European Personal Aero-Transportation. Using of the Double-Flutter Flight Principle for Manufacturing of Personal Flying-Cars by European Aircraft and Car Manufacturers

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Abstract

It is very clear that the car industry is in a great difficulty due to market demand decreasing. A first cause is the vanishing of oil reserves expected in the several decades. Replacement of regular with electric cars for personal transportation is only a temporary solution because another root cause of decreasing cars demand remains: the crowding of cities and roads with interminable lines of cars. In most of our cities, the classic car lost its main advantage: speed. On the other hand, thousand of cars stopped in traffic create another problem: carbon dioxide and monoxide emissions and the subsequent greenhouse effects. Not only cities are crowded. Even the motorways and roads outside the cities became crowded. It seems that the number of classic cars has increased up to a critical point and new solutions for our civilization development should be found now. The 100^+ years of history of classic car as the main personal transportation mean of our civilization is coming to an end and another mean should replace it.

The present paper affirms that the next personal transportation mean will be the flying-car using the double-flutter flight principle exposed by the authors in a previous paper. The double-flutter flight principle consists in the production of lift using two flutter moves. A piston engine having an oscillating shaft induces vibration of an elastic grid which in turn induces oscillations of a number of blades. That grid together with oscillating blades forms an efficient permeable surface which pushes downwards the surrounding air. According to the law (theorem) of momentum conservation, a force appears lifting the flying-car upwards. According to calculations, the flight of flying-car using the double-flutter flight principle is about three times more efficient than present helicopters. In addition, the flying-cars using the double-flutter flight principle are much more reliable than helicopters due to the absence of lifting rotors (rotors of helicopters flying within cities can hit buildings, electricity cables, trees etc.).

European car producers together with aircraft manufacturers should take into account the possibility of replacing the classic with the flying-car in the not too distant r future. Conversion of classic car production lines in lines for production of flying-cars is affordable if the flying-car uses the double-flutter flying principle. This affordability is based on the following facts: the flying-car that uses the double-flutter flying principle, current piston engines with straightforward changes for weight reduction and power delivery via oscillations move instead of rotation. The composite manufacturing lines will be used with small changes for manufacturing of cabin, engine fairing and permeable surface grid of flying-cars.

Initially, the price of a flying-car will exceed the price of a classic car, but in 10-15 years the two prices should reach parity. This will happen because the flying-car using the double-flutter flight principle is in essence a simple machine, less complicated than the classic car: The cabin is made of composite materials having 1...5 seats, the piston engine(s) transmit power to the permeable surface by means of a connecting rod, the landing gear is composed of three small legs/wheels placed under cabin.

The development of a European flying-car could be an important and desirable initiative action of the European Community because the worldwide market for flying-cars (excepting USA) flying-cars is evaluated at about $500 billions a year. The total US market would be similar [1].

Key words: flying car, aero automobile, air-cars, car manufacturers, car manufacturing, double flutter

Nomenclature

A, amplitude of vibration, [m]
A_g, grid's area, [m^2]

c, blade's width (chord), [m]
C_z, lift coefficient, dimensionless
C_D, drag coefficient, dimensionless
D, plate's rigidity, [N·m]
F, force, [N]
h, thickness, [m]
L, blade length (span), [m]
m, mass, [kg]
P, power, [W]
R, radius, m
s, grid eyelet side, [m]
t, time, [s]
T, vibration period, [s]
v, speed, [m/s]
W, weight, [N]
y, vibration elongation, [m]
α, incidence angle, [º]
δ, logarithmic decrement, dimensionless
μ, surface density, [m]
ν, vibration frequency, [s^{-1}]
ρ, density, [kg/m^3]
σ, flexural strength, [Pa]
ξ, damping coefficient
ω, vibration pulsation, [s^{-1}]

1. General

Today, the car industry is practically in a crisis. There are many causes. The first is the depletion of oil reserves, which are expected to vanish in several decades. However, this is not the main cause. The Replacement substitution of regular with electric cars for personal transportation will only be a short term because the root cause of crisis is the crowding of cities and roads. In most cities of advanced countries there are lines of stopped or slowly moving cars These situations extended even on large motorways which are often blocked although have many traffic lanes.


Figure 1-Intersection having a high no. of levels


Figure 2-Image of cars overproduction

Increasing the number of levels at intersections also seems to have reached a limit (fig.1).
On the other hand, tens of thousands mass-produced cars are stocked for better days (fig.2).

The thousands of cars stopped in traffic create another problem: carbon dioxide and monoxide emissions and the subsequent greenhouse effects.

Nevertheless, car manufacturers store thousands of new cars for better days (fig.2) while it is not sure that those good days will come.

It seems that the number of classic cars has increased up to a critical point and new solutions for development of our civilization should be found now. The 100^{+} years of history of classic car as the main mean of personal transportation in our civilization is coming to an end and another mean should replace it. This new mean should be a compact flying machine having extraordinary features as specified below:

1- extremely high reliability and safety;
2- no need for roads, runways or other special operation areas;
3- vertical take off and landing;
4- high efficiency of flight;
5- the speed of air accelerated by the propulsion system is kept below reasonable limits for avoiding the destruction of the taking-off & landing terrain;
6- the noise produced by the lifting/propulsion system is kept below reasonable limits;
7- crash resistant structure;
8- All weather operation;
9- completely automatic flight including avoidance of high speed collisions with building, relief and other flying cars;
10- permissible side collisions at low or moderate speeds with buildings, terrain or other flying cars;
11- a sufficiently high flight speed;
12- presence of at least two rescue techniques in the case of malfunction regardless of height and flight speed;
13- any person having no special aptitudes or training should be able to drive the machine (the driver must not be a certified pilot);
14- affordable convertibility of car industry for production of flying cars ;
15- compatibility with the current layouts of cities, towns and villages;
16- reasonable acquisition price and low cost of maintenance.

At present, no classic flying machine can accomplish such restrictive conditions. A new personal transportation vehicle which accomplishes the above 16 conditions will have an important impact not only to the car industry. It will have an important impact on civil aircraft manufacturers, too, because it is expected to reduce demand for low and medium range aircraft because, for distances up to 1000 km, a flying car with a speed of 250 km/h will be preferable to the passenger aircraft due to the long time needed for travel from home to airport and from airport to destination.

