscillator

Figure 3 – Schematization of typical Coanda effect architectures

- when blowing ratio is below 0.1 the primary jet has a low influence by Coanda surfaces and centreline velocity decreases due to entrainment of the secondary flow;
- when blowing ratio is above 0.1 the main jet has vectored in a radial direction and it has not the behaviour of a free jet; if the blowing ratio increases the vectoring capability increases.

Some interesting patents have been also presented by Smith, forcing the typical Juvet architecture into three dimensional architectures.

c. *Enhanced Coanda nozzles with moving surfaces*
many authors, especially involved in aeronautic propulsion have developed Coanda deflection systems based on moving surfaces and on the pilot jet controlled applications with movable appendices. The first application has been developed by Wing [33], focused on two-dimensional thrust vectoring of a primary jet using a secondary jet deflected via a Coanda surface (Figure 3-a), producing an unsatisfactory jet deflection about 36°. Wing concluded that the result was influenced by a lack of momentum in the primary jet and that the nozzle design would require a better optimization to produce larger vector angles.

d. Another aeronautic related study has been conducted by Mason [34], enhancing the experimental setup by Wings and analysing the possibility of thrust vectoring. Mason used geometry more accurate than Wings' one and focused his attention on thrust force more than on a jet vector angle. The vector angles produced are larger than the results obtained by Wing. The largest angle achieved is still relatively small (35°).
Mason's work is a direct reference for this project, because it is focused only on propulsion performances and constitutes the first attempt at creating a fully controllable Coanda jet.

e. *Coanda effect based oscillators*:
Coanda effect based fluidic oscillators has not used directly as nozzles because of their complex geometry but they are used both for anti-icing applications, drilling, and flow separation control. Even if not strictly related to this work oscillators (Figure 2-d) are cited because they constitute the only Coanda effect application that could realize prior than H.O.M.E.R. nozzle an easy to control the dynamic deflection of a fluid jet really without any other moving part. In particular the fluidic oscillators can be used to produce pulsating fluid jets which can improve the effectiveness of active flow control.

BENEFITS OF H.O.M.E.R. NOZZLE

H.O.M.E.R. nozzle constitutes a novel generation of nozzle with vector jet and thrust capability and has been designed to overcome the limitations of the preceding Coanda effect nozzles.

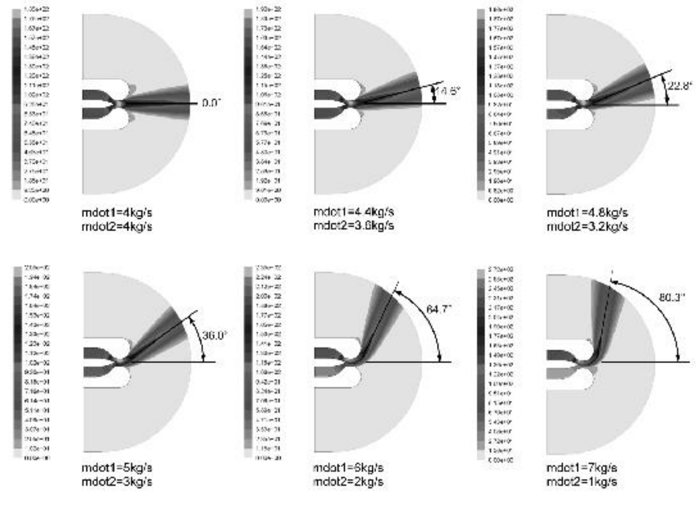


Figure 4 – example of static deflection which can be produced at constant mass flow outlet by varying the mass flows of primitive fluid streams

By very initial CFD simulations it presents very encouraging. In particular it has been verified that it can be easily controlled both in terms of primitive jets speed or mass flow, producing excellent performance both in static (Figure 3) and in dynamic conditions and demonstrates a very low inertia (Figure 4).

