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Expert conference: Cigarette/candle smoke effects

Hanna Eriksson, Adem Nasic and Björn Palmqvist
TMAL02, Linköping University, 2018

Background

The typical behaviour of the smoke from a cigarette is shown in Figure 1; a smooth column of smoke at the beginning and then expanding in a more circulate pattern. Does this mean that the flow is turbulent or laminar?

Usually, the Reynolds number can tell if a flow is turbulent or laminar. The Reynolds number is the ratio between the inertial forces and the viscous forces in a fluid, and is a important parameter when the flow should be analyzed. In a laminar flow, the viscous forces are dominant and the velocity of the flow usually relatively low. The turbulent flow though, is dominated by the inertial forces, and occurs usually at high velocities. The Reynolds number can also tell when the transition from laminar to turbulent flow occurs. For example when designing aircraft wings, it is of high interest to know the behaviour of the flow around them, in order to analyze the performance of the aircraft and the strength of the wing.

1 Cigarette smoke behaviour

Heated smoke rising from a cigarette can be described with three flow regions. The first region being smooth laminar flow which after a distance enters the second region where the flow behaviour changes where it starts to flutter and finally it starts to transition into the third region of unsteady turbulent flow. This behaviour can be attributed to what is known as the Reynolds Number seen in the equation below. [1]

$$Re = \frac{\rho * V * d}{\mu} = \frac{V * d}{\nu} \quad (1)$$

Where ρ is fluid density, V is local flow velocity, d is characteristic length, μ is dynamic viscosity and ν is kinematic viscosity. As the Reynolds number increases, either by increasing the length d or velocity V or decreasing viscosity ν, it will eventually reach a critical point where turbulent flow will occur [2]. Why exactly this transition happens is a very complex process which is still being researched, it is thought to be triggered by different types of flow disturbances varying on such factors as pressure gradients, compressibility or heat transfers [3].

[4] Due to being continuously heated by the cigarette, the outgoing smoke is very warm and has a lower density in relation to the cold air around it. The smoke then rises and as it does it gains speed due to being less dense than the surrounding air, creating a sort of buoyancy similar to a helium balloon. As the smoke comes out is of laminar flow but as it accelerates, eventually it will reach its critical point Reynolds number and transition to turbulent flow.[5]

Fig. 1 . Smoke from a cigarette

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Active anti flutter control

Carlos Rodriguez Andrade, Rohith Prem Maben, Yuvarajendra Anjaneya Reddy and Ankith Hegde
TMAL02, Linköping University, 2018

1 Introduction

Dynamic Aero-elasticity is the branch of physics and engineering that deals with the interactions between the inertial, elastic, and aerodynamic forces that occur when an elastic body is exposed to a fluid flow. Flutter is a dynamic instability of an elastic structure in a fluid flow, caused due to the body's deflection and the force exerted by the fluid flow and undergoes simple harmonic motion, zero net damping, and so any further decrease in net damping will result in a self-oscillation and eventually failure.

This oscillation/vibration can cause structural failure and hence considering flutter characteristics is an essential part in designing an aircraft. In order to reduce this damping effect the passive methods currently being used are:

- Material stiffening
- Mass balancing

The FAA regulations require a commercial transport to be flutter free at speeds 20 percent greater than the design dive speed. [1] In fighter aircrafts,[2] The total damping coefficient, shall be not less than 3 percent for any critical flutter mode for all altitudes and operational flight speeds.

2 Motivation for Active flutter supression

There are several advantages in moving to the active system for flutter suppression over the traditional passive approach. Stiffening and mass balance solutions are too expensive. If the problems arise in the latter stages of the design process it requires redoing and altering aerodynamics and inertia. As stated in [3], if a subsonic commercial aircraft wing increases aspect ratio above ten, substantial stiffness for flutter suppression may be required. The aeroelastic vibrations characterized by weak damping reduce the fatigue life of the structure and consequently lead to catastrophic failures of the aircraft components.

Non linearities arising from control surface free play, stiffness non linearities due to large deformations, structural damping non linearities and aerodynamic non linearities lead to limit cycle oscillations (LCO). LCOs are sustained constant amplitude oscillations due to aeroelastic interactions. In these cases the passive systems act as a narrow pass filter in the linear zone and requires feedback control, capable of negating these oscillations[4]

3 Methodology

The working principle of an Active flutter suppression follows that the aircraft motion would be captured by sensors that in turn would command the control surfaces or other changes in the shape of the aircraft to achieve desired dynamic behaviour.[5]

Unlike flight control systems for stable aircrafts such as gust alleviation, ride comfort and handling quality, an Active flutter suppression requires stabilizing of an unstable plant which are of high frequencies and complex flutter mechanisms.

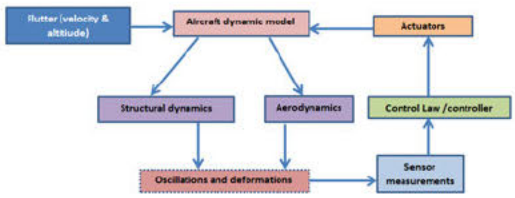

Fig. 1 . Active flutter suppression block diagram

4 Measurement and control law

Accelerometers and strain gauges are often used. While accelerometers can directly measure oscillations (integrating the acceleration twice), strain gauges measure the deformations of the structure caused by the surrounding unsteady flow. Both bending and torsion gauges are installed. All of these devices are designed to sense the motion of the structure itself (see Fig.1), however, there are also emerging sensing techniques which focus on direct sensing of the unsteady flow around the surface, as stated in [6] hot-film gauges provide direct information on flow oscillations caused by gust or flow oscillations.

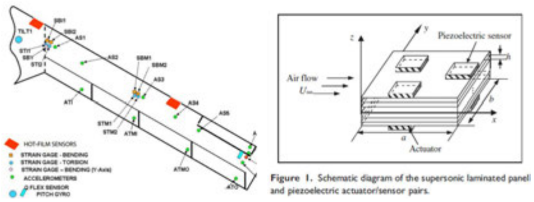

Fig. 2 . Sensors

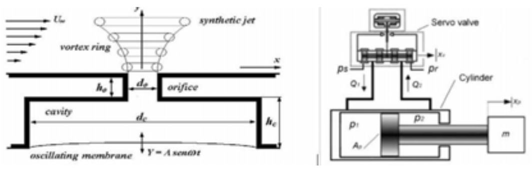

Fig. 3 . Synthetic Jet and electrohydraulic actuators

Besides, some other new technologies such as fiber bragg grating (FBG) sensors are also used for flutter detection [7]. As explained in [8] and [9], since the wavelength of maximum reflectivity depends on several parameters such as fiber temperature or mechanical strain, Bragg gratings can be used as strain sensors.

4.1 Actuators

As stated in [10] the main decisions that must be made to design a flutter suppression system are the selection of an actuator, of a control objective and of a control law.

Closed loop action of control surfaces possible with high band width actuators. Electrohydraulic servoactuators are often employed to deflect control surfaces. However, active flow control emerging techniques such as synthetic jets actuators (SJA) at the walls are also used to change the flow around the wing either by blow or suction. These technologies rely on adding or removing fluid at the wing surface which is equivalent to shape modification.

Some of the advantages of SJAs for flow control over control surfaces are: less complicated mechanisms, less weight and control reversal is avoided.

As explained in [11] the actuator consists of a spanwise slot on the upper part of the wing through which air is sucked in and then blown out with added momentum. This way the flow around the wing can be changed for gust alleviation.

5 Testing

Prototype testing on scaled models have been taken up both in experimental flight tests for validation of mathematical models, ground vibration tests and wind tunnel tests. The identification, in flight, of the aeroservoelastic characteristics of a flight vehicle pose a challenge due the input and output used for system identification would be noisy.

Fig. 4 . few of the testbeds used for Active flutter suppression system (from top)NASA DAST.Lockheed X56,B-52 and F404

6 Current developments

In the year 2000, rapid developments occurred in computational structural dynamics simulations and Assessment of fatigue life of structures due to aeroelastic oscillations. The years leading to 2010 demonstrated optimized aircraft structures to overcome low speed flutter characteristics by composite materials. From the year 2012, investigations were carried out for composite materials behaviour using advanced computational tools against the AFS associated problems.[12]

7 Challenges in Active Flutter Supression

From a certification point of view, AFS increases the complexity in the certification process mainly due to multidisciplinary nature and requiring uncompromising reliability.

Secondly, availability of test data to the aeroelastic community is largely varying due to import restrictions and defense issues. Thirdly, inconsistent and widely accepted equations for active control applications.

Other challenges and research areas include designing control laws by means of higher order multi-degrees of freedom mathematical models, along with validation and verification. Also a transparency in approaches and reduction of sensor noise and error [7].

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Expert Conference : Active Boundary Layer Control

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TMAL02, Linköping University, 2018

1 Introduction

When a flow is travelling downstream on a surface, due the friction effects the flow will experience a reduction in velocity as it gets closer to the surface. This velocity reduction causes an energy loss of the flow and it will be more significant as the flow goes downstream. In a nutshell, the pressure is against the flow and so pushes the flow backward at some points close to the surface. This phenomenon is called adverse pressure and it become larger and larger closer to the trailing edge[1]. As it is demonstrated in Fig-1 when the separation take place the flow will be reversed and not be attached to the surface anymore. The flow separation during take-off and landing due to high angle of attack causes loss in the lift force and hence increases drag over a large portion of the wing surface. Flow control therefore energizes boundary layer over the wing surface and suppresses flow separation. The goal here is to being able to control the separated flow over an airfoil.

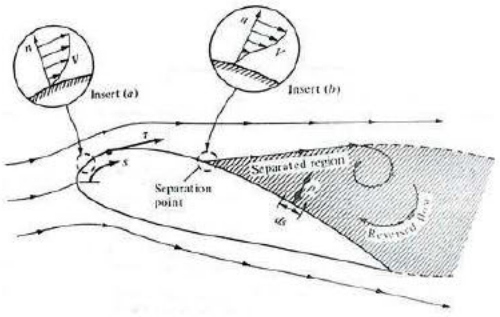

Fig. 1 . Flow separation of an airfoil

2 Active Boundary Layer Control

Active control is the use of additional artificial influences beside the natural boundary and initial conditions on stability or excitation of boundary layers and on separation in flows. These additional influences are active influences because they imply an unsteady or at least adaptive change of boundary or flow conditions with the help of external energy. Active flow control methods use outer energy in different forms to influence the flow field[2].Below are few of the techniques that are being used to actively control the boundary layer.

2.1 Smart Vortex Generators

Vortex generators have been used extensively among airplanes for more than five decades as the most efficient way to fight against flow separation. VGs are basically designed to increase Cl_{max} and reduce stall velocity of an aircraft[3]. However, having VGs assembled on a wing will also cause additional changes in performance simply because they are designed to operate in a specific region and specific flight condition[4]. For instance, it will increase drag significantly at the cruise condition[3].In order to increase the efficiency of VGs, researches turned their attention to smart vortex generators (SVGs) which will be deployed at the necessary situations. A study carried out by Baret and Farokhi scrutinizes the active vortex generators on a NACA airfoil[3]. After testing different type of vortex generators in a wind tunnel it was concluded that ramped vortex generators with close spacing placed at 8% of chord will be the optimum configuration for Vgs. A stall sensor as well as an optimal controller was provided inside the wing box to detect the separation and deploy the Vgs to required height [4]. In figure 2 it is apparent that at 10-degree angle of attack stall takes place at clean wing. However, by activating SVGs stall angle will increase to 14° and the reduction of lift beyond stall angle is less than clean wing. Nevertheless, VGs are deployed with respect to angle of attack which means with higher the angle of attack the Vgs will be deployed at higher height. In Fig - 3 Lift and Drag coef-

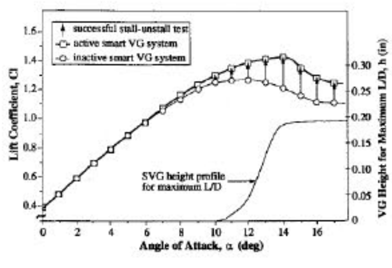

Fig. 2 . Lift coefficient at different angle of attacks using VGs and clean wing

ficients are demonstrated in three different conditions, they are inactive VGs (clean wing), active VGs (deployed on demand) and fully extended VGs(passive). From Figure 3 it can be investigated that having a passive VGs will result in an unnecessary increase in drag without any lift enhancement which leads to decrease L/D significantly as it is shown in Fig-4. However,

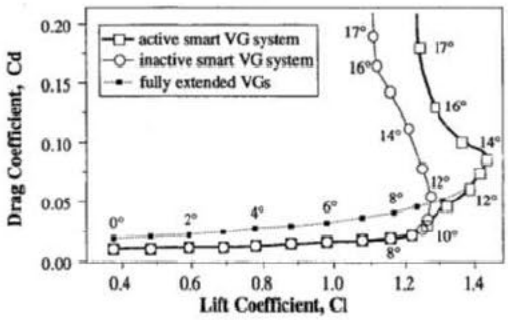

Fig. 3 . Cd Vs Cl with different VG condition

while below stall angle SVGs are more effective, beyond stall angle there will be an identical performance of Active and Passive VGs as shown in both Fig-3 and Fig-4.

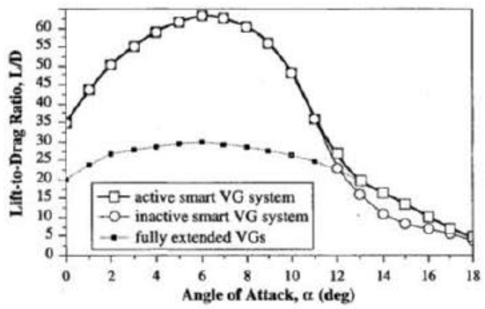

Fig. 4 . Angle of attack Vs. Lift to Drag ratio

2.2. *Blowing*

It is process of re-energizing the boundary layer by the process of addition of momentum to the boundary layer to counteract the adverse pressure gradient. Blowing jet is placed at the trailing edge of the wing to obtain maximum performance in various flow conditions. A wind tunnel test was performed at Reynold's Number 5e+05 NACA 0012 airfoil with the jet placed at 0.8C [5]. The lift-to-drag ratio increases continually up to jet widths of 3.5 % to 4% of the chord length along with jet width and then decreases. Hence, the blowing jet widths of 3.5% to 4% of the chord length are extremely effective. When the amplitude of the jet was increased, the stall angle remained same[5].

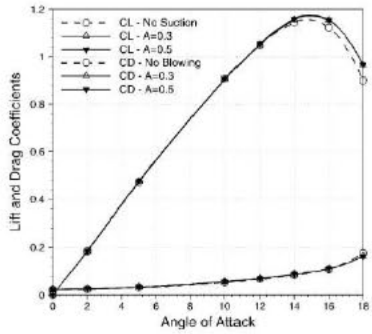

Fig. 5 . Lift Co-efficient and Drag Co-efficient for different amplitudes of Blowing[5]

2.3. *Suction*

It is process of energizing the boundary layer by the process removal of momentum from a low momentum fluid inside the boundary layer. The experiment was repeated with suction at 10% of the chord. When the jet width is increased, the separation bubble is effectively delayed; hence, the separation bubbles and vortices are almost entirely eliminated in a jet width of 2.5% of the chord length .Therefore, a suction jet width of approximately 2.5% to 3% of the chord length is the most effective to extract maximum lift to drag ratio. The stall angle increased from 14° to 21° when the jet amplitude was 50% of the freestream velocity.

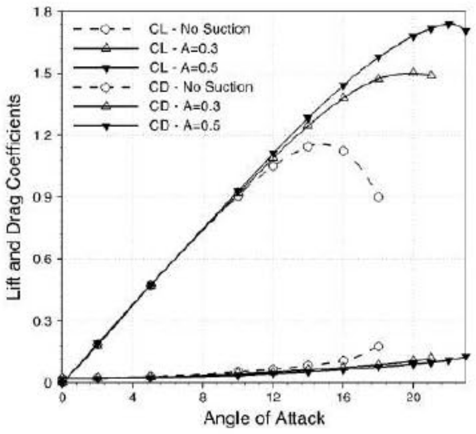

Fig. 6 . Lift Co-efficient and Drag Co-efficient for different amplitudes of Suction[5]

2.4. *Heat Transfer*

The decrease and increase in temperature of air and liquids respectively results in decrease of viscosity of the medium which in turn affects the Reynolds Number, an important factor in determining the transition region. The increased viscosity diminishes the frequency of the unstable waves and hence the amplification rate. When the transition regions for Mach 0.55 to M 2 were studied, it was found that transition Reynolds number varied T_w^{-7}, with T_w being wall temperature[6]. This method is feasible for aircraft's using cryogenic fuels such as liquid hydrogen, liquid methane as large heat sink is available and the weight of the required cooling system is less than thee fuel saved due to drag reduction[7]. The heating of water by the heat produced due to propulsion in the submarines results in less skin friction drag.

