Elbit Systems

Israel Aerospace Industries

Technion – Israel Institute of Technology
Faculty of Mechanical Engineering
Internal Combustion Engines Lab

MAFAT
Directorate of Defense Research & Development (DDR&D)
Aeronautical Division

Association of Engineers, Architects and Graduates in Technological Sciences in Israel

טכנולוגיות הנעת כלי טייס בלתי מאוישים

הכנס הארצי השישי

חוברת תקצירים

הפקולטה להנדסת מכונות, הטכניון
חיפה
כ"ח טבת תשע"ז
26 בינואר 2017

Conference Program

6th Conference on Propulsion Technologies for Unmanned Aerial Vehicles

Thursday, January 26, 2017
Shirley and Manny Ravet Auditorium, D. Dan and Betty Kahn Building
Faculty of Mechanical Engineering, Technion, Haifa

8:30 – 9:00	**Welcome and Registration**
Opening session	**Chairman: Leonid Tartakovsky,** Technion
9:00 – 9:30	**Welcome:** ***Daniel Rittel***, Deputy Senior Vice President, Technion ***Yoram Halevi*****,** Dean, Faculty of Mechanical Engineering, Technion ***Uri Zvikel*****,** Head, Propulsion Branch, Directorate of Defense Research & Development, MAFAT ***Emanuel Liban*****,** Chairman, Israel Society of Mechanical Engineers
9:30 – 10:00	**Keynote lecture:** **Pushing the efficiency of internal combustion engines and UAV systems** ***Robert Wagner*****,** Director, Fuels, Engines, and Emissions Research Center, Oak Ridge National Laboratory, USA
Morning plenary session	**Chairman: Yitzhak (Itche) Hochmann,** Edmatech (the session will be held in English)
10:00 – 10:25	**UAV platforms in IDF – current usage issues and future trends** ***Shlomi K.*****,** Head, UAV Department, Air Force, IDF
10:25 – 10:50	**Orbital FlexDI: Providing reliable and efficient heavy-fuel IC engines for the UAV industry** ***Geoff Cathcart & J.H.Tubb*****,** Orbital, Australia
10:50 – 11:15	**Coffee break**
Noon plenary session	**Chairman: Hemi Oron,** Elbit Systems (the session will be held in English)
11:15 – 11:40	**Boosting technologies– a theoretical study about limits for small combustion engines** ***Roland Baar*****,** Chair of Combustion engines, Technical University Berlin, Germany
11:40 – 12:05	**Reduction of Development Time and Number of Suppliers using Development Kits for Individual Complete Propulsion Systems** ***Karsten Schudt*****,** Managing partner, 3W International GmbH, Germany
12:05 – 12:15	**Best Student Poster Award Ceremony**
12:15 – 13:40	**Lunch**

Session "New Concepts "	**Chairman: Jacob Feldman,** Israel Aerospace Industries (the session will be held in English)
13:40 – 14:00	**A New Hydrogen-Based PCM Open-Cycle Micro Engine** ***Eran Sher*, A. Lidor, A. Zibitsker and D. Weihs**, Technion, Israel
14:00 – 14:20	**High efficiency split-cycle engine** ***O. Tour, H.B.Tour and Ehud Sivan***, Tour Engine Inc., Israel - USA
14:20 – 14:40	**XMv3 High Efficiency Cycloidal Engine demonstrator** ***A. Shkolnik, Nick Shkolnik***, LiquidPiston, Inc., USA
14:40 – 15:00	**HCCI combustion process in Wankel engine** ***Guy Ben Haim & L. Tartakovsky***, Technion, Israel
Session "Engine Design & Performance – 1"	**Chairman: Michael Shapiro,** Technion (the session will be held in English)
13:40 – 14:00	**Speed reducers design for piston engines** ***Luca Piancastelli***, Department of Industrial Engineering, University of Bologna, Italy
14:00 – 14:20	**Study of knock in a UAV engine** ***Ran Amiel & L. Tartakovsky***, Technion, Israel
14:20 – 14:40	**High-Speed Infrared Imaging for Analysis of a Diesel Engine Supplied with a Premixed Methane-Air Charge** ***M-A. Gagnon[1], E. Mancaruso[2], L. Sequino[2], P. Tremblay[1], S. Savary[1], J. Giroux[1], Vincent Farley[1] and F. Marcotte[1]***, 1 – Telops, Canada; 2 – Instituto Motori, Italy
14:40 – 15:00	**Control system of a small UAV engine** ***Idan Biner***, Aeronautics Defense Systems Ltd., Israel
15:00 – 15:20	**Coffee break**
Session "Engine Design & Performance – 2"	**Chairman: Gil Finder,** Israel Defense Forces (the session will be held in Hebrew)
15:20 – 15:40	**Engineering design considerations in UAV fuel systems** **Ron Raz,** Elbit systems Ltd., Israel
15:40 – 16:00	**Pollutants emission implications of a hybrid propulsion system** ***Erez Mosafi***, Ledico – Bosch, Israel
16:00 – 16:20	**The Independent Modular Drive based on Axial Flux Electric Motors** ***Alexander Sromin***, ALBUS Technologies Ltd., Israel
16:20 – 16:40	**UAV Integrated Propulsion system guidelines & consideration** ***Hanan Kapara***, Elbit systems Ltd., Israel

Session "Alternative Propulsion Technologies"	**Chairman: Ariel Dvorjetski,** Directorate of Defense Research & Development, MAFAT (the session will be held in English)
15:20 – 15:40	**Fuel cell technologies for UAV applications** ***Ehud Galun*****,** Directorate of Defense Research & Development, MAFAT, Israel
15:40 – 16:00	**Electrical Power Sources for Elbit SUAV Family** ***Vladimir Livshits*****,** Elbit systems Ltd., Israel
16:00 – 16:20	**Energy Case Based on Hydrogen Generator** ***O. Dahan, I. Dayee, A. Schechter, Idit Avrahami*****,** Ariel University, Israel
16:20 – 16:40	**A novel hydrogen production method for UAVs fed with fuel cells** ***Guy N. Michrowski*****,** Terragenic, Israel
Closing remarks 16:40 – 16:50	**Leonid Tartakovsky**, Chairman Organizing Committee

Posters session

1. Power Watch Algorithms for Drone Li-ion Batteries

Alex Nimberger & Niles Fleischer, Algolion Ltd.

2. Multifunction Micro Turbine Generators (MiTG) based on mass production turbocharger

B. Arav[1], R. Shulman[1], V. Kaminsky[2], R. Kaminsky[2], A.Filippov[2], A. Lazarev[2], 1 – TurboGEN Technology, Tel-Aviv, Israel; 2 – Turbotekhnika, Moscow, Russia

3. Using Morphological Research to improve Micro Turbine Generators (MiTG)

B. Arav[1], S. Besedin[2], V. Kaminsky[3], R. Kaminsky[3], 1 – TurboGEN Technology, Tel-Aviv, Israel; 2 – Microturbine Technology, St. Petersburg, Russia ; 3 – Turbotekhnika, Moscow, Russia

4. Long Distance Airborne UAV

Shemer Slaav, Technion – IIT, Israel

5. Powertrain for the 2017 SAE Student Car

T. Lipshitz, D. Brudner, I. Hirsh, A. Sacks, A. Asraf, M. Abraham, D. Jacobson, P. Moscovitz, D. Alfisi, O. Kozlovsky, O. Marksheid, P. Ruff, D. Buntin, D. Zadok, R. Baltzan, Technion – IIT, Israel

6. Effects of diesel particle filter on nanoparticle emissions and energy efficiency of in-use buses

R. Fleischman, R. Amiel, L. Tartakovsky, Technion – IIT, Israel

7. Air pollution by nanoparticles in diesel-propelled passenger trains

V. Abramesco, Technion – IIT, Israel

8. Lubricant oil pressure in a Formula-SAE Student race car

N. Dabush, Technion – IIT, Israel

9. Reforming-controlled HCCI process

A. Eyal, Technion – IIT, Israel

10. Design of an optically accessible research single-cylinder engine

N. Dekel, O. Gur, A. Asraf, T. Almogi, D. Epstein, Y. Lung, A. Ben Ari, Technion – IIT, Israel

11. Stagnation-point ignition of a fuel spray-oxidant mixture

G. Kats & J. B. Greenberg , Technion – IIT, Israel

12. Optimization of Extinguishing Powder Dispersal

A. Shalel, T. Bar, D. Katoshevski, Ben-Gurion University of the Negev

Organizing Committee

- *Leonid Tartakovsky*, Faculty of Mechanical Engineering, Technion – Israel Institute of Technology, **Conference Chairman.** Email: tartak@technion.ac.il
- *Daniel Budianu, Israel Aerospace Industries*
- *Ariel Dvorjetski,* MAFAT, Ministry of Defense
- *Jacob Feldman*, Israeli Aerospace Industries
- *Gil Finder*, Israel Defense Forces
- *Yitzhak (Itche) Hochmann*, Edmatech Advanced Engineering Consultants Ltd.
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- *Michael Shapiro*, Faculty of Mechanical Engineering, Technion – Israel Institute of Technology
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Mrs. Ruthie Bouscher, meruthi@tx.technion.ac.il *Phone: +972-4-8292065, Fax: +972-4-8295711*

Best Student Poster Selection Committee:

- *Emanuel Liban,* Israel Society of Mechanical Engineers – **Chairman**
- *Daniel Budianu,* Israel Aerospace Industries
- *Ariel Dvorjetski,* MAFAT
- *Jacob Feldman,* Israel Aerospace Industries
- *Nir Geva,* Elbit Systems
- *Yitzhak (Itche) Hochmann,* Edmatech
- *Michael Shapiro,* Technion

Welcome address

Eng. Emanuel Liban

Chairman, Israel Society of Mechanical Engineers

Welcome to our speakers, guests from abroad and dear audience!

Decade ago we encouraged and supported the ICE Lab of Technion to concentrate on R&D activity in the domain of small and medium UAV propulsion systems instead of being a General IC Engine Lab.
The logic behind it was:
* Israel is one of the leading countries in development, production and operation of a wide range of UAV's and there is a need for R&D and scientific support
* There is quite modest R&D activity in the field of Small UAV propulsion around the World and therefore the Lab of Technion had a chance to take the leadership
Thanks to the efforts and determination **of Dr Leonid Tartakovski, the Chair of this conference,** we witness today that this **Lab** is achieving Local and International Recognition and Reputation.
Three comments for the future:
* The small UAV Industry is moving to Electric, Hybrid and Fuel Cells using different energy sources for Propulsion. This activity is also attractive to R&D in different Academic Institutions and draws the imagination of young people.
It is multidisciplinary engineering and Technion has the opportunity to excel in this Field.
* The Internal Combustion Engines will stay with us for the foreseeable future: With all the research done in the world the Energy density of the complete IC Propulsion System is more than 20 times better than the best Battery based one.
We have to tap and use the huge advances and technologies from the Automotive Industry that succeeded to improve the fuel consumption, to reduce the weight and cost.
The Challenge for the UAV engines is Reliability and ownership costs
* We have to understand that the approach has to be as to a complete new Power Plant taking into account Reliability, Cost and Efficiency considerations of all the components.
The Power plant Designers are struggling to improve the Fuel Consumption by a fraction of one percent while a two digit percent in energy consumption is lost in inefficient components such as propeller, generator, intake and exhaust systems.
This conference will address some of those issues and serve as a stage for new ideas and products.

I wish to all of us to enjoy this day.

Emanuel Liban

Chairman of Mechanical and Aerospace Engineers
Association of Engineers and Architects in Israel

Oral presentations

Keynote address

Pushing the efficiency of internal combustion engines and UAV systems

R. M. Wagner

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Presenting author email: wagnerrm@ornl.gov

Keywords: gasoline compression ignition, low temperature combustion

The one truth in transitioning research and new concepts to application is that innovation will always outpace the state of technology. No better example can be found than in the transportation sector. Since the advent of the internal combustion engine more than a century ago, there have been significant breakthroughs and innovations which have gone unused in production environments due to the state of technology – until now. The combination of new regulations, consumer expectations, and emerging vehicle architectures in the on-road transportation industry has pushed engine technology development at an unprecedented pace. More specifically, the internal combustion engine has undergone a remarkable evolution due to significant advances in engine technologies, sensors, and on-board computing power. The combination of these technologies is enabling unprecedented control of the combustion process, which in turn is enabling robust implementations of high efficiency, low temperature combustion (LTC) modes which blend the best characteristics of more conventional spark-ignition and compression-ignition technologies. A major class of LTC combustion modes are kinetically controlled and governed by the fuel kinetics and in-cylinder reactivity stratification. This dependence on kinetics and reactivity stratification has been a major roadblock to implementation due to the inherent unstable nature of these combustion modes. More specifically, these combustion modes operate on the edge of stability where small variations in engine boundary conditions may result in unintended excursions that lead to undesirable emissions, reduced efficiency, and abnormal combustion events which have the potential to destroy the engine and/or emission controls systems. Oak Ridge National Laboratory (ORNL) has several ongoing research programs focused on the development and implementation of LTC modes on multi-cylinder engines with production-viable hardware. This includes gasoline compression ignition (GCI) modes which are driven by the local in-cylinder stratification of equivalence ratio and temperature to control the combustion process, and reactivity controlled compression ignition (RCCI) modes which make use of two fuels with different reactivity or ignition delay characteristics to further drive and control in-cylinder stratification. Understanding the potential of these combustion modes – as well as understanding emissions challenges – is important to pushing the efficiency of the next generation of internal combustion engines. This presentation will explore the potential of these high efficiency combustion modes and opportunities with UAV systems.