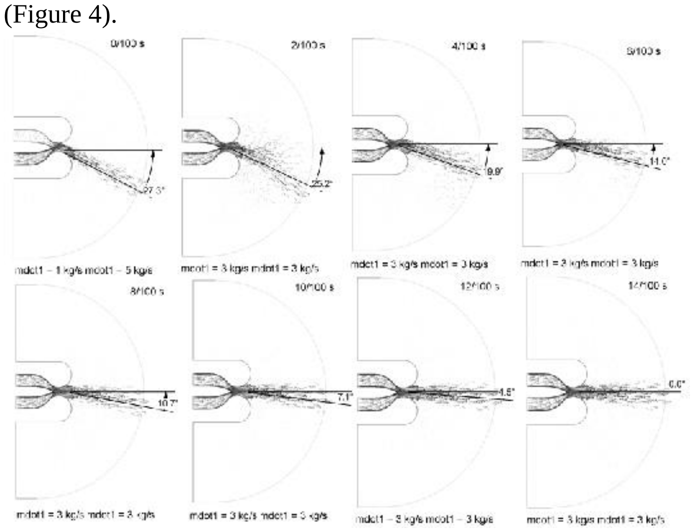


Figure 5 - Dynamic example with mass flow inlets which changes from 1 kg/s and 5 kg/s to 3kg/s and 3 kg/s (frame captured with a 2/100 s step)

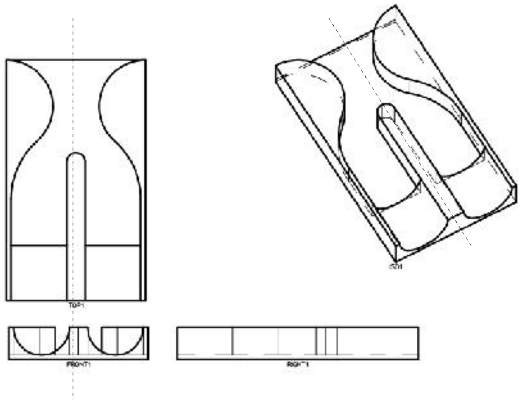


Figure 6 – Example of the 3D tested nozzle simulating turbofan behaviour

Similar tests have been conducted to with a control possibility in terms of rotational speed of two electric turbofans (Figure 5) obtaining similarly encouraging results.

By the above considerations it can be verified that the vector performance, in terms of vector angle can be described as a function of the momentum flux ratio for various mass flow inlet values, but also in terms of angular velocity of turbofans.

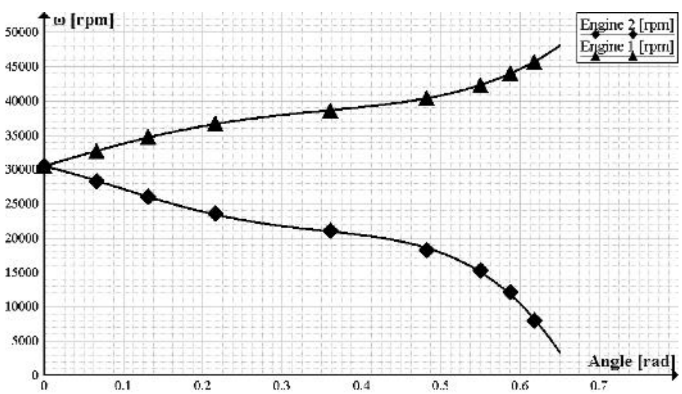


Figure 6 – Angular velocity of both turbofans described as a function of the rotational speed of both turbofans.

HOW PEACE CONTROL SYSTEM CAN ENHANCE THIS NOZZLE

The introduction of PEACE, a plasma control system based on electrostatic control of jet adhesion, can enhance the HOMER nozzle giving it an enhanced possibility of control to the system.

This low complexity, fast and not invasive active control will ensure a better usability of the system because the thrust direction could be controlled with enhanced precision, transitions could be governed with ease, transition times could be reduced and emergency situations could be governed, in particular it can be possible to avoid the worst possible situation which is related to the failure of one of the primitive jet streams.

In this case by an accurate electrostatic dimensioning of the PEACE system the naturally deflected jet could be governed making it exactly straight.

Another benefit of this system will be related to the avoidance of problems related to the possible resonant vibrations which may be present in case of the resonating regime of flux. By the use of this active control system and Coanda adhesion system it could be possible to avoid any resonance problem and to focus the nozzle design on operational needs.

