HC-1 Aircraft Concept

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1. Introduction

Recent studies show that in the future, natural calamities may have an even more striking effect on the areas which are targeted by nature's outbreaks. As the global population will increase from an estimated 7.5 billion people in 2020 to more than 9 billion people in 2050, a natural disaster in a very crowded urban area or an isolated rural area may have devastating effects. For such situations, there is an imperative need for a vehicle with a high response speed, capable of intervening in rough areas and of landing on water.

The following goals need to be achieved:

a) Take off and landing challenges

- Vertical take off and landing;
- Capability of landing on water and rough soil.

b) Transportation challenges

- Speeds around 300 kps;
- Improved transporting abilities;
- High response speed to emergency situations.

c) Emergency situatuation challenges

- Versatile equipment, adaptable to various emergency situations.

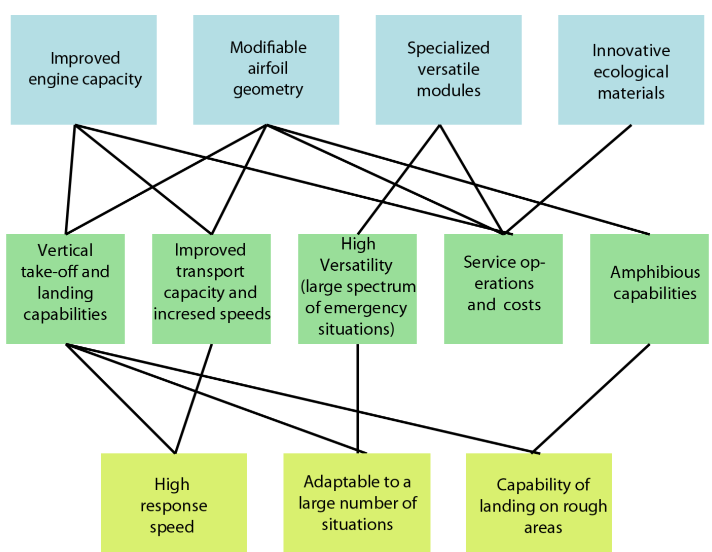

Figure 1

The diagram above (Figure 1) illustrates the topics we chose to debate. In the following chapters you will find details about aerodynamics (Chapter 2), information about the aircraft structure (Chapter 3) and issues concerning rescue situations (Chapter 4). You will also come across some general cost and feasibility facts in Chapter 5.

2. Aerodynamics and Propulsion

2.1. Problem statement

2.1.1. Efficient flying

The concept aircraft's goal is to improve aerodynamic design to achieve efficient flight. In order to be efficient, an aircraft needs to combine the capabilities of a helicopter with those of a classical airplane. It needs to have an acceptable lift to drag ratio at low-speeds and to achieve a practical high-speed flight. These criteria affect fuel consumption, environmental effects, aircraft speed and the payload capacity of the aircraft.

2.1.2. Vertical flight

In order to be able to intervene in a larger number of emergency situations the aircraft must be able to take-off and land vertically. Moreover, our concept should be able to land on rough terrain and on water so that a larger spectrum of emergency situations could be covered.

2.2. Technical approach

2.2.1. Coanda Effect(take off, landing and low speed flight)

We propose a unique airfoil design that uses the Coanda Effect to achieve flight. Around the bended wing an air stream will be formed as a result of the Coanda Effect. Using the modifiable airfoil geometry we may change the direction of the airstream so that it counteracts the weight of the aircraft. In this way we will be able to achieve vertical landings and take-offs,which are both critical in emergency situations. To determine wether this design is feasable, we will physically evaluate our concept. The basic shape of the airfoil can be seen in Figure 2 .