2.5. Acoustic

Sound at particular frequencies and intensities could change the transition process of boundary layer[8]. This study focuses on the effectiveness of internal acoustic excitation in which the sound originates from a narrow opening on the wall surface and aerodynamic characteristics of NACA 23015 airfoil have been investigated experimentally and numerically.
The solution of the flow equations are presented for different angle of attack range degrees, at some excitation frequency values, with the two-excitation location from the leading edge (6.5% and 11.5%) of chord. The experimental tests are separately conducted in two sections, open-typed wind tunnels at the Reynolds number 3.4×10^5 for the measurements and 10^4 for the visualization[9].The results indicate the enhancement of the flow mixing and momentum transport due to internal acoustic excitation produces a suction peak at the leading edge of the upper surface of the airfoil and that suction peak results in an increase of lift and narrower wake. By the flow visualization, it is found that the locally introduced unsteady vorticity causes the separated boundary layer to be reattached to the surface and the internal acoustic excitation energizes the boundary layer, this leads to decrease in the turbulent kinetic energy at the upper surface of the airfoil. The excitation location was the most affected parameter on the internal acoustic excitation technique and the results indicated that, the excitation location close to the leading edge is the more efficient and the internal acoustic excitation at 6.5% of chord lead to increase lift by 45%, while at 11.5% of chord results in increase 35% increase[10].

3 Conclusion

In the presented work, different techniques to actively control the boundary layer have been under scrutiny through different research. Result of each study has been illustrated through graph which shows the values of Cl and Cd enhanced using active control techniques. Results show lift enhancement of 9%, 14%, 35% and 45% for blowing, SVGs , Suction and acoustic techniques respectively. However, in some techniques such as blowing due to complexity of design and manufacturing in will not be easy to implement it in an actual flight[4]. However, as the further work it is possible to work on techniques with smaller actuators and less complexity to make it more practical.

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EXPERT CONFERENCE: Forward Swept Wings (FSW)

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TMAL02, Linköping University, 2018

1 Introduction

Forward swept wing configuration is based on a negative angle of sweep, if compared to the traditional swept wings. This configuration was used for the first time in Germany in 1936, right before the second world war. Initially, the German company Messerschimdtt AG experimented the concept of forward swept wings; but the first airplane to fly with this kind of configuration was the Junkers Ju 287 (made once again by a German company, Junkers GmbH) in 1944.

Fig. 1 . Junkers Ju 287

Forward swept design was found to be more stressing for the wings; at that time there still were not materials suitable for such application. When the composite materials started to be available for aviation purposes, this kind of configuration could actually be adopted. In fact, U.S. Airforce managed to build an aircraft with this design around 1975, the Grumman X-29, while the Russian company Sukhoi developed the Su-47.

Fig. 2 . Grumman X-29

Fig. 3 . Sukhoi Su-47

The forward swept wing, since its weight is more towards the front, is mounted further downstream than the backward swept wing: this allows the aircraft to have more room for objects like, for instance, bombs. This was the main searched advantage, since, as we will see afterwards, this kind of wing does not have such aerodynamic advantages.

2 Aerodynamic principles

As the backward swept wings, the forward swept wings were designed to delay adverse compressibility effects and reduce their severity when they do occur [1]. Due to their swept angle, the normal mach number can be reduced by a factor of $cos(\Lambda_{LE})$. However, the main difference between both wing designs is the direction of the spanwise flow, which not only provides certain advantages but also drawbacks, commented in section 3. The figure 4 provides an accurate visualization of the direction of the spanwise flow [2].

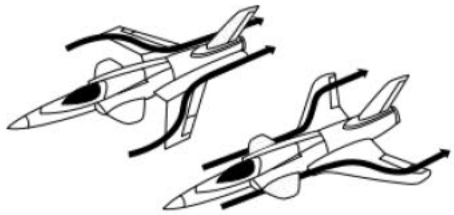

Fig. 4 . Spanwise airflow over a forward swept wing and over a backward swept wing [1].

Whilst the boundary layer over a backward swept wing develops from the wing root towards the wing tip, the boundary layer over a forward swept wing develops from the wing tip towards the wing root. This inward flow has a direct impact in the aerodynamics of forward swept wings, such as the favourable stall-progression pattern shown in figure 5. Due to the fact that the stall occurs first at the root in forward swept wings, aileron effectiveness is preserved at high angles of attack with a consequent improvement in maneuverability [1].

3 Advantages and drawbacks

Aerodynamic advantages can be grouped into reduced drag and enhanced maneuverability at transonic Mach

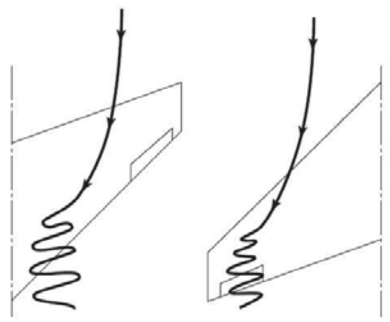

Fig. 5 . Stall-progression patterns for a forward swept and backward swept wing [1].

numbers and at high-angles of attack. As it occurs in all swept wing distributions, a swept angle helps to postpone compressibility effects. Indeed, the shock wave which occurs on the upper surface is delayed until almost the trailing edge, so it becomes as detrimental as possible. Comparing BSW and FSW with the same leading edge sweep angle, the shock wave occurs closer to the trailing edge for FSW, therefore it lowers down the shock strength and wave drag. Moreover, FSW have higher aspect ratio than similar BSW: this decreases induced drag. As it has been said before, the flow goes from the tip to the root. This phenomenon leads to better maneuverability due to the effectiveness of the aileron even at high angles of attack [1].

Furthermore, FSW have a smaller effective sweep angle than geometrical one at the leading edge (which is the other way around for BSW). This condition leads to a favourable behaviour for laminar flows. Due to the relationship between Reynolds number and sweep angle shown in equation 1 (where U_1 is the slope of the normal velocity to the leading edge and $\overline{Re}$ is the Reynolds value when transition occurs);

$$\overline{Re} = \sin\Lambda \cdot \left(\frac{Re}{U_1}\right)^{\frac{1}{2}} \tag{1}$$

Then, the lower the sweep angle, the higher the Reynolds number of the flow will be, which turns into a higher Reynolds number before transition for tapered FSW [3].

In addition to that, FSW allow an easier gear installation. Finally, turbulent flow from the fuselage does not contaminate the leading edge flow of FSW (due to inward flow, Figure 4) as it occurs in BSW, which leads to no disturbances of the laminar flow [3].

One of the main disadvantages that forward swept wings face consists on the structural divergence the wings suffered, in other words, aeroelastic divergence. At backward swept wings, the bending produced by the lift distribution reduces the streamwise angle of attack in the wing. The decrease of incidence angle of the wing will oppose to the elastic twist, hence, self reduces the possibility of structural wing divergence. On the other hand, the opposite behaviour will be faced for forward swept wings. Indeed, the spanwise incidence angle of wing will be increased due to the bending produced by the lift, enlarging even more the elastic twist. Therefore, divergence speed will be much lower for this kind of sweep configuration [4]. This effect would be mitigated by using modern composite materials to manufacture the wing, increasing the torsional stiffness, hence, the divergence velocity.

Apart from the structural issues, stability control is a topic to discuss about. Indeed, forward swept wing (negative Λ) will produce lateral instability.

When analyzing the roll stability, it can be observed in equation 2[5], it is obtained an unstable behaviour ($(C_{n_\beta})_w < 0$) for the wing contribution due to the negative angle of the FSW.

$$(C_{n_\beta})_w = C_D \frac{\bar{y}}{b} sin2\Lambda > 0 \rightarrow Stable \tag{2}$$

A similar phenomenon is experienced in the jaw stability, indeed, it can be observed in equation 3[5] that in FSW configuration an unstable ($(C_{l_\beta})_w > 0$) behaviour is faced when a sideslip angle is induced.

$$(C_{l_\beta})_w = -\frac{1}{4} C_L sin2\Lambda < 0 \rightarrow Stable \tag{3}$$

In addition, a higher wing-fuselage interference will take place since flow is developed from the tip to the root. Implementation of winglets could be problematic too.

4 Conclusions

Forward swept wings have been an attractive configuration due to some of their direct advantages such as enhanced maneuverability, wave drag reduction and favourable behaviour at laminar flow conditions. Because of all these reasons, its use has mainly been related to military applications.

Nevertheless, its development is currently on stand-by since many structural and stability control issues are still unsolved, making this wings concept not as useful as backward swept wings.

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Expert Conference: Albatross Flight

Matko Stokov, Adarsh S Bharadwaj, Gábor Veres and Shreyasu Subramanya
TMAL02, Linköping University, 2018

1 Introduction

Albatrosses are the largest seabirds ranging in the Antarctic Ocean and the North Pacific. As sailing to open seas in the Age of Exploration, sailors soon learned that the appearance of albatrosses either meant good sailing winds approaching or the warning signs of storms. Therefore they become associated with good fortune and were considered untouchable; even in times of severe famine on board no bird was to be killed. This gives ground to the myth that killing an albatross brings curse to the ship and its whole crew, as also reflected in Samuel Taylor Coleridge's poem *"The Rime of the Ancient Mariner"* [1].

Besides their great size (the wingspan of the largest albatrosses can reach 3.4m), albatrosses are widely known for their ability to travel very long distances with just an occasional flap of its wings. Once airborne, they can travel for weeks, sometimes up to 500 miles a day without returning to the shore. This is possible by employing specific flight maneuver techniques, such as dynamic and slope soaring [2].

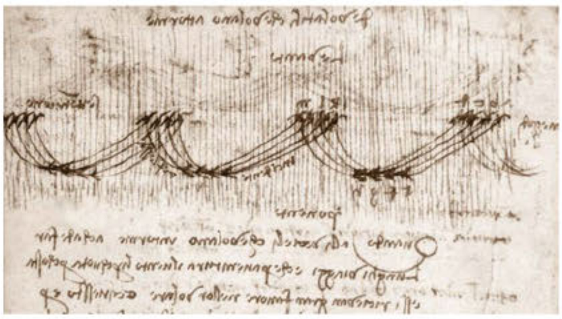

Fig. 1 . Dynamic soaring illustrated by Leonardo da Vinci [3].

As early as in the 15^{th} century, Leonardo da Vinci was the first to document dynamic soaring while studying the flight of birds in order to develop human-powered flying machines. Later at the turn of the 19^{th} and 20^{th} century Lord Rayleigh described how birds gain energy in wind shear layers but also in continuous gradients in wind speed. [3] As we understand today, this is the reason behind albatrosses often flying close to the sea surface, as described in the following chapter.

2 Dynamic Soaring

The velocity boundary layer or "wind sheer field" forms up to about 10 to 20 metres above sea level. Exploiting the dramatic increase in velocity to generate lift, albatrosses fly in a cyclic pattern known as dynamic soaring which allows them to glide just above the sea for a long time spending almost no energy.

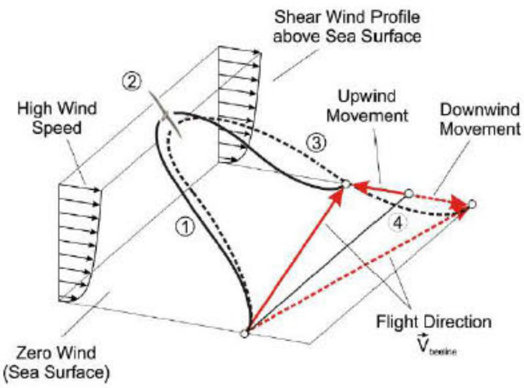

Fig. 2 . Illustration of soaring patterns adapted by albatrosses [4].

Sachs [4] studied the flight and dynamic soaring patterns of albatrosses. He identified four phases, as shown in Figure 2. A windward climb (1), followed by a curve from windward to leeward at peak altitude (2), then a leeward descent (3), and finally a reverse turn (4) close to the sea surface that leads seamlessly into the next cycle of flight. This soaring pattern is known as the Rayleigh cycle. The energy gain needed for flying without flapping their wings is achieved when they change the direction from windward to leeward side. Continuous soaring is then obtained by repeatedly passing high velocity gradient layers above the sea surface and thereby exchanging the gained kinetic to potential energy. Further to dynamic soaring, high speed is achieved with a flight direction transverse to the wind direction. Figure 2 also shows two path cycles, with a net upwind flight (straight line) and a net downwind flight (dotted line). In order to compensate for the lateral displacement of individual soaring cycles they have been observed to fly in alternating soaring cycles.

Besides dynamic soaring, albatrosses also exploit upward force components generated when the wind is redirected by steep objects or waves, and thereby gain height. This phenomena is called slope soaring.

3 Dynamic soaring applied to aircrafts

3.1 Similarities with an albatross

As described by Lord Reyleigh, albatrosses are even able to soar upwind by harvesting wind energy for wind speeds above 3 m/s. There is also a potential for using the same maneuver with an Unmanned Aerial Vehicle (UAV), however, they should be able to soar above the sea level and quickly change course relative to wind. This is a slightly different soaring method than that of an albatross, who wanders only in a certain direction, rarely changing its course.

Another distinctive difference between an albatross and a UAV flying like an albatross would be in minimum closeness to the surface. Ocean waves are much smaller than ridges or cliffs of mountains, which would imply that an albatross must fly very close to the sea surface to extract the wind energy more efficiently. The same dangerously close maneuver would be expected from a UAV, and while flying close and even grazing the surface with its wingtips is not a problem for an albatross, for a UAV it would mean certain destruction. That kind of maneuverability could perhaps be duplicated by a sophisticated autopilot.

3.2 Glider velocities in practice

In his paper, Richardson [5] claims that gliders flying over mountain ridges reached speeds about 10 times of the wind speed blowing over the ridge. For a cruise speed of about 25 m/s, a lift to drag ratio of 30 was estimated for the tested glider. While the Rayleigh cycle, described earlier in the chapter 2, predicts that for wind speeds of at least 5 m/s, a maximum achievable speed would be about 9.5 times the wind speed in the upper layer, the field measured value comes in quite a close agreement with the theoretical maximum value. Another interesting observation in those field measurements was that of the accelerometer, which recorded peak accelerations of about 100 g's.

The fastest way to cover a certain distance over sea surface by the method of dynamic soaring for a UAV would be along diagonal lines relative to wind direction. This is because a transverse velocity vector and windward velocity vector can be exploited, which would give maximum velocity, as shown in Figure 3.

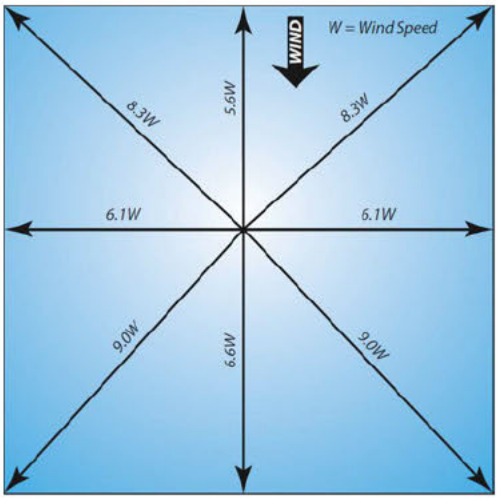

Fig. 3 . UAV travel velocity polar diagram showing maximum theoretical velocities obtainable by dynamic soaring relative to wind direction [5].

The following expression shows the relation between the UAV's or albatross' velocity and wind speed for the optimum loop period:

$$V_{\max} = \frac{(V/V_z)_{\max}}{\pi} \cdot W$$

where $V_{\max}$ is the maximum achievable velocity, W is the wind speed, and $(V/V_z)_{\max}$ represents values of the glide ratio. For L/D values $\gg 1$, the glide ratio is closely equal to lift/drag (L/D) ratio.

This relation can be used to predict the maximum theoretical cruising velocity for a given wind speed, or a minimum required wind speed for a certain cruising velocity.

4 Discussion

Dynamic soaring employed by albatrosses is a highly efficient technique to gain energy from wind conditions, and is also one of the main techniques adopted for remote controlled aircrafts.

The application of albatross-like flight technique was investigated in detail by Richardson [5], as he considered the possible development of a robotic albatross UAV that could soar over the ocean using dynamic soaring like an albatross. The robotic UAV would be faster considering its superior strength and better aerodynamic performance. Some uses for such a device would be search and rescue, environmental monitoring, weather monitoring, and surveillance.

For building such an aircraft, structural stability should be considered for long range flight, and an autopilot for close surface maneuvering.

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LINKÖPING UNIVERSITY

Lift generation of forward flying helicopters/rotors

Andrés Gacía López and Michael Avraham Ajzental
TMAL02, Linköping University, 2018

1 How a helicopter works?

The functioning of a helicopter is based in the Third Newton's Law, which says that for every action there is an equal opposite reaction. In the case of the helicopter, the movement of the blades creates a down airflow and with reaction is the generation of lift that takes off the aircraft. All the data references were taken from the Federal Aviation Administration [1].