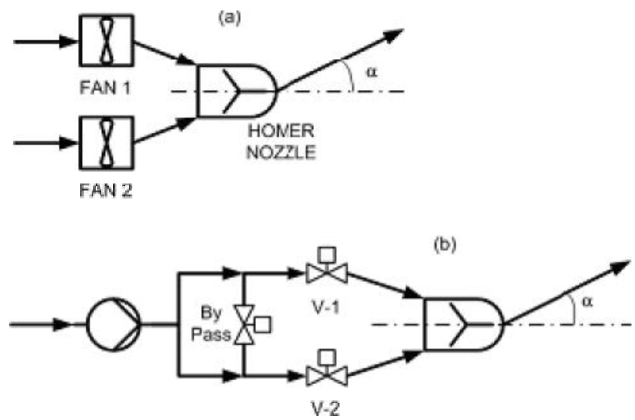


Figure 7 –Homer Nozzle electric plant configurations: (a) alimented by two independent fans; (b) with a single compressor and regulation valves.

ACHEON (Aerial Coanda High Efficiency Orienting-jet Nozzle) is the application of HOMER nozzle specifically oriented to the aerial propulsion together with the PEACE plasma control system. It constitutes the simplest and safest system to realize a jet propulsion with dynamically orienting thrust.

The strong point of this idea is the simplicity of the control but it is enhanced by a supplemental closed loop electrostatic control which allows a more precise control and emergency in many cases of failure. The ACHEON nozzle can produce by itself a radical improvement of the traditional concept of aerial vehicles. This innovation constitutes a long term research which can produce effective industrial results in the second part of this century.

It is a milestone concept which can accelerate the development of a novel generation of aerial vehicles with enhanced performances in terms of manoeuvrability and reduction of takeoff and landing spaces. In particular it will produce different propulsion concepts based on traditional jet systems but also on breakthrough innovation and green electric propulsion systems such as the ones presented in Figure 6.

EXPECTED RESULTS

The ACHEON project fits perfectly into the European guidelines for future air transport. It aims to verify the feasibility of a novel propulsive concept with orienting jets, transferring a general fluid-dynamic application to air transport propulsion. It will produce a technological feasibility analysis both using traditional jet engines and novel electric propulsion systems, generating an effective standard for a novel greener and safer air transports. CFD simulations and their validation trough experimental activities are the planned activities in different conditions, to understand the possibilities and the limits of this innovative application.

Due to reduced budget it is necessary to approach the testing of real applications through the use of reduced scale models. Reduced scale experiments are often used as a proof of concept for aeronautic vehicles. They are widely used in wind galleries even if comparisons of earlier results obtained on small-scale models and full-scale flight tests indicated considerable scale effects on aerodynamic characteristics.

Calibration of tests assumes an imperative importance and the definition of correct can mathematical models. It assumes a large importance the use of aerodynamic similitude correlations and corrective scale factor relations which could be defined by a large use of CFD.

Also during initial flight tests it has been adapted to emulate the jet behaviour by compressed-air engine simulators. In particular these kinds of static tests could be initially sufficient to verify vector jet capabilities of ACHEON systems which could be precisely controlled also at extreme angles of attack.

The results of the reduced scale testing indicate the parameters which have the largest possible influence flight characteristics, even if it cannot permit the analysis of small configuration features, such as wing fillets at the wing trailing-edge juncture with the fuselage. There is also a lack of precision in the prediction of the characteristics of models for some conditions, especially when ailerons were deflected. NASA's report to the industry stressed that, based on these results; TDPF should not be used to predict spin recovery characteristics. However, the criterion did provide a recommended approach to design of the airplane and to predict main aircraft flight characteristics.

The application of dynamically scaled models can provide aviation communities with an effective asset and a valuable tool to provide guidance and understanding in a critical safety-of-flight area. Data obtained in the model tests can also support the definition of recommended recovery procedures to be used by pilots during developmental tests and operational aircraft. For these reasons model tests have become a routine segment of aircraft development programs especially during the preliminary and feasibility phase of a novel project.

The real problem of reduced scale test model is related to interactions between the CFD and the stability and control (S&C) communities are limited. CFD specialists are not always aware of the needs of the S&C specialists, and the S&C specialists believe that CFD has been oversold as a replacement for physical testing. In recent years, important efforts were made to bring the groups together in a research program, formerly known as Computational Methods for Stability and Control (COMSAC). These projects aim to predict Reynolds number effects on propulsion and stability.

The next major breakthroughs in dynamic free-flight model technology should come in the area of improving the prediction of Reynolds number effects and the methodology based on Froude similitude, which could be used to produce a better correlation technology based on reduced scale model results and a more effective provisional evaluation of the main characteristics of full scale model. However, to make advances toward this goal will require a continued commitment, similar to the ones made during the past 80 years for the continued support of model testing together with full scale testing which could not be suitable with the dimensions of a project such as a level 0.

Another important element which needs to be improved is related to the effort of implementing data from CFD and free flight reduced scale models in full scale vehicle simulation by the use of appropriate tools. The project could produce significant results in this methodological approach.

ADVANCE TROUGH EU AIR TRANSPORT DIRECTIONS

The main goals of the project are: a detailed analysis this vector propulsive system, its design methods and the definition of and novel aircraft designs based on this concept. By these activities it could be produced a systemic answer to many themes of European research and necessary innovation for a future aeronautic scenario defined by European policies and FP7.

In particular, the ACHEON project aims to produce a long term innovation for the realization and commissioning of more efficient and green air transport systems.

TECHNOLOGICAL ADVANCEMENT AND EXPECTED PATENTS

This project presents a major aims to produce a step advance and systemic innovation in air transport. This peculiarity assumes a particular importance that only few research ideas will have, becoming a precious instrument to maintain and reinforce the global leadership of the European aeronautics industry.

In particular is expected the realization and patenting of the first Coanda effect nozzle both for aeronautic propulsion and for any other industrial application.

This research will open the road to many visionary aerial concepts defined in the past and unrealized or unsuccessful because of the absence of adequate thrust vectoring techniques, but can also lead to radically new concepts most efficient, green, safe, reliable and flexible than any other vehicle ever conceived.

CONCLUSIONS: STRENGTHS OF THE ACHEON CONCEPT

The strengths of the ACHEON concept are:

- it constitutes a simple and rational vectoring jet and trust orienting system;
- it defines modular applications with and to an high level of standardization of its components;
- it increases aerodynamic efficiency, performance and manoeuvrability of airplanes;
- it reduces energy consumption, greenhouse gasses emissions, take off and landing spaces;
- it opens novel possibilities such as hovering capability and vector flight;
- it open the road to novel concepts of aerial vehicles based on vectoring jets;
- it present an enhanced control possibility by electrostatic plasma;
- it presents an enhanced safety even in the case of primitive stream failure by plasma control built in.

In particular the ACHEON project aims to define:

1. a systemic and organic solution through a novel propulsive system with dynamic vectoring capabilities;
2. dimensioning and design methodologies in different configurations;
3. control methods and algorithm parameterized to main physical and geometric parameters, ;
4. analyze possible short time applications to actual aerial vehicle concepts;
5. explore radical new air transport concepts maximizing the benefits of this thrust vectoring systems.

ACKNOWLEDGMENTS

The present work was performed as part of Project ACHEON | Aerial Coanda High Efficiency Orienting-jet Nozzle | supported by the European Union through the 7th Framework Programme.