Figure 3-Flying car having wings


Figure 4-Moller's 'Skycar' having 4 propellers actuated by 4 Wankel engines


Figure 5-Moller's 'Volantor' - 8 propellers actuated by 8 Wankel engines


Figure 6-Volocopter-A drone for transportation of passengers-18 electric motors driving 18 propellers

2. The present state of the art

There are already a lot of proposals of flying-cars. Some proposals simply added two wings and a propeller to a car. For example, fig.3 shows such a proposal [2].

Others replaced the wheels of presents car with four ducted propellers as professor Paul Moller did (fig.4) [3]. Moller tried and another variant (fig.5) using 8 propellers actuated by 8 engines [4].

In fig. 6 one can see a flying machine having a multitude of small propellers incorporated in a rigid body or at the end of long braces [5].

Other designers proposed a kind of convertibles or helicopters transformed in flying-cars.

It is very clear for everybody that all the proposed solutions do not accomplish all the 16 conditions specified at point no.1. For this reason it is hard to believe that solutions presented until now will have any commercial success.

3. The essence of double-flutter effect

Designing a practical flying-car is a hard task. We consider that the 16 conditions can be accomplished only by a special flying machine which uses a new principle for creating of lift: the so called 'double-flutter' effect [6, 7].

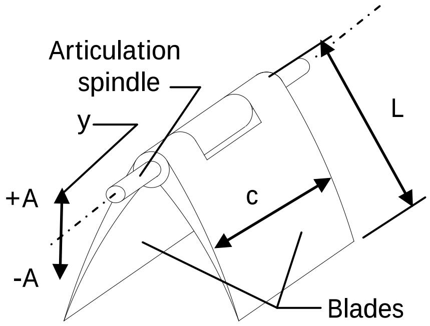

Figure 7-The oscillating spindle of a pair of blades produce the 'double flutter' effect

Figure 8-Experimental stand for testing of vibration of a pair of blades articulated on a spindle

Here is a synthesis presenting some essential features of double-flutter effect. The 'double flutter' effect appears when the spindle of two articulated blades is actuated in a vibratory motion (fig. 7).

This effect is responsible for the apparition of an aerodynamic force which can be used for lifting a flying machine.

Assume that the articulation spindle of blades vibrates in the vertical direction. As a result, the two blades begin to open and close under the action of aerodynamic and inertia forces.

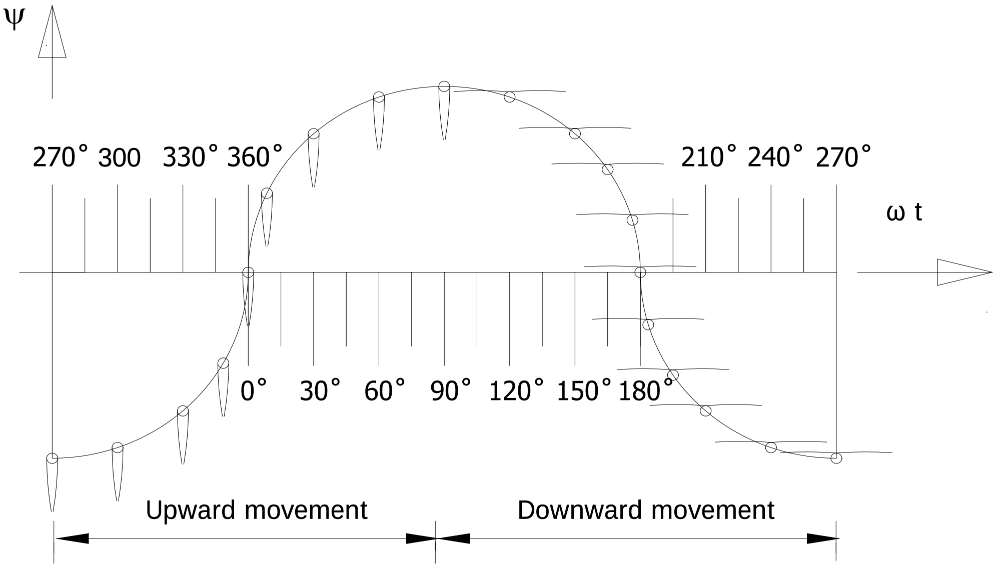

Figure 9-Movement of pair of blades

Experiments showed that the two blades move with a remarkable precision producing unidirectional pulses of air (fig.8). When blades vibration is examined with stroboscopic light, it can be observed that the blades are opening and closing in an extremely short time and they are completely opened during most of the downward motion and completely closed (folded-trailing edges in contact) during most of the upward motion t (figs.9, 10, 11).

The spindle articulation of blades oscillates harmonically according to formula (1), the vibrating speed and acceleration are given by formulas (2), (3) and inertia force and dynamic drag are given by formulas (4) and (5) respectively. Opening and closing of blades take place near the upper and lower point when the inertia force and dynamic drag are about equal.

$$y = A \cdot \sin \varpi t \qquad (1)$$

where A is vibration amplitude, ω is pulsation and t is time.

$$y' = \varpi A \cdot \cos \varpi t \qquad (2)$$

$$y'' = -\varpi^2 A \cdot \sin \varpi t \qquad (3)$$

$$F_i = -m \cdot y'' = -m \cdot \varpi^2 A \cdot \sin \varpi t \qquad (4)$$

where m is the mass of one blade

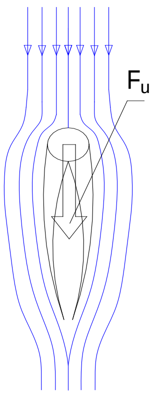

Figure 10-On the upward movement, the pair of blades are folded forming together a symmetric airfoil having a small aerdinamic drag