This presentation will also include a perspective on longer-term opportunities for pushing the efficiency of UAV systems with additive manufacturing and high performance computing. More specifically, this will include a discussion of the potential for additive manufacturing for enabling unconstrained engine design and engine-airframe integration for improved efficiency and light-weighting, and the potential for the development of a full three-dimensional high-fidelity virtual UAV environment to accelerate innovation and design.

Acknowledgement
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UAV platforms in IDF – Current usage issues and future trends

Shlomi K.[1]

[1]Head of UAV, Intelligence and EW Department, Materiel Command, Israel Air Force
Keywords: IAF, UAV, Future Trends, Propulsion, Safety , Fleet Management, Big Data

In the last 45 years, the IAF has been operating UAS (unmanned Aerial Systems) for various operational requirements and scenarios.
The UAV Department in the IAF Materiel command is overarching this effort, fulfilling thoroughly its mission: keeping up safety of flight of the UAV platforms, while preserving availability 24/7 for the operational arena. Moreover, as operational demands keep growing, the department is taking responsibility in managing the UAV force build-up programs from the technical side, hand in hand with the Ministry of Defence.
Those programs evolve development of new unmanned systems, together with modernization of aging UAS.

The operational usage for UAS in the Air Force has a long heritage and legacy. Those will be presented in the presentation with some examples for the "DDD" arena – Dirty, Dull and Dangerous missions, emphasizing the need for "Terrain Dominance" missions, being performed today solely by UAVs.

From the engine portion, the Department is leading the UAV engine management throughout the fleet. The challenges of managing operational fleet from the engine engineers would be presented and elaborated in the presentation, emphasizing two focus areas of the department today : On the first side - maintaining Military UAVs, using ICE (Internal Combustion Engines) where safety , withstanding MIL standards is required, while managing advanced maintenance contracts (PBH, CLS). This 50-100 Hp family of Engines is the workhorse of the fleet, and as such requires continuous involvement in engine safety upgrade, with the OEM.
On the other side - Maintaining Mini-UAS, using mostly electrical engines, where simplicity is a mandatory requirement. While preserving safety, the operating concept is different as well as the technical understanding that the MIL Spec for those UAS is not written anywhere.

Looking into the future, the IAF is promoting new concepts in operating the current and future UAVs. Automatic and autonomous safety features of engine controlling, real-time monitoring and "Big Data" analysing systems will become in the near future a requirement from the department for the future safety management concepts. Those capabilities will enable the IAF to enhance the safety of the UAS. We believe that those methodologies will enhance the integration of the UAS in the civil airspace as well. From the energy side, IAF is promoting new concepts into the operational realm, such as upgraded turbocharging up to 35Kft, promoting operational evaluation of Fuel Cell for Mini UAS, and other items that will be shared in the presentation.

The continuous enhancement of the UAS within the Air Force, working closely with the OEMs, will help keeping the local industry as a world leader in the UAS arena. As the operational challenges keep growing, the IAF will be mostly, the first user to adopt the future technologies.

Orbital FlexDI: Providing reliable and efficient heavy-fuel IC engines for the UAV industry

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email: gcathcart@orbitalcorp.com.au
Keywords: Heavy Fuel; Direct Injection; Two-stroke; Rotary; Engine management

Orbital has been successfully developing and integrating a unique air-assist direct injection combustion system for a wide range of engines and applications for more than 30 years. This includes outboard marine engines, motorcycles and personal water craft (PWCs). These products have been successfully commercialised for consumer products operating on gasoline fuels, with the first commercial introduction in 1996 on the range of Mercury Optimax engines.

In more recent times Orbital has been refining this technology specifically to enable reliable operation of Spark Ignition (SI) Internal Combustion (IC) engines using both Kerosene based heavy fuels such as JP5 (NATO F44), JP8 (NATO F34), Jet A, Jet A1, as well as Diesel (NATO F76). The ability of the system to operate on a multitude of fuels has led to the adoption of "FlexDI™" as the brand name for this technology. Traditionally, these "heavy fuels" are associated with operation in either Compression Ignition (CI) engines or jet turbine engines. For UAVs, it is critical that the engines combine high power density (power per unit displacement), low weight, and low vibration signature, as well as high efficiency for long endurance applications. For the small to medium UAVs requiring 3 to 100kW from the engine, the SI IC engine provides a superior platform to meet these objectives when compared to the CI IC engine or jet turbine engines. However, a SI IC engine requires technology to enable reliable, low maintenance operation on heavy fuels.

Typical issues with heavy fuel operation using SI engines are:

- spark plug fouling/carboning
- poor combustion stability across the total load/speed range
- poor startability (a problem exacerbated under cold environmental conditions)
- excessive combustion deposits including ring groove/ring jacking, and
- over-sensitive combustion to environmental conditions including ambient air temperature, engine operating temperature, atmospheric pressure and humidity.

These issues/shortcomings are overcome by adopting the Orbital developed FlexDI™ system. The presentation will cover content including engine test data from both dedicated research and production systems to demonstrate the desired characteristics of modern SI UAV propulsion systems operating on heavy fuels.

At the core of Orbital's FlexDI™ system is an air-assisted direct injection fuel system, capable of injecting a finely atomised liquid fuel spray directly into the combustion chamber of an internal combustion engine. With the lower volatility of the heavy fuel, the very small fuel droplet size provides a greater surface area of the fuel to the increasing temperature in the engine cylinder during compression, resulting in more rapid evaporation of the fuel. This forms a reliable spark-ignitable and combustible mixture. By injecting the fuel directly into the combustion chamber, contact with cold metal surfaces can be avoided which would otherwise lead to coalesce of larger droplets, inhibiting combustion especially at cold ambient or cold start conditions. The FlexDI™ system has shown the ability to cold start down to -30°C within 10 seconds of cranking on numerous applications without the need for any pre-heating of the engine, fuel, or intake air. Conversely, for hot conditions or high load operation, direct injection also allows the fuel charge to be injected later in the engine cycle, limiting the residence time, and effectively quenching the typical "knocking" or uncontrolled combustion of these low effective Octane fuels at these conditions. The inherent properties of the fuel system combined with advanced engine management strategies has proven the system to be highly robust to all ambient conditions, from low to high temperature, and sea level to the application altitude ceiling.

Stratification of the injected mixture can result in improved tolerance to changes in bulk air/fuel ratio or mixture strength. The air-assisted injection system can provide a high degree of charge stratification of fuel as well as air injected into the combustion chamber through the direct injector. This results in a very wide band of operating bulk air/fuel ratio. An optimised system can show a stable combustion operating range of greater than 10 air/fuel ratios when operating on heavy fuels thereby reducing sensitivities to changes in atmospheric conditions, throttle settings, and production tolerances. A single calibration can be used across the complete production run of engines, with no end-of-line or pre-flight adjustment being required. This makes the system virtually maintenance free for the operator.

Fuel consumption for SI IC engines can be greatly reduced with the optimisation and application of the FlexDI™ system. The mechanisms for the reduced fuel consumption can be engine type dependent, taking advantage of the properties of the FlexDI™ system via different means. Whilst the mechanisms for 2-stroke engines are different to 4-stroke engines and rotary engines, the common elements are the knock reduction allowing higher compression ratios when operating on heavy fuels, plus good mixture preparation resulting in high combustion efficiency (maximising the energy content in the fuel) for all these engine types. Typically, the largest reduction in fuel consumption is seen at the light and part load conditions including the areas associated with cruise or loiter depending on the application. Fuel consumption reductions as large as 40% are seen in these areas when compared to the same IC engine using carburettor or electronic port fuel injection (see Figure **1**). The fuel consumption reduction at these conditions can lead to direct improvements in the endurance limits of the air vehicle.

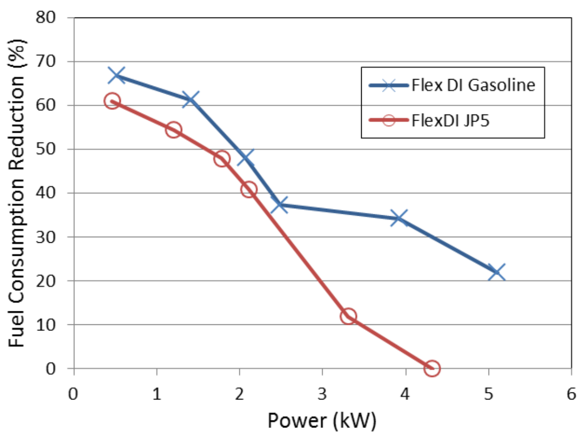

Figure 1 Fuel consumption reduction of a 2-stroke engine compared with carburetor gasoline baseline

It is the authors' conclusion that in order to provide a propulsion solution for the developing and future UAV industry, engine designers need to start with the building blocks that will provide a highly tolerant and reliable system. One such building block is a combustion system that provides the key characteristics of enabling heavy fuel operation, high efficiency and tolerance to operating variables such as temperature, fuel types, mixture strength etc. These requirements are satisfied by the Orbital developed FlexDI™ system.

Acknowledgement

The authors would like to acknowledge the dedicated employees at Orbital Corporation who have directly or indirectly supported the research, development and production activity referenced.

Boosting technologies– a theoretical study about limits for small combustion engines

R. Baar*

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Keywords: Turbocharger; efficiency; operation range; altitude

One of the first milestones of turbocharger development was a flight record. General Electric installed a turbocharger in LePere's biplane. In the year 1919 reached an altitude record for aircrafts of 10.092 meters. Since the development of Diesel engines in passenger cars Turbochargers became a mass product and now are one of the most important technologies of combustion engines that affect power, efficiency and emissions. Compared to a supercharger the main advantages of the turbocharger are the use of exhaust energy, its small size and the easy way to control boost pressure. Ships use combustion engines with turbochargers to a maximum power of nearly 90.000 kW, whereas the smallest passenger car turbocharged engine has a power of 40 kW. The range of specific power within current engines is 40 to 100 kW/l.

The development of small boosting devices is limited because of customer demands for very small engines on the one hand and thermodynamic limits on the other hand. Flight applications have moreover other demands compared to passenger car applications. The main purpose of the presented study was a theoretical approach of the limits and options for boosting devices in a power range below the standard. The work was performed using the engine process simulation tool GT power. A well-known and calibrated engine model was modified to analyse different scenarios. Sub-models have been modified according to known scaling rules. The following variations have been investigated:

- Power between 20 and 200 kW
- Cylinder number of 1, 2 and 4
- Turbocharger and supercharger boosting

Comprehensive analyses will be shown concerning the influence of the boosting technology on power and fuel efficiency in different flight and altitude situations. One of the most important issues was the extrapolation of unavailable boosting devices. This has been done based on the experimental experience of a wide range of turbochargers and superchargers. Besides the effect of pulsations have been considered as the exhaust pulse frequency has a strong impact on the turbine operation.

The presented results have general character and show the limits of boosting devices in small combustion engines.

Reduction of Development Time and Number of Suppliers using Development Kits for Individual Complete Propulsion Systems

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Keywords: complete propulsion units, development services, individual propulsion concepts, gas engines, heavy fuel (HF) engines

In a drastically changing market environment in which many small and mid-sized firms as well as start-ups are active in addition to large corporate groups, the R&D environment plays a decisive role for rapid market development with the quick, efficient development of new UAV systems. Whether a fixed-wing concept, a copter, or a VTOL system is involved is unimportant here.

Propulsion using gas or heavy fuel (HF) internal combustion engines continues to present a particular challenge for aeronautical engineers precisely in regard to engine configuration and engine cooling as well as their positioning within the aircraft. These hurdles can be circumvented through outsourced development of the entire propulsion units.

Development time, the number of suppliers, and the market launch of new UAV systems can be thereby significantly abbreviated. Cost savings based on less error-prone development are moreover possible.

Experience, technical know-how, and the testing possibilities of the R&D units play a decisive role particularly during the development of individual propulsion concepts being created on the basis of customer requirements. Decisive here is that all of the development work is delivered from a single source. Thus in addition to development processes, communication processes within project management can also be streamlined.

The development work here includes the creation of propulsion systems consisting of a gas or HF internal combustion engine, generator with or without starter, fuel injector, control electronics, engine mount, propeller, air guide, and engine cover.

The savings potential, greater development speed, and reduced error potentials can be illustrated using examples and calculation models. These facts and figures are based on empirical values, which 3W International GmbH has been gathering since introduction of the development service for complete propulsion units.

