Innovation design analysis of the optimal aerodynamic adaptive smart structures for disk-body solar Hybrid Electric aircraft and airship concepts

Authors: Yury Ravikovich¹, Leonid Ponyaev¹, Mikhail Kuprikov¹ and Raphael Domjan²

1- Moscow Aviation Institute (MAI), Volokolamskoe shosse, 4, Moscow, 125993, Russia
2- SolarXplorers SA, Rue Galilee 7, CH-1400 Yverdon-les-Bains, Switzerland

yr@mai.ru, plp@mai.ru, kuprikov@mai.ru, rd@solarstratos.com

Abstract. The innovation integrated design analysis of the concept of finding any optimal aerodynamic structure with adaptive intelligent systems as a means of changing facility of the geometric shape of the surface by integrating the disc wing-body of a solar Hybrid Electrical aircraft (HEA) and an airship to reduce weight, power and fuel sources is very relevant today and focused on the international research EC programs of future green ecology air transportation. The universal digital method for optimizing the CAD aircraft design is presented which is focused on achieving the goal of minimum weight-drag-frontal stability of the layout from the virtual center of mass allows us to get the layout of the aircraft from the conditions of reducing the time of full flight operation of E-Mobility and low cost for priority with realize a short take-off and landing (STOL) with high angle of the flight path and compact infrastructural restrictions in the terminal slot configurations of modern urban airport infrastructure and achieving zero toxic & noise regulation by IATA/ICAO. The joint results of EC international R&D collaboration to accelerate the synergy effect of new aircraft concepts.

1. Introduction
Strategy developing of the new Hybrid-Electric aircraft (HEA) and airship concept in the MAI design departments and laboratories was focused on the additional use of solar films for covering the wing and tail section as positive result of the good test experience on the Swiss SOLARSTRATOS aircraft with one & two pilots as shown in Fig. 1 [1].

Figure 1. The pictures of the SOLARSTRATOS aircraft on the ground and in flight presented by Director Raphael Domjan
The main task was to minimize the weight of the aircraft with increased rigidity at the junction of the wing with the fuselage (as the main problem identified) and maximize the use of solar electricity due to the wing and tail surface. Its main project strategy and possibly future positive results provide a positive example for innovative research and development of a new promising international program. New high technologies include new materials, light alloys, and pre-stressed structural analysis for any new integrated hybrid electric aircraft (HEA) or disk-shaped solar airship wing in design analysis with digital design (CAD/CAM/CAE) as its use for creating new high-capacity hybrid aircraft/airships, taking into account the allowable deformations and deflections of the wing as shown in Fig. 2 [2].

**Figure 2.** Flow field visualization at take-off & cruise conditions for CAD initial aerodynamic load model with the flexible wing configuration.

Design calculations show that this more effective result will increase with the implementation of the effect of aerostatic unloading of a non-flammable (NFL) hydrogen gas-lift system or a cryogenic reservoir with LH2 for the development of the any versions of Cryoplane Jet and HEA by FUTPRINT50 vision as show on Fig. 3 [3], since environmental transport operations that require a shortened and short take-off and landing at an airfield are more relevant today. Unlike a heavy civil transport aircraft, for an aerostatic light-then-air (LTA), weight restrictions on dimensions are not limiting, since the physical law “cube-cube” is a positive principle constructive winning approach.

**Figure 3.** Any versions of the Cryoplane projections with jet engines and hybrid electric propulsion (HEP) with component systems as priority FUTPRINT50 design architecture concept

2. **Vision of the new innovation low weight Hybrid Electric aircraft and solar disc airship**

The main vision of the concept with a high payload aircraft as a hybrid electric aircraft and airship will focus on greater aerodynamic efficiency, since the use of symmetrical disc shaped geometry (DSG) as a more optimal 3D shape for a light weight rigid frame and a soft elastic coating with two gas cavities—helium/NFL hydrogen and superheated air was developed by MAI research several years ago and patented as the DSG Thermoplan project [4]. It is necessary to highlight the main advantages of this demonstration project for the test flight version of the LTA of the AIA-40 Thermoplane (unique in world 40 meters in diameter of a torus-shaped ring of composite material) with two Awards – Golden Arch of Europe and Birmingham US Awards:

