Hydrogenius
Flying with a Fuel Cell

EWADE 2009, May 14th 2009, Sevilla

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Agenda

- Research in Aircraft Design at IFB
- Berblinger Price 2006, City of Ulm
- Fuel cell applications in aviation
- Fuel cell technology and components
- Project Hydrogenius
- Outlook
Research:  Aircraft Design

Solar aircraft: icaré

Fuel cell aircraft: Hydrogenius

LUFO III, „Demonstrator Model“

Research focal point „Unmanned Aerial Vehicle“

EU, NACRE Development of an IEP

LUFO III HICON, Weight prediction for high lift devices

Weight prediction tools FAME-W, FAME-FANCY
Hydrogenius: Team

- Prof. Dipl.-Ing. Rudolf Voit-Nitschmann: Project Management and Public Relations
- Dipl.-Ing. Len Schumann: Airframe and Aerodynamics
- Dipl.-Ing. Steffen Geinitz: Propulsion System and Integration

- Currently six diploma theses
- 11 student assistants for technical documentation, public relations, simulation and construction
- Eight thesis completed related to the project Hydrogenius
Hydrogenius: The Beginning

Berblinger Preis 2006

- Environmental Sustainability
- Operating Efficiency
- Reliability
- Light Weight Construction Methods
Hydrogenius: Objectives and Benefit

- Flagship initiative for fuel cell technology
  - Enormous public effect of aircrafts
  - Impressive demonstration of fuel cell performance

- Impulses for fuel-efficient mobile applications

- Experimental aircraft to investigate fuel cell systems under extreme conditions

- Certification of hydrogen and fuel cell technology in aviation

- Integration to education at the faculty
  - Already six student research projects and diploma thesis are prepared
Hydrogenius: FC Applications in Aviation

Airliner

- Substitution of Auxiliary Power Unit (APU) and Ram Air Turbine, onboard water generation for facilities etc.
- Increasing power requirements due to substitution of hydraulic and pneumatic systems by electric systems (more electric aircraft)

UAV & MALE/HALE

- Low noise operations, low thermal signatures, innovative configurations due to electric propulsion system

General Aviation

- Economical, ecological, quiet and comfortable operation, new configurations possible, advanced safety concepts
Fuel Cell: Pros and Cons

- Zero-emission
- High efficiency
- Low noise
- Vibration-free
- Electric drive allows innovative aircraft configurations
- Hydrogen can be produced renewable
- High amount of weight
- High amount of volume
- Widespread hydrogen infrastructure is missing yet
- Complex hydrogen storage and fueling
Hydrogen-Storage

- Low energy-density of the storage system
- High pressure tank is the best solution
- Aircraft fuel tank has a capacity of 11 kWh/kg, a hydrogen tank 2.1 kWh/kg
- Lithium-polymer-akkus have a spec. Energy ~0.16 kWh/kg up to 0.2 kWh/kg
- Without tank we get 12 kWh/kg for conv. fuel and ~ 33.3 kWh/kg for hydrogen
- Tank ZM180 by Dynetek (350 bar)
  - 4.2 kg hydrogen at a tank weight of about 93 kg
  - Caloric equivalent to 16.2 l petrol
Fuel Cell: System in Preliminary Design

Almost every fuel cell system offering 50-70 kW net power and weighing not more than about 250 kg is applicable.

The preliminary design uses as a reference „HY-80™“ fuel cell system of NuCellSys GmbH.

The system delivers 68 kW maximum power and weighs about 220 kg.

Currently new fuel cell systems offer more than 85 kW at weights under 200 kg are state of the art.
Electric Motor and Power Electronics

- Electric motor by **Sineton**
  - three-phase brushless permanent magnet synchronous motor
  - weight: 25.5 kg
  - efficiency: 0.94
  - up to 72 kW at 2500 rpm (peak) and 58 kW at 2300 rpm (continuous)

- Power electronics by **drivetek**
  - weight: 8 kg
  - Communication via CAN-Bus
  - Liquid cooling

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Hydrogenius: Multidisciplinary optimized Configuration

- Separation of „power“ and „propulsion“ generation
- Very large variable pitch propeller for increased efficiency
- Slow turning propeller for low noise operation
- Propeller turns in nearly undisturbed incident flow
- Small and light retractable landing gear
- Fuel cell system enclosed in the airframe
- Optimized aerodynamics, with reduced drag similar to sailplanes
- Side-by-side cockpit for increased comfort and installation space
- Suitable for daily use
Hydrogenius: System Integration

- system modul
- stack modul
- tank
- seat
- avionics
- crashnose
- landing gear

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Hydrogenius: Structure and Safety

- Side-by-side cockpit
  - Large installation space for fuel cell system
  - Variably constructed (weight balancing)
- Light weight sandwich structures

- Safety structure for increased passenger protection
  - Use of carbon-/aramid fiber hybrid fabrics for crash energy absorption
- Backup battery system
- Complete aircraft parachute rescue system
Hydrogenius: Technical Data

- Motor power: ~ 60 kW
- Max. speed: > 270 km/h
- Best climb rate: > 4 m/s
- Take-off distance: < 450 m
- Fuel capacity H2: 4,2 kg
- Service ceiling: > 4000 m
- Span: 16,86 m
- Wing area: 14,10 m²
- Wing loading: 60,3 kg/m²
- Length: 8,11 m
- Empty weight: 663 kg
- MTOW: 850 kg
- Payload: 180 kg
- Certification according CS-22
Hydrogenius: Comparison

- **Hydrogenius**
- **Scheibe SF 25C**
- **HK 36 Super Dimona TT80**
- **WT 9 Dynamic**

**Energy Consumption for 100 km**
- Hydrogenius (green)
- Scheibe SF 25C (red)
- HK 36 Super Dimona TT80 (yellow)
- WT 9 Dynamic (blue)

**Range at 180 kg Payload**
- Hydrogenius (green)
- Scheibe SF 25C (red)
- HK 36 Super Dimona TT80 (yellow)
- WT 9 Dynamic (blue)

**Max. Climb Rate**
- Hydrogenius (green)
- Scheibe SF 25C (red)
- HK 36 Super Dimona TT80 (yellow)
- WT 9 Dynamic (blue)

**Max. Cruise Speed**
- Hydrogenius (green)
- Scheibe SF 25C (red)
- HK 36 Super Dimona TT80 (yellow)
- WT 9 Dynamic (blue)
Hydrogenius: Current Status

**Technical:**
- Preliminary design is completed
- Currently: Construction of wing, fuselage, empennage and retractable landing gear in cooperation with PIPISTREL, coolant system, as well as integration of aircraft parachute system

**Organizational:**
- Acquisition (necessary funds and tangible means)
- Acquisition of a fuel cell system
- Acquisition of the powertrain components
- Public relations and trade show participation (e.g. AERO Friedrichshafen)
Hydrogenius: Cooperation with Pipistrel
Experiences gained from icaré II

icaré II has its maiden flight in 1996 and was completely developed and constructed at the faculty of Aerospace Engineering and Geodesy. Thereby, knowledge in

- unconventional configurations for low energy consumption
- light weight structure
- electrical propulsion systems
- funding via sponsors

Icaré II is still the most powerful manned solar powered aircraft and still in use for research.
Hydrogenius: Sponsoring

- So far sponsored by nearly 20 companies, institutes, foundations and private persons
- Supported by the whole aerospace faculty of the university of Stuttgart with its nine specialized institutes