Downstream services such as service and maintenance, as well as possible scaling of the UAVs, are also examined closely in the development service and aligned with the end customer's potential requirements. For instance, the sporadic use of different engines in a standardized system environment is thus possible. UAVs can thus be developed that can be deployed on the market based on their propulsion options thereby offering the end customer broad added value.

A New Hydrogen-Based PCM Open-Cycle Micro Engine

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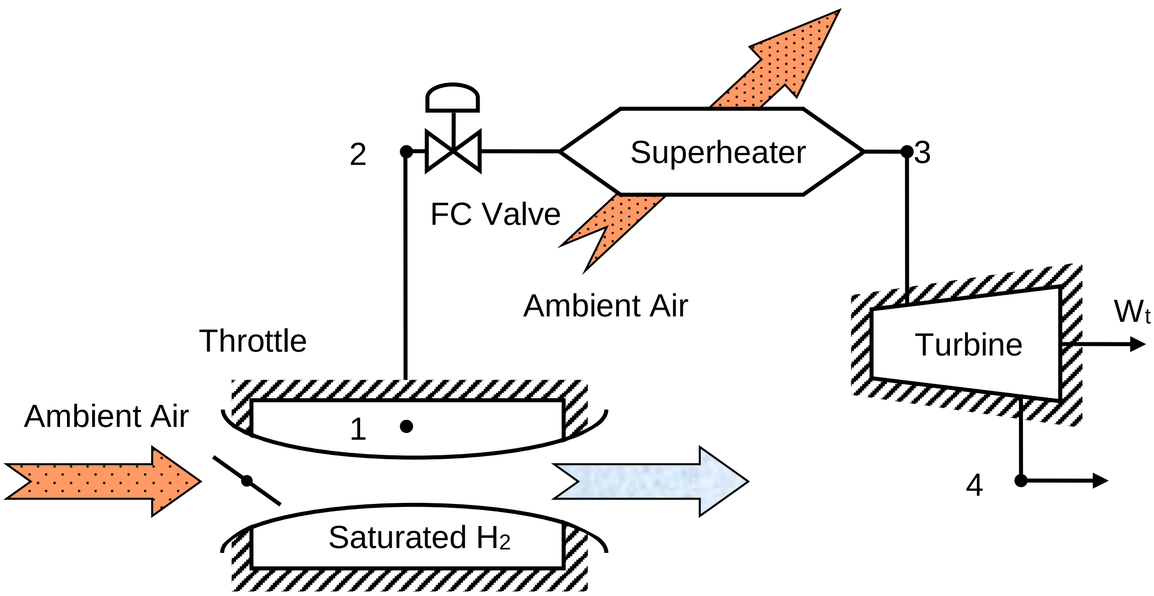
Keywords: Micro engines, Micro PCM energy storage, Hydrogen-based PCM, Energy conversion

A PCM open-cycle engine is a distinctive cycle that uses the ambient air as its hot reservoir and an on-board hydrogen storage as its cold reservoir. Here we present new concept for a hydrogen-based PCM open-cycle micro engine having high specific energy, with applications in MAV systems, among other possible uses. The new PCM open cycle engine, is capable of overcoming two major problems of PCM engines: the significant energy losses at partial loads, and the power control inherent difficulties. The present new concept decouples the liquid boiling heating process from the vapors superheating stage. While this system is inherently unstable (as other PCM systems), it is shown that it can be effectively controlled with a simple PID controller.

The general design of the new system is presented in the figure. The key to the present proposed configuration lies in controlling the in-container heat flux to support the gas generation rate on demand.



Schematic diagram of the new hydrogen-based PCM Open Cycle System

Acknowledgments

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High efficiency split-cycle engine

O. Tour[1, 2] H.B.Tour[1, 2] and E. Sivan[1, *]

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[2]Tour Engine Inc.
* Presenting author email: ehud@TourEngine
Keywords: Internal combustion engine; split-cycle engine; fuel efficiency; reduced emissions;

The Tour engine splits the conventional 4-stroke cycle between two cylinders: The first cylinder (denoted the Cold-Cylinder) is used for intake and compression. The compressed air is then transferred from the compression cylinder into an intermediate chamber that serves as a combustion chamber as well as a gating mechanism. A second cylinder (denoted Hot-Cylinder), serves as a power cylinder.

Theoretically, splitting the four-stroke cycle of the internal combustion (IC) engine between two cylinders, rather than executing the complete cycle within a single cylinder, has the following significant efficiency advantages:

- **Keeping colder temperatures at the Cold-Cylinder.** As the Cold Cylinder does not host combustion, the cylinder's temperature is kept low, which enables more efficient compression while maintaining common compression ratios.
- **Increasing the Hot-Cylinder (power cylinder) expansion ratio**. This feature increases the conversion of thermal energy to kinetic energy. A larger expansion ratio also permits less deliberate heat rejection (active cooling) as the larger expansion acts as a cooling mechanism.

Over the years, several other split-cycle designs have been proposed (first attempt made by Brayton cycle engines back in the 19th century) but none has matured. Those engineering efforts could not overcome inadequate working fluid transfer between the two cylinders that led to poor combustion and thermodynamic losses. They also failed in designing a reliable, properly sealed and none-restrictive inter-cylinder crossover chamber.

Tour Engine Inc. has developed a unique inter-cylinders gas exchange mechanism that fully addresses and resolves the above-mentioned shortcomings of other split-cycle designs. Figure 1 show, recently built, state of the art, 1 kW engine. This engine is commercially aimed to power, within the U.S.A, tens of millions households.

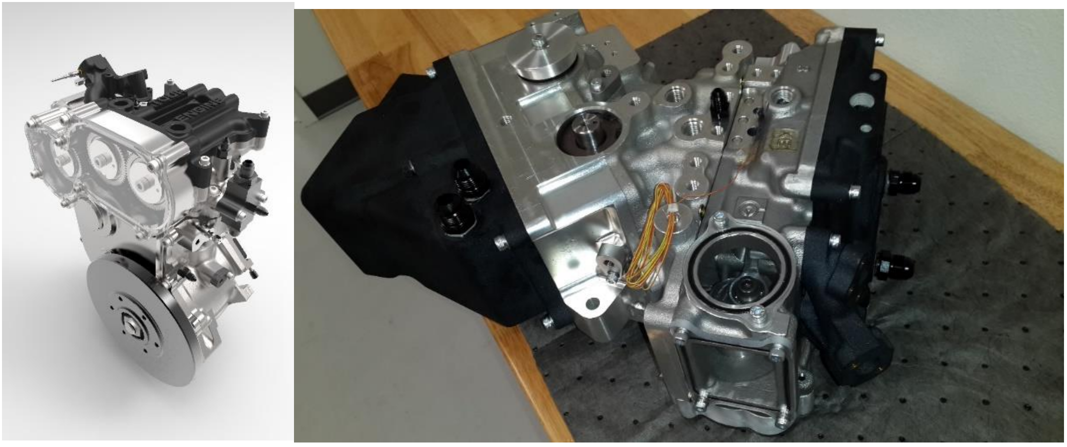

Figure 1. State of the art 1 kW engine: Left. Computer Image. Right. Assembled engine

Computer simulations, predict considerable performance gain over current state of the art engines (above 40% BTE at conventional gasoline operating conditions). In addition, the design utilizes existing engine hardware and components and hence can be easily adopted by the industry.

The Tour Engine's IC engine is a platform technology that revolutionizes the way IC engines are used. It can be used in transportation and stationary power generation applications and has the potential to significantly reduce global fuel consumption and pollution levels.

The Tour engine has a superior power to weight ratio. As other Split Cycle Engines, it fires each revolution rather than every two crank revolutions therefore its power to weight ratio is at least equals to common four stroke engines. However, the smaller Cold-Cylinder dimensions together with the lighter materials it requires (because of the lower temperatures it needs to endure) gives an edge over other engines. This fact, together with the fuel usage efficiency, makes the Tour Engine ideal for Aerial vehicles.

Acknowledgement
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XMv3 High Efficiency Cycloidal Engine demonstrator

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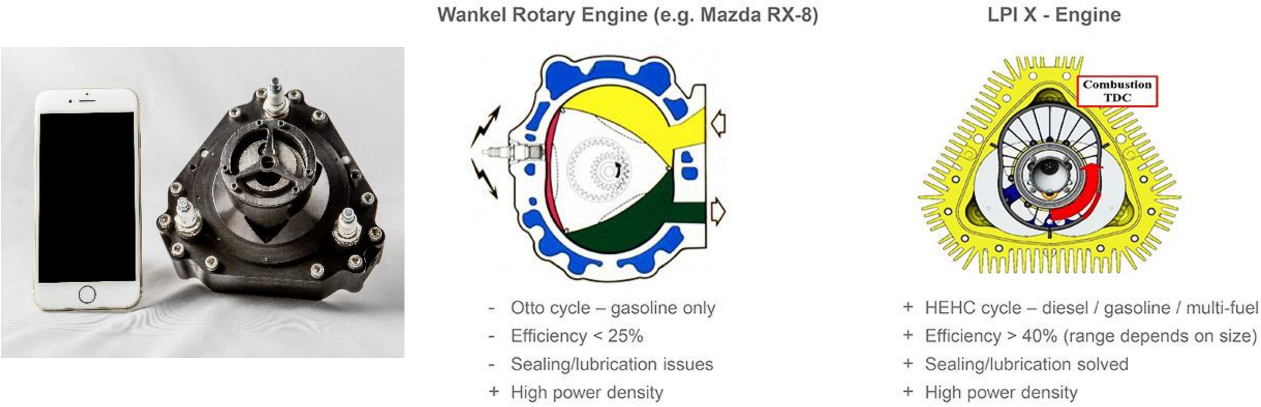
Keywords: Rotary Engine; High Power Density, High Efficiency, Low Vibration



Rotary engines offer high specific power for propulsion, with the simplicity of having just a few moving parts. However, these engines are typically limited by poor combustion characteristics, poor fuel economy (reduced endurance), and poor lubrication / durability.

This talk describes the development status of the XMv3 engine, a novel 4-stroke rotary engine which operates on an optimized thermodynamic cycle dubbed the High Efficiency Hybrid Cycle (HEHC). The HEHC thermodynamic cycle combines: 1) high compression ratio; 2) constant-volume combustion; and 3) over-expansion. This combination offers high thermodynamic efficiency with low exhaust pressure / temperature / noise. In addition to this, the new rotary architecture offers very high power density and low vibration.

The 'X' engine geometry utilized by XMv3 is similar to an inverted 'Wankel' type rotary engine. While the X engine retains the advantages of high power density and vibration-free operation, the new architecture overcomes some of the traditional weaknesses inherent in the Wankel. Specifically, the X engine offers improved combustion, efficiency, blowby, lubrication and durability characteristics over the Wankel. Furthermore, the X engine has 1.5 combustion events for each rotation of the shaft, which reduces peak torque on the propeller / frame.

The 70cc SI XMv3, produces 3 bhp at 10,000 rpm while weighing 1.7 kg. The engine is simple, having only two primary moving parts, which are well balanced to prevent vibration. This talk describes analytical and experimental studies carried out on the XMV3 prototype, including variation of compression ratio, combustion chamber shape, SI and CI operation on diesel, spark plug type, rotor port geometry, and integration of the engine into go-kart demonstration vehicle.

HCCI Combustion Process in a Wankel Engine

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Keywords: HCCI ; Wankel Rotary Engine; UAV Cruise ; Combustion Efficiency

As the Wankel (rotary) engine enters its 7th decade, it remains a strong competitor in the midsize unmanned aerial vehicle (UAV) market, mainly due to its inherent power-to-weight ratio advantage over conventional piston engines. It has however fallen out of favour with mainstream automobile producers, largely due to its higher specific fuel consumption and difficulty in meeting new and ever stricter emission regulations.

The homogeneous charge compression ignition (HCCI) combustion process might hold the key to improving Wankel engine efficiency. In HCCI combustion, a premixed homogeneous charge of fuel and air is introduced into the engine and auto ignited upon reaching its auto-ignition temperature. HCCI combustion is characterised by simultaneous combustion of the premixed charge, resulting in a heat release process which is faster than in conventional spark ignited (SI) combustion (See fig. 1). Initiating this combustion close to top-dead-center (TDC) results in higher combustion pressures and a cycle, which resembles more closely the constant volume heat addition of the theoretical Otto cycle (fig. 2).