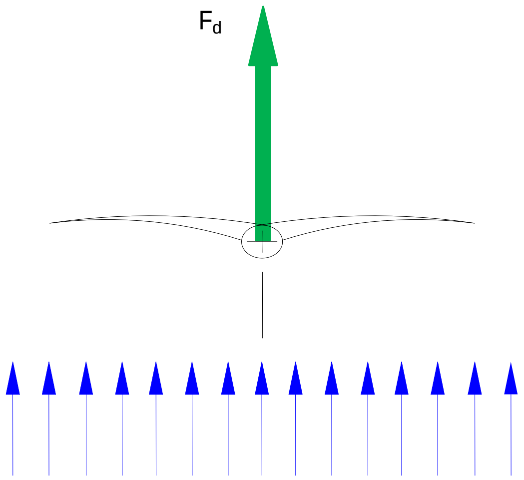

Figure 11-On the downward movement, blades are opened having a large aerodynamic drag

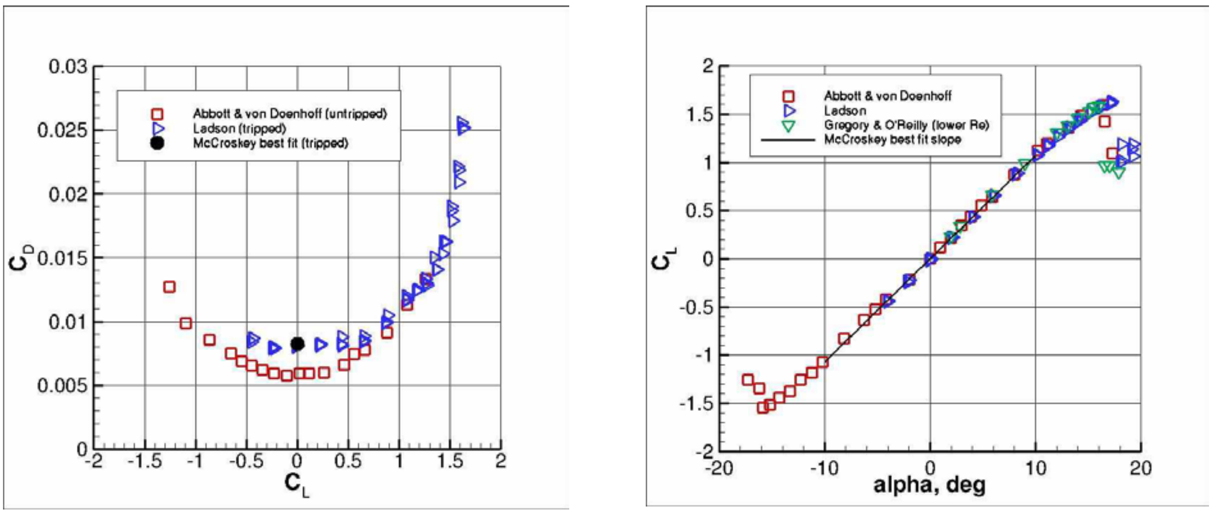

Figure 12- C_D and C_L of NACA 0012 airfoil

$$F_d = C_D \frac{\rho \cdot y'^2 \cdot L \cdot c}{2} \qquad (5)$$

where C_D is the dynamic drag coefficient, ρ is air density; L and c are dimensions of blade.

It can be easily seen that in the proximity of $\omega \cdot t = (2k+1) \cdot \pi/2$ [k=0, 1, 2, 3...], inertia forces are maximum and dynamic drag is minimum because the air speed y' tends to be zero. For this reason, blades open and close quickly creating the appearance of a sudden opening and closing. This remarkable effect permits the manufacturing of an extremely precise and simple mechanism for opening and closing of blades without the need of an actuation lever.

Assume that the closed blades form a NACA 0012 airfoil (fig.12). For such an airfoil the dynamic drag coefficient for incidence angle α=0º is C_D=0,007 [8]. When the blades move downwards, the dynamic drag is very high, C_D=1.17 [9].

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It is very clear that the pair of blades works even more efficient than a NACA 0012 airfoil used for wings of an aircraft because the dynamic drag coefficient on upward movement always has the minimum value C_{Du}=0.007 while the lift coefficient has the maximum value $C_L = C_{Dd}$=1.17 during the downwards motion of blades.

Assume a permeable surface composed of a grid and a multitude of blades articulated by that grid (fig.13).

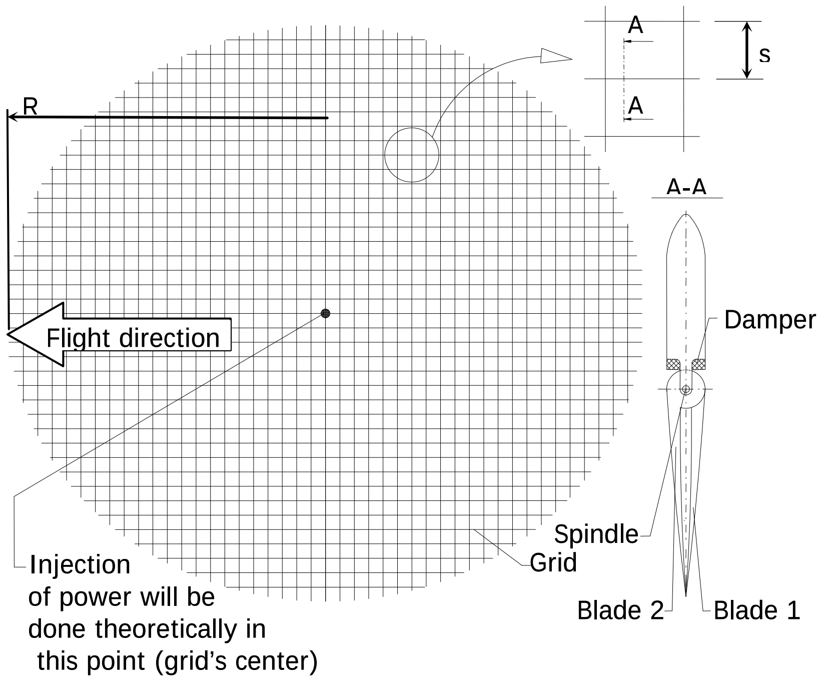

Figure 13-Upwards view of vibrating permeable surface composed of a net of composite material and blades