1.1 Function of each rotor

Typically, a helicopter have 2 rotors, the main rotor which allows the craft to take off, fly forward, backward, and laterally; and the second one, which is called the anti-torque rotor.
The main rotor produces a torque in the cabin, and to maintain the helicopter stable the anti-torque is needed in the tail to generates lateral thrust and creates a moment against the one that is being produced by the main rotor.
The main problem of this rotor is that it produces a lateral thrust.

1.2 Blades' angles

The movement of an helicopter is based on the blades' angle.

COLLECTIVE PITCH VARIATION:
To take off, the blades have to produce more vertical force than the helicopter weight force, and this is generated by modifying the angle of attack in all the blades to get the maximum lift. The increasing of this angle generates more lift by increasing the pressure below each blade.

CYCLIC PITCH VARIATION:
The functioning of the helicopter when it is hovering depends on the pitch angle of the blades, which can make the aircraft steer in any direction by modifying it. When one side of the blades disc has a higher angle of attack than the other side, the helicopter moves to the direction where the blades have the less angle of attack.

1.3 Forward Flight

To generate the forward movement of the helicopter the cyclic pitch variation of the blades has the main function. In order to get this movement, the lift generated in the backside of the aircraft has to be higher than the front-side part.
It is obtained by increasing the backside's and reducing the front-side's angles.
When the different lift forces appear, the higher value of one of them creates a torque which inclines the resultant force of the upper part of the craft, appearing the thrust (Figure 1).

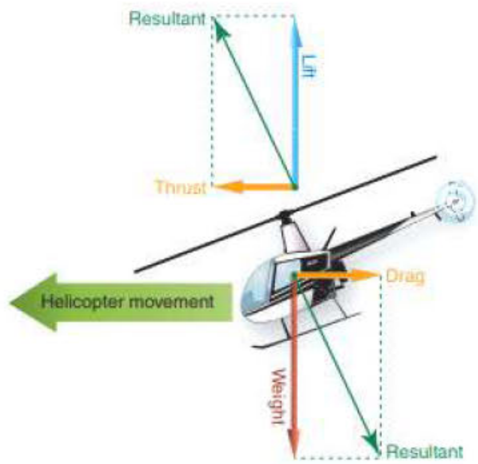

Fig. 1 . Balance of forces in an helicopter. Reference: [1]

When it starts to moves forward, the aircraft descends (lose altitude) because some of the lift is lost and transformed into thrust. Therefore, lift and weight are not equal anymore. This fact is solved with the velocity. Lift grows with the squared of the airspeed velocity, so the lift and weight forces becomes equal again. This is called **Translational Lift**. This is the reason why the aircraft climbs when it is accelerating. The acceleration of the helicopter causes the airflow on the bottom of the blades to go more horizontally and it reduces the turbulence and the appearing of vortex, a fact that is reflected in a increasing of the efficiency of the rotor disk.

2 Inconveniences of Helicopters

The angle's variations in blades is used to solve two problems of the helicopter stability: lateral thrust and dissymmetry of lift.

2.1 Lateral thrust

As it has been stated previously, the tail rotor generates lateral thrust, and it is neutralized by modifying thrust in the other direction with the angle of the blades.

2.2 Dissymmetry of lift

In forward flights, the helicopter's forward speed is equal to the velocity of the airflow, and the air flows in the opposite direction of the aircraft. The relative airflow across the blades is not the same in all the rotor disk. When rotating, there is always a time when the blade is in the same direction of the helicopter movement, has the airflow against its direction and hence an increase in its relative wind. On the other hand, in the opposite side, in its favour, reducing the helicopter's forward speed. In Figure 2 it is possible to understand that situation in a better way. The highest relative airflow in the blades occurs in the right side (point A), then it decreases until the blade is completely in the left side, where the relative wind speed is at its lowest. That happens because the blade is in the same direction of the airflow. After that, the blades continues to rotate and the relative wind speed velocity starts to increase until finally reaches again point A, repeating everything again.
Lift force generation depends on the square of the velocity. The blade in the right side of the aircraft is called Advancing Blade because when the relative wind speed reaches its maximum velocity, more lift is generated. On the other hand, the left side of the aircraft is called Retreating Blade because when the relative wind speed reaches its minimum velocity, less lift is generated. This situation is called Dissymmetry of lift, which is the unequal lift generation in the blades. This difference can make the helicopter be uncontrollable and, in counterclockwise rotation, make it roll to the left.
The way to have equal lift forces in both sides is due to blade flapping, on in other words, to change the angle of attack of the blades in each position of its rotation: In Advancing Blade, decreasing it and producing less lift; In Retreating Blade, increasing it and producing more lift. In Figures 3 and 4 it is possible to see the difference in forces of lift distribution without and with flapping, respectively.
Besides that, it is necessary to have an angle's limitation on the Retreating Blade. At higher forward speed and consequently high angle of attack, this blade can stall.

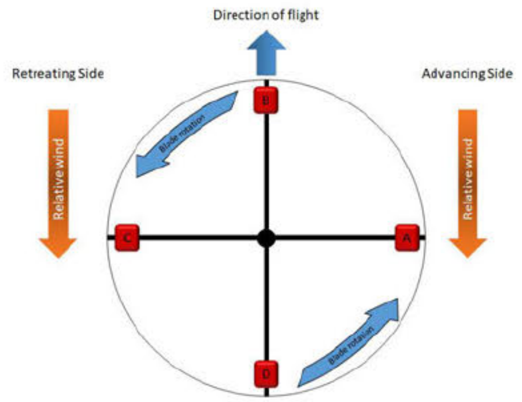

Fig. 2 . Airflow in an aircraft forward flight - top view.

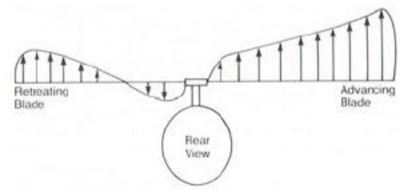

Fig. 3 . Lift distribution without flapping. Reference: [2]

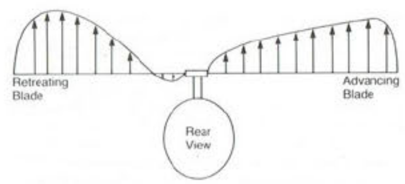

Fig. 4 . Lift distribution with flapping. Reference: [2]

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Health risk by Cosmic Radiation Exposure

Szu-Tung Chen, Xin Jie Duan, Cheng Yi Guo and Meet Agrawal
TMAL02, Linköping University, 2018

1 Introduction

Cosmic radiation is high energy radiation with subatomic particle. They mainly come from the outside of solar system. Most of them are consist of protons(89%) and atomic nuclei(10%). Cosmic rays can produce showers of secondary particles that sometimes reach the surface of the earth[1].
In 1912, Victor Hess carried three enhanced-accuracy Wulf electrometers to an altitude of 5,300 metres in a free balloon flight. He detected that the ionization rate increased to about four times of the ground rate[2]. It is from that time, people have started to explore the mysterious radiation.

2 Health risks

Cosmic ray collisions in the body can be harmful because the pions from radiation will quickly decay into mu mesons, or muons, which penetrate to the ground. As they pass through our bodies, they produce ions and break chemical bonds[3]. They can also damage the DNA in our cells. Even a single cosmic ray has a large amount of energy. Cells may be destroyed or mutation of some disease like cancer or cataract may occur[4]. These radiations can do no significant harm for people on the ground.
Cosmic radiation is affected by atmosphere. For a single person on the ground, radiation exposure is only 0.3-0.4 [mSv/y] [5]. Fig.1 shows the average cosmic radiation exposure in 2008.

Source of exposure		Annual effective dose (mSv)	
		Average	Typical range
Cosmic radiation	Directly ionizing and photon component	0.28	
	Neutron component	0.10	
	Cosmogenic radionuclides	0.01	
	Total cosmic and cosmogenic	0.39	0.3–1.0#

Fig. 1 . Average Cosmic radiation exposure

Without enough thickness of atmosphere, it is said that the pilot of an aircraft probably absorbs as much radiation as a worker in a nuclear power plant. Since they work in upper atmosphere, they face much more radiation(around ten times) than people on the ground[6].

Some airlines choose to fly over poles, because it can save upto $35,000 to $40,000 per flight in fuel costs alone. But correspondingly, radiation of flights over the poles are 3 to 5 times higher than domestic flights closer to the equator[6]. Below is the image of Nowcast of Atmosphere Ionizing Radiation for Aviation Safety on Oct. 4, 2018

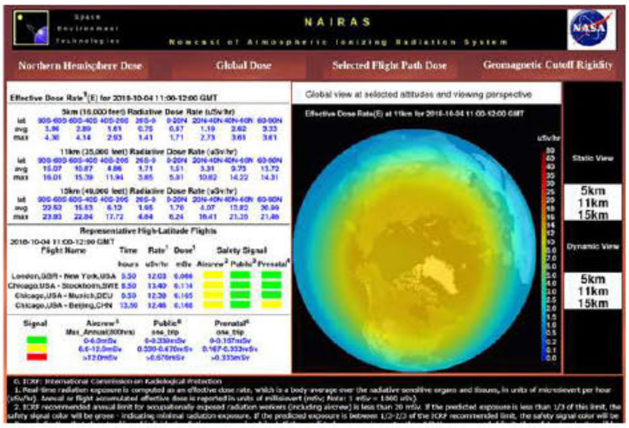

Fig. 2 . A NAIRAS model shows radiation levels over the northern hemisphere on Oct. 4, 2018 [7]

The situation become more serious with astronaut in deep space. They would have thousands of subatomic particles pass through his or her body every second[4]. One estimate from NASA reveals that about one third of the DNA in an astronaut's body would be cut by cosmic rays every year[3]. The structure of the fuselage can be coated with shielding materilas like composite built from Polyethylene(PE) and low-Z materials, which are convincingly proven effectives towards these radiations[8] . Learning how to protect humans from radiation exposure is an important step in future space exploration.

3 Mitigation of Health risks caused by cosmic radiation

The following sections will discuss methods to mitigate health risks caused by cosmic radiation from the perspectives of astronomers, flight passengers, and ordinary civilians.

3.1 Cosmic radiation protection - Astronomers

Astronomers have the greatest health risk caused by cosmic radiation as they receive the largest amount of radiation from the universe and it is much higher than anyone else on the earth[9]. Several methods are developed and employed to ensure the safety of astronomers. Inside the spacecraft, astronomers are protected by the radiation shield layer wrapped around the spaceship[10]. The radiation shield layers can be made of aluminum alloy, CFRP, or Gold Foil (most commonly used). These materials are proven to be effective in blocking radiation but they also have their own pros and cons[10]. CFRP is a relative light material in terms of weight and it can also provide space debris protection, but it is also the most expensive material[11]. Aluminum alloy provides the most effective shielding and it is inexpensive, but due to its heavy mass, it reduces the payload carried on the spaceship. Finally, gold foil is the lightest material, and it also provides reasonably good shielding effect, but another layer has to be added to protect it from the space debris[12].

3.2 Cosmic radiation protection - flight passengers

There are numerous methods available to protect the flight passengers from the high radiation at high altitudes of flight. First, the airline companies can upgrade their facilities by adding an additional layer made of soft aluminium foils in the blanket provided to passengers for long-haul flights[13]. Secondly, windshield can also be made from CFRP or other radiation shielding materials so that passengers can close the windshield during the flight to reduce the effect of radiation[13]. Finally, passenger can also purchase radiation protection clothes and wear them during the flight. The radiation protection clothes won't necessarily be complicated and technical, it can be simply made of two cottons with an layer of tinfoil in between[14].

3.3 Cosmic radiation protection - ordinary civilians

The above-discussed methods are for extreme conditions and these won't happen in our day-to-day life. Most of the earth's surface is shielded by the earth's natural magnetic field generated by the flowing liquid metal at the center of the earth. Ozone layers also provides protection from these radiations, especially UV radiation[15]. As a ordinary civilian, what one can do is, to protect the earth and the ozone layer, reduce the greenhouse gas emission and the carbon footprint[15].

4 Conclusion

In this paper we discussed the health risks caused by cosmic radiation and presented several methods to mitigate the effect of cosmic radiations. While gold foil and tinfoil are proven to be effective, light, and inexpensive material to shield from the radiation, it is also important to pay close attention to solar variation and changes in cosmic radiation and protect the ozone layer - a natural effective protection shield for all lives on earth.

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Expert Conference: Hypersonic flights

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TMAL02, Linköping University, 2018

1 Introduction

Throughout the history, human being has always dreamt with the idea of going faster, as depicted from the evolution of means of transport. Supersonic flights have been so far the fastest transports that humanity has achieved inside the atmosphere, but there is one further step, hypersonic flights, which speed goes beyond Mach 5. It requires huge technical development, since the aerodynamics have to be specifically modified and the structure of the object has to overcome temperatures above 1273 K. The border between supersonic and hypersonic is set arbitrarily because there is not a huge physical difference among them.

2 History

After the WW2, due to the technical achievements obtained during this time, there was an astounding need of applying that new knowledge and improve it. After achieving supersonic speeds in 1947 with the Bell X-1, American scientist continued researching in enlarge the speed of aircraft with V-2 German rockets. Finally, a modified German V-2 was achieved in February 1949 with maximum speed of 8,288 kph, which means that flew above Mach 5 becoming the first hypersonic flight ever. Afterwards, the first satellites were thrown to the atmosphere and the need of studying hypersonic conditions was mandatory. In 1956 the studies of hypersonic conditions started in NACA's Langley laboratories ending in the X-2 (Mach 3) and in the X-15 unmanned prototype which reached Mach 8. This research was incredibly helpful for the development of the nuclear missiles which heads reach supersonic speeds and even for the Discovery program (Mach 24 in reentry). [1] [2] [3]

3 Physics

It is necessary to define the hypersonic flow regime as the speed of Mach Number 5 and above. Nevertheless, it can also be defined as speeds where sramjets do not produce net thrust. While the definition of hypersonic flow can be quite vague and is generally debatable (especially due to the absence of discontinuity between supersonic and hypersonic flows), a hypersonic flow may be characterized by certain physical phenomena that can no longer be analytically discounted as in supersonic flow. The peculiarity in hypersonic flows are Shock layer, Aerodynamic heating, Entropy layer, Real gas effects, Low density effects and Independence of aerodynamic coefficients with Mach number.[4]

Once it is known what the hypersonic flow and its main characteristics are, it is time to start talking about hypersonic aerodynamics. The main characteristic of hypersonic aerodynamics is that the temperature of the flow around the aircraft is so great that the chemistry of the gas must be considered. When an object moves through the air at greater Mach Number, the production of electrons in the shocked layer of air which surrounds the object has a significant effect on some of the properties of the shocked air. It occurs especially in the ionosphere where the ambient electron density is no longer negligible. The influence of electrons is felt not only on aerodynamic quantities such as heat transfer, drag and flow field, but also on physical quantities such as transport properties, radiative emission and absorption, and electromagnetic signal interaction.

At hypersonic speeds, the molecules break apart producing an electrically charged plasma around the aircraft. Plasma physics then are simply the physics of a gas. Large variations in air density and pressure occur because of shock waves, and expansions. At hypersonic velocities a detached shock surrounds a blunt nosed object as it travels through the atmosphere.[5]

We can observe an schematic diagram of the flow of air around a hemisphere cylinder in Figure (1).

The shock front is a non-equilibrium region in which energy is being transferred from the translational degrees of freedom of the air molecules to various internal degrees of freedom. Immediately adjacent to the surface of the missile is the boundary layer (a narrow region in which the tangential gas velocity increases from zero at the surface to the local flow ve-

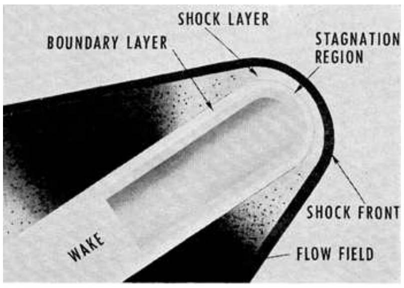

Fig. 1 . Flow about a hemisphere cylinder moving through the atmosphere at hypersonic speeds.

locity in the shock layer). In between the shock front and the boundary layer is the shock layer (a region of thermodynamic equilibrium). Finally, the wake (or afterflow region) is a region of low density, high temperature and turbulent flow.[6]

4 Problems and Solutions

4.1 Temperature

Kinetic Energy becomes heat. For hypersonic flights, where very great speeds are reached, aircraft surfaces get temperatures over 1,000ºC. This might lead to overheating problems and, in some cases, the aircraft might burn. That happened, for example, to the V-2 rocket in 1949, which burned up when reentering into the atmosphere [7]. In order to avoid burning, aircraft surfaces must be covered with a thermal protection system [8].