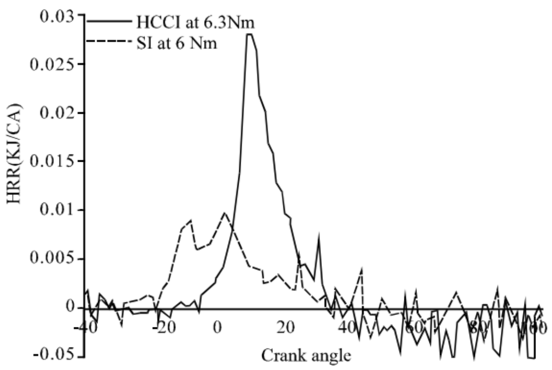

Fig.1: Comparison of SI and HCCI vs. combustion Heat release rates combustion (adapted from N. Noraz al-Khairi *et al* (2011)

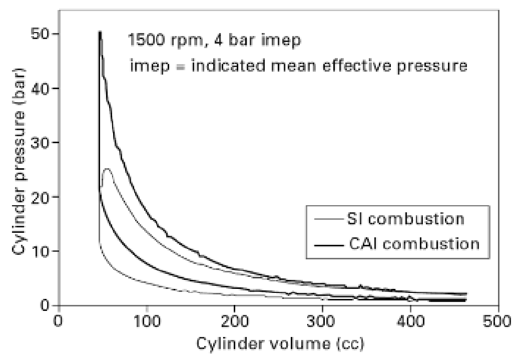

Fig.2: In cylinder pressure traces volume, for SI and HCCI (adapted from Zhao (2006))

HCCI is however not without its challenges, the main challenge being that of combustion control. Since HCCI is a process driven by chemical kinetics and utilizes a premixed homogeneous charge, combustion timing cannot be controlled directly as in spark ignition (SI) engines (via spark) or in compression ignition (CI) engines (via injection timing). Much research effort has gone into finding suitable control strategies for HCCI with varying degrees of success. Another challenge of HCCI is a narrow operating range, limited by ringing (a destructive occurrence of pressure waves caused due to high pressure rise and heat release rates) at high loads, and misfiring (when the fuel does not receive enough energy to reach its auto-ignition point) at low loads. These limits are avoided in some engine prototypes, by operating the engines as SI or CI engines where HCCI combustion is problematic.

A way to reduce the control problem in a UAV is to select an operating regime in which engine load is kept fairly constant or is varied within a small operating range. UAV cruise is an example for such a regime, where a small engine operating range can be selected based on available data. In other UAV operation regimes (take-off, high speed operation etc.) the engine can be switched back to normal SI or CI operation.

The authors believe that the Wankel engine design might favour HCCI operation. First, as no flame front exists per-se (combustion occurs simultaneously in the entire volume), the problems associated with rotor trailing edge squish flow prohibiting flame propagation are averted. Second, as HCCI combustion is rapid, taking place in a smaller amount of crank angle (CA) degrees, heat losses associated with Wankel combustion chamber design are reduced. Moreover, the same turbulent flow which prohibits flame propagation in SI combustion, coupled with the heat transfer during the compression stroke could possibly result in thermal stratifications within the combustion chamber. The temperature gradients resulting may cause different chemical reaction rates throughout the charge, resulting in a sequential auto-ignition with lower heat release rates (Saxena *et al* (2013)). A lower heat release rate is beneficial in extending the HCCI high load limit.

The aim of this research is to validate theoretical feasibility of HCCI operation (which has been shown possible in the CFD simulation work of Resor (2014)), attempt to achieve HCCI operation in select cruise operating points of a given UAV engine (where compression ratio, combustion chamber design, fuel introduction technique etc. remain unchanged), and to find out whether HCCI operation increases engine efficiency. This was done by adopting a simulation approach previously developed by Tartakovsky *et al* (2012) to simulate HCCI combustion. To avoid the ringing limit, a conservative minimum lambda value of 1.3 was chosen for all HCCI simulations.

Representative UAV cruise operating points were chosen based on data provided by the UAV manufacturer. As it is expected to be able to operate the engine as a normal SI engine or a stratified charge rotary engine (Walker *et al (1987)),* the fuels explored are the primary reference fuels iso-octane (gasoline equivalent) and n-heptane (diesel fuel equivalent).

Results show that HCCI combustion is possible with both iso-octane and n-heptane fuels, and at an altitude of up to 15,000 ft. However, because of the constraints described previously (the basic engine design remains unchanged), and the lower air density at the altitude simulated, auto ignition could only be achieved by intake air pre-heating or introduction of hot recirculated exhaust gasses (EGR). As both of these methods reduce volumetric efficiency considerably, the theoretical efficiency gain could not overcome the adverse effect of decrease in intake charge density, and thus the operating range power demand could not be reached. This problem was enhanced when using iso-octane as the fuel, since its auto ignition temperature is higher and thus more pre-heating or hot EGR is required. These results are unacceptable for a UAV, limiting use of such an HCCI engine to power generators or range extenders of electric cars.
In order to solve the problem of low intake air density, a turbocharger was incorporated into the model. This modification was also based on previous work done by Tartakovsky *et al*, who attempted to restore engine power at high flight altitudes. With the addition of turbocharging, power demands of the operating range could now be met.

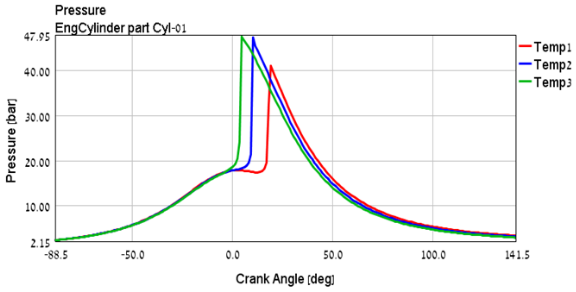

Fig.3: HCCI combustion of iso-octane: typical pressure vs. crank angle

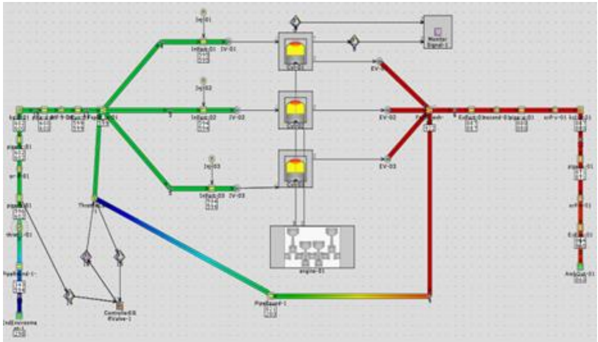

Fig.4: GT- Suite model overview

The brake efficiencies of the turbocharged SI engine and the turbocharged HCCI engine were explored. Results for a representative operating point within the UAV's cruise range at two altitudes can be seen in fig 5-6. The results show a 22.7% increase in efficiency at the lower altitude, and a 9.8% increase at the higher altitude. HCCI efficiency is lower at the high altitude operating point since higher engine speeds were needed in order to reach the power requirement, and this caused HCCI ignition advance to a less than optimal point, slightly before TDC. As the efficiency of the turbocharged SI engine was simulated for wide-open throttle (WOT) conditions (the waste-gate was varied in order to control power), HCCI efficiency improvement is expected to be even higher in the realistic case where a throttle is used.

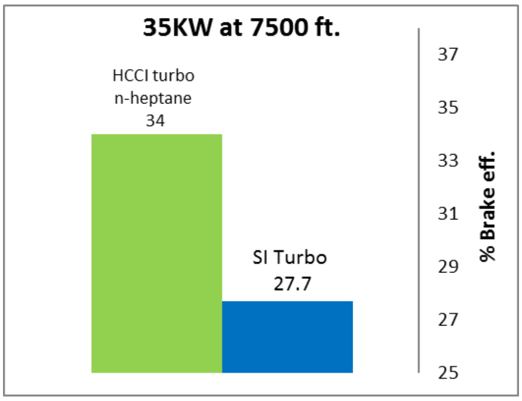

Fig. 5: Brake efficiencies for turbocharged HCCI and SI engines at WOT and 6150 rpm, producing 35KW at 7500 ft.

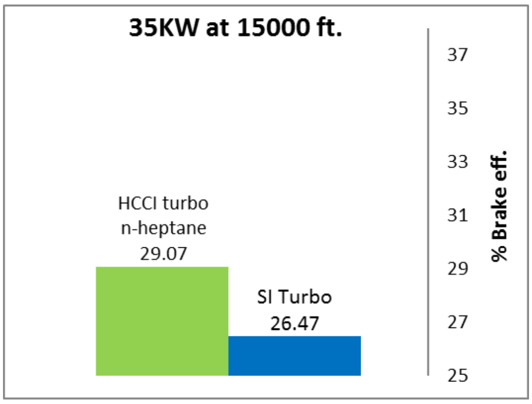

Fig.6: Brake efficiencies for turbocharged HCCI and SI engines at WOT and 7050 rpm, producing 35KW at 15000 ft.

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Speed reducers design for piston engines

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Keywords: Speed Reducers; Gears; UAV; Piston engine

The power speed reduction unit (PSRU) is the device that is loaded by the generating unit and the thrusters. Propeller induced, gyroscopic and inertia loads are extremely important for PRSU bearing selection and life evaluation. Engine power become easily a secondary factor for bearings and housing design.

Propeller induced, gyroscopic and inertia loads are extremely important for PRSU bearing selection and life evaluation. Engine power become easily a secondary factor for bearings and housing design. For this reason, it is important to select the best bearing assembly for the specific application with the required propeller. After a general discussion about PRSU and housing design, a very simplified method for bearing life calculation is introduced in this paper. It is based on similar, proven and extremely successful design of existing PRSUs. This method compares the life of these design with the new one. Aerobatics and general aviation loads are also compared. This paper demonstrates that the selection of a CFRP fixed pitch propeller for aerobatics keeps the load approximately to the same level of a general aviation aircraft. This is true in the case of plywood-reinforced off-the-shelf propeller for the general aviation load history. Aluminum alloy propellers are to be discarded for aerobatic use.

For each scenario in the load model of Table 1, the designer will calculate the gears, the bearings and shafts loads. Then he will calculate the cooling/lubrication requirements. The designer will verify that the housing will contain the displacements within the required limits. Finally, the hot stress point of the housing will be kept under the maximum allowed for fatigue life.

Table 1. aerobatic loads.

Operation	Power	RPM	Load	Time
Takeoff	100%	100%	100%	5 %
Climb	100%	100%	100%	20%
Fast Cruise	90%	86%	90%%	20%
Cruise	80%	82%	85%%	53%
Aerobatics	100%	100%	100%	2 %

A very simplified method for bearing life calculation is introduced in this paper. It is based on similar proven and extremely successful design of existing PRSUs. This method compares the life of these design with the new design. Aerobatics and general aviation loads are also compared. It is demonstrated that the selection of a CFRP fixed pitch propeller for aerobatics use keeps the load approximately to the same level of a general aviation aircraft with a plywood-reinforced off-the-shelf propeller. A numerical example validates the design method.

Study of knock in UAV engine

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Keywords: Knock; knock control; SI engine;

The knock phenomenon is a limiting factor in the development of spark ignition (SI) internal combustion engines (ICE), and various ways for knock detection, prevention and mitigation have been suggested over the years to deal with this problem. Aviation platform have increased sensitivity for the knock phenomenon effects, because occurrence of knock can lead to destruction of the entire platform in case of an engine failure. Aviation platforms also operate in low pressure environment, and turbochargers are frequently used to improve the performance at high altitudes. Although turbocharger provides the benefits of increased power output, improved fuel consumption and the ability to design s downsized engine, they also increase the engine's intake air temperature due to higher pressure ratio needed as the air density drops, and thus, making the engine prone to knock occurrence. [1] In addition, environmental conditions such as altitude, initial ground temperature, humidity and flight velocity can change drastically in short period of time in aerial platforms, Therefore, it is important to be aware of the combined effects of the aforementioned factors on the emergence of knock following takeoff and to have tools to monitor and predict knock occurrence. In this computational study, a novel approach was suggested for evaluation of the combined influence of engine's operating parameters and environment conditions on knock occurrence in reciprocating SI turbocharged engines. This method can be used for risk management and also for assessing engine's predicted performance in various conditions during flight and prior to takeoff and also for taking measures to prevent knock at real-time operation.

A computer model of Rotax 914 engine was built using the GT-SUITE software. The Rotax 914 is a 4-cylinder SI four-stroke turbocharged engine with 2 spark plugs per cylinder, which is in wide use in aerial platforms.

The accuracy of the model was validated by comparing the values of the main performance parameters measured in the laboratory to those obtained from the computer model. The difference between the model predictions and the real engine experiments was less than 3%.

For knock prediction, the auto-ignition delay time (induction time) was calculated using the Livengood–Wu integral (eq. 1) [2] with the Douaud and Eyzat correlation (eq. 2) [3]:

$$I(t)=\int_0^t \frac{1}{\tau}dt \qquad (1)$$

$$\tau = 17.68\left(\frac{ON}{100}\right)^{3.402} p^{-1.7}\exp\left(\frac{3800}{T}\right) \qquad (2)$$

The auto-ignition delay time - τ (milliseconds) is the time for which a homogeneous mixture must be maintained at temperature, T (Kelvin), and pressure, p (atm), before it auto-ignites. The integral border – t, is the elapsed time from the start of the end-gas compression process to the auto-ignition time. Knock is predicted to occur when the integral attains the value of "1".

For knock intensity analysis we used the knock index (KI) expression suggested in [4]:

$$KI = 10000u\frac{V_{TDC}}{V}\exp\left(\frac{-6000}{T}\right)\max(0,1-(1-\phi)^2) \qquad (3)$$

Where: KI – Knock index; u- Percentage of cylinder mass unburned; V_{TDC}- Cylinder volume at top dead center; V – Cylinder volume; T – Bulk unburned gas temperature (K);Ø - Equivalence ratio in the unburned zone.