For research purposes, such a permeable surface can be easily linked to a reciprocating (piston) engine as schematically presented in fig.14.
First assume that the grid is a rigid body. In this hypothesis we can easily calculate the average lift force F_L:

$$F_L = \frac{F_{Dd} - F_{Du}}{2} = \frac{1}{2} \cdot C_{Dd} \cdot \frac{\rho_a \cdot v_d^2}{2} \cdot A_g = \frac{\pi}{4} \cdot C_{Dd} \cdot \rho_a \left(\frac{4 \cdot A}{T}\right)^2 \cdot R^2 = 4 \cdot \pi \cdot C_{Dd} \cdot \rho_a \cdot A^2 \cdot \nu^2 \cdot R^2 \qquad (6)$$

where F_D is the dynamic drag of downward moving grid (closed blades), C_D is dynamic drag coefficient of a circular plate, ρ_a is air density in normal conditions, v_d is the average speed of grid during downward motion, A_g is area of circular grid, A is oscillation amplitude of grid, T is the oscillation period of grid, ν is oscillation frequency of grid and R is grid's radius.

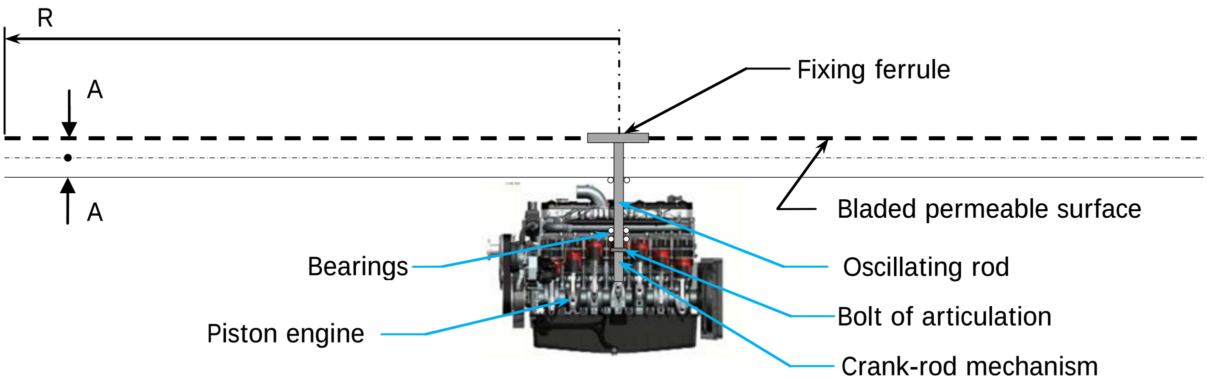

Figure 14- Driving of a vibrating permeable surface by means of a piston engine

For calculation of lift force, the dynamic drag of grid during upward motion was taken as being about zero (due to the small value of C_{Du} and small value of speed v_u (v_u=v_d).

In (6) we took the average downward speed of grid $v_d = 2A/(T/2) = 4A\nu$, grid area $A_g = \pi \cdot R^2$.

In Table 1 are calculated values of lift force for a permeable surface having radius R=3.5 m, ρ_a = 1.225 kg/m^3, A=2...10 cm, ν =10...100 Hz, c_{Dd}=1.17.

Table 1

Crt. no	A, cm	ν, Hz	F_L, daN
1	2.5	10	1.4
2	3.5	20	10.8
3	4.5	30	40.2
4	5.5	40	106.7
5	6.5	50	232.9
6	7.5	60	446.6
7	8.5	70	780.7
8	9.5	80	1273.7
9	10.5	100	2431.2

We can easily calculate the power needed to create this lift:

$$P = \frac{F_{Dd} \cdot 2A}{\frac{T}{2}} = \frac{2}{T}\left(\frac{1}{2} \cdot c_{Dd} \cdot \frac{\rho_a \cdot v_d^2}{2} \cdot A_g\right) \cdot 2A = 32 \cdot \pi \cdot c_{Dd} \cdot \rho_a \cdot R^2 A^3 \cdot \nu^3 \qquad (7)$$

The results are given in Table 2.

Table 2

Crt. no	A, cm	ν, Hz	P, kW
1	2.5	10	0.0
2	3.5	20	0.2
3	4.5	30	1.1
4	5.5	40	4.7
5	6.5	50	15.1
6	7.5	60	40.2
7	8.5	70	92.9

8	9.5	80	193.6
9	10.5	100	510.6

If we do a comparison with a small 2 places aircraft (Lancair 320, see fig.16) we see that the flying car using such a permeable surface uses a smaller power for propulsion (92.9 kW instead of 120 kW (Lycoming Textron O-320 piston engine) at Lankair 320) for a higher maximum take off weight (780.7 daN=796 kgf relatively to 764 kg at Lankair 320) [10].

Figure 16-Lancaur 320 light aircraft

Figure 17-Robertson R22 light helicopter

If we do a comparison with a light helicopter, for example the Robertson R22 helicopter with two places, the take-off weight is 635 kg and necessary power is 112kW (Lycoming O-320 –piston engine) [11].

It is clear that the flying car using such a permeable surface is more efficient than a light helicopter and even than a light aircraft for the same number of transported passengers because the weight/power ratios are: 796kg /92.9kW =8.57 kg/kW for the flying car using a vibrating permeable surface, 764kg/120kW=6.37 kg/kW for light aircraft and 635kg/112kW=5.67 kg/kW for light helicopters.

4. Comparison with flight of insects

The flying car using the double-flutter effect is an efficient machine because its flight resembles in a specific way the flight of insects. The insect flight is the most efficient known flight [12].