4.2 Mach cone

Hypersonic flights are the ones above Mach = 5, and for those speeds the angle of the Mach cone is lower than 12º [9].

$$\mu = sin^{-1}(\frac{1}{M}) \tag{1}$$

If M=5 then μ=11.54º.

If the nose shock-wave intersects any part of the aircraft (wing, tail…), this might produce great structural problems due to the vibrations produced. So that, aircraft must be very slender and wing must be perfectly designed in order to avoid collisions with the shock-wave. In most cases, a delta wing is used in order to avoid those collisions.
Instead of facing Mach cone as a problem, it can be used to generate lift in wave-riders, for example, Boeing X-51 A scramjet, which uses shock-waves to generate lift.

4.3 Drag

For hypersonic flights, the most important component of the Drag is the pressure-wave drag. This drag is about the 80% of the total drag, with values of the drag coefficient near to 0.04 [10]. This fact must be taken into account when designing the propulsion system in order to achieve the thrust enough to equal the drag increase.

5 Future

To sum up, engineers from all over the world have been doing their research in order to accomplish their purpose: making hypersonic flights possible lowering all (or at least most) of the "problems" that they carry.

As an example, we must point out the X-60A, a GOLauncher1 (GO1) Hypersonic flight research vehicle designated by the U.S Air Force [11]. Its main purpose is to increase the frequency of flight testing while lowering the cost of maturing technologies including scramjet propulsion, high temperatures and autonomous control. Its propulsion system is the Hadley liquid rocket engine, which uses liquid oxygen and kerosene propellants in order to be able to acces high dynamic pressure flight condition between Mach 5 and Mach 8.

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LINKÖPING UNIVERSITY

Concorde 2.0: Ongoing supersonic transportation projects

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TMAL02, Linköping University, 2018

1 Supersonic Airliners of Today

Since the retirement of the Concorde back in 2003 there has been no civilian supersonic airliners in operation. This is however about to change as several companies are working on new supersonic aircraft designs. There are four major projects in the works. These are Spike Aerospace, Aerion Supersonic in co-operation with Lockheed Martin, Boom Technology and NASA in cooperation with Lockheed Martin. [1] [4]

Each of these projects are facing some problems in the development of a new supersonic aircraft. At supersonic speeds the fuselage and the wings have to be narrower at the same time as these parts are under higher stresses and temperatures which causes difficulties in production. The fuselage also has to be stronger because of high pressure difference between cabin and atmosphere due to high altitudes. Another problem the supersonic aircrafts has to face are the international regulations, making flights at supersonic speeds above land prohibited. The regulations are in place because of the sonic boom that's created when an aircraft flies faster than the speed of sound.

2 Spike Aerospace

Spike Aerospace was founded in 2013 making it a relative young company and their primary focus is to reduce effect of sonic boom. Business idea of the company is to build a quiet supersonic airplane the Spike S-512 that will carry maximum 18 passengers and will be able to operate at Mach 1.6 over cities, producing a muted background noise at level less than 75 PLdb. This in comparison to the sonic boom of the Concorde at 105 PLdB.
Concept design has long small body with long nose, wings look to be a combination of back swept wing with tailless delta in the middle (wing structure is similar to B2's wing). Engines are placed at the tail instead of horizontal tail wings. To make fuselage structure simplier and strong enough engineers decided to get rid of windows for passengers and instead have 4K cameras outside of the cabin and thin screen along side walls inside the cabin. The preliminary design is shown in figure 1. The company's airplanes are intended to start fly in the beginning of 2021 and start deliveries in 2023. [7]

Fig. 1 . Preliminary design of the Spike Aerospace supersonic aircraft.

3 Aerion Supersonic

Aerion is an American company founded in 2003 when an investor group led by Robert M. Bass bought the company ASSET group (Affordable Supersonic Executive Transport). The reason why ASSET was purchased was that the company had since the early 1990s performed research on supersonic natural laminar flow, a phenomenon making it possible to reduce drag and operation cost at velocities above the speed of sound, and acquired enough information about it to become one of the world leading companies at the subject.

Aerion's current design of a supersonic aircraft is the AS2 and is shown in figure 2. It was announced in 2014 and is an executive jet aircraft able to carry up to 11 passengers, with the goal to reach cruise speeds of Mach 1.4 over water and Mach 0.95 over land. The company is however working with authorities in the US and Europe to certify the aircraft for speeds up to 1.2 Mach over land, since in right weather conditions it is possible to fly at such speeds without creating a disruptive shock wave. In its current state the aircraft has three turbo fan engines, one situated under the vertical stabilizer and one under each wing. It has short wings in order to reduce parasite drag and slightly resembles Lockheed Martin's F-104 Starfighter.

During May of 2017 the company started a collaboration with GE Aviation with the goal to design a new supersonic engine for the AS2, and in December of the same year Aerion invited Lockheed Martin to join forces on the AS2 project. The aircraft is scheduled to make its first flight in 2023 and entering full service by 2025. [1]

Fig. 2 . Preliminary design of the Aerion and Lockheed Martin supersonic aircraft.

4 Boom Technology

Boom Technology is an American start up company founded in Denver 2014. Since early 2016, Boom Technology has participated in the top ranked start up incubator program by Y-combinator and has secured investments from Japan Airlines, Virgin Group and several venture funds. What Boom Technology is trying to achieve is a way of flying at 2.2 Mach with as many as 55 passengers and reducing traveling time by half during flights over sea, for example between New York and London. This will be done by combining materials and technologies proven on other passenger aircraft's into a revolutionary design. The aerodynamics of the aircraft have been refined through extensive wind tunnel testing with the aim of generating more lift for less drag to improve fuel efficiency and allowing supersonic travel at lower fares. The propulsion system is a setup of three medium-bypass turbojet engines with no after burning possibilities. [2]

Fig. 3 . Preliminary design of the Boom Technology supersonic aircraft.

5 Lockheed Martin and NASA

Since the year of 2016 NASA has worked with defense giant Lockheed Martin on a supersonic aircraft, called X-59 Que-SST. The aircraft's design is shown in figure 4. One of their biggest obstacles is the sonic boom, mentioned in section 1. Their goal is to reduce the sonic boom to a sonic thump. The idea is to design the airplane so that the shock waves are aliened in such a way that the pressure gradually builds up, producing a thumb at only 75 PLdB. [6] [3]

NASA is aiming for the maiden flight in 2021. Since flying supersonic over land isn't allowed due to the regulations mentioned in section 1, NASA plans to make community overflights and gather response data from the communities. The hope is that the data will make supersonic flights legal over land and thus creating a whole new market. [5]

Fig. 4 . Preliminary design of the NASA and Lockheed Martin supersonic aircraft.

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EXPERT CONFERENCE: Sonic Boom Reduction of Supersonic Aircrafts

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1 Supersonic Flows and Shock Waves

With the ever increasing urge to travel faster and faster we move from subsonic to supersonic speeds. When an aircraft flies at the speed of sound it is said to fly in the supersonic speed regime. Once it flies beyond Mach 1 the fluid which comes in contact is no longer incompressible, hence we see disturbances in the form shock waves, expansion waves. These compressibility effects are caused due to abrupt changes in pressure, density and temperature of the medium. The airflow behind the shock wave breaks up into a turbulent wake creating a drag called wave drag which severely impacts the performance of an aircraft. [1].

A sonic boom as seen in Figure 1 is a sound that

Fig. 1 . F-22 Raptor undergoing Sonic Boom.

is created due to shock waves whenever an object travels through the air faster than the speed of sound. A larger amount of energy is contained in a sonic boom. Sonic booms of an aircraft can cause structural damages and cause discomfort to living creatures. Neither is the sonic boom omnidirectional nor does it occur at the moment the object crosses Mach 1. Sonic boom is rather a 3-Dimensional cone that is formed behind the aircraft, which grows proportionally and dies out gradually.
Usually when an aircraft flies in a subsonic speed regime, the aircraft produces pressure waves in front of the wing, similar to waves in water when a stone is thrown into it. These waves become tightly packed ahead of the aircraft than at the rare side. Until the aircraft travels slower than the speed of sound, these waves are nested within each other, .i.e., one pressure wave within another pressure wave. These pressure waves do not intersect each other in subsonic regime. But when the aircraft travels faster than the speed of sound things change. When a pressure wave generated intersects another pressure wave already present, they are forced together forming a Mach cone [1]. The pressure rises at the nose and steadily decreases to a negative pressure as the wave approaches the tail, after which it again sharply increases to its normal pressure. This pressure profile is plotted is called the N-wave. So therefore, the N-wave causes two booms- first when the pressure rises and the other when the pressure returns to normal as seen in Figure 2.

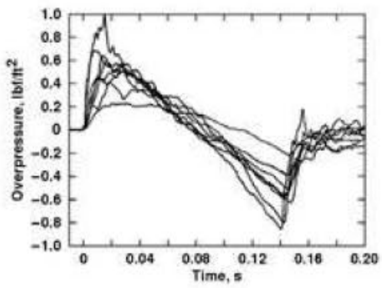

Fig. 2 . N wave representing the pressure distribution across the aircraft body.

2 Environmental Issues and Regulations

The greatest barrier for supersonic flight is the environmental restrictions because of the sonic boom generated when aircraft speeds exceed speed of sound.
The noise generated when the aircraft is traveling at supersonic speed, has a wide range of distance, approximately 80 Km around the aircraft. Such a large range of noise can cause many problems for the environment.
After the development of the Concorde aircraft, was when the sonic boom generated by it was taken into consideration. In 1968 the Aircraft Noise Abatement Act was created in order to establish standards regarding supersonic flight. *FAA* [2].

3 Methods of Reducing Sonic Boom

3.1 Past Developments

To reduce the effects of sonic boom, it becomes necessary to reduce the pressure change effectively so that the loud noise is reduced to a quieter sound. Following are the examples of developments that have taken place to reduce the intensity of sonic boom:

1. F-5 E: The nose of the F5 was replaced with a longer version. NASA took 1300 sonic-boom measurements from various ground sensors. "The results showed that there was an 18 percent reduction in the initial impulse pressure. This resulted in the reduction of larger pressure variation. The noise levels measured were found to be 4.7 decibels lesser than the regular F5", as taken from *NASA* [3].
2. SR-71: The Blackbird had a diffuser at the engine. "The shock waves hitting the main body would flatten out against the diffuser, resulting in a quieter sonic boom due to smoother movement of airwaves" , as taken from *Lockheed Martin* [4].

3.2 Experiments

In the past, NASA's Dryden Flight Research Centre came up with the concept of introducing a long nose on an existing F-15B aircraft. This modification consisted of a 24 ft long nose which was intended to breakdown the shock waves into 3 smaller ones before it reached the main body. This project known as the Quiet Spike Testing aims to induce Laminar Flow Control which reduces the turbulent cross flow on the wing which causes shocks. The underlying principle is the conversion of the traditional N shaped shock waves to a less intense S shaped waves as described by *NASA's Dryden Research Centre* [5].
"Currently, NASA continues to research by creating "superbooms" which are generated when aircraft accelerate or decelerate but can be heard at only one place. If the locations are planned correctly these "superbooms" can be heard only over places with minimum disturbance such as a desert or a water body. This project is currently being tested with microphone arrays over land. The tests are being performed by F18 aircraft to create sonic booms over Florida in USA. They are also researching a way so that shock waves produced such that only a general pressure rise is developed instead of a loud boom. The data collected from these tests will aid in designing future supersonic aircraft"- *NASA's Dryden Research Centre* [5].

4 Future Concepts

1) Spike S 512: This is a future aircraft that is designed to produce noise levels less than 70 db. The sweep of the wing is designed in a way to reduce the shock waves. "The S-512's sonic boom signature on the ground is further reduced by careful optimization of the shape of the airplane. Extensive use of advanced Computational Fluid Dynamics (CFD) software was made to optimize the shape parameters of the wing and fuselage to minimize shock wave strength. Interactions between shock waves and flow expansion regions located on the surface of the airplane were analyzed, and design of the flow expansion regions was refined to mitigate the strength of the waves" as quoted by *Spike Aerospace* [6].

2) Lockheed are developing a Quiet supersonic X- plane which believes in streamlining the aircraft to eliminate the sonic boom. "The idea is to create a sleeker shape that distributes the shock waves over a broader area, and add lifting surfaces like a canard, stabilator, and T-tail to further minimize impact points between the airframe and the air, creating fewer shock waves. Ditching the cockpit canopy in favor of an electronic vision system eliminates another boom point", as seen in Figure 3 which is taken from *X-59 QueSST* [7].

Fig. 3 . Main Design Features of QueSST.

5 Conclusion

Summarizing the above discussed methods and concepts we can say that there have been considerable developments in the research towards decreasing intensity of the sonic boom. It can be concluded that in future we can expect supersonic flights without sonic boom.

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Hypersonic effects in water

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1 Introduction

Supersonic in air is a well established term and it's when you travel faster then the speed of sound, also known as Mach 1. When the speed exceeds Mach 5 it's called hypersonic.
Since air is a gas the density and therefor the friction is very low. But, what is happening when we try to go supersonic in a liquid, like water?

2 Supersonic in air

Sound waves are pressure waves that travel in an elastic medium. The speed of which the waves are travelling are mostly dependent on the density and temperature of the medium. Since density, temperature and the composition of the air depends significantly on the altitude the speed of sound will vary. For an example is the speed of sound in dry air with a temperature of 20°C at sea level approximately 343 m/s while at an altitude of 10668 m it's 295.4 m/s. *Supersonic speed* [1].
For an object that travels near or faster than Mach 1 new auditory effects will occur. When an object is travelling at speeds underneath Mach 1, sound waves will be sent out in all directions while if the speed exceeds Mach 1 the object will travel faster than its own sound waves. At this point the sound barrier is broken, the sound waves becomes compressed by the object and it will result in sound waves with different intensities in different directions. This is when one will hear the famous shock wave, "the sonic boom" *Shock wave* [2]. It can be compared with the doppler effect where a traveling object that is emitting sound will compress the sound waves before it self and behind they will be elongated. *Doppler effect* [3].
Because a shock wave happens almost instantaneously and the total enthalpy along with temperature is constant the total pressure downstreams of the shock wave will be less than upstream *Shock Wave pressure drop* [4]. This pressure drop will sometimes force moist air around an object to reach its saturation level at which it can not "hold" its water any more. This will result in a temporary cloud, or a vapor cone. See Fig. 1.

Fig. 1 . Formation of a vapor cone around aircraft.

3 Supersonic in water

Since water is considered incompressible, the speed of sound is relatively high compared to air: approximately 1450 m/s at 20°C. So when you want to reach a hypersonic speed in water, you need to break the sounds barrier. Because of the high drag the water will cause, it takes a lot of energy to drive something through the water at this speed (in comparison: for common underwater vehicles the speed limited to about 40 m/s because of the high drag above this velocity). Theoretically it would maybe be possible to break the sounds barrier under water, but it has not been done yet neither we have the technology to do so right now.
In fact, before even getting close to reaching the speed of sound under water an other phenomena called cavitation will occur. Cavitation is the phenomena were small bubbles of vapour will form. Beside the other problems it will cause, it would also mean that the object would not be travelling through water anymore but instead through an bubble of a water/steam mixture. The effects of cavitation are explained extensively in section 4.

4 Hypersonic effects in water

4.1 Cavitation

Cavitation happens when a liquid is accelerated to high velocities, and is getting pushed away faster than it can react. This will leave behind an area of low pressure, often in the form of vapour bubble, the bubbles will expand as the pressure is reduced further. When the bubble reaches a high pressure area, it will violently collapse. These vapor cavities will cause a extremely high local pressure (about 800 MPa!). Usually objects are designed to avoid cavitation because of the damage it causes, but in some cases it can be used to our advantage (as explained is section 4.2). The effects of cavitation on a hydrofoil can be seen in Fig. 2.

Fig. 2 . Cavitation on a Hydrofoil.

To know when the cavitation will occur the cavitation number can be calculated by using a formula. This equation will estimate how close the pressure in the liquid flow is to the vapor pressure, which will tell if cavitation can occur or not. See Fig. 3. *Cavitation number* [5]

$$\sigma_{inlet} = \frac{P_{inlet} - P_{vap}}{\frac{1}{2}\rho V_{inlet}^2}$$

Fig. 3 . Formula for cavitation number.

4.2 Supercavitation

Beside its negative effects, cavitation can also be used as an advantage. Supercavitation is a technology used to increase the speed of an object moving trough the water. The nose of the object is used to create a bubble around the object. An example of this can be seen in Fig 4. This means that the object is no longer traveling through a liquid, but through a gas. This significantly reduces the skin friction drag on the object, enabling it to travel at higher speed. An example of the use of supercavitation is the supercavitation torpedo *VA-111 Shkval* [6]. Using this technology the torpedo was able to reach a maximum speed of about 100 m/s. This is not even close to going hypersonic.