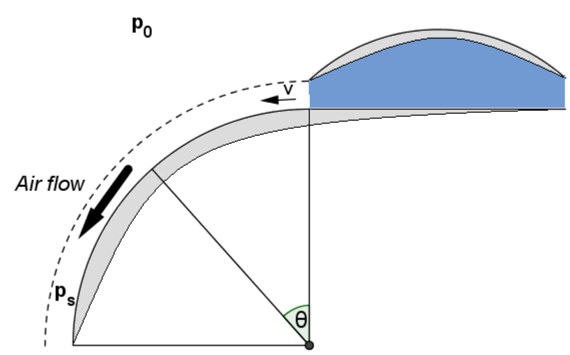

Figure 2: Wing section

Let us consider p_s the pressure of the air from the air stream, p_0 the outside atmospherical pressure and v the speed of the air flow. Using Bernoulli's equation we obtain:

$$p_s + \frac{\rho v^2}{2} = p_0 \Longrightarrow p_0 - p_s = \frac{\rho v^2}{2}.$$

Let us consider a small portion of the air flow, with mass dm, width h and area dS. Because the air is moving circularly, we may apply Newton's Second Law, succesively obtaining the following relations:

$$(p_0 - p_s)dS = dm \cdot a_n$$

$$\frac{\rho v^2}{2} dS = dm \frac{v^2}{r}$$

$$dm = \rho dSh$$

$$\frac{\rho dS}{2} = \frac{\rho dSh}{R} \Longrightarrow R = 2h.$$

So the equations above give us a relationship between the dimension of the engine's nozzle and the radius of the outer part of the wing. If we are to numerically approximate this value we find that if $h = 0.4m$, then $R = 0.8m$, which is technically feasable. A more accurate evaluation of our concept can be made without neglecting the dynamic viscosity of the air. A detailed mathematical model is presented below, with $v(r, \theta)$ the speed of the air situatied at a distance r from the center of the circle determined by the wing, and θ the angle formed with the main axis of the wing.

$$dF = \eta \frac{dv}{dr} \cdot dS$$

$$p(r) + \frac{\rho v(r, \theta)^2}{2} = p(r + dr) + \frac{\rho v(r + dr, \theta)^2}{2}$$

$$\rho \frac{v(r)^2 - v(r+dr)^2}{2} = dp$$

$$dp = -\rho dv(r)v(r)$$

$$dSdp = dma_n \Longrightarrow dSdp = \rho dSdra_n$$

$$dp = \rho dr \frac{v^2}{r}$$

$$\rho \frac{v^2}{r} dr = -\rho v(r) \frac{dv(r)}{v(r)}$$

$$\frac{dr}{r} = -\frac{dv(r)}{v(r)}$$

Integrating this last relation leads us to

$$\ln\left(\frac{r}{\mathcal{C}_1}\right) = -\ln\left(\frac{v(r)}{\mathcal{C}_2}\right),$$

for determinable constants $\mathcal{C}_1$ and $\mathcal{C}_2$

Further more we can use the Coanda Effect to assure flight at low speeds, by so making the aircraft more efficient.

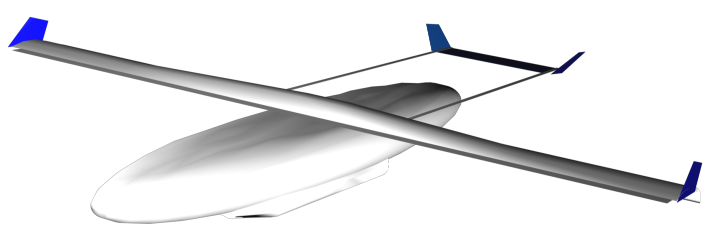

Figure 3

2.2.2. High Speed Flight

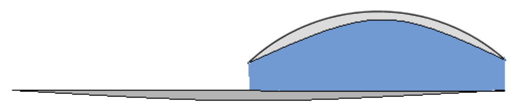

Figure 4: Wing section at high speed(the wing is fully bended)

As we may estimate the maximum speed that the aircraft could reach is 300 kts. By modifying the geometry of the airfoil the aircraft improves high-speed flight efficiency and makes the transport of the wounded faster.

2.2.3. Propulsion Our aircraft will use a classical propulsion jet-engine which is incorporated in the

wing to improve aerodynamics and to allow a laminary flow on the airfoil surface. We will calculate the air flow required for the aircraft the be capable of vertical take-off and landing. Let Q be the air flow and v the speed of the airstream. p is the momentum of the air particles. A mathematical model which allows us to compute the value of the airflow is presented below.

$$Q = vhl \Longrightarrow v = \frac{Q}{hl}$$

$$dp = \rho dSv^2dt$$

$$dp = dmv$$

$$\frac{dp}{dt} = \frac{dmv}{dt} = \rho Qv$$

$$mg = \rho Qv$$

$$mg = \frac{\rho Q^2}{hl} \Longrightarrow Q = \sqrt{\frac{mghl}{\rho_{air}}}$$

The graph bellow (Figure 5) shows the dependence of the airflow to the mass.