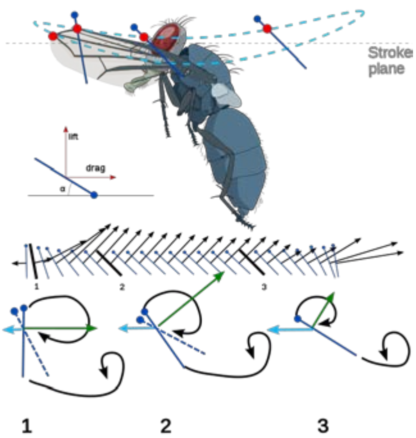

Figure 18-Insect flight-down stroke

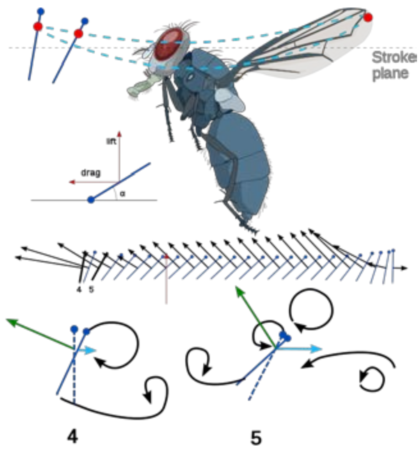

Figure 19-Insect flight-upstroke

In figs 18 and 19 are presented the reasons: During flight the insect continuously rotate the wing for minimum drag and necessary lift. In the case of double-flutter permeable surfaces, the movement is simplified to a minimum drag movement (upwards) and maximum lift movement (downwards).

5. Vibration forms of permeable surface

The vibration of grid is much more complicated than that presented in fig.14. Assume that the grid together with blades is a round plate having mass=m, radius=R, thickness=h, density=ρ. Its vibrations are described by the equation (8) [13]:

$$\frac{\partial^2 W}{\partial r^2} + \frac{1}{r}\frac{\partial W}{\partial r} + \frac{1}{r^2}\frac{\partial^2 W}{\partial \theta^2} = \pm\omega\sqrt{\frac{\mu}{D}}W \qquad (8)$$

where W is vertical displacement of a point of plate, r, θ are the polar coordinates, ω is the vibration pulsation of plate, $\mu = m/\pi R^2 = \rho \cdot h$ is the surface density of plate, $D = \frac{Eh^3}{12(1-\nu^2)}$ (ν is the Poisson's coefficient, E is the elasticity module) is plate's rigidity.

Assume that the plate having radius R=7 m and thickness h=0.1m is made of carbon fiber composite M49/42%/200T2x2/CHS-3k-bi-directional 0/90º. Features of this material are: ρ = 1.47 kg/m^3, E = 5.5×10^{10} Pa, σ=920 N/mm^2 (flexural strength).

For this material, measurements show an acceptable logarithmic decrement $\delta = \ln\frac{A_1}{A_2} = 0.125$ and damping coefficient $\xi = \frac{\delta}{\sqrt{(2\pi)^2 + \delta^2}} = 0.02$

If the grid's eyelets having side s=25 mm, rib's thickness h_r=0.55 mm, ribs' height h=0.1 m, blade width (chord) c ≈ s/2 = 12.5 mm, blade length (span) L ≈ s = 25 mm, simple calculations leads to the apparent density of grid ρ_g = 200 kg/m^3.

For simplicity, we make the hypothesis that aerodynamic forces are balanced in every point of grid by the motor forces and vibration of grid's center is A=50 mm. In this hypotheses, for the given grid parameters, using finite element analysis (see fig. 20 for meshing) we found that the first three forms of vibrations are ν_1=23.72Hz, ν_2=37.206, ν_3= 84.465 Hz. The three vibration forms are given in figs.21, 22 and 23.

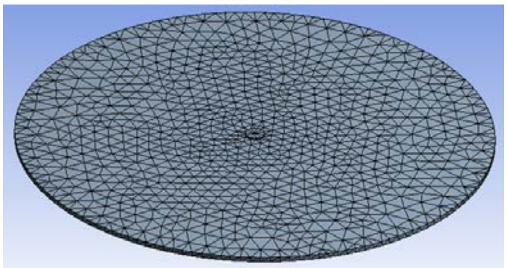

Figure 20-Meshing of disc for finite element analysis.

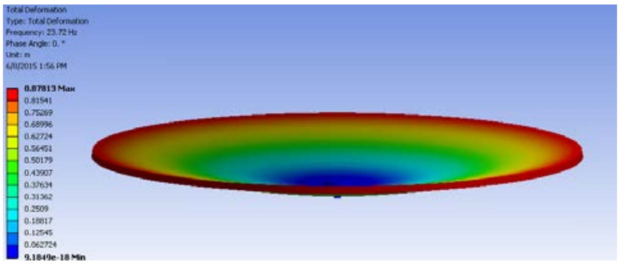

Figure 21-The 1-st vibration form ν_1=23.72 Hz

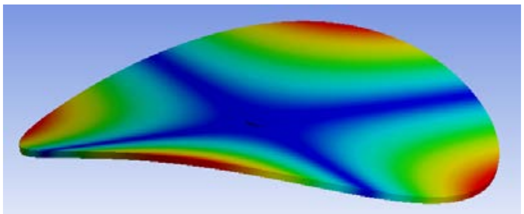

Figure 22-The 2-nd vibration form ν_2=37.206 Hz

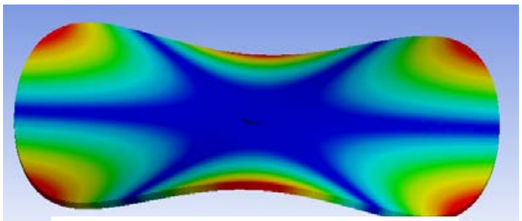

Figure 23-The 3-rd vibration form ν_3=84.465 Hz

As it can be seen in fig.21, the amplitude of grid edge can reach a high value, $A_{R=3.5m}$=0.88 m.

Taking the average speed of grid in vertical plane as $v_a = \frac{\sum_1^{15} v_i}{15} = 41.9 m/s$, for R=7 m, ν_1=23.72Hz, the value of lift force calculated using formula (6) is:

$$F_{Lva} = 2172.2 daN = 2214.3 kgf \qquad (9)$$

This force is much greater that that calculated in the hypothesis of rigid grid (L=796 kgf) which demonstrates that increasing of vibration amplitude of grid due to vibration at resonance leads to higher values of lift.