The simulations were performed using the DOE (design of experiments) method, in which influence of the entire possible combinations of defined parameters (Table 1) on knock appearance and engine power were analyzed at various rpm at maximum torque regimes. In our case, brake power and KI in Cylinder 1were the response functions that were investigated.

Table 1. Base input parameters for DOE.

Input Parameter	Range	Steps
Humidity	0-0,8 @Sea	4
Altitude	0-15000 feet	6
Initial ground temperature	240-320 K	6
Octane number	90-95 RON	4

When applying OLS surface fit with quartic resolution at 5500 rpm engine speed (maximum speed of engine continues operating) the following polynomial equation, which describes the KI response surface is obtained:

$$\begin{aligned} KI &= 65.27 + 62.0788\cdot W + 38.8053\cdot X - 17.7505\cdot Y - 30.8715\cdot Z + \\ &+ 24.812\cdot W * X - 29.318\cdot W\cdot Y - 14.8442\cdot W\cdot Z + \\ &+ 3.9465\cdot X\cdot Y - 10.3989\cdot X\cdot Z + 3.9962\cdot Y\cdot Z - \\ &- 3.6938\cdot W^2 + 7.8628\cdot X^2 + 3.2122\cdot Y^2 + 3.2076\cdot Z^2 - 28.329\cdot W^3 - \\ &- 8.5049\cdot X^3 + 0.5554\cdot Y^3 + 0.1221\cdot Z^3 - 12.5565\cdot W^4 + 2.0141\cdot X^4 \end{aligned} \quad (4)$$

Where: W – Ground temperature; X – Altitude; Y – Relative humidity; Z – ON.
In the same way, the polynomial equation, which describes the brake power response surface is as follow:

$$\begin{aligned} P &= 70.8611 - 9.5966\cdot W - 2.9888\cdot X - 0.9785\cdot Y - 0.3955\cdot Z + \\ &+ 3.6374\cdot W * X - 1.5921\cdot W\cdot Y + 0.0186\cdot W\cdot Z + \\ &+ 0.6899\cdot X\cdot Y + 0.0282\cdot X\cdot Z - 0.0186\cdot Y\cdot Z + \\ &+ 0.03\cdot W^2 - 1.6254\cdot X^2 - 0.073\cdot Y^2 + 0.0154\cdot Z^2 - 2.2539\cdot W^3 - \\ &- 1.2378\cdot X^3 + 0.0166\cdot Y^3 + 0.0213\cdot Z^3 - 0.349\cdot W^4 + 0.5514\cdot X^4 \end{aligned} \quad (5)$$

In conclusion, the effects of the different possible combinations of environment conditions and operating parameters on knock intensity and brake power (or any other related response) can be expressed in one equation at a certain regime. It is possible to create a set of equations describing the entire operation range of an engine, and to include the parameters of a knock control treatments for use when knock alert is received, in order to close a control circuit and to eliminate knock occurrence. Such equations can be used prior to takeoff for knock risk evaluation based on flight plans. Future research should include creating a complete set of knock intensity equations for a specific platform, and implementing it for use in real-time flights.

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High-Speed Infrared Imaging for Analysis of a Diesel Engine Supplied with a Premixed Methane-Air Charge

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Keywords: Infrared; Imaging; Internal Combustion Engine; Diagnostics; High-speed

Efforts are continuously made to improve internal combustion engines' (ICEs) efficiency. Lowering fuel consumption and reducing soot formation are among the challenges being addressed when seeking to improve engine designs. Among the strategies used to improve combustion efficiency is the use of a dual-fuel configuration engine where natural gas (CH_4) serves as the primary fuel while a "pilot" amount of liquid diesel fuel is used as an ignition source (Korakianitis, 2011). The pilot liquid fuel normally contributes to only a small fraction of the engine power output (Papagiannakis, 2004).

In this work, ICE characterization was carried out on an optical engine where the piston's crown has been replaced by a sapphire window. High-speed infrared imaging of the engine was carried out at 26 kHz by looking at a 45° fixed mirror located in the extended piston axis. Air was also replaced by a premixed air-methane charge in order to improve combustion and lower the amount of soot deposits. The different phases of a combustion cycle, i.e. intake, compression, fuel injection, working stroke and exhaust, were investigated using four different spectral filters (broadband, CO_2 red-spike, through-flame and hydrocarbon). The selectivity provided by the infrared spectral filter allowed following different chemical as the combustion reaction progress. The use of multiple spectral filters also allows the observation of diesel fuel under both liquid and gaseous phases as shown in Figure 1. The results illustrate how high-speed IR imaging can provide unique insights for research on ICEs.

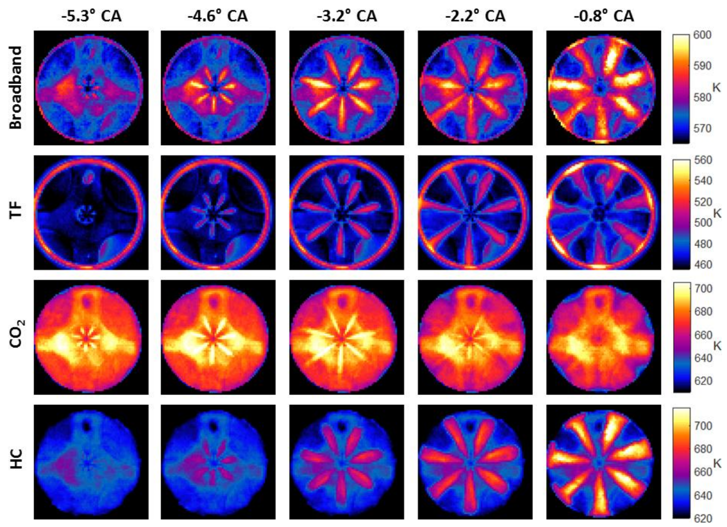

Figure 1. Various stages of the diesel fuel injection seen through different infrared spectral.

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Small UAV Engine Management System based on an Automotive ECU

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Keywords: UAV; ECU; Engine Management;

UAV Engines should be able to operate faultlessly in various operation scenes, in various altitudes, in extreme cold environment on one hand and extreme hot environment in the other hand. Therefore, an engine control unit (ECU) became compulsory in order to meet the necessities of the multiple customers.

The main challenges in a small UAV engine control are; the small components, especially the miniature electronic fuel injection (EFI) system, the light-weight small dimensional sensors and actuators, and a proper engine management unit to control and activate them all.

An automotive, verified ECU is a good starting point to be improved to meet the requirement of an aerial vehicle. Nevertheless, a lot of modifications have to be done e.g. adding an extra dimension to the fuel injection maps and to the ignition map using the barometric pressure or manifold pressure, definition and integration of suitable fall-back behaviour for all the sensors and actuators and operation of redundant (dual or triple) systems to avoid single point of failures (SPF). This method allow the engineer to develop a management unit to meet his needs without giving away the common knowledge that was gained over years of automotive ECUs development. For example, the automotive ECU can handle charge temperature variation but has to be modified to handle charge pressure variation. Therefore, an extra look-up table is added to compensate for the pressure.

Table 1. Theoretical Fuel Injector Pulse Width Variation with Pressure (@ constant CHT, RPM)

Pressure [10^4 x N/m^2]	Injector Pulse Width [ms /ms in sea level]
Sea Level – 10.13	1
8.988	0.88
7.95	0.78
7.012	0.69
6.166	0.61
5.405	0.53

Table 2. Theoretical Fuel Injector Pulse Width Variation with Ambient Temperature (@ constant CHT, RPM)

Ambient Temperature [C]	Injector Pulse Width [ms /ms in 20C]
-20	1.16
-10	1.11
0	1.07
10	1.03
20	1
30	0.97

Engineering design considerations in UAV fuel systems

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Keywords: UAV engines, Fuel system for UAV SI engines

SI (Spark Ignition) engines are still very common on UAV platforms, ranging from 2 stroke, 4 stroke to rotary (Wankel). The fuel system is part of both the platform and the engine. In this lecture I shall concentrate on the UAV side, and describe a few design examples: filtration architecture, pumping redundancy and proof of design tests.

The requirements for UAV fuel systems may be complex as for military & civil aviation, but the engines are generally RC model airplane or general aviation piston engines.

The fuel system for a UAV engine is designed to support the unique UAV requirements, mainly, long missions that cause the fuel weight to be a major part of the platform weight. High altitudes up to 40K feet, and operation in extreme temperatures ranging from -54 °C caused by altitude, to +70 ˚C caused by solar radiation, special maneuvers such as launching, landing in net, or parachuting, and short turnaround intervals.

Fuel system design considerations come from several areas: The engine requires specific fuel flow and pressure, stable and good quality (no air or water contamination), maintenance constraints of fast refueling or engine replacement, platform safety and reliability, weight and balance.

Fuel system architecture takes all the above considerations and combines them with the engines specific requirements such as carburation, port or direct injection, different types of fuels like Mogas Aviation gasoline, or heavy fuel.

The main parts of a fuel system are: tank, pumps, regulator, filters, breathers, check valves, quick disconnects, and tubing. Fuel system sensors: level, pressure, flow, temperature, and composition.

Fuel system requirements effects on design, examples:

- Pressure: regulator, closed loop on the pump, pulsation damping, return line.
- Redundancy: pumps, regulation, sensors, injectors, tanks
- Volume efficient packaging: weight & balance, transfer between tanks, flexible tank, unusable fuel.
- Maneuvering: collection tank, suction logic, control of sloshing, foaming.
- Maintenance: fueling with air removal system, quick disconnect, transparent filters, fuel level, special tools, drainage, sampling.

Discussion of the main problems in fuel systems: cavitation, pressure regulation.

Pollutants emission implications of a hybrid propulsion system

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Keywords: Hybrid propulsion; Pollutants emission; Hybrid configurations

The ECE R100 specifications are valid for the safety-relevant requirements for the electric drives of road vehicles belonging to class M and N with a design-dependent maximum speed of more than 25 km/h and which are equipped with one or more electric drive motors that are not connected continuously to the power supply as well as for meeting the requirements of their high voltage components and systems that are connected galvanically to the high voltage bus bars of the electric drive. These regulations do not apply to the safety-relevant requirements of road vehicles after a collision.

The known hybrid propulsion configurations are shown in Fig. 1.

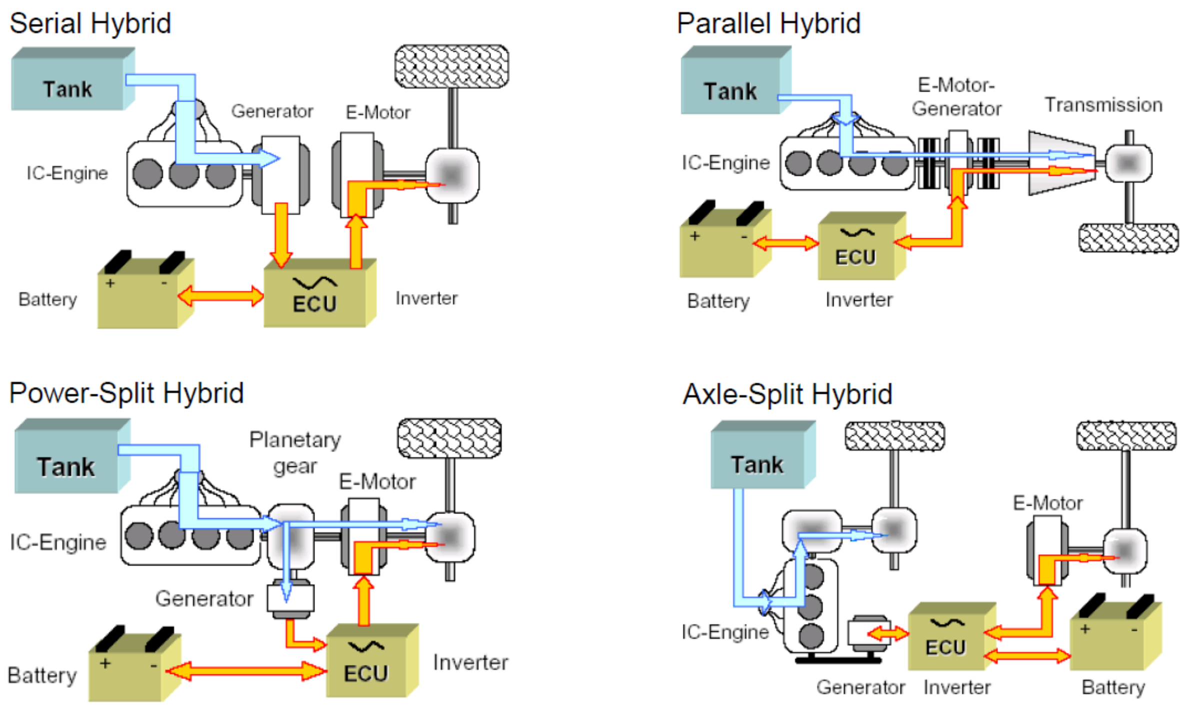

Figure 1. Hybrid propulsion configurations

The overview of various types of electric energy storage technologies is shown in Fig. 2