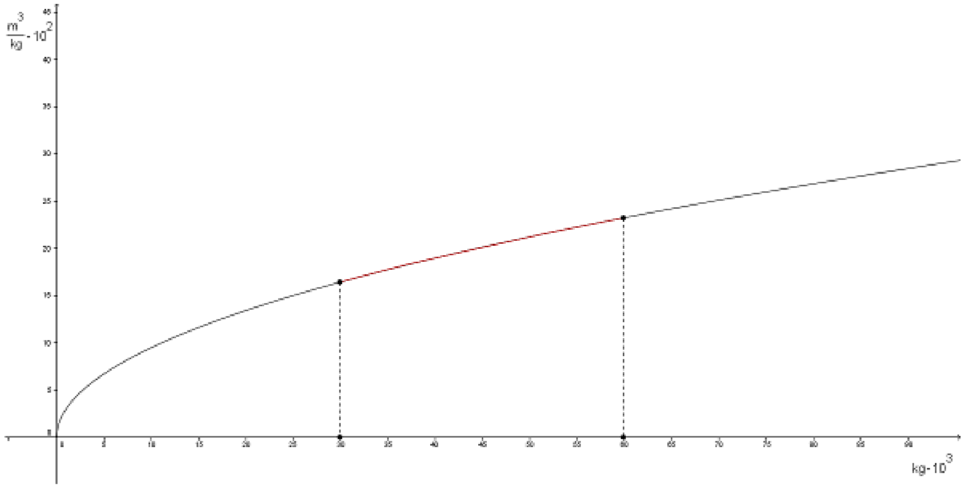

Figure 5.

2.2.4. Other development concepts

If vertical take-off and landing will be available at a higher cost, because of the bigger fuel consumption and the more complex mechanism, the concept aircraft will fly efficiently at high-speed too. However, to increase the efficiency, several studies put forward an efficient design. We propose an easy to install winglet which increases flight efficency. Potential benefit of winglets is that they reduce the strength of wingtip vortices, which trail behind the plane. When other aircraft pass through these vortices, the turbulent air can cause loss of control, possibly resulting in an accident. This possibility is greatest after take-offs, where departure speeds create the strongest vortices.

3. Structure and Materials

3.1. Problem statement

3.1.1. Structure issues

The resistance to high temperature and the reduction of weight are important for achieving efficent flight. Innovative materials and structural systems need to have a certain weight limit without affecting the structural integrity or damage tolerance. Tests revealed that an overall reduction of 20% of the weight is required.

3.1.2. Environmental issues

Aircraft debris and wreckage may cause damaging effects for the environment; some materials on the aircraft are toxic and the production of some of these materials consumes the natural resources of Earth (gas, iron etc.) and their disintegration may take up to 2000 years.

3.2. Technical approach

3.2.1. Structure issues

In order to achieve flight,the development of high temperature resistant materials is required to make the use of the Coanda Effect fesable. Because of the high-temperature of the air stream expelled by the jet engine the materials from which the wing is built should be extremely resistant. Non-autoclave fabrication for high temperature materials will be developed. Polymer-matrix composites are valuable in the aerospace industry for their stiffness, lightness and heat resistance. It is best to use phenolic resins, for building the fuselage and even some engine components (because they are exposed to great heat), as they are resistant to high temperatures and epoxy resins for the main structure. It is recommended that it is best to use laminates for their better integrity, the fiber layout design is formed of two unidirectional composites joined together. [16] Using such materials increases reliability of the aircraft and microscopic cracks (caused by the pressurization process) appear less often. This fact reduces maintenance cost and in the end, operating costs.

3.2.2. Recycling used materials

Statistics predict that by 2050 resources as oil and gas will be considerably less. The best solution to preserve our resources and even our green planet is to recycle used materials.