It can be observed that the noise caused by the vibrating grid is small due to the low working frequency.

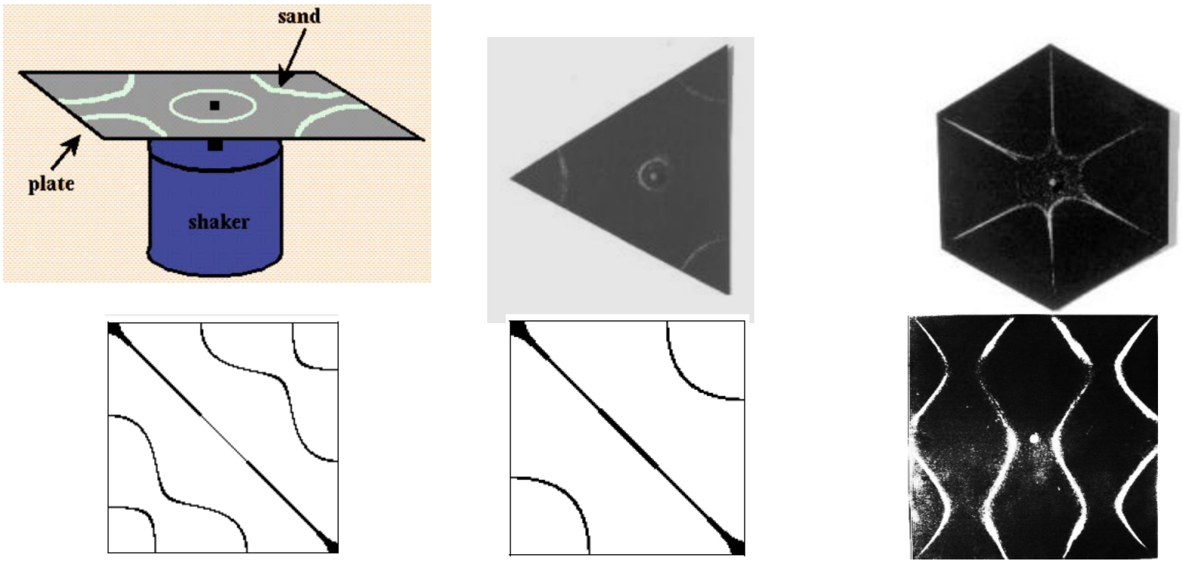

Figure 24-Vibration modes of triangular, square or hexagonal shapes

The flying machines using the double-flutter effect must work at resonance for avoiding power loses. When vibration frequency is far from resonance, power loses appear because a part of engine power is used against grid natural movement. Working at grid at resonance is possible due to high fatigue resistance of composite materials.

We have to specify here that this kind of flying machine offers multiple possibilities of design. The grid can vibrate at the next proper frequencies ν_2=37.206 and ν_3= 84.465 Hz for example. At these frequencies, maximum vibration amplitudes are smaller but the working frequencies are higher.

The grid can have a multitude of shapes. The vibration forms of plates are known as Chladni patterns. In fig. 24 testing equipment and some of vibration modes of square, triangular or hexagonal plates can be seen [14].

6. Structure and maneuvering of flying car using the double flutter effect

The design and structure of such a flying car can be seen in fig. 25a, b, c and d. It can be seen easily that such a flying machine accomplishes all the 16 requirements specified at point 1.