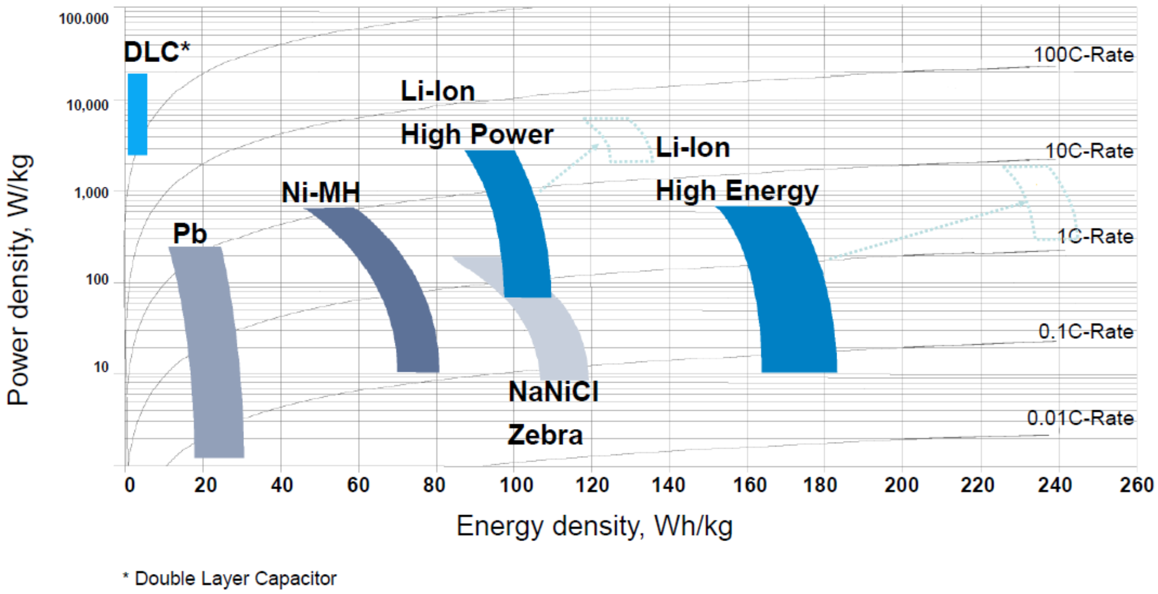

Figure 2. Various electric energy storage technologies

The following functions can be integrated in the inverter:
 -AC/DC - DC/AC converter, converts DC into AC and vice versa.
 -Amplifies HV-battery-voltage and vice versa
 -DC/DC converter reduces HV-Battery-voltage to 12 V on-board network voltage
 -Drive of the MG
- Drive of electric A/C compressor

The Independent Modular Drive based on Axial Flux Electric Motors

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Keywords: axial flux; coreless; controllable clutch; independent module; electric drive

The independent modular drive (Fig. 1) has been developed for full electric and hybrid propulsion systems where redundancy, compactness and platform design flexibility are the key features. It is an electric drive comprising of a number of closely stacked concentric electro-mechanical modules to apply torque to a common drive shaft through controllable clutches.

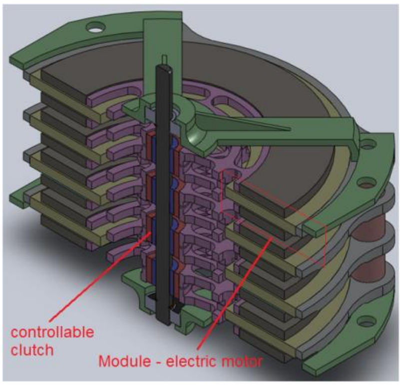

Figure 1. The independent modular drive scheme.

The control system provides following functions during the drive operation:
(1) controllable distribution of the torque between the modules
(2) controllable mechanical/electric connection/disconnection of the modules
(3) mechanical self-disconnection of a stuck or damaged module from the common shaft.

Each module is a stand-alone disk-shaped axial flux coreless electric motor based on a proprietary ALBUS stator and rotor technology (patents are pending). It is very compact and has no magnetic circuit speed losses and thus achieves excellent efficiency and very high power-to-weight ratios at high speeds. To be used with slow speed propulsion systems, the drive can be equipped with a speed reducer.

A prototype of propeller drive 4x12kW (20 kW peak) equipped by a 1:3 planetary speed reducer was built and partially tested. Below Table 1 concludes the performances:

Table 1. The prototype performances

Parameter	**unit**	**value**
Cont. output module power @ max. speed	kW	12
Max. output module power @ max. speed (1 min)	kW	20
Max. speed (not reinforced version)	rpm	6,000
Module weight	kg	3.0
Overall weight	kg	16.5

Acknowledgement

This work was supported by the CSO of Israel.

UAV *Integrated* Propulsion system guidelines & consideration

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Keywords: UAV engines, UAV Propulsion system, Integrated Propulsion system

In this lecture I'll describe the many aspects that have to be taken into account when we design an Integrated UAV propulsion system.
The UAV propulsion system is different from the General Aviation (GA) propulsion system by some aspects and parameters that are influenced from a wide range of operational requirements such as long endurance, high electrical power generators, high altitude and geographical unique conditions.
Other parameters that we should deal with is the O-level technician that commonly handles the UAV on the flight line instead of GA engine technicians, so our goal is to design a low maintenance system that will help to reduce maintenance effort and downtime.
The propulsion system should be designed to include all propulsion system components and auxiliary systems as a single power pack; in general it's connected to the engine frame and can be removed from the UAV as one piece.
The UAV propulsion system should be equipped with various control functions that in the GA world are manually handled by the pilot such as carburettor icing, or Air filter blocked by dust, sand or ice.
The UAV propulsion system is located generally at the aft part of the air vehicle to reduce contamination effects for the avionic and the mission systems that are located in the aircraft payload bays. This arrangement needs consideration for cooling air ducts that serve sub-systems such as intercooler, coolant radiator, high power generator, and engine naturally hot spots like a turbocharger.
The UAV Propulsion system should be designed to minimize the interface points with the air vehicle.
However, the mandatory main interface channels, similar to the turbine engine, are still the fuel lines, control lines and electrical power lines.
The UAV propulsion system is designed to be started and operated in extreme low temperatures that may render the use of special auxiliary heating systems.
De-icing Systems can be integrated in the system and can use the residual heat from the exhaust gas and coolant.
The UAV propulsion system safety considerations should include fire detection, suppression and elimination, using dedicated sensors and fire extinguishing systems.
In my presentation I will give examples for all the issues I mentioned above.

Fuel cell technologies for UAV applications

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UAVs and Fuel Cells are two rising technologies that are about to join. Both the technologies and joining them will be discussed. UAVs as technology that is seeking for new efficient energy solutions and Fuel Cells as well known technologies with new matured advanced keys. Unmanned vehicles for; aerial, ground, and underwater are progressively important fundamentals of defense mission abilities, in its application, mission requirements, performance, and benefits are priority considerations in choosing vehicle electric power options. Some unmanned vehicles are currently powered by batteries; fuel cells as other technologies, including solar energy systems and internal combustion engines, are also options. Among the alternatives, fuel cells have excellent, the best, capability to provide benefits critical to the success of unmanned vehicle missions. They can deliver more power per unit weight while reducing a vehicle's heat signature and noise. A fuel cell's uninterruptable power density can reduce vehicle size and extend mission endurance. Such improved capability could justify a cost premium. The design and fabricate a fuel cell system for application as a power source in UAVs. The fuel cell system consists of a fuel cell stack, hydrogen generator, and hybrid power management system. Various fuel cell technologies as PEMFC stack with an output power of hundreds watt range are reviewed. Comprehensive review of fuel cell science and engineering is about to be presented including up-to-date review of fuel cell fundamentals; current versus history; competing technologies; types; advantages and challenges some electrochemical principles; system evaluation factors.

Electrical Power Sources for Elbit SUAV Family

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Keywords: Unmanned Aerial Vehicles; Electrical Power Sources; Batteries; Fuel Cells

ISTAR is a subsidiary of Elbit Systems LTD and its UAV enterprise. ISTAR UAVs includes the Hermes family of tactical UAVs and the Small-UAV family.
Electric driven SUAVs are usually powered by rechargeable Li-ion batteries. Aside numerous advantages of the Li-ion battery's technology, such as: high power and energy density, high efficiency, modularity and a very small environmental impact; there are several disadvantages, like a long charging time and safety issues.
Moreover, Li-ion technology is about exhausted its potential in terms of theoretical energy density. For larger energy densities and as a result longer UAV endurance time, a different technology required.
A fuel cell (FC) is an electrochemical device that converts the chemical energy of fuel oxidation directly into electricity, and thus is not limited by Carnot's Law.
A fuel cell operates much like a battery - electrical energy is formed in a process that involves reducing oxygen at the cathode and oxidizing a fuel at the anode. A solid (or liquid) electrolyte is placed between the anode and the cathode. But unlike a battery, where all the electrochemically active materials are stored inside its case, in fuel cells all the chemically active materials (oxygen/air and fuel) are stored outside and fed in when needed. Thus, a fuel cell will generate electricity as long as there is a supply of fuel and oxygen.
In the recent past, an official test flight was carried out in Israel. The test flight was without precedent, since it is the first ever test of a fully operational system using the fuel cell based power system, including take-off and recovery with an operational payload integrated onboard. Equipped with the fuel cell system, Skylark® I will offer its users enhanced flight duration, doubling the current endurance of the Li-ion battery powered UAV.
In this lecture, several major types of batteries and fuel cell systems, in general, and hydrogen on-board storage and supply systems, in particular, will be reviewed.

Energy Case Based on Hydrogen Generator

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Keywords: Hydrogen Generator, Fuel Cell, On-demand energy

ABSTRACT

This research project presents an integrated application of innovative generator - portable, friendly and efficient for the purpose of producing hydrogen on-demand for use with a hydrogen-based fuel cell. Hydrogen is produced in a chemical reaction between water and hydride material. The system controls the rate of mixing ingredients, regulating the reaction's temperature and pressure in the generator to gain the desired output hydrogen flow rate. The hydrogen produced is fed to the fuel cell to generate electrical power that is stored in the battery. The energy case was designed for all-terrain vehicles, considering typical off-the road dynamic vibrations. This Energy case has the potential to increase the battery range and life-span by hundreds of percent in mobile applications (electric bicycles, electric vehicles, drones, etc.)

INTRODUCTION

When it comes to environmental and safety, electrical vehicles are considered preferred alternative for gasoline-derived vehicles. However it requires reliable and efficient solutions for energy storage. The main applications use batteries (such as lithium-Ion) for energy storage, however they are often limited due to low power density (ratio of energy to weight) and driving range [1] . It is also confined to areas with electrical power supply. This is a limitation for All-terrain Vehicles (ATVs), vehicle used in agriculture or constructions, electrical bicycles or other off-the road electronic vehicles. The use of hydride solutions for on-demand hydrogen production was previously suggested by several groups [2-6], however none of these groups showed a continuous hydrogen production in portable devices with high energy efficiency, since they mix sodium solutions with catalyst.

In this study we suggest an innovative and efficient method in which the sodium powder is mixed with the water. This method allows higher energy densities/ the system suggested is a range extension system that will allow off-the-road electrical vehicles to be work even at areas far from electrical power. The energy case we suggest is based on fuel cells and on-demand hydrogen generator.

OBJECTIVES

The goal of this study was to design and build a portable, reliable, light, efficient and easy-to-use for long duration system which will produce on-demand energy, with consideration of environmental parameters and design requirements, and to implement the system in coordination with the mechanism for generating electricity.

METHODS

The designed independent and portable system performs a complete integration of hydrogen-based fuel cell and a generator, which produces hydrogen on demand. The system is demonstrated on a dynamic tool, which is in constant motion.

The system includes a mechanical hydrogen generator based on chemical reaction of hydrate sodium and water. This innovative method allows very high power density (of up to 10 gr of Hydrogen for every 100 ml of water), which supplies a constant power of 30Watt for long durations (up to 8 hrs) with a low weight of about 3 Kg. products replacements is easy and safe. The input components are tap (or even sea) water and sodium- which are relatively light, safe to carry and have long shelf life. The reaction products (other than water and hydrogen) are environmental friendly and can be recycled if necessary.

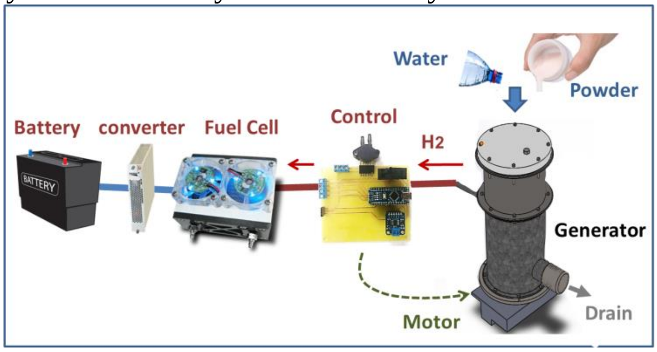

Figure 2: Schematic Description of the Energy Flow in the Energy Case

Other components are a standard PEM fuel cell, a control unit, pipeline and power converter. The control system is sensitive to changes in pressure, flow rate, voltage and current. The case includes also a suspension and restraint vibrations systems (for off-road vehicles) and a condenser to prevent water evaporation (which might decrease in system efficiency).
A schematic diagram of the energy flow is shown in Figure 1 and a draft of the energy case is shown in figure 2.