3.2.3. Technology Validation Strategy

Material development will follow classic strategy and probably the materials from above will be available in the near future. The feasibility of the concept will be demonstrated HC-1 aircraft computational design tools, materials processing and composite fabrics. The validation process should include design and analysis testing. Conclusion: Recycling materials are a priority in the near future, a fact that will maintain the well being of the planet. We hope that in several years the technology needed to produce this kind of fabrics will be available. By this, our aircraft will solve the pointed problem statement.

4.Rescue operations

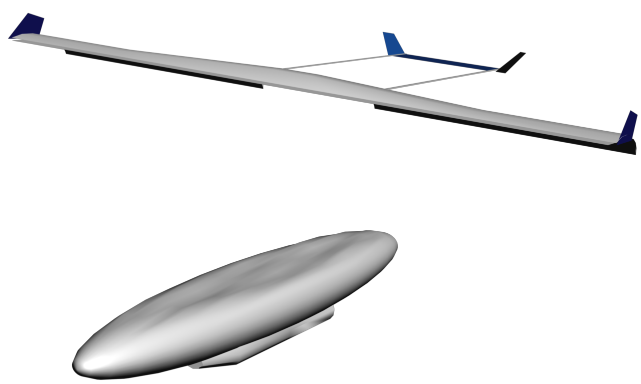

Figure 6. Perspective image of both modules

As we've described in our introduction, the need for a performant rescue operation vehicle is urgent. Both the populations living in crowded urban areas and in isolated rural areas are exposed to the threat of natural calamities. Our aircraft combines the capabilities of an helicopter with those of a classical aircraft and we hope it will manage to handle most of the emergency situations that we may encounter in the future. By using different modules, our aircraft manages to be extremely versatile. By separating the aircraft into two separate units - the unit that assures flight and the rescue unit (Figure 6)- the concept is extremely versatile. While the flight module is standard on all aircrafts, the rescue modules can be adapted for any situation. With a simple release switch, the two units can be separated in minutes, allowing a better reaction time and for the aircraft to be properly equipped for any situation. Our concept inludes the construction of a series of modules - an ambulant hospital module, a cargo module, human transport module, fire-fighter module and more are to be developed in time. We propose a short description of the fire fighter module. By vertically hovering over water the aircraft fills a bottom tank using a pressure pump . Then by hovering over the affeced zone it might concentrate all the water flow over the fire. Because of it's hovering capabilities our aircraft can easily cope with such situations. It is also crucial that the aircraft could land on water. We propose a simple module construction which will include two ballast tanks on the side of the aircraft. The tanks will be filled with air but the separation wall between the module and the tanks could be removed by so allowing the aircraft to increase it's cargo volume.

5.Costs and feasability

The fact that the HC-1 presents detachable modules that are independent from the aircraft body is a very important change from past aircrafts. Since the modules can be quickly detached from the aicraft's main body, if a module has a functioning error, it can be immediately removed and sent to be repaired, without affecting the aircraft body.

Since the aircraft uses polymer-matrix composites, it does not necessitate much maintenance. The manufacturing of HC-1 in modules allows for parts of the aircraft to be built in centers around the world, in areas where labour costs are lower. Also, if the HC-1 project is taken into consideration for mass production, the cost will be drastically lowered. We estimate that the average cost of a HC-1 aircraft body would be around 50 million dollars, and the average cost of a module around 5 million dollars, depending on the model.

Conclusion

The Romanian Scientist Henri Coanda is one of the world's pioneers in aeronautics. He is considered the parent of the modern jet engine and is mostly known for descovering the Coanda Effect regarding the motion of a fluid around the bended surface of an airfoil. Though this effect is not intensely used in today's aerospace industry, we propose an aicraft concept which uses this effect to manage vertical take-off and landing. To this extent we have explained in Chapter 2 how our aircraft will function, based on Bernoulli's equation and the Coanda Effect. The modifiable geometry of the wings allow the aircraft to achieve vertical lift. Once the HC-1 reached a cruise altitude, the wings will sistematically bend to the direction of the fixed part of the wing. The adaptable modules make it possible for the aircraft to be used in various rescue missions, from an earthquake impact area, from where people can be quickly transported, to a large forest fire that can be put down with the Firefighter Module. Depending on all the various module models, the possibilities are virtually endless.

In honour of the innovative ideas of Henri Coanda, ideas that have shaped the fundations of jet engine, we have named our aircraft after the Romanian scientist.

Resources and references

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