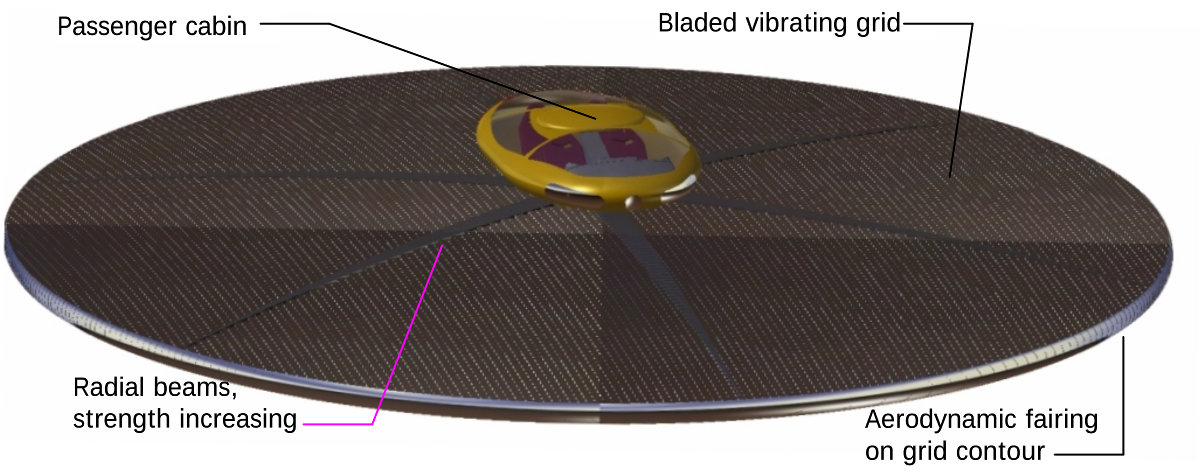

Figure 25a-View upwards of flying-car

Figure 25b-View from front of flying-car

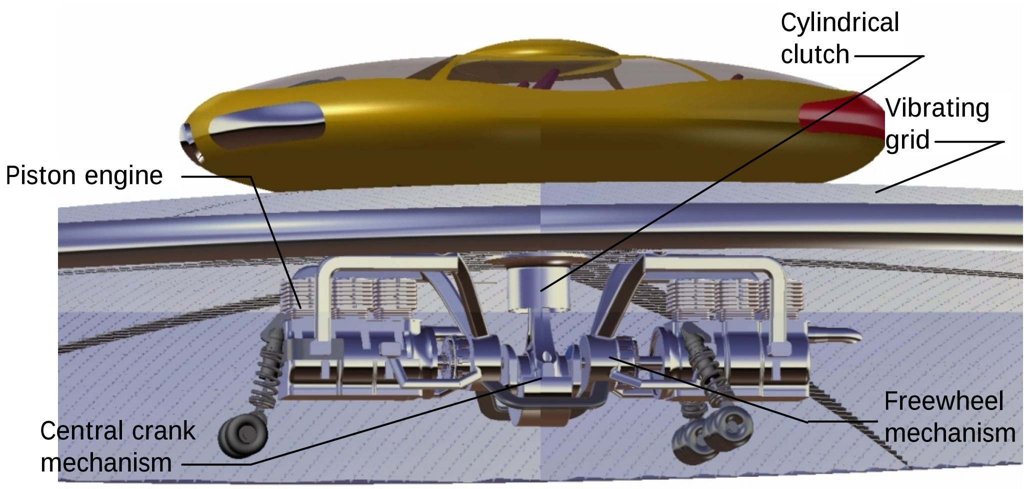

Figure 25c-Side view of flying-car showing design details (engines' fairing and oil cavity of central crank-rod vibration mechanism are not shown

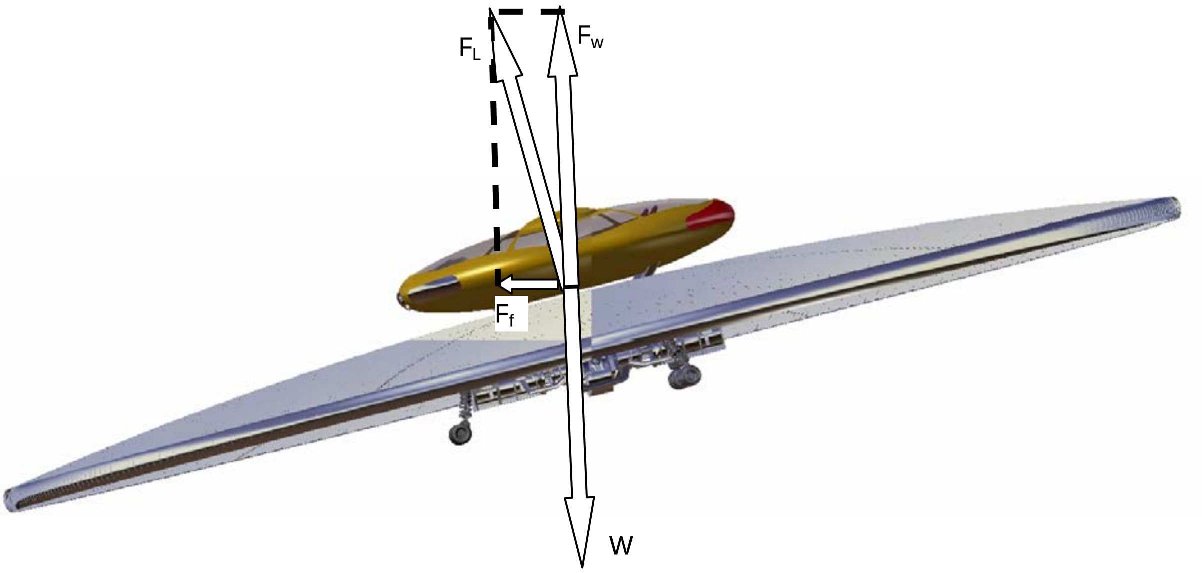

Figure 25d-Side view of flying-car flight ahead

The landing gear presented in fig.25b is necessary for taxiing in parking to the taking off place.

In fig. 25c one can see the main components permitting starting and flying of machine: Both engines are started and actuate the central crank-rod mechanism by means of freewheels. The electronic control system increases progressively rotation speed of engines while the cylindrical clutch begins to vibrate the grid until grid's frequency is equally to frequency of engines. When the vibration frequency is equally to the proper frequency of grid, the vibration amplitude of grid edge is maximum and the flying car is taking off.

In fig. 25d one can see how the flying car can move forward. The lift force F_L is decomposing in F_w which balances the weight of machine and F_f which pulls the machine forward. The flight of flying car is similar to helicopter's flight: when permeable surface is slanted to a direction, the machine is moving to that direction.

Other practical designs of flying cars can be seen in figs. 26, 27, 28 (viewed from above). In these cases, power is first injected in the vibration beams (made of carbon composite, too) and then transferred to the blades by means of elliptic grids.

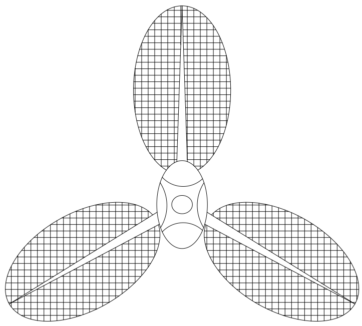

Figure 26-Permeable surface having 3 elliptic grids

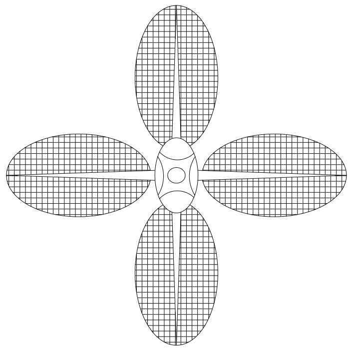

Figure 27- Permeable surface having 4 elliptic grids (var.1)

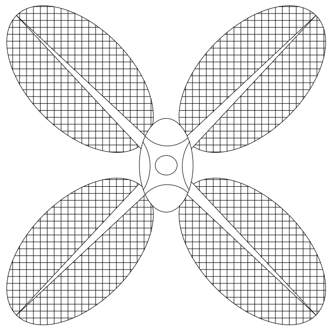

Figure 28- Permeable surface having 4 elliptic grids (var.2)

7. Safety of flying car using double-flutter effect

Such a machine has multiple safety features. Firstly, it has 2 piston engines. If the first engine stops, the second allows safely landing. If the second engine stops, the onboard computer decides if the emergency landing will be performed by the compressed parachute existing on board (when height is over 200 m or by dynamic drag of grid (all the blades are closed during fall due to dynamic pressure of air) and the reaction cartridges (when height is less than 200 m.