- the geometry of the LTA as a promising aerodynamic shape eliminates constant orientation in the direction of the crosswind that is an inevitable drawback for feathering the wind when the asymmetric
geometry and the strain gauges of the stress distribution according to color images cigar-shaped / ellipsoidal airplane/ airship using computational numerical methods for the analysis of stresses from the loads and vibrations [5, 6];

- the disk shaped form of a symmetrical geometric shape allows you to implement the lightest design when using a uniform distribution of loads in a structure with hybrid and solar electric systems in a frame integral structure and on domes with high strength of the composite torus with its of pre-stressed loads method (PSLM as the principle of tension of the spokes of the Bicycle wheel frame), as shown in Fig. 4 [7];

- the benefits of a disk-shaped LTA Thermoplane MAI in the form of a representation in Fig. 5 are reduced from the use of a two-volume gas scheme, one volume of which is intended for refueling with helium (or hydrogen with a non-flammable additive), and the second volume-with superheated air with the selection and disposal of exhaust gases from the main unit of propulsion systems or gas turbine engines, which allows you to create an advantageous balanced DSG scheme that does not require additional ballast and maintenance of filling stations at the point of unloading the payload;

![Figure 4. Tensometry analysis of stresses and vibration loads cigar-shaped/ellipsoidal drops and the disc-shaped geometry](image-url)

- the placement of a solar nano-film battery (SNFB) covering the entire upper surface of the dome allows you to use both a successful example of high-altitude flight of a SOLARSTRATOS aircraft, and the advantageous use of spaced and contour-mounted rotary electric motors with a gyroscopic horizontal control stabilizer (as in the drone control loop) to balance and counter wind gusts, as well as to create the required horizontal thrust of the DSG main engine.

![Figure 5. Disc shaped airship Thermoplane MAI projection images and drawings](image-url)
3. Future weight reduction potential for a new STOL aircraft/airship with disc geometry

The increase in the size of the LHA came into conflict with modern airport infrastructure and led to the search for alternative options for Arctic aircraft and airships for structurally layout circuit solutions with protection from minimal sound and vibration problems to cope with this contradiction. Design studies based on computer aircraft design (CAD) calculation method have been carried out at MAI for many years, and positive experience has been gained in conducting structural and parametric analysis of the impact of aviation infrastructure limitations when basing aircraft on the choice of alternative design options for new adaptive concepts with a wing-bearing fuselage or an unusual Flying-V layout. The goals of the aircraft design ideology are to focus on integrating 3D projections in the form of an aircraft body or an aerodynamic layout of the body and wing with minimal drag, fuel consumption, and noise/sound levels during the entire flight in the sky and near the airport. An important feature of the CAD process is the dominance of some particular criteria over others and the increase in the significance of certain particular criteria to the level of the general criteria of the aircraft concept, as shown in Fig. 6 [8].

![Figure 6. Project of the Delft University of technology (Netherlands) in the form of a flying-V body wing (BW) as an environmental project with improved aerodynamics and MAI or Airbus BW concepts](image)

Solving the direct problem of designing an aircraft leads to multiple options, and, consequently, to significant time and material costs. In this regard, the model of solving the inverse problem of aircraft design is of particular interest, i.e. the situation when the rational values of parameters correspond to the permissible minimum or maximum value of the characteristic, which clearly follows from a set of restrictions as shown on the Fig. 7 [2]. Problems of this type are characterized by a fairly frequent absence of points of function optimum in the considered interval and a smooth gradient of its growth.

![Figure 7. Any design versions of the strategy for the conceptual design of the disc aircraft](image)
system with the real center of mass and drag of the hybrid electric STOL aircraft/airship for various applications, either for long-distance or to regional flights. As part of the research work at the MAI University, a comp-digital structural and parametric analysis of alternative layouts of any aircraft concept with a request passenger capacity was carried out and may see in Fig. 8 [6].