Fig. 4 . Formation of supercavitation on an airfoil.

5 Conclusion

As it seems, it is impossible to achieve true hypersonic speed in water due to cavitational effects, which occur far before one will even reach supersonic speed in water. Even thought the use of supercavitation will help to reach higher velocities (for now up to 100 m/s) it wont be sufficient. We would need to find other methods or techniques to reach hypersonic speed in water, if it even is possible. To have some comparison: in 2005 the X-43 from NASA was able to break the speed record in air by going as fast a Mach 9.6!

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Contactless energy transfer systems

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1 Introduction

Energy management is one of the main concerns in modern devices and vehicles as we are aiming to optimize its consumption. For now, the main technology used to transfer electrical energy is by cable, but it has some limitations, as it adds a significant weight,is a huge waste of space, and it can be a big source of maintenance issues. Therefore, Contactless Energy Transfer Systems (CETS) have been studied and developed in a wide variety of industrial sectors.

2 Principle of CET

This technology is so far one of the main trend in electronic and electrical research fields and a lot of dif ferent tracks have been studied different results. We first have to know that managing electrical energy is noth ing more than just moving energy from a starting point to an other through a medium. In common systems, the medium is copper but air, water, body tissue, light waves or inductive fields can also be suitable [1]. To de cide which CETS to use, it may be useful to think in the application that the device is going to have, and the condition in which it will work as those are parameters that can influence its efficiency.

3 Types of CETS

There are four main types of CET, acoustic waves, light waves (also known as "optical waves"), inductive coupling and capacitive coupling.

3.1 Acoustic CETS

This technology uses sound waves as its main medium for transmitting energy. For this, instead of a plug-cage to insert a cable and transmit electricity, this technology uses a power circuit to transform the electrical energy into a pressure wave, which is "a wave in which the propagated disturbance is a variation of pressure in a mate rial medium"[1]. Then, a transducer receives this pressure wave, transforming the energy of the disturbance into electricity. For this, piezoelectric materials are usually used, since one of their main characteristics is to generate voltage out of pressure.

[1] *pressure wave*. 2011. In *Merriam-Webster.com*. Retrieved October 8, 2018, from `https://www.merriam-webster.com/dictionary/pressurewave`.

3.2 Light CETS

Light wave CETS use certain wavelengths to trans mit energy. This wavelength are usually in or near the visible spectrum [2]. A known system that uses this is a photovoltaic diode (PVD) paired up with an optical power beam. The beam is directed into the PVD and then transformed back into electric energy.

3.3 Inductive Coupling CETS

Inductive coupling CETS consist on a DC/AC resonant converter, the air gap in the transformer and the AC/DC converter. The DC is converted into high fre quency AC, then it varies with the "K" factor[2], and then converted back to DC. There are four types of induc tive CETS, depending on the way the transformers are used; cascade transformer, multiple secondary winding and sliding.

3.4 Capacitive CETS

Capacitive CETS consist on two primary and two secondary metal plates, and a high frequency resonant power electronic converter. The resonant converted gives energy to the primary plates, which are placed with the secondary plates near them, the secondary plates are isolated. An electric field is created, allowing a displacement current to pass on from primary to secondary plates. An electric inductor may be added to in series with the secondary plates to increase the output power [2].

4 Comparison

The four types of CETS previously mentioned have advantages and drawbacks. The acoustic CETS can be more reliable than the others when certain frequency and size of transmitter and receiver are used, it can also be

[2] Coupling factor.

used where electromagnetic fields are not allowed, also it can be more efficient if the distance from the transmitter to the receiver is much larger than its the radio of each, whereas if the distance is smaller, they are less efficient. For light CETS, one disadvantage is that increasing the distance of transmission will increase losses because of diffraction. An advantage is that it can deliver huge amounts of energy over short distances. For the capacitive CETS, the plates act as an isolating barrier, making surroundings less of an issue. The constrained electric field also helps to redue electromagnetic interference.

5 Future use

CETS will imply a huge gain of weight and space in our vehicles and especially in aircraft. The only physical transfer systems left will be flow pipes like for example fuel pipes between the inner, outer and central tank of an airplane. These deletions may open up new horizons in design, aerodynamics studies or accommodations in our vehicles and lead us to a knew era with more efficient planes and vehicules.

The most concrete example is the Solar Impulse project launched in 2003, it was intended to create a plane which would be able to fly only with electrical engines days and nights. By adding photo voltaic cells on each wings (empennage included) they used a contactless energy (solar to electric) to supply the engine.

6 Conclusion

CETS are an upcoming technology that will reduce maintenance costs and increase reliability due to the removal of cables. It will also give more freedom of movement as it will help to reduce weight and space loss. Depending on the desired use, it is convenient to check each of the CETS advantages and disadvantages over the rest, to be sure that it will perform at its best. For vehicles, like planes, CETS will translate into a reduction of weight and wings might get a thickness reduction, as connection equipment will not be required, and also the drive range can increase thanks to the previously mentioned photo voltaic cells.

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LINKÖPING UNIVERSITY

Expert conference: The Hyperloop

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1 Introduction

Is traveling from New York city to Washington D.C. in 30 minutes just an imagination or slowly becoming a reality? Hyperloop is the new trend based on a concept from Elon Musk who wants to make the development as an opensource project. "How does this technology work and what is standing behind Hyperloop will be explained in the next paragraph." [1] Hyperloop is based on moving capsule approaching to subsonic speed which is propelled electromagnetically in close long tubes. Musk's theory is that pods will be held in the air on a cushion of the air. Similar to the work of other companies with the idea of "MAGLEV". To managae the air cushion underneath the capsules strong electro-magnets are needed. [2]
The HL (Hyperloop) belongs to the group of HSR (High speed rail) and APT (Air passenger transport). One of the biggest issues at higher velocities is the parasite drag. Therefore the aerodynamic of the train is getting really important. The difference between any usual train and the HL will be, that the HL is going through a pipe, which is almost evacuated. This means there will be a certain under pressure, to reduce the influence of the air pressure. The tube is composed of 3 parts. In the station is normal atmospheric pressure. When the capsule moves to the second part the hermetic doors close the area and the special ultra-high vacuum pumps set up the pressure to the values about 10-8 Torr. (Atmospheric pressure is at the level 760 Torr = 1.013×10^5 Pa). The last chamber is 'departing' chamber with usual air pressure. [3]
The idea of hyperloop predicts low travel costs connected with high energy efficiency of the ride as well as cheap source of energy.[3] The idea to provide the needed power, is to cover the pipes with solar-panels.

2 Pros and Cons Hyperloop

The biggest advantage will be the time saving. If you can travel with more than 1000 km/h with almost no acceleration time, distances are no problem anymore. You also won't need long check-in times and security checks anymore. It will also fit in the necessary setup

Fig. 1 . Real capsule of Virgin hyperloop-one company which was already tested in Nevada - United States of America. [4]

for the city of the future. Which will look totally different to nowadays cities. There will be a time, when you can also get into the city by public transport or self-driven cars. So, you can leave the hyperloop at stations all around the city and get to your office by self-driving or -flying cabs. There will be no traffic jams anymore and the cities getting free of all the exhausts. It also fits in the future transport systems, things getting faster and you can also stuff the pipes with transport wagons.
The supply of the needed electrical power will be managed by covering all the pipes with solar panels there will be more power generated then needed for the hyperloop, so you will gain power and you won't increase the total power consumption. Another advantage will be that the tracks are also protected against weather, birds and other objects due to the pipe. And the automation of this system will reduce the risk of human failures. Last but not least if any failures occur, the wagon will stop in the worst case, but it won't fall of the sky for example. [5],[6]

On the other side when the wagon stops somewhere in the pipe, how do you get the people out? The easy part will be to get rid of the vacuum but you are still far away from any official exit to get the people out. Also, it will be super expensive to setup the infrastructure with the pipes and the special designed stations. Also, the stations should be in the center of the city otherwise you will lose again a lot of time to get into the center by public transport or cabs. On top building ground in the city centers is also super expensive so there will be another problem to install the needed stations. And there are still no exact values

about the amount of energy this transportation system will need. If it goes by night, there won't be a any sun which can take care for the energy consumption. So, you must think also about energy saving systems.
Another big issue will be the security. The track they are building in California right now is in the middle of an earthquake hot spot. There are also plans to build it next to highways – what's about car/truck crashes into one of the pillars. And Terrorist can attack now the whole track. And if there is an accident with a speed of 1000 km/h that will do a lot of damage, to the environment as well as to the track itself. So, if the track isn't repaired it can't be used.
A fundamental basic point for the construction will be that due to the high speed there can't be any sharp curves or abrupt changes of height. Finally, this technology was already introduced in the 70's: Maglev trains. China has been the country who wants to include this technology into its infrastructure, but it failed on the already established infrastructure and the also upcoming fast trains. [5], [6]

3 Comparison of Hyperloop with other ways of transports

3.1 Hyperloop versus regional aircraft

Nowadays, planned routes for the Hyperloop only take a narrow segment of the range in which commercial aircraft operate. Since, the distance of the routes varies up to 1100 km it is directly a competitor to the regional jets. [7] As can be seen in the table the expected time savings are considerable, and they would be even higher if we compute the needed time for the boarding, security checks at airports and the consumed time to go to the airport (far away from the city center in some cases). The size of the tubes is similar to the size of the cabin of a regional airliner, with a capacity of 28 people per wagon, then for achieving the same capacity as an regional jet (for example, the ATR-600 can load up to 78 passengers[8])several wagons would be needed. Regarding the performance, maximum accelerations are double or triple the ones that take place during aircraft operation and the maximum cruise speeds (1200 km/h and 0.85 Mach) are considerably higher then airplanes. The combination of these two factors explain the significant amount of time reduction. On one hand, the cost of a line is quite expensive compared to the infrastructure of air traffic, however there is little man control and surveillance and security is hoped to be improved for this kind of travel.

Origin	Dest.	t_Hyp (min)	t_jet (min)
St.Francisco	Los Angeles	35	75
Toronto	Montreal	39	70
Helsinki	Estocolmo	30	55
Mumbai	Chennai	63	110

Table 1. Examples of actual planned routes duration.

3.2 Hyperloop versus bullet trains

The second set of comparison is done with the bullet trains, one of the best examples would be the shanghai maglev train of china. Bullet trains are one of the fastest on ground mode of long range transport present today.[9]
Bullet trains can reach speeds of almost 500 kmph and are already functional in many parts of the world. The main reason of comparing bullet trains to hyperloop is the technology both the vehicles use. On the basic principle both of the mode of transport use maglev technology for movement.[10]
The major difference is that in case of hyperloop a vacuum is created in a tube in order to mimic flying at high altitude to reduce drag. This creates a very energy efficient system.
The table put up show the major performance parameters between the hyperloop and the bullets train.

Component	Hyperloop	Bullet Train
Speed	1000 kmph	500 kmph
Technology	Maglev+near vaccume tube	Maglev
Cost of setting up	9 billion	1.2 billion
Cost per pax for 50 kms	around 2 dollars	6 dollars
Status	Experimental stage	Functional

Table 2. Hyperloop vs. Bullet train comparison.

From the table when we consider the speed, the hyperloop in its test stages had reached 387 kmph but it is expected to reach speeds of 1000kmph which is almost double the speed that the bullet train can attain, this means the same distance is covered in half the time, more number of trips two and fro and more passengers can be transported.
Contrary to the above point the cost of setting up of the hyperloop is very high compared to the bullet

trains but the cost per passenger is low which makes it a favorable mode of transportation for a common man. Also, other than the performance parameters when environmental impact is taken into account, the hyperloop creates negligible emissions and has a much smaller civil engineering footprint when compared to bullet trains. The design of the hyperloop makes it immune to bad weather and uncertain environmental conditions like earthquake etc.
Hence comparing both, It is clear that hyperloop has an upper hand. But the fact that hyperloop is still in experimental stages where as the bullet trains are already functional shows there is a large margin for analyzing and further improvement for hyperloop.

4 Conclusion

Hyperloop is the technology of the future coming to life in present times. With its high speed performance and time saving travel, it is a much needed mode of transport in today's growing world. Also considering the point that this technology does not consume lot of energy and that the required energy will be derived from solar panels, this makes hyperloop a sustainable mode of transportation. But it is also very ambition project, to include such systems in the old cities over the world will get difficult and more expensive then planed.
Comparison of hyperloop with HSR (High speed rail) and APT (Air passenger transport) shows promising results for hyperloop.
To answer the question if hyperloop would be a success or a hyperflop and would not reach the expectation lies in the test of time. As hyperloop is still in the experimental stages this statement can be determined after it comes into operation. As engineers, new and innovative projects should always be appreciated and intrigue us to take it a notch higher. Keeping this in mind, hyperloop is definitely one of the most anticipated projects to come into action and shows a positive trail.

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Electric Flying Vehicles

Jakub Krejbich, John Walder, Marcus Pettersson and Tim Hennies

TMAL02, Linköping University, 2018

1 Introduction

Electric powered transportation has been prevalent in the automotive industry and the rail way industry for many years, but has yet to have a large impact within the aerospace industry. The aviation industry is responsible for around 2 % of all human induced CO2 emissions and 12% of global transportation CO2 emissions [1].

One solution to reduce the environmental impact of the aviation industry is the implementation of electric and hybrid electric aircraft as a means of commercial and private transportation. Battery technology has yet to reach the point where 100% electric flight is sustainable in a commercial application. Some smaller scale aircraft and concepts, like the NASA X-57 Maxwell, have been created that are capable of electric powered flight. Currently the pioneering technology used to increase fuel efficiency and reduce emissions include hybrid electric and turbo electric propulsion systems.

2 Full Electrical Flight

NASA is working on developing the first all-electric x-plane, called the X-57 Maxwell. The plane will be built by modifying an already existing aircraft to use electric propulsion, with the main purpose of validating and demonstrating the benefits that electric propulsion may yield for the future of aviation. [2].

The X-57 Maxwell will use 14 electric motors powered by batteries that drive propellers mounted on the wing. Only the two primary motors mounted on each wingtip however will be used whilst cruising. The other 12 are high-lift motors with the sole purpose to accelerate airflow over the wing during take-off and landing through a technology knows as distributed electric propulsion. By using this setup, the performance is increased in many different areas such as fuel efficiency and handling performance. According to NASA, they can see as much as a fivefold decrease in energy consumption [3].

Using DEP technology works especially well for electric aircrafts due to the importance of efficiency as a result of current limitations on batteries and energy storage, and NASA hopes that their implementation of the distributed electric propulsion system will provide critical data to other companies who are also working towards a future of electric aircrafts.

A major drawback of fully electric flight is the energy density of batteries. With current battery technology fully electric flight is not feasible for commercial flight. Another drawback of fully electric flight is that fuel weight is not consumed during flight, which does not reduce the required lift throughout the flight.

3 Turbo Electric Flight

One workaround of the cons of fully electric flight is turbo-electric propulsion technology. The propulsive and power-producing devices are decoupled and individually designed and optimized [4]. Turbo-electric propulsion is divided into fully turbo-electrical and partial turbo electric. With a fully turbo-electric system the thrust is completely produced by electric fans(e-fans). While in a partial turbo-electric system the energy for the e-fans is produced by another Turbo fan engine (compare fig. 1).

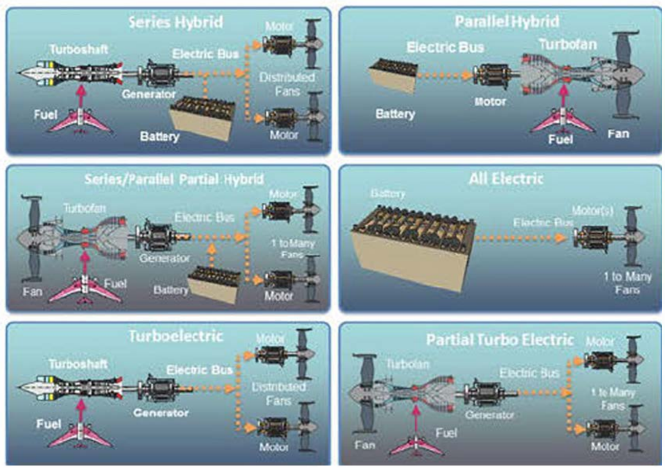

Fig. 1 . Types of electric propulsion [5]

The power is supplied by one or several gas generators(turboshaft engine) and is transmitted directly to electric driven propulsion, that can utilize a propeller or ducted fan. Decoupling the propulsion sys-

tem from the power generation system provide opportunities to optimize both configuration as the thermodynamic constraints no longer apply to the thrust generation system and vice versa.
As the energy storage is one of the main challenges for electrical flight, this technology provides a feasibility that manufacturers can currently implement. E-fans can be adapted into arays of small fans like on the NASA N3-X concept. This example is a blended wing body configuration that uses its body as lift generating surface. It is projected to have a high specific power weight (>10 kW/kg at 98% efficiency [5]). The trailing velocity sink behind an aircraft fuselages produces drag due to shear layers and high velocity gradients. A wide blown engine array can reduce the total drag by distributing the velocity evenly thus removing the sink. Furthermore, boundary layer ingestion can cause additional drag reduction by positioning a fan in the aft of an aircraft.
The bypass ratio for turbo-electric propulsion is the mass flow rate through the fans divided by the mass flow rate through the (core-) power plant. Therefore, very high bypass ratios and high efficiencies can be achieved [4].
Electric transmissions provide lower transmition losses when compared to traditional geared transmitions (0.23-0.4% vs 4-5% [4]). One disadvantage of electrical propulsion is the limit of achievable airspeeds. The combination of turbofan and e-fan engines mitigates this drawback. Higher velocities than any full electric configuration can be reached. Scalability is another challenge of full electrical flight, and can be easily achieved by combining turbo machines with electrical machines.
Turbo-electric technology is may be applicable for the next generation of aircraft. Before emissions can be reduce completely, new power sources and configurations have to be developed.

4 Hybrid Electric Flight

Another category of electric powered aircraft is called hybrid electric. Hybrid means supplying one engine with multiple types of power. The aim of the hybrid power distribute the benefits each propulsion type and distribute the benifits within the applicable flight modes. This brings the possibility of energy recovery. However, there are some nuisances that have to be dealt with. One of these restrictive factors is the weight and larger süace requirements of hybrid engines when compared to turbine engines. [6]. Once these disadvantages are mitigated, the final product is a machine with significantly lower fuel consumption and emissions which is therefore environmentally friendly.
Unlike turboelectric, the fan is powered by both, turboshaft and battery. It can be further divided into series hybrid and parallel hybrid, which uses battery and fuel powered turboshaft engine at the same time.
For the series hybrid engine, the turbo engine and the electric motor are arranged in series. The conventional engine serves here only as a source of energy for the electric motor or battery. An issue might be an unavailability to fully optimize the working area of the internal combustion engine[6].
An example of a hybrid powered aircraft is the aviation start-up called Zunum. The American company is currently developing a series hybrid small regional aircraft that uses fans with integrated electric motors and controllers. Thanks to the exceptionally efficient low-pressure fans, the company claims that the aircraft requires 40% less runway length and causes 75% less noise. The batteries are located inside the wings. Since there is no need to carry as much fuel, it can be designed into more aerodynamical friendly shape, helping the aircraft to achieve the required performance. Zunum is expected to have a seating capacity of 10 to 50 passengers with a range of almost 500 km [7].
All in all, hybrid powered aircraft have a great potential for the future. Since the technology uses both conventional engines and electric motors concurrently, it is a necessary step to start using the fully electric airliners. So, if mankind wants switch to electric power in the future, the starting point must be hybrids.

5 Conclusion

Electric flight is necessary in order to completely reduce the emmisions from the aviation industry. Hybrid electric flight is the necessary stepping stone to help reduce emmisions and envirnomental impact of the industry. The current state of battery technology limits that feasibility of fully electric commercial transportation. The X-57 Maxwell is an example that the concept will be feasible in the future. With the current state of technology hybrid-electric and turbo-electric propulsion systems will be utilized in order to decrease emmisions and the environemntal impact of the aerospace industry.

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Electric aircraft: alternative power sources

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TMAL02, Linköping University, 2018

1 Introduction

We live in an era, marked by a very rapid development in technology, which is constantly searching for alternative power sources and promoting the electrification of everyday things. We have come a long way in all these years, modern technology allows us to have electric bikes, motorcycles, cars and we've reached a point where we even want to electrify planes. The main topic in this article will be the presentation of the alternative power sources for the airplanes that we find interesting.

2 Electric propulsion

As we know, electric cars are becoming popular, and we are also trying to follow that trend in the aircraft industry. Companies are investing a lot of money in the research of the electric airplanes, but they are still in the early stages.
The main concern about the electric powered airplane is that we have to power the electro motor with batteries. As it is known, our batteries do not have the required capacity to replace the standard aviation fuel. For example the specific energy of the avgas is around 43 MJ/kg, and our best battery has around 0.9 MJ/kg. This means that for every kilogram of fuel we replace with batteries, we add around 50 kg to the total weight of the airplane. Also the charging of the batteries causes skepticism, as it is known that charging is a time consuming process and for example the companies operating the aircrafts are not really fond of their planes being inoperable for longer durations. However this problem can be easily solved by replacing the battery packs.

The future is not that dark for the electric airliners, there are new types of batteries, called solid state batteries, which are being developed and could bring higher specific energy. Also the electric aircrafts are not limited by the oxygen from the atmosphere, since they carry everything with them. However the propeller has to provide enough thrust to propel the aircraft forward, which might be a problem in higher altitudes when the density drops.

Fig. 1 . Fully electric powered aircraft by Pipistrel [1]

Fully electric airplanes actually exist. The example is Pipistrel Alpha Electric, which could revolutionize pilot training and drastically decrease the training costs. [1] The Pipistrel alpha Electric an be seen in 1

Another thing to mention is the hybrid electric power train. Hybrid propulsion is one of the first steps to the electrification of our airplanes. It is a combination of a gas turbine and electric motor, which reduces the need to carry batteries with us, because the gas turbine is charging the batteries using a generator. This type of propulsion will be implemented faster than the fully electric propulsion. [2]

3 Solar powered aircrafts

The sun is one of the biggest power sources that we can access on planet earth and one of the greenest as well. The best way so far to utilize this energy are solar cells. Since energy consumption and environment is a big problem in transportation, especially aviation, solar cells might be the solution. Today there are a few working aircraft that fly using only the power of the sun. To harness as much energy as possible and create a lot of lift these solar aircrafts have large wings to accommodate for the many solar panels required to generate the necessary amount of energy. One of the working prototypes today is the Solar Impulse 2. The plane has a wingspan of 72 meters to accommodate the 17248 monocrystalline silicone cells. The solar cells harness energy from the sun and the energy is used to charge the lithium polymer batteries. The batteries power four 17.4 HP engines. [3] Unfortunately you need batteries since the solar cells are not enough to maintain constant flight. Flight during night is also a problem, since the batteries wont charge which means the plane is time and location dependent. But when the conditions are perfect the plane has managed flights as long as 8,924km and it was airborne for 4 days 21 hours and 52 minutes [4]. This plane is just a concept and not meant for commercial use, but it shows where the future is headed and what we can expect.

Fig. 2 . Solar powered aircraft concept [3]

As we can see from the Figure 2, the aircraft has solar cells all over the wings and even the horizontal stabilizer is covered in solar cells. It can also be seen that it has four electro motors, which rotate the propellers.

4 Hydrogen powered aircrafts

When it comes to powering smaller aircraft, Hydrogen might be the future. Fuel cells are always increasing in efficiency, and with the introduction of the new hydrogen fueled cars, aircraft might be the next step. A hydrogen fuel cell works like a battery, but instead of charging the battery, the power is harnessed by converting hydrogen gas to water in a similar manner. In doing so the only emissions produced are water and heat. The heat is used to heat the cabin and water which is a highly natural part of the atmosphere at the altitudes that small aircraft operates. But how efficient is the hydrogen in providing power?

As a comparison we can look at the Cirrus SR-20, a avgas powered four seater aircraft. [5] It's powered by a 200 hp continental engine weighing in at 140 kg.[6] The fuel tanks contain around 125kg of 100 ll gasoline, so the power train weighs around 265 kg. Then we look at a commercially existing hydrogen powered car solution, the Toyota Mirai. The Mirai has a fuel cell stack of 370 cells weighing in at around 57 kg [7]. It has hydrogen tanks which store 5 kg of hydrogen at 700 bar and has a total weight of around 90 kg [8]. A typical electric motor of similar capacity as the Mirai has a weight of 30 kg and a power output of 154 hp. With battery and other parts needed we are looking at a similar weight, 3/4 of the power output, clean energy and a similar endurance. All in all it sounds like a reasonable solution for the future. Then why isn't it already implemented? The big problem is the storage of the hydrogen, with diffusion and volatility. You would need very rigid fuel tanks, which can hold the high pressure needed to store the hydrogen. Hydrogen is also very flammable, which could be disastrous in a plane. On the other hand, it can be released in the atmosphere, since hydrogen dissolves by itself.

Fig. 3 . HK36 Super Dimona [9]

Just how possible is it then? Boeing made a fuel cell powered plane back in 2008, based on a Diamond HK36 Super Dimona (Fig. 3), which achieved straight and level flight powered only by hydrogen fuel cells. Back then the plane could not reach the power needed for takeoff though, and so they used a lithium ion battery as a booster for the electric power. [10] But who knows what kind of power we will see in the years to come?

5 Conclusion

To conclude, there are a lot of alternative power sources which could propel our airplanes in the future. However our technology is not yet on the level which would allow us to realize all of the ideas and concepts. In the near future we can expect the first hybrid powered airliner. We are also curious to see what the future holds for the hydrogen powered airplanes. But the right combination of the different types of propulsion explained above, could make aviation more sustainable.

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LINKÖPING UNIVERSITY

Expert Conference: Unconventional Takeoff and Landing methods

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TMAL02, Linköping University, 2018

1 Introduction

To understand the subject of unconventional take off and landing methods, the first question is, what defines a conventional landing and take off method (hereafter CTOL). CTOL can be defined as a method which uses the length of a runway to build up aerodynamic lift from the speed at which the aircraft is moving. The landing sequence is the opposite of takeoff and also demands a runway to control the speed and therefore the lift.

In some sense the unconventional landing and take off was envisioned before the conventional method. Leonardo da Vinci (1452-1591) had an idea to use vertical takeoff to get off the ground with his early aircraft concept called the Helical Air Screw [1]. The benefits of not using a runway and be able to hover above the ground, just like Leonardo da Vinci's ideas, triggered different research projects. Most of the projects were carried out in between 1950 and 1970, with the aim to find a solution for vertical take off and landing (hereafter VTOL) [2]. The goal was to combine the take off and landing benefits from a helicopter and combine them with the speed and range of an aircraft. Many of the experiments failed, but some succeeded. One of the early aircrafts was the Lockheed XFV-1 which took of vertically on its tail, flew like an airplane and landed on its tail again [2]. A decade later the first widely used VTOL airplane, the Harrier Jump Jet, which is still used today, was introduced. Today the new F-35B is planned to replace the Harrier in the U.S marine corps.

2 Classifications

Different types of takeoff and landing methods were listed, figure 2. All the methods have been used on different aircrafts. The methods for takeoff and landing for spacecrafts will not be further developed in this report.

Abbreviation	Explanation
CTOL	Conventional takeoff and landing
STOL	Short takeoff and landing
CATOBAR	Catapult launch and arrested recovery
STOBAR	Short takeoff but arrested recovery
HTHL	Horizontal takeoff and horizontal landing (spacecraft)
VTOL	Vertical takeoff and landing
VTVL	Vertical takeoff and landing (spacecraft)
VTOHL	Vertical takeoff and horizontal landning
ZLL	Zero length launch systems
VTHL	Vertical takeoff and horizontal landning (spacecraft)
HTVL	Horizontal takeoff and vertical landing (spacecraft)
V/STOL	Vertical and/or short takeoff and landing

Fig. 1 . Different classifications of unconventional landing methods with a brief explanation.

3 Technologies

There have been numerous technologies to achieve the aforementioned takeoff and landing methods. The different technologies have a high impact on the aircraft performance in hover and flight. When comparing VTOL/STOL airplanes to the CTOL contemporary ones, aircraft performance (flight speed, payload capacity, range) in all aspects is usually sacrificed in order to achieve vertical flight capabilities.
Some of the technologies used for unconventional takeoff and landing are discussed in this chapter.

3.1 Thrust vectoring

3.1.1 Tilt rotor

Technology, where the thrust and lift are provided by the same rotors. Vectoring of the thrust is achieved by tilting the rotor axis relative to the rest of the aircraft. Usual placement of the rotors is on the tips of the wings. Most of the aircraft built using this method utilize two turboprop engines (V-22 Osprey) but tests have also been done with up to four rotors. This method of VTOL has the highest hover lift efficiency for it's disk loading [1].

3.1.2 Tilt wing

Similar to the tilt rotor but with a difference of the rotors being fixed to the wing and the wing inclination angle is used for the thrust vectoring. The main advantage for tilt rotor is the smaller down load on the wing thus smaller required power for hovering. However, the disadvantages are a more complex tilt mechanism and difficulties with wing mounted fuel tanks [3].

3.1.3 Nozzled jet

The most prevalent method for fighter aircraft to achieve VTOL capabilities. The exhaust of the jet turbine is directed through movable nozzles that allow for vectoring the thrust between vertical and horizontal. For additional roll and yaw control, bleed nozzles on wingtips and nose are needed. If older nozzled fighters used a shared exhaust from a single lift turbine, like the Harrier, then the newer generation F-35B gets its lift thrust from the turbine exhaust and a seperate fan, that is shaft-connected to the turbine.

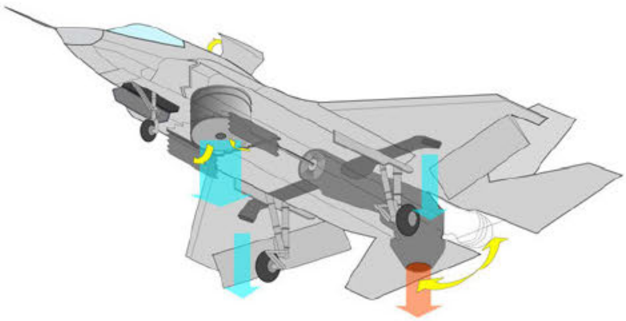

Fig. 2 . Figure of F-35B. The aircraft has a nozzle that can be rotated from horizontal to vertical (By Tosaka [CC BY 3.0 (https://creativecommons.org/licenses/by/3.0)], from Wikimedia Commons).

3.2 Tail sitter

Method for takeoff and landing, where a horizontally mounted engine brings the plane up vertically. The aircraft will also land vertically. In the air, the plane works just like a regular airplane.

The Lockheed XFV-1 had its first flight in 1954. The purpose for the design was to use VTOL for start and landing on ships. By the use of a powerful turboprop engine and two counter-rotating propellers in the front of the plain, the aim was to start the aircraft vertically on its tail and like a helicopter, take off and fly like an ordinary airplane. However, the project was delayed due to reliability problems and later canceled in 1955 [4].

Vertijet is an airplane which starts vertically, but instead of an engine with propellers it uses a jet engine. When landing vertically, the aircraft uses a “hook” to attach it self to a mobile trailer. The trailer is also used for take off. This method, compared to the XFV-1 which started and landed from the ground, did not have to be designed with a robust tail, with the purpose of carrying the load of the aircraft on the ground [5].

3.3 Assisted

3.3.1 Catapult launch and Cable arrested landing

This type of takeoff method is typically used in aircraft carriers, where runways are short. The aircraft is accelerated along a track to achieve takeoff-speed with a catapult action. The catapult action can be achieved by different means like pressurized steam cylinder, hydraulic chambers, electromagnetic motor rails. Initial technologies include flywheel, gunpowder [6] and weight and derrick methods. The catapult tracks are built into flight decks and a release bar is used to attach the nose gear to the catapult mechanism. At the time of launch, the release bar is propelled along the track, pushing the airplane at high speed. Velocity attained by catapult action and the apparent wind speed is enough for the aircraft to takeoff in a short distance [7]. In the same way, aircrafts are brought into rest in short distance by attaching a cable to the arrester hook present on the underbelly of the vehicle. The tension provided by the cable helps reducing the velocity and hence landing distance.

3.3.2 Parachute landing

This technology is commonly used for UAVs. Some UAVs are not provided with landing gear to avoid complicated structure and to save up on cost and weight. In general for UAVs this method is used for landing in tough terrains and during emergency landings.

4 Future

Different solutions to make takeoff and landing more fuel efficient are being evaluated. One of the projects is GABRIEL, created by the European Union. The GABRIEL project evaluated the possibility to use Magnetic Levitation (MAGLEV) to assist airplanes at taxiing, takeoff and landing [8]. The use of MAGLEV at takeoff and landing would reduce the fuel consumption and emissions [9]. Airplanes could also be rebuilt to reduce weight. A small prototype of a MAGLEV track has been built and tested. Since the velocities are much lower on the prototype than a full scale model the results can not be transferred directly, however the tests shows that the prototype did fulfill the requirements [8].

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Expert Conference: Electric car/truck: Future concepts with just-in-time energy reception

Mathelin Gauthier, Jeanne Guillaume, Satya Vadlamani and *Aditya Vinnakota*
TMAL02, Linköping University, 2018

1 Introduction

The growing climate crisis makes countries shift direction regarding personal transportation. For example some European countries have decided to ban sales of petrol and diesel cars by the following decades. Car manufacturers are doing the same such as Volvo which said it would manufacture only fully electric or hybrid cars from 2019. Following this idea, we wondered what are the possible technologies that could improve electric vehicles, especially the regarding the battery charge time.

2 Current Technologies

Nowadays, electric cars are getting more and more popular around the world, mostly because the cost of production of the batteries is decreasing and the autonomy is increasing. For example, the battery manufacturing cost per kWh was around 1000$ in 2010 whereas is costs about 230$ currently. The forecast cost in 2030 is lower than 100$ per kWh[1], that would mean that it is less expensive to buy electric car rather than thermal cars for the same performance.

One negative aspect about electric vehicles is their charging time which can lasts more than a day for a for domestic plug. The car manufacturers are competing to reduce this amount of time by creating more powerful charging facilities. For example, Tesla released the Tesla Supercharger in 2012 which provides around DC of 140 kW. Tesla's CEO Elon Musk announced in 2017 a new kind of charger: the Megacharger[2] which will be used for the Tesla Semi, a concept of an electric truck. The power of this charging system was not announced yet but it is estimated to be at least 1 MW.

This following graph shows the battery charge rate of several levels of charging device. The most powerful (Supercharger) is able to fully charge the Tesla model S within 75mn which is relatively fast comparing to more conventional AC plugs but still far from just-in-time energy reception.

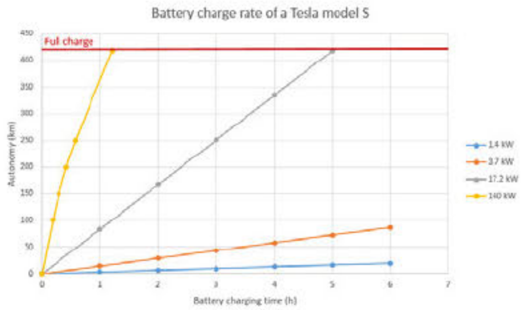

Fig. 1 . Battery charge rate of a Tesla model S

3 Future Technologies

Some cars and trucks manufacturers are looking for new technologies, which can provide a faster recharging, a longer cycle life and a reduced environmental impact. Among these technologies, one attract more attention : the solid-state battery. [3]

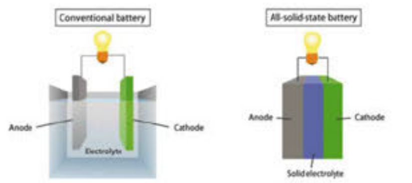

Fig. 2 . Comparison between Lithium battery and All-solid-state battery. Source : https://www.androidauthority.com/lithium-ion-vs-solid-state-battery-726142/

The solid state batteries work in the same way as every conventional battery, except that the electrolyte, namely the part which bond the anode with the cathode, is solid instead of being liquid.

This kind of battery is already used in several objects such as pacemakers, Radio-frequency Identification (RFID) or wearable devices because the lifespan of such a battery is estimated to be between 15 and 20 years [4]. Here is a table which summarize the main pros and cons of the solid-state battery [5]

Pros	Cons
Electrolyte nonflammable	Fragile / Bad choc resistance
Excellent thermal stability	Expensive manufacturing
Low self discharge	Fragile / Bad choc resistance
Long life cycle	
Non sensitive to overcharge	

The manufacturing of solid-state batteries is very expensive. Consequently, only small batteries are produced nowadays. It fits perfectly with every technology which require little power but a long lifetime. However, researches are currently made to increase the power of such a battery in order to include this kind of battery in electric cars.

One important point as well is that the battery charge is way faster compared to a Lithium one, due to its non-sensitivity to overcharge. As an example, the company ***Fisker*** works on a solid-state battery, which enable 700 miles ($\approx 1100km$) of range after one minute charging.[6]. This technology is expected between 2020 and 2023. *Toyota* also announced being working on solid-state batteries for its electrical vehicles. The company announced a fully charge within two or three minutes. Once more, the introduction of this technology into electric cars is expected in 2022.[7].

Finally, solid-state batteries has a higher energy density (up to twice more than a lithium battery) [8]. This means that the same amount of energy can be provided by a battery twice smaller, regarding the volume of this one. And this is a real pro as well, as far as transportation systems are concerned.

4 Vehicle propulsion Technologies

For the vehicle the energy carrier can be a fossil fuel or electricity which is generated by a battery.Depends on the energy carrier the vehicle propulsion systems are classified.The two main types of vehicle propulsion systems are electric propulsion systems and hybrid electric propulsion systems.

4.1 Electric propulsion systems

The electric propulsion systems are classified as Electric vehicles (EV'S) and Battery electric vehicles(BEV'S).Which means the drive train powered by battery.Since the energy density of the batteries does not permit driving autonomy , and the time required to refuel is not negligible compared to conventional vehicles.[9].

4.2 Hybrid electric propulsion systems

Keeping the advantages of an electric vehicles in mind, identifying the cons in terms of power and range, to boost up the power and range , by combining the electric propulsion system with the internal combustion engine, the requirements can be achieved and the combination is called the Hybrid electric vehicles.The Hybrid electric vehicles are classified into different types of configurations based on the systems.

4.2.1 Classification of HEV

Parallel hybrid electric vehicles will have two prime movers, so that it can operate on both Internal combustion engine and Battery either individually or simultaneously.

In series hybrids, only one energy carrier can be sourced at one time, cannot use simultaneously.

4.3 Some discussion about the future based on the past strategies

All the above are ongoing technologies, but not effectively.The problem lies in the fueling time difference and the range between the electric cars and conventional vehicles(Which runs with internal combustion engine). The outcome of ongoing research should benefit and meet the customer requirements as much as internal combustion engine do. As of now,(i.e, 2018) in terms of sustainability (zero emissions) the electrification technology is very much succeeded. Other than that, electrification technology did not match few measures as internal combustion engine do.There are so many concepts with the change in the battery technology are out,for example the new truck from Volvo called Volvo FL electric releasing in 2019 with 2-6 batteries can give a range of 300 kilometers with one charge, and battery should be recharged for 10 hours straight if it is alternative current and 1-2 hours with direct current[10].Still it makes a huge difference compared to fueling the car with gasoline or petrol. Here are some future concepts of just in time energy reception and discussion about how could this happen.The battery is the main source for the electric vehicles.

5 Conclusion

The progress has been seen from many years and welcomed the electric vehicle technology.But it has not reached up to the level in terms of cost and time for fueling if compared with the normal conventional vehicle since it is available readily and less cost.But the change over is required from normal vehicles to electric vehicles , because of environmental factors.For that mass marketing to reach and teach the people how it works, hope technological advancements and polices will change to create an ease for the transition.

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Expert Conference: *Search and Rescue* UAVs

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TMAL02, Linköping University, 2018

1 INTRODUCTION

According to the Cambridge Dictionary, UAV is the *"abbreviation for unmanned aerial vehicle: an aircraft that is operated from a distance, without a person being present on it."*. [1]

In this report we specifically talk about *Search and Rescue UAVs*, these are UAVs used by emergency services and rescue teams perfected for searching for targets (persons or objects) in almost any type of environment providing live visuals and data. [2]

2 UAVS IN *SEARCH AND RESCUE MISSIONS*

Search and rescue UAVs play a vital role when it comes to finding survivors, detecting entry points for rescue teams and scanning areas from above. They send all this data to the pilots on the ground, which is then communicated to the rescue team. They are employed for decreasing the search time, avoiding unnecessary danger for humans and performing operations where the target would be unreachable for rescuers or other search and rescue equipment.

2.1 Typical Uses [3] , [4]

- Natural disasters: floods, tsunamis, hurricanes.
- Fire in buildings or nature.
- Gathering data from accidents from above in remote areas.
- Measuring data in order to prevent accidents in gas, nuclear and chemical industries or to scan these areas in case of accidents, where it is too dangerous for humans.
- Inspecting power lines, wind turbines and bridges.

2.2 State of the Art

During the past few months, a number of developments have been made to drones in order to assist *Emergency Response, Search and Rescue* professionals and to save the lives of thousands of migrants in the Mediterranean Sea. Also, UAVs have played an important part on the aid and relief programs created after earthquakes, for example, in Nepal and Ecuador. These tools have truly changed the mentality of professionals who need to make quick and decisive decisions in emergency situations. These effects can be seen in real-world situations.

When this kind of technology started, regular drones had cameras attached, giving rescuers an idea of what was happening in a disaster zone. However, the data was not as accurate and reliable as the drones deployed nowadays will give. Further development led to more exact data, which was obtained with the help of thermal imaging. The drones are now capable to withstand different temperatures and environmental conditions depending on the disaster they are facing.

A recent study for the development of *SAR* drones was conducted to detect vital signs of people in war zones and other disasters. These drones are being designed to remotely measure heart rates and breathing rates and also, to detect the movement of victims involved in major accidents. [5]

Two great examples of this type of UAVs are the following:

- Fire Fighting Drone: Latvian company *Aerones* created an UAV which, according to the company, can fly up to 984 feet [6]. This is higher than most firefighting trucks can reach with their ladders. The drone is fitted with a water hose connected to a fire truck. It is still under development but *Aerones* hopes the machine will be ready for real operations soon [7].
- DJI Matrice 201: *Matrice 200 Series* can be used for inspection of power lines, *SAR* operations, firefighting and also, for emergency responses. It is capable of flying even at sub-zero temperatures due to the higher reliability of its battery. It has a thermal and optical feed for detection and surveillance in real time [8] [9].

3 DESIGN AND MISSION OF A *SAR* UAV

The most important design parameter for a SAR mission is to optimize the search strategy in a way that the probability of finding the target is maximized, in a minimised timeframe [10].

3.1 Preliminary mission parameters

Several points should be kept in mind regarding *"how we search"* for a certain Subject/Object (S/O or target), such as: [11]

- The **Probability of Area** is the chance of finding the S/O in a certain area.
- The **Probability of Detection** is the chance of locating the S/O in a certain area by using a definite technology.
- The **Sweep Width** is a number, which defines the mean capability of a sensor to find and identify a particular S/O while having a specific set of atmospheric conditions.
- The **Average Maximum Detection Range** is the mean span, above which the sensor cannot find the S/O.
- The **Critical Separation** is the spacing between sensors in a search area, where the S/O is in the middle of two UAVs without overlapping coverage of each sensor

3.2 Mission requirements [11] , [10]

- Inherent design characteristics of the vehicle such as range, speed, duration of battery, sensor imaging properties, resolution of cameras.
- Operational requirements such as landing and take-off parameters.
- Post-processing diagnostics.
- Searching pattern (optimising goal).

3.3 Systems used

There are many different SAR UAVs currently in use, designed for varying use cases. These can be divided into two groups:

- **Rotorcraft**: Being the most common among the different UAVs used for SAR purposes. Rotorcraft UAVs are highly versatile and are often equipped with some kind of camera for surveillance purposes. What makes them ideal for SAR operations is that they can land in almost any place, allowing them to carry a certain payload to any place needed.
- **Fixed wing UAVs:** Mostly used for military purposes, UAVs with fixed wings also have a good amount of use in SAR operations. Although they are not as flexible in use as their rotorcraft counterparts, these drones can generally obtain larger speeds and longer flight times. This makes them ideal for surveillance of larger areas.

4 ADVANTAGES AND DISADVANTAGES

The usage of SAR UAVs comes with an unique set advantages and disadvantages:

Advantages

- **Cost:** Due to the aircraft being unmanned, the operational cost are low. They are especially cheap in use for situations where helicopters are the alternative.
- **Response time:** As was discussed earlier, UAVs can often be deployed very swiftly, which is a great asset considering how critical time often is in SAR missions.
- **Risk:** UAVs can be used in areas where it is too dangerous for rescue teams.
- **Mobility**: When the terrain is hard to navigate, UAVs are the ideal solution. Due to their possible size, they can also be designed for indoor areas.

Disadvantages

- **Flexibility:** UAVs can only do what they are programmed and designed for. SAR operation requirements are varied, making it difficult for a drone to be able to function appropriately in every situation.
- **Operators:** A specialist has to operate the drone. Training them takes up valuable time and resources.
- **Obstruction:** UAVs could obstruct other aircraft during operations by taking up airspace.

5 Conclusions

It can be concluded that these machines can support emergency services in critical situations and rescue operations. They even surpass the capabilities of human professionals by the innovations in this area. However, they will only reach their optimal performance when the specific design takes all the parameters that affect a *SAR* process into account. Even if perks exist regarding this kind of technology, crucial characteristics for this matter get improved: time response, costs and danger decrease where the searcher's mobility increases.

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Unmanned cargo transportation systems

Simon Brodbeck, Ole Hansen, Jakob Söderberg and *Davide Derobertis*
TMAL02, Linköping University, 2018

1 Introduction

A UAV is defined as an aircraft that is capable to fly without pilots present in the aircraft itself. It can either be remote controlled or fly autonomously and it is possible to reuse it.

UAVs are making their way into our modern society and have great potential to contribute to the future of transportation. The transport UAVs are now at the very beginning of their development, especially in the integration into our current infrastructure, which is not adapted to UAVs. To successfully implement them into our society we need a common understanding of the possibilities and limitations of a UAV in order to adapt our current infrastructure.

2 Concepts

2.1 Rotary winged UAVs - Drones

One of the most practical and innovative way to transport goods through the air from one point to another is without doubt the drone. The propulsion of this cargo transportation system is based on at least 4 lifting rotors designed to achieve a vertical takeoff and landing (VTOL) and, at the same time, to provide a forward flight mode in order to achieve a more efficient travel. With respect to the power system, it is frequently purely electric and uses rechargeable batteries for energy storage.

In general its weight and dimensions vary according to the payload they are designed for, but so far they usually weight less than 25 Kg. In this regard, an essential parameter to take into account is payload. In order to be used for every kind of transportation, the internal cargo bay needs to host at least 3 Kg of goods and, at the same time, it has to ensure that products are fixed and can not move during the flight despite different weather conditions.[1]

In recent years, a true example of a real cargo drone prototype has been given by Boeing. With a weight of around 340 Kg, length and width of 4.5 m and 5.5 m respectively, it represents the biggest drone ever made so far. Thanks to eight counter-rotating engines equipped with six-foot-long blades, it can reach a top speed of 110 Km/h and carries a payload of almost 230 Kg.[2]

2.2 Fixed wing UAVs

Fixed wing concepts generally neglect the vertical take off capability in order to provide a maximum operational range and higher speeds.

In order to still be as independent as possible from other ground infrastructure, fixed wing UAVs are often launched by a catapult and have to be recovered on their launch site. In flight they are usually driven by one or more propellers and operate on a battery powered engine setup with the possibility of swapping out batteries after each delivery to reduce turn around times.

Since fixed wing aircraft can't hover, but are meant to be able to stay airborne throughout their entire trip, individual deliveries can only be made by dropping a parachuted parcel. This delivery method is not very accurate and therefore can't operate in urban areas but is sufficient in rural areas or other place with suitably large open spaces.

An already operating example by the company "zipline" is able to do up to 160km long multi-delivery runs with a payload of up to 1.75kg and has a top speed of up to 128km/h.

This concept wont be a solution to urban deliveries, but its properties enable it to make high priority deliveries to rural or otherwise hard to reach areas. Therefore it is presently used for medical supplies in Rwanda.[3]

2.3 Comparison

When it comes to choose between these two typologies, a lot of factors play a significant role. Most importantly there will always be a trade off between the three main properties, which are maneuverability, range and payload capacity.

In a scenario where high maneuverability is required and can be traded for a shorter range, a drone would be the superior choice. Vice versa a fixed wing UAV would perform better if the requirements are the opposite. Due to desired design limitations in size, there is not too big of a difference in payload capabilities.

2.4 Integration of UAVs into the existing airspace

UAVs with either rotary or fixed wings are already quite good developed, but integrating them into our existing airspace infrastructure will be quite challenging. A UAV can be controlled remotely or can even fly completely autonomous.

The first challenge will be to integrate and certify remotely controlled aircraft systems. The "European RPAS (Remotely-Piloted Aircraft Systems) Steering Group" developed in their final report [4] a roadmap for integrating RPAS into the European airspace. According to the roadmap the following activities will have the largest effort to implement: the communication and separation between IFR and VFR flights, the access to the airspace, Airport operations and emergency situations.

To address the first two problems researchers from the DLR therefore suggest in [5] to introduce a new class of airspace. This would require new standards and new Air Traffic Management (ATM) procedures. Also the certification regulations would need to be adapted for UAVs. There are also still some technical issues that need to be solved: like the redundancy and precision of the flight navigation system [5]. But small niche applications with uncrowded airspace can already benefit from unmanned cargo flights like emergency supply after natural disasters or medicine supply in developing countries [6].