8. Final design of flying car using double-flutter effect

In a final design, the piston engines should be replaced with engines having oscillating shafts (fig.29). Design of this types of engines is simple, being similar to Pescara's burnt gas generators with free pistons. The efficiency of such engines should be around 50% due to the absence of the crank-rod mechanism. The design of engine having oscillating shaft is described in detail in [6].

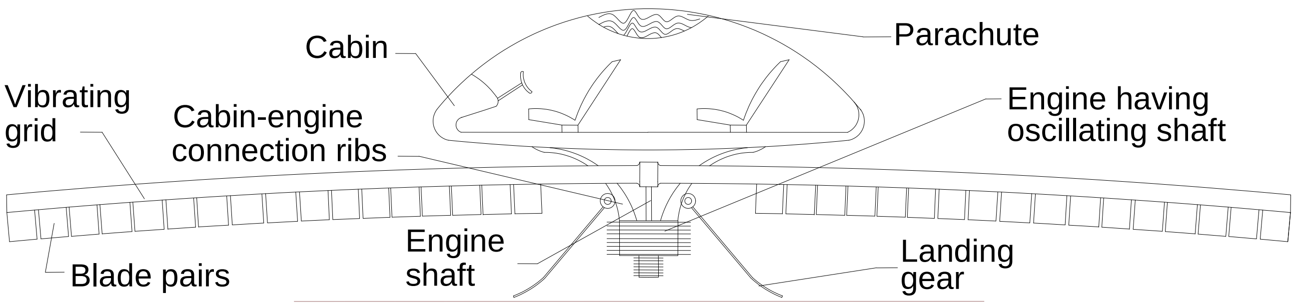

Figure 29-The final design of flying machine using the double flutter effect

9. Introduction of flying cars in our civilization

The new type of personal transportation will easily be accommodated by the present structure of cities and home designs (see fig. 30).

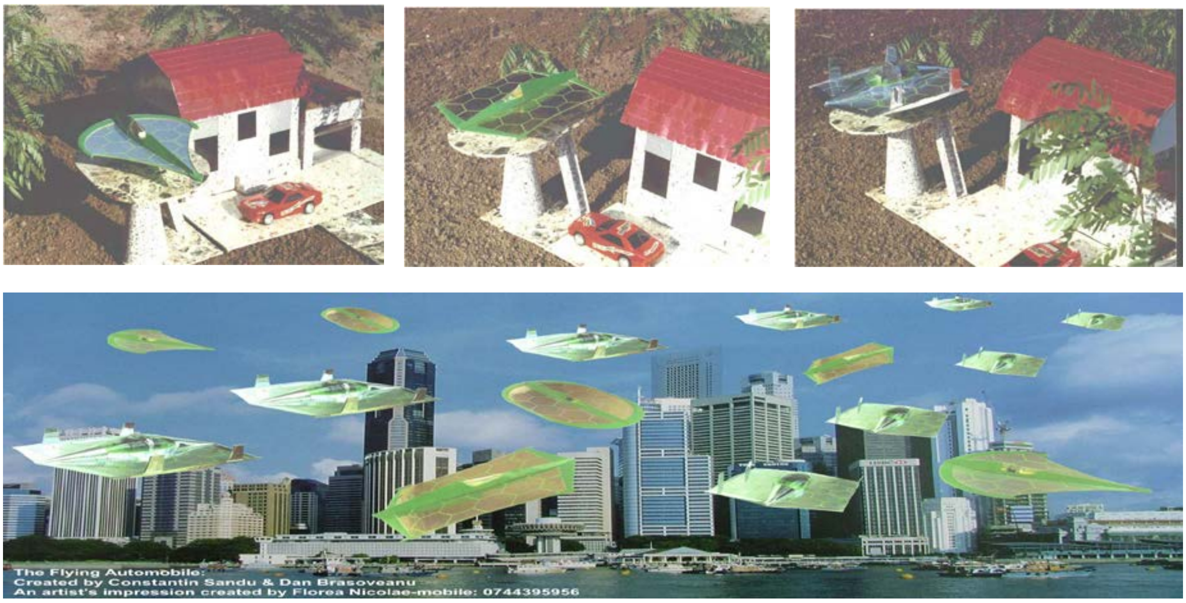

Figure 30-Hoses and cities in future

10. Military applications

Due to high maneuverability and sudden changes of direction, this type of flying machine can be used for fight in cities or irregular terrain or as military drones.

11. What car-manufactures should do now

The car-manufacturer should start studies and experiments using the simple equipment presented in fig.14. After familiarizing with this principle and basic technology they can do a step forward for lightening of engines and increasing of fatigue life of carbon fiber composite. They have to use thin (thickness 0.015...0.05 mm) carbon fiber fabrics pre-impregnated with resin. For the highest fatigue resistance special resins have to be used and the percent of carbon fiber should be preponderant in composite structure.

12. Conclusions

-The flying car using double-flutter effect is in our opinion the next personal transportation mean of our civilization.
-It is more efficient than the helicopter and even small aircraft and satisfies the 16 restrictive conditions specified at point 1. It does not use high air speeds for creating lift as helicopters and aircraft and for this reason it is suitable for use as personal transportation mean in cities.
-It is a safe machine because has 2 engines and other independent salvation means.
-Noise perceived in proximity of this machine is low when the working frequency is low because the human ear has a reduce sensitivity at low frequencies (when frequency is under 16 Hz noise in no longer perceived by the human ear). When working frequency is higher than 30 Hz, active noise control can be easily used cancelling practically the noise.
-The high level of present car technology should permit an affordable conversion of car-industry for mass manufacturing of flying cars using the double flutter principle. This could solve the crisis of car-industry and the problem of cities overcrowded by classic cars. Car manufacturers should start just now to study this necessary conversion.
-Short and under-medium distances (to 1500 km) should be covered by air-cars and medium and long distances (1500-3000 km) should be covered by aircraft.
-Business of air-car will be the next important world business evaluated to a total market of 1 trillion USD. It is very possible as an important number of classic cars will be substituted by flying cars in the next 3-4 decades.

-The present European concept of flying car could lead to the development of a specific flying car design in opposition to other flying car concepts launched in research by EC competitors.

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