REFERENCES

1. Kondratieff, N. D. "On the Notion of Economic Statics, Dynamics and Fluctuations". Moscow, 1924, also in Problems of Economic Fluctuations (1936), Institute for Business Cycle Research.
2. Kondratieff, N. D. Dynamics of Economic Development: Long Cycles and Industrial Growth in Historical Context. Macmillan, London, 1998.
3. Schumpeter, J., Depressions: Can we learn from past experience?, Econ. of the Recovery Program, 1934
4. Schumpeter, J., The Historical Approach to the Analysis of Business Cycles, NBER Conference on Business Cycle Research, 1949.
5. Goldstein, J., Long Cycles: Prosperity and War in the Modern Age, Yale Univ. Press, New Haven, 1988.
6. COM 494 of 2 December 1992: ‘The future development of the common transport policy’.
7. COM 370, 12/09/ 2001: ‘European transport policy for 2010: time to decide’.
8. COM 446, 20/09/2005: Thematic Strategy on air pollution.
9. DIR 96/62/EC on ambient air quality assessment and management (Air Quality Framework Directive).
10. COM 640 01/12/ 1998: ‘Air Transport and the Environment’.
11. VISION 2020, Report of Group of Personalities, January 2001
12. COM 370, 12/09/2001: The white paper
13. REG No 1702/2003, 24/09/ 2003: ‘Environmental certification of aircraft, their parts and appliances’.
14. COM 317 (2005) 27 September 2005: Aviation and Climate Change
15. EU Council Conclusions 2 December 2005- Reducing climate change impact of aviation
16. COM 03/03/2010: Europe 2020: a European strategy for smart, sustainable and inclusive growth
17. Trancossi M., Dumas A., Madonia M., Giuliani I. and Baffigi, IT. Patent n. RE2011A000049, “Ugello ca-pace di deviare in modo dinamico e controllabile un getto sintetico senza parti meccaniche in movimento e suo sistema di controllo”, 30/06/2011, owned by University of Modena and Reggio Emilia;
18. Trancossi M., Dumas A., “Coanda Syntetic Jet Deflection Apparatus And Control”, SAE Technical Papers N. 2011-01-2590, Issn 0148-7191, 2011;
19. Trancossi M., Dumas A., “ ACHEON: Aerial Coanda High Efficiency Orienting-Jet Nozzle ”, Sae Technical Papers N. 2011-01-2737, Issn 0148-7191, 2011;
20. Trancossi M., Dumas A., Cfd Based Design Of A Nozzle Able To Control Angular Deflection, ASME Int. Mechanical Engineering Congress And Exposition 2011, Denver (CO), USA, November 2012;
21. Trancossi, M., “An Overview Of Scientific And Technical Literature On Coanda Effect Applied To Nozzles”, SAE Technical Papers N. 2011-01-2591, Issn 0148-7191, 2011;
22. Coanda, H., US Patent n. 3,261,162, Lifting Device Coanda Effect, 1936, USA;
23. Coanda, H., US Patent # 2,052,869, Device for Deflecting a Stream of Elastic Fluid Projected into an Elastic Fluid, 1936;
24. Newman, B. G., The Deflexion of Plane Jets by Adjacent Boundaries, in Coanda Effect, Boundary Layer and Flow Control , edited by G. V. Lachmann, Vol. 1, Pergamon Press, Oxford, 1961, pp. 232–264;
25. Bradshaw, P., “Effects of Streamline Curvature on Turbulent Flow,” AGARDograph , 1990, AGARDo-graph AG-169;
26. Postma, A. K., Smith J. D. and Trent D. S., Development of a Concept for a High Capacity Pneumatic Conveying System Employing a Fluid Attachment Device for Use in

Underground Excavation, Final Technical Report, US Bureau of Mines, 1973;
27. Juvet, P. J. D., Control of High Reynolds Number Round Jets, Ph.D. Thesis, Department of Mechanical Engineering, Stanford University, 1993;
28. Allen, D. S. and Smith B. L., "Axisymmetric Coanda-assisted vectoring," submitted to Exp. Fluids, December, 2007;
29. Smith, B. L., High-speed jet control, United States Patent Application 20070158468;
30. Smith, B. L., High-speed jet control, United States Patent 7757966, 2010;
31. Allen, D. S. and Smith B. L., "Axisymmetric Coanda-assisted vectoring," submitted to Exp. Fluids, De-cember, 2007
32. Allen, D. S., Axisymmetric Coanda-Assisted Vectoring (2008). All Graduate Theses and Dissertations. Paper 90. http://digitalcommons.usu.edu/etd/90
33. Wing, D. J., “Static Investigation of Two Fluidic Thrust-Vectoring Concepts on a Two- Dimensional Convergent-Divergent Nozzle,” Tech. Rept. NASA TM-4574, Hampton, VA, 1994.
34. Mason, M. S., and Crowther, W. J., “Fluidic Thrust Vectoring of Low Observable Aircraft,” CEAS Aerospace Aerodynamic Research Conference, June 2002.