3 Users and application

UAV can be utilized when delivery of payload has to be accomplished in "hard to reach" areas or in locations where most of the transport is relying on ground-based vehicles. Since UAV's are currently limited in payload weight and size, they are suitable for lighter and smaller payload, such as letters, small packages or take away food. Companies such as Amazon, Walmart and Dominos are researching the possibilities of delivering their payload with UAVs in the future and have already made some deliveries.[7]

The military has been using UAVs for transporting payload e.g modified K-Max helicopters are used as UAVs in Afghanistan. The fact that UAVs can operate for a longer time than an aircraft with crew makes the UAV and its development interesting for the military. There are ongoing projects with the goal to create a UAV with long range capabilities and establish a network of routes that can haul cargo over long distances without having to transfer the cargo between different instances or hubs in order to make the delivery directly to where it is needed. [8]

Due to their current limit in range, using UAVs for longer transportation is currently unfeasible. In the area of last mile deliveries however, UAVs have the capability to replace current methods which relays on mostly trucks or cars. Replacing trucks will result in lower costs, less environmental impact and shorter delivery times. One application for UAV delivery is in citys where most of the deliveries are made by trucks. An armada of UAVs could replace the trucks and thus less traffic has to travel on an already overloaded road network. If a UAV delivery system were to be established in a city, problems such as noise, integration and legal issues should be solved. Current models of UAVs are very noisy and require additional infrastructure to function properly in a city environment. [9] [10]

To compensate for the UAVs weakness in range, UAVs can also be used in conjunction of trucks to extend their range. A single truck with a number of UAVs can be used to deliver packages to multiple destinations in a shorter time, such in suburbs. This configuration can also be used to reach rural areas where roads are in poor conditions or even non-existing.

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SABRE Rocket

Naoufal Chiguerch, Marvin Raupert, Josef Sen and Quentin Fourcoual
TMAL02, Linköping University, 2018

Introduction

The technology of SABRE stands for “Synergistic Air-Breathing Rocket Engine” and is a concept under development by “Reaction Engines Limited”, based in Oxfordshire (England). This unique rocket engine concept makes it possible to fly directly into orbit and return in a single stage with a taking off and landing on a runway. All components of a certain aircraft would be completely reusable. Otherwise it is possible to reach the opposite side of the world in under four hours. Reason for that is the design of the hypersonic precooled hybrid air-breathing rocket engine. The technology is still in development, but various test trials show successful results. [4] [5]

Functionality

The technology of SABRE could operate in two different modes. It utilizes both jet turbine for lower speed (taking off) and rocket technology for higher speed. Both modes generating thrust using the rocket combustion and the nozzles. The construction of a SABRE rocket is shown in figure 1. [4]

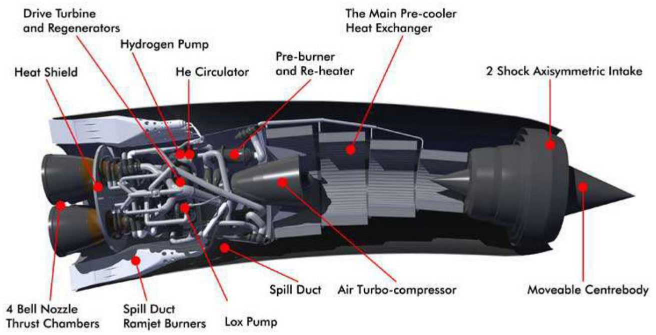

Figure 1: Construction of the SABRE rocket [1]

During the air-breathing mode in the lower atmosphere the oxygen component of its fuel is drawn in from the air like a normal jet engine. In fact of this, the amount of oxygen that needed to be stored is reducing and the thrust-to-weight ratio of the aircraft is increasing. At a certain speed the engine converts to full rocket mode. During this mode the engine uses only its own stored supplies (hydrogen and oxygen). [1] [4]

The reason that these two technologies have not been combined until now is that the incoming air into the engine could not be cooled down quickly enough during the compression. Accordingly, normal existing jet engines cannot provide enough thrust to get into space without overheating.

The new cooling system of SABRE overcame this hurdle. Now it is possible to cool the air entering the engine from 1000°C to -150°C in a hundredth of a second. The scientists have also made it possible that no ice forms during the cooling process. [4]

In figure 2 the way of the air and the circulation of helium in the engine is shown. The airway can be divided into three sections.

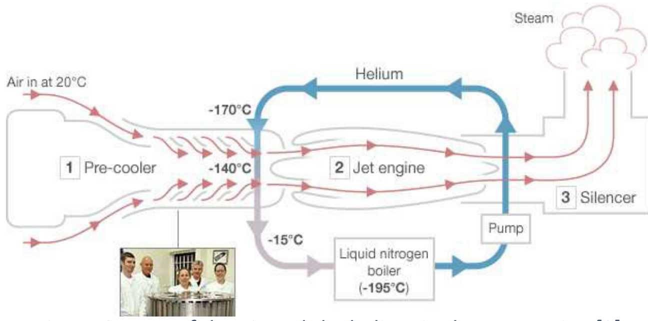

Figure 2: Way of the air and the helium in the test engine [2]

The first section is the pre-cooler. During the flight hot air enters the pre-cooler and with the help of cold condensed helium the temperature drops down very fast. In the jet engine (second section) the chilled oxygen is compressed and burnt with fuel to provide thrust. For keeping the helium chilled, it is pumped through a nitrogen boiler. In this third section, called the silencer, water is used to dampen the noise from the exhaust gases. The third section only exist in the test model. [2]

A closer look at the pre-cooler reveals the special structure, shown in figure 3.

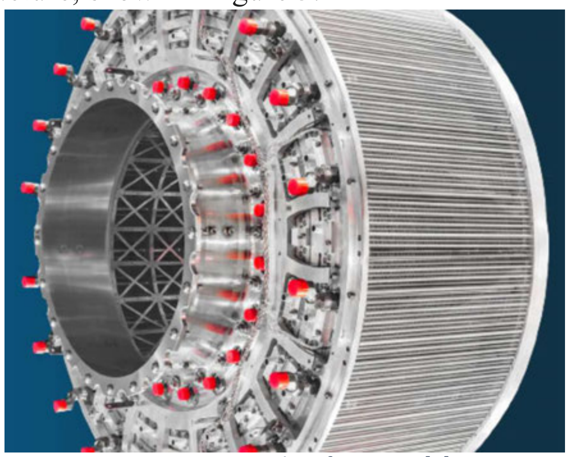

Figure 3: Pre-cooler of a SABRE [3]

The hot air flows around an array of thin pipes filled with condensed helium. All in all, the pipes have an overall length of hundreds of kilometers. The resulting high surface, also shown in figure 4, is the reason for the cooling. The technology behind the not possible icing remains a company secret. [3]

Figure 4: Air flows around the internal structure of the cooling system [2]

Next to the cooling system the figure 5 shows in simplified form the complete SABRE cycle. The air (blue) from the intake is going through the pre-cooler and the turbo-compressor. The compressor provides a high-pressure air supply to the combustion chamber which allows operations from zero forward speed on the runway and during ascent up to Mach 5,5 in air-breathing mode. At higher altitude with lower density the engine switches to the rocket mode to get the orbital velocity (Mach 25).
The air is cooled with helium (green) that has been itself cooled with the liquid hydrogen fuel (purple) by using the HX4 (heat exchanger). After the pre-cooler the helium is further heated in HX3 by the product of the pre-burner. This energy could drive the turbine and the liquid hydrogen pump (LH2). [2] [6]

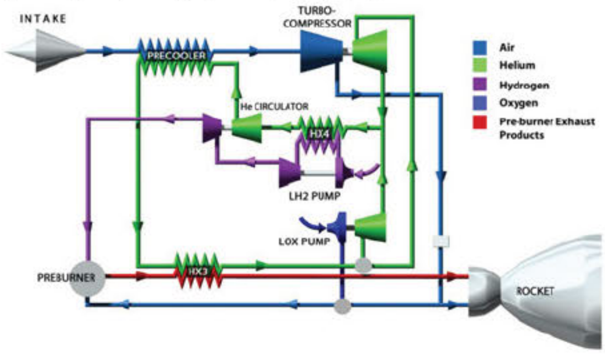

Figure 5: Simplified SABRE cycle [6]

If the engine changes to rocket mode the energy to drive the LH2 pump and the liquid oxygen pump (LOX) is completely produced in HX3.

This way of reusing the heat increases the engine efficiency. As the figure 5 shows, the use of lightweight heat exchangers is required and the key technology to develop SABRE engines. [6]

Conclusion

This technology is the biggest breakthrough in aerospace propulsion since the invention of the jet engine. It has the potential to dramatically lower the cost of space flight in fact of the completely reusable space vehicle and reduce fuel burn by 5-10 % while enabling aircraft-like access to space. Also, the better thrust-to-weight ratio makes the engine so potentially valuable. To make the final version of the engine, the scientists of "Reaction Engines Limited" need more money. [2] [4]

Authenticity and Plagiarism

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Expert Conference: Vertical Landing Rockets

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TMAL02, Linköping University, 2018

1 Why Vertical Landing Rockets?

There were attempts of landing a rocket propulsion starting at the beginning of the 1960s but there were only attempts by single persons and from a very low height (e.g. Bell Rocket Belt). The main reason to start developing vertical landing rockets professionally was the goal to reduce the cost of space transport by reusing rockets. Historically, rockets flew most of the time only once or they had to be recovered and restored for a lot of money (e.g. SpaceShuttle with landing in salty water). The fuel and oxidizer represent only a very little part of the launch costs while the rocket itself represents the majority. Therefore, the ability to reuse at least the first stage of the rocket is useful to lower the costs even though the vertical landing needs extra fuel and lowers the payload but the future must show how much money the vertical landing of rockets really can save. The two main companies working on vertical landing rockets are SpaceX and Blue Origin. While Blue Origin has the goal to sell trips to the space for civilians, SpaceX mainly offers transportation flights for satellites or supply missions to the ISS.[1] To fulfill these tasks, the rockets have very different designs and requirements for the vertical landing. While the falcon rockets (SpaceX) are thin and tall and the boosters are separated in a higher altitude, the New Shepard rockets (blue Origin) are thicker and smaller because they only should reach about 100km height. Despite these different requirements there are some basic technical designs which are used to land a rocket or rocket-booster smooth and safe on earth. [2]

2 Current Trends

2.1 SpaceX - Falcon 9

Falcon 9's first stage consists nine Merlin engines tanks containing liquid oxygen and rocket-grade kerosene (RP-1) propellant in what they call their proprietary Octaweb arrangement. After ignition, a hold-before-release system ensures that all engines are verified for full-thrust performance before the rocket is released for flight. Then, with thrust greater than five 747s at full power, the Merlin engines launch the rocket to space. Falcon 9 is capable of generating more than 7600 kNs of thrust. The first stage engines are gradually throttled near the end of first-stage flight to limit launch vehicle acceleration as the rocket's mass decreases with the burning of fuel. The engine arrangement can sustain thrust and continue missions even with up to two engine shutdowns providing high reliability to the launch vehicle.

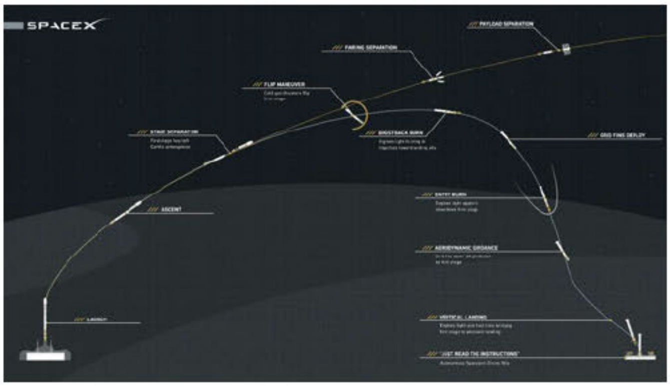

Fig. 1 . SpaceX Falcon 9 Mission Sequence.

The first stage is shutoff at stage separation and the nitrogen thrusters help flip the booster rocket to push back towards the landing pad; this is called the boostback burn. The booster is flipped one more time before the booster enters the atmosphere and the grid fins are deployed and these titanium grid fins carefully control the alignment of the booster as it enters the atmosphere. Once in the atmosphere the booster engine lights up again to create a virtual heat shield and slow the descent of the booster rocket. At this point the grid fins correct the alignment of the booster rocket and correct its flight path. As the rocket enters the final phase of its descent the engines light up in a 1-3-1 pattern to further reduce the approach speed of the booster and the gimbal in the central engine to have the right alignment and the landing legs are deployed close to touch down and the booster is shutoff upon touchdown at either the landing zones on land or the drone ships out at sea. Stage two later inserts the satellite into orbit to complete the mission. [3]

2.2 Blue Origin - New Glenn and New Shepard

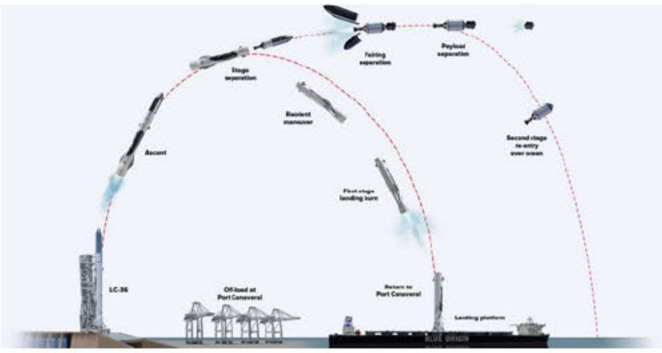

Fig. 2 . Blue Origin Mission Sequence.

The flight path seems to be planned in a fashion similar to the SpaceX mission and is yet to be tested. It is designed to be much larger than the Falcon 9 carrying much more powerful engines called the BE – 4. The main difference is the design of the landing gear and its use of aerodynamically shaped fins to be used for alignment during re entry similar to the grid fins on the SpaceX booster rockets. The New Glenn also will have 7 of their BE-4 engines while the SpaceX Falcon 9 uses 9 Merlin 1D engines to power their rocket.[4][5]

3 Performance

There are a few things a rocket/stage of a rocket must have to be able for vertical landing. The biggest difference in comparison to rockets without vertical landing is that you need extra fuel for the landing. Most rockets use all their fuel to bring their payload to space or the required place but for vertical landing rockets extra fuel is required to reignite the engines to slow down the rocket for a smooth touchdown. This effects the payload the rocket can carry to space because the extra fuel is a part of the payload which else could be used for other things. Additionally, there are a few other features a rocket needs to land vertical and these parts are all extra weight which lowers the payload. The rocket needs extra grid fins for steering the rocket while flying through the earth's atmosphere. They must be movable and very heat-resistant to resist the high temperature created by the friction of the atmosphere. Depending of the usage of the rocket extra thrusters are required at the stage which shall land vertical to flip the rocket to the right position at the beginning of the way back to earth. For the landing itself the rocket also needs landing legs to secure a stable standing after the landing. Additionally, the rocket needs a regulation which processes all the real-time data and controls all the parts necessary for the landing. [2] [6]

4 Future Prospects

The development of reusable rockets will initially lead to an improved access to the low earth orbit satellites. This means that deployment and maintenance of satellites will not only be cheaper but easier too. SpaceX aims to take these rockets further with the proposed private lunar mission and a slightly more ambitious mission to Mars using the BFR Rocket.[7] These inter-planetary missions will be open to the public for the first time in history.

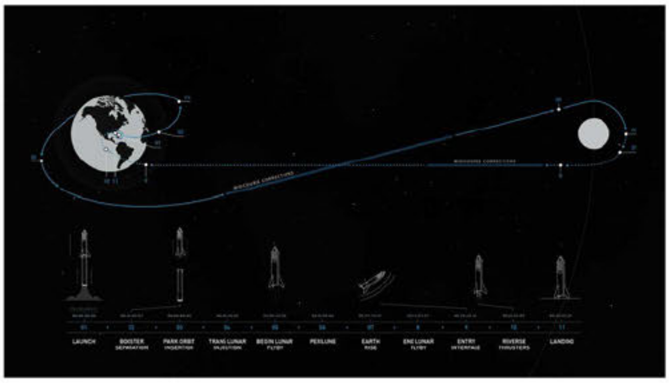

Fig. 3 . SpaceX Lunar Mission Sequence.

Apart from space travel, these rockets could also replace long distance commercial aircrafts someday. Taking advantage of the high operating velocity and service ceiling, these rockets can cut down inter-continental travel time exponentially. With more research efforts put into reusable rockets, we might be able to witness inter-continental rocket travel which can operate just like an aircraft with the airport turn around times within 60 minutes.

5 Environmental Impact

Vertical landing rockets can cut down the use of expendable components by more than 70 percent. This directly affects the carbon footprint during manufacturing and operations.
Additionally, since most of the components return back to earth, these rockets significantly reduce the contribution to the existing space debris crisis.

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