**Figure 8.** Optimal CAD aircraft design structure for any aerodynamic concept shems

The analysis shows the advantages of the layout made according to the above method (LHA-5 flying wing scheme) in relation to other non-traditional schemes and with minor losses for the base aircraft. At the third level, a structural and parametric analysis of the LHA infrastructure reveals the geometric shape of the layout within the layout space:

- Along one or two circles for the Cryoplane selected for the fuselage of the FUTPRINT50 project,
- Two-body design advantageous for Cryoplane safety with separate LH2 tanks,
- The body and disk of the flying wing favorable for the STOL version
- Teardrop or elliptical fuselage, etc.

To improve the aerodynamic parameters of the wing, as shown in Fig. 9, feather vertical endings can be used for new projects of Airbus aircraft, as well as adaptively deformable wing structures and skin in the form of a kind of plastic scales-thin plates that are installed overlapping. The material can be flexible plastic, and a thin elastomeric streamlined shell is installed on top with blowing or suction of the boundary layer to reduce aerodynamic drag [2].

**Figure 9.** Feather vertical endings of MAI test and Airbus aircraft designs with adaptive e-wing
The adaptive actuators, as shown in Fig. 10 left A [9], changing the shape of the wing, can be different, for example, a curved shaft-lever. By loosening and straining the rods, you can change the spatial shape of the 3D frame. The adaptive wing can not only control the aircraft. The device can be rotated and perform the functions of changing the curvature of the wing profile for the STOL aircraft.

Figure 10. Adaptive e-drives can change the profile shape of the wing in different positions and flexible wing transform configuration as ‘reconfigurable’ cellular honeycomb fillers.

The novelty of the idea is that the wing contains any ‘reconfigurable’ cellular honeycomb filler. There are no elastic elements in it: the structure is made flexible by sliding hinges that connect individual rigid elements, as seen in Fig. 10 right B [9]. This is a mechanical version of flexagons-structures made of paper that change shape when laid out in folds. Creating a cellular structure is assumed by casting using a mold or using 3D printing with composite materials - carbon fiber. Modern printers are able not only to form a composite 3D part, but also to create such interweaving of threads that give the part exactly the specified strength characteristics.

The conducted researches have shown that for different types of aircraft the nomenclature of constraints is practically equivalent. However, in absolute terms, constraints are not always critical. The analysis of constraints allows us to formalize them in scalar and in functional form. These requirements are formed at the stage of external design, and at the stage of internal design they are specified in the specification of the main technical requirements. The analysis of the variety of infrastructure constraints and requirements shows that they can be systematized and classified according to the priority characteristics.

Many infrastructure constraints either directly or indirectly influence on the choice of the main parameter values and the dimension of the aircraft aerodynamic structure and complete components. The influence of infrastructure requirements on the dimension of the aircraft will be considered through the example of top architecture factors for which it is critical.

4. Cryogenic cooling components for adaptive design analysis and test for high-temperatures superconductors (HTS) systems of any optimal electric generators and motors

Any MAI research on the technical appearance and calculation of the technical characteristics of the HTS cooling component system for the hybrid-electric power plant of a new aircraft and a disk airship can be used for new research in cooperation with the EC FUTPRINT50 program. A new design scheme for an optimal cryogenic cooling system based on the Brighton reverse cycle using turbomachines with the main design scheme for using cryogenic systems for cooling capacity and temperature level is proposed for a mathematical model created using thermodynamic models of individual circuit elements that take into account the efficiency of each element, hydraulic losses in the paths of all system elements: Calculation of hydraulic losses in the channel of the contour element, taking into account the thermal control of regenerative heat exchangers with the calculation of the turbocharger and turboexpander. This includes the development experience of a two-stage neon
electric compressor and a turbo expander with a promising high-speed system of unique suspension on pneumatic bearings and their testing of the effectiveness of a cryogenic cooling system on the laboratory demonstrator as shown in Fig.11 [9].