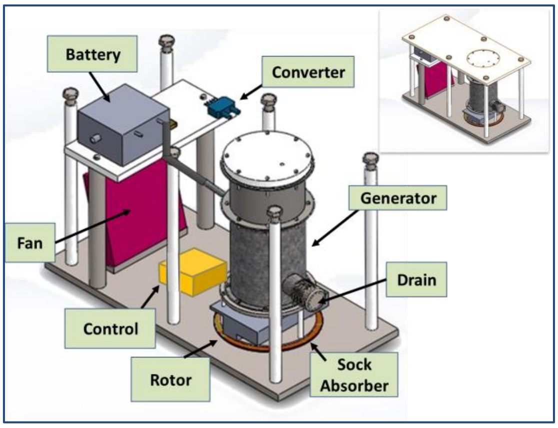

Figure 3**: Description of the Energy Case and Components**

PRELIMINARY RESULTS

Figure 3 shows preliminary measurements including pressure, temperature, flow rate, and motor RPM. As shown in the graphs (Figure 3), the system holds a fairly constant desired flow rate. These values vary depending on the RPM and temperature - which activates the mechanism for introducing the salt generator. These results confirm the viability of the required desired flow rate, the quantity of which will enable the operation of the fuel cell and power generation capacity.

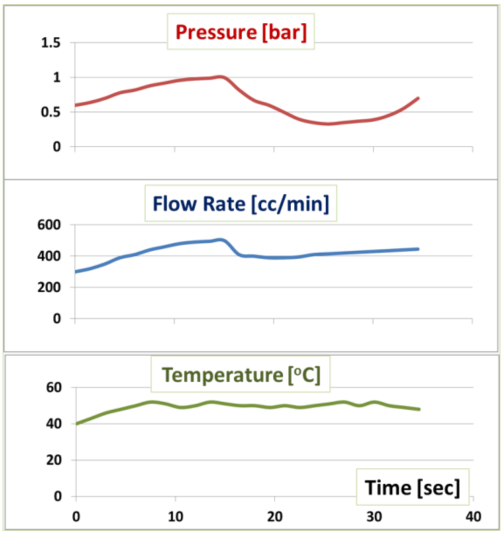

Figure 3: Preliminary Measurements Results

CONCLUSIONS

This project demonstrates the feasibility and efficiency of the designed energy case. The system was proven to work and produce on-demand hydrogen-derived electricity continuously for a period of 8 hours. Although the generator meets the requirements of the project and beyond, further tests improvements are still required.

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Development of a revolutionary hydrogen fuel – a potential for a fuel-cell propulsion

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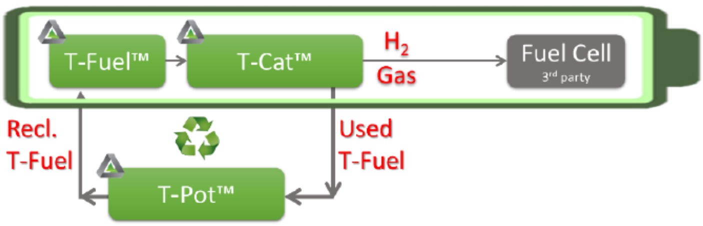
Energy storage reinvented. Terragenic's revolutionary hydrogen energy storage technology enables a system with five times the energy capacity of standard lithium batteries and with only few seconds charging time. Using the developed technology an e-UAV's flying range can be significantly extended assuming same system volume and weight. Our innovative, patent pending, hydrogen-on-demand system is rich in energy while being safe, green, cost competitive and easy to handle, so to give distinct system and integration related benefits.
The T-Fuel next generation (Gen-2), currently under development, features three times higher energy density than that of Gen-1.
Terragenic's technology application space is vast and includes energy storage systems for electric vehicles, drones, phones and off-grid/back-up storage and power generation devices.

Brief of the lecture topics	• Status of TerraGenic activity: Established in 2014, the company completed development of its technology, e-bike (250w) and 10kW hydrogen generators prototypes, and the submission of fundamental patent applications. • Fuel basic characteristic overview • Added value of the T- System™ for fuel cell system • Potential use-cases/users • Next generation T-Fuel, x3 higher energy density
Brief of market focus	Terragenic's technology application space is vast and includes energy storage for electric vehicles, UAV, e-bus, e-bikes d (prime focus) and others including off-grid/back-up storage and power generation devices (secondary focus).
Brief description of the technology and key competitive advantages	TerraGenic's hydrogen storage for air born systems/automotive provides safe, cost competitive and energy rich storage solution. 

Utilizing its innovative, patent pending, hydrogen-on-demand T-Fuel™ and T-Cat™ (generation) system, we deliver a hydrogen battery that is:
1. Highest energy density
2. Safe (non-explosive, non-flammable)
3. Green (fully recyclable)
4. Cost effective

Poster presentations

Power Watch Algorithms for Drone Li-ion Batteries

*Alex Nimberger, Ph.D., Co-founder and CTO & Niles Fleischer, Ph.D., Co-founder and CEO of Algolion Ltd., Israel
*Presenting author email: alex@algolion.com

Introduction:

The use of lithium ion batteries (LIBs) is constantly expanding with double-digit increase every year. These high energy and power rechargeable batteries are well suited for powering drones (UAVs / RPAS). One system that we are developing is for preventing lithium ion batteries from exploding. Algolion is developing a breakthrough solution to the critical safety problem of Li- ion battery fires based on our predictive intelligence algorithms that provide for the first time a week advance warning of potential safety events.
An additional category of algorithms, Power Watch(C) that we are developing will let operators of UAVs choose in real time how they want to utilize the remaining capacity of the LIB to best meet mission requirements.
Each UAV development engineer/operator has three wishes:

1. To increase the time of flight (endurance);
2. To perform all tasks of the mission successfully;
3. Moreover, and most importantly, to return the drone safely to base.

The Problem

At present, in UAVs in flight generally only the battery voltage is measured which is a very poor and only a rough estimate as to how much longer the UAV can remain in flight since the voltage profile of LIBs during discharge is relatively flat. Also, since the operatinal mode may not be constant since the flight conditions may change, it would be helpful if a technolgy was avaialable so the UAV operator could get in real time an accurate estimation of the remaining flight length available based on expected use patterns.

The Solution

Algolion's Power Watch (patent protected) avoids range anxiety and mission failures since it is used to predict the useful remaining battery life under various flight scenarios. The estimated energy consumption needed to achieve the flight plan is compared to the calculated energy and power (rate capability) of the LIB. Steps can be taken to match the remaining flight plan parameters with the actual remaining capacity. The "Power watch" application in UAVs will improve the reliability of the system, extend the endurance of the drone and increase the number of charge-discharge cycles of the battery, thereby lowering the cost of operation.

Multifunction Micro Turbine Generators (MiTG) based on mass production turbocharger

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Keywords: MiTG; APU; Turbocharger; CHP

Systems based on Micro Turbine Generators (MiTG) technology, with target performances such as: electric power ≤ 15-30 kW, rate speed in range of 80,000-200,000 RPM, specific power no less than 0,3-0,5 kW/kg, power density no less than 140-160 kW/m3) have a higher potential in some common applications [1,2,3,4]:

- in hybrid propulsion systems Unmanned Ground/ Aerial /Sea Vehicles and Mini City Vehicles (design Plug-in Hybrid Electric Vehicle – PHEV), in application of Micro Range Extender Generator (MiREG). The appliance of MiTG provides: 1) in the designing phase – reduction of the vehicle weight and energy consumption for the movement, especially for corps vehicles. It'll let enhance power reserve (autonomous operation duration), payload mass and PHEV map stability in difficult conditions; 2) – in the upgrading phase – possible substitution ICE REG to MiREG (power-equal but with lower weight and smaller dimensions) and similar results achievements;
- in different Vehicles, such as Auxiliary Power Unit (APU), parking heaters and coolers. Due to them cars always are ready to use and living conditions for the crew are as required;
- in residential sector, are Combined Heat (Cooling) and Power (CHP и CCHP) Systems. They operate with alternative energy sources and provide independent power supply, primary fuel saving (fuel efficiency up to 85%), CO_2 emissions reduction and 15-30% lower costs of electric power for consumers;
- as exhaust gas energy recover of powerful diesel and fuel cells.

Modern low power MiTG is similar effective in comparison with ICE-generator, but has simpler design (one rotating part) and other technical and economic advantages (multifunction and possible collaborating with other power plants, high power rating, low weight and small dimensions, multifuel capability, environmental safety, reduction in operating costs, etc.). However, the main problem of increasing in MiTG competitiveness and demand is the necessity to reduce their price from 900-1000 $/kW to 300-400 $/kW [5,6].

Authors design series of multifunction MiTG (el. power 3-15 kW), Figure 1. Undoubtedly mass production can reduce cost production. However, there is another way for reducing MiTG price and quick launching into manufacture [4,7]. There is a strategy MiTG based on turbocharger mass production (more than 60 million per year). The similarity of construction and maps of MiTG turbocharger and turbine and small-size turbocharger, gives reason for their unification. Modern turbochargers are low mass-dimension (3-8 kg), high efficiency and reliable in difficult operating conditions. They are of low price and lowest exploitation costs. Their construction meets the requirements specified for MiTG.

Several concepts are designed. «TurboGEN Technology» presents MiTG concept (el. power up to 2 kW, rate speed up to 120,000 min^{-1}, propane fuel) unified with automotive turbocharger by «Garrett», Fig.1. Using the permanent magnet alternator «Bental Motion Systems» company [7].

According to authors, hybrid electric turbocharger has high MiTG potential appliance (el. power up to 10 kW, rate speed up to 100,000 min^{-1}). It is designed by "Turbotekhnika" on basis of turbochargers of mass production and passed all the necessary tests, Fig. 1. [8].

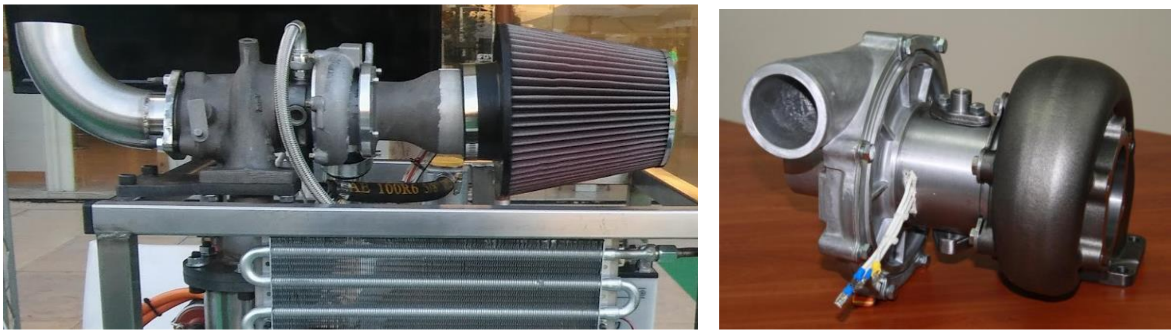

Figure 1. MiTG «TurboGEN Technology» concept (a) and
hybrid electric turbocharger (b) «Turbotekhnika»
on basis of turbochargers of mass production

Thus the perspective appliance of mass production of turbochargers as a basis for MiTG is determined and confirmed in the designing phase. In case of success unification will let produce a row of multifunctional low-power generators, which will have the demanded weight-size parameters and resource along with low price and little exploitation costs.

Acknowledgement
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Using Morphological Research to improve Micro Turbine Generators (MiTG)

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Keywords: MiTG; constructive layouts, morphological synthesis

MiTG have considerable development potential. They can have different structural layouts and basic parameters. It is necessary to develop the principles and methods of Morphological Research to improve MiTG. MiTG Morphological Research (Structural Synthesis) let output a reasonable structural layout and compose aggregates, taking into account labor input reduction, assurance of reliability, reducing the price and exploitation costs on servicing and repair. Largest Synthesis effect may be achieved in the initial design stages [1]. Structural Synthesis methods include the development of morphological tables (numerous alternative solutions). Analysis of alternative solutions set allows to define the area of rational solutions for the next design stage - parametric optimization.

MiTG consists of two main units: high-speed gas-turbine engine, made together with electric generator, and power converter generating high-frequency alternating current into the current of demanded parameter [2]. Radial flow compressors, radiaxial turbines, permanent magnet synchronous generators are applied. The main part of MiTG is integrated rotor consisting of compressor, turbine and generator rotor. This is the only rotating part (frequency up to 200,000 RPM and more), Fig.1a. Usual gas (air) bearings are used, they don’t need to be serviced and oiled.