![Figure 11. MAI research design analysis and lab test complex of the cryogenic cooling components for HTS versions](image)

5. The main key results of MAI R&D innovation aircraft conceptions
The main key results of the complex design analysis and research at MAI in the direction of creating new aircraft both aircraft and airships using the concepts of hybrid electric propulsion (HEP) and new aerodynamic schemes with adapting wing structure and bird ending tips for the placement of both liquid hydrogen tanks, cryogenic cooling systems and the use of light solar film panels are as follows:

- the digital aircraft design computer software package has been created for the optimal choice of the aircraft's aerodynamic layout according to the criterion of minimum weight costs and an increase in aerodynamic quality by 10-12% in comparison with the classic scheme, which puts the Wing Body integrated circuit in the first place with high-level lift capabilities for STOL while reducing the initial power of the HEP by 7-10% due to the ground and Coand effects (GCE) and boundary layer control (BLC) from blowing along the center section and part or all of the wing span and adaptive transforming wing profile;

- the use of additional volumes to accommodate liquid hydrogen for the classical scheme requires the creation of a cross-section 8-shaped fuselage, which increases drag by 5-7%, and for the wing disk shaped, an additional increase the lift power capacity by 13-15% at high angles of attack;

- with the use of liquid hydrogen, the use of cryogenic cooling systems with new high – speed electric motors simplifies the implementation of lighter and more compact electrical systems based on the HTS superconductivity effect and reduces weight costs by 15-17%, and with the use of current-film solar cells-an additional gain in weight up to 3-5%.

6. Conclusion
The new strategy of find the modern aircraft architectures as better then operation today is focus to any best new aircraft systems, components and materials. The forward innovation integrated design analysis of the concept of finding any optimal aerodynamic structure with adaptive intelligent systems as a means of changing facility of the geometric shape of the surface by integrating the disc wing-body of a solar Hybrid Electrical aircraft (HEA) and an airship to reduce weight, power and fuel sources is very relevant today and focused on the international research EC programs of future green ecology air transportation. The universal digital method for optimizing the CAD aircraft design is presented which is focused on achieving the goal of minimum weight-drag-frontal stability of the layout from the virtual center of mass allows us to get the layout of the aircraft from the conditions of reducing the time of full flight operation of E-Mobility and low cost for priority with realize a short take-off and landing (STOL) with high angle of the flight path and compact infrastructural restrictions in the
terminal slot configurations of modern urban airport infrastructure and achieving zero toxic & noise regulation by IATA/ICAO. The joint results of EC international R&D collaboration to accelerate the synergy effect of new aircraft concepts for high tech digital aviation industry.

7. References
[1] Javet R, Domjan R 2018 Pionniers et Aventuriers de l’Energie Solare ISBN: 978-2-8289-1719-7 FAVRE SA, Lausanne Suisse p 136
[2] Ponyaev L 2018 The Periodical Geometry of Engineering Design Principals by use the Optimal Spherical Transformation to the Disc Shaped LTA Scientific Technologies S&P Journal PSSN 223-2966 pp 1-5
[3] Walter A, Ricardo G, Ravikovich Yu, Ponyaev L etc. 2020 Thermal Management challenges for HEA – FUTPRINT 50, Conference EASN papers, 2-4 September, Italy
[4] Ponyaev L 1996-97 Thermoplane ALA-40/ALA-600 Catalog Brassey’s World Aircraft & System Directory p 545
[5] Dolgov O, Kuprikov M, Kuprikov N 2010 Features of detecting the moment-inertial appearance of perspective aircraft in the early stages of design Bulletin of the Moscow Aviation Institute 2 (17) pp 1-4
[6] Kuprikov M 2003 Structural-parametric synthesis of the geometric shape of the aircraft under severe constraints Moscow MAI p 64
[7] Ponyaev L 2018 Scientific Technologies, S&P Journal PSSN 223-2966: Moscow, Russia, Natural & Technical Science 9 pp 60-65
[8] Delft University FLYING-V Body Wing Aircraft – New Ecology Project Yandex News 5 June 2019
[9] MAI Science R&D Cryogenic Cooling Systems Reports 2018-2019-2020 Conference papers 2018/2019