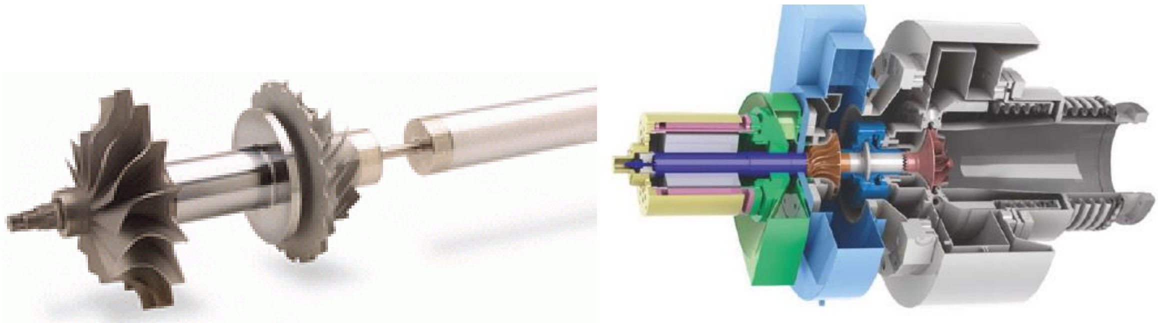
Morphological Synthesis MiTG allows to select three structural rotor layouts. They are efficiently equal but differs by labor input and difficulties to provide the assurance of reliability:

1) - usual layout of factory made MiTG (el. power 30-200 kW) [2] with rotor and generator stator before the compressor. Generator is cooled by opposing air flow, that comes into compressor. Generator rotor shaft is connected with compressor shaft by means of elastic element of low bending stiffness. This connection balances inaccuracies of fabrication. Turbocharger and generator are balanced separately. Other ways of connections are also possible, for example, hirth coupling, implemented by «Microturbine Technology» [3], Fig.1b. It is necessary to exclude the intrusion of rotor bending vibrations natural frequency into the interval ±30 % of running frequency. It’s impossible to provide the assurance of MiTG reliability without this task solution. In concept the layout with some modifying let use turbochargers and generators of mass production. The layout is implemented in «TurboGEN Technology» concept (el. power up to 2 kW) [4]. During the starting mode generator works motor mode.

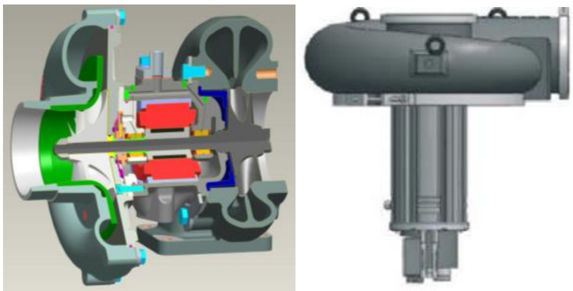
2) - layout using hybrid electric turbochargers. Their peculiarity is integration rotor generator/electromotor and turbocharger rotor shaft, and also mounting the stator in the bearing body. Production of the original bearing box is required, however it is possible to use turbine and compressor wheels and casings of mass production. The layout is implemented, for

example, in the concept of «Turbotekhnika» (el. power up to 10 kW) [5]. During the starting mode generator works motor mode, Fig.1c;

3) - layout using power turbine, connected with high-speed generator [6]. This layout is implemented in «ETC system» concept by «Bowman» (el. power up to 60 kW), Fig. 1d.



a) b)



c) d)

Figure 1. Structural layout of MiTG: typical rotor design (a); MTG-100 «Microturbine Technology» (b); electric turbochargers «Turbotekhnika» (c); «ETC system» by «Bowman» (d)

We carried out a detailed analysis of structural layouts on the basis of expert estimates and calculations. Rational structural layouts must comply with the appointment, application conditions, requirements and modern upgrading trends. Analysis reveals their advantages and disadvantages, potential defects and ways to prevent from them.

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Long Distance Airborne UAV

Shemer Slaav - Technion*, Student (8) project - Technion

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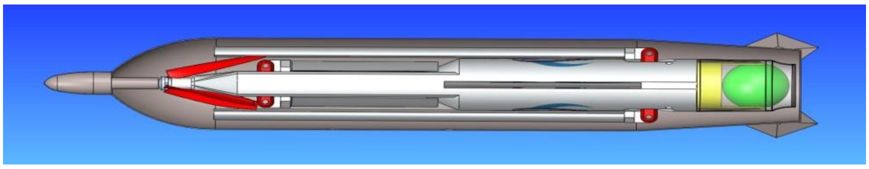
Keywords: UAV, Long Range, Airborne,

The described system is about the need to have line of sight (visual, IR, RF) intelligence in real time and at long distance (>1,000 miles) above hostile territories.
Currently there are two known method in order to achieve the above mentioned needs. Low earth satellite (LEO) and very large long distance UAV (NNN).
However, both have disadvantages. The LEO "visits" the target periodically. It cannot "hover" about the target. Use of Geo Stationary Satellite (GEO) cannot have the required resolution and it is not affordable for most countries. While the long range UAV is also expensive and not affordable. Furthermore, due to the limited speed of such UAV the deployment at long distance may take 6-8 hours. Meaning, it may not be available to collect intelligence when such information it needed.
The proposed system is to cover the gap. A specially designed UAV will be packed into an existing cluster bomb. It will be cries close to the desired target by fighter aircraft (F 16, F 15 or any other) at a cruise speed (~500Kt). At a desire location the cluster bomb will be dropped at a standard qualified manoeuvre. After a short delay, a retarding parachute will be deployed. Upon arrival to the desire air speed, the UAV will be released from the cluster bomb and will unfold the air surfaces (wings, rudder, etc). It will start the engine and fly to the target acting like observation UAV/ It will transmit the information via data link. Upon completion of task or using all its fuel' it will self destroy itself. Using this method will shorten the time to target by 1:5 (aprox) as compare to long distance UAV.
The project was design by a group of students during their BCS study at Faculty of Aeronautics and Space Sciences to the following spec:

- Max. velocity 100 $[kts]$
- Flight ceiling 10 $[Kft]$
- Max. payload weight 15 $[Kg]$
- Min. loiter 9 $[Hrs]$
- Climb rate 100 $[ft/min]$
- Rate of turn 5 $[°/sec] - 15[°/sec]$
- Angular resolution 0.1 $[Mrad]$

Fit for a standard cluster bomb



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Powertrain for the 2017 SAE Student Car

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Keywords: Formula; SAE; Engine ; Powertrain

The Technion Formula SAE team is designing the fifth iteration of its vehicle. This year the team is significantly changing the concept of its vehicle, specifically within the powertrain team. The team is changing the Suzuki GSX-R600 engine to a KTM 450-EXC engine. The reason for the change is a long term goal to reduce weight from the vehicle and due to the intake restrictor that the Formula Student rules require, there is more potential for the weight to power ratio of the vehicle.

The powertrain team is responsible for: intake, exhaust, fuel, cooling, engine management, gear shifting, telemetry and researching a turbocharger for the following year. The team's goal is to significantly reduce the weight of all engine systems and have a total weight of 60kg for all engine systems including the engine block itself.

The intake system is composed of: an air filter, throttle body, restrictor, plenum and injector. In order to level the playing field at the competition, a 20mm restrictor on the air intake is required. As a result, simulations and analysis of the intake manifold geometry is crucial to get the most power out of the engine. In order to reduce the choking effect of the restrictor, geometrical analysis using GT suite and CFD (flow simulations) are used. To reduce the weight of the intake system, it will be produced out of carbon fiber, requiring extra strength analysis to ensure that it can withstand the vacuum inside the manifold.

The Formula Student rules have a strict limit on noise levels allowed for the engine. The noise is limited to 103 db(C) at idle engine speed and 110 db(C) at a pre-determined engine speed based on the bore of the engine and size of the cylinder. As a result, an analysis of noise and acoustics is required in order to design an exhaust manifold that is both quiet but reduces the amount of backpressure in the system to reduce negative effects on the engine's power.

Due to the change in the engine type, all of the cooling parameters must be determined from scratch. Currently the team is working on building a working GT Suite engine model to determine the geometry for the radiator and fan. While the engine simulation is being built, the team is using the data of the original radiator and fan and performing CFD analyses to determine the effect of changing the cooling system's location from the front of the vehicle to the back.

The fuel team's goal for 2017 is to design a lightweight, yet reliable system. The entire system has a maximum weight of 2.5 kilograms excluding fuel. The team has been doing comprehensive research to determine which components yield the greatest weight savings while meeting the requirements of the injection of fuel into the engine. The system is made up of a fuel tank, fuel pump, filter and pressure regulator.

The team is designing a complex shaped tank unlike previous years where a simple tank was designed for ease of manufacturing. Due to the fuel tank's location under the driver, a complex shape allows for freedom in the design of the tank and allows the team to take advantage of all the space available. Initial force and flow simulations have been done to ensure that the tank is strong enough and will always maintain a continuous flow of fuel despite the lateral forces that act on the car while steering.

The transfer of power from the engine to the wheels is achieved using a differential connected to the rear axle. In order to cut weight from the suspension system and reduce the weight of the braking system, the team is looking into a single braking system for the rear of the vehicle. The team is currently testing a system to put a disk and caliper on the differential, allowing for one caliper and disk to stop the rear part of the vehicle. Currently the team is doing dynamic testing to determine whether the system overheats and whether it affects the dynamics of the vehicle as with differing forces between the wheels (while turning), there could potentially be a different in the braking power between the wheels.

This year the gear shifting team is planning an electronic system instead of a pneumatic system, specifically for weight reduction. The electric system will weigh less than half of what previous pneumatic systems weighed while providing more torque to shift gears. The team's goal is to shift gears in 100ms to allow the driver to seamlessly continue in the event. This year the team is also planning to use ignition and fuel cut functions to shift gears without actuation of the clutch, allowing for a significant reduction in the overall weight of the system.

The telemetry team is responsible for sending vehicle data to an external computer allowing team members to monitor the vehicle during the competition and give feedback to the driver based on the vehicle's state. In recent years, the Formula team had difficulties during the endurance event such as the engine overheating and trouble with fuel consumption. By monitoring the vehicle during the event, the team can let the driver know if he/she should slow down due to engine overheating or fuel consumption numbers that could prevent successful completion of the event. The team is designing a program from scratch that will provide all the data necessary to the team members monitoring the car during the event.

The final aspect of the engine team is that which is responsible for testing the engine, tuning it and the designing the engine's electrical system. Due to the change in the engine, the team must build new fuel and ignition maps to improve the power and torque output of the engine. As a result, the team is building an engine testing stand that will be used to initially start the engine and then tune the maps. The engine management and electrical team is also looking to significantly lower the weight of the electrical system and increase its reliability and organization. A strong emphasis is being placed on planning the wiring harnesses.

The 2017 Formula Student powertrain team is advancing in the planning of all engine systems and making sure that the change in engine type goes as smoothly as possible. The team's aim is to start the engine on the vehicle with all relevant systems by mid-April and have a running car by the beginning of May. The team is also planning ahead for the 2018 racecar and is planning a turbocharger system that will be assembled onto the vehicle at the end of the competition season in order to significantly boost the vehicle’s power.

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Effects of diesel particle filter on nanoparticle emissions and energy efficiency of in-use buses

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Abatement of particle emissions by road transport is considered one of the main challenges in the quest for better air quality. Studies released in the last decades have indicated that particles produced by diesel engines represent serious urban air pollution problem and cause adverse health effects.

Because of the long service life of heavy-duty diesels (approximately 15 years for buses), there is a large number of older-technology vehicles on the road. Cleaning up exhaust gases from these older vehicles presents an opportunity to improve air quality. Thus, retrofitting older buses with diesel particulate filter (DPF) is a cost-effective measure to quickly and efficiently reduce particulate matter emissions.

This study experimentally analyses the impact of DPF retrofitting on particulate emissions and engine performance aspects of in-use diesel buses. For the purpose of this research, 18 in-use interurban and urban diesel buses of Euro III technology generation were retrofitted with DPFs from three different manufacturers.

The influence of DPF on engine emission particle number concentrations and size distribution were measured and evaluated at various engine operating modes. Engine-out and tailpipe particle emissions were measured three times during a period of 12 months of buses operation after DPF retrofit installation. Moreover, buses fuel economy, backpressure build-up, lubricating oil quality, as well as maintenance and drivability aspects were investigated .

DPF retrofitting was found to cause an increase of 1.8% to 0.6% in fuel consumption, depending on the bus type. However, it also reduces in average by 96% the total number based particle emissions. Mass based particle emission reductions are found to be 96% as well.

Air pollution by nanoparticles in diesel-propelled passenger trains

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Keywords: ultrafine particles; diesel train; particle concentration inside a carriage; push-pull train; single-deck carriage; double-deck carriage

Locomotives with diesel engines are widely spread worldwide and are an important source of air pollution. Pollutant emissions by locomotive engines affect air quality inside passenger trains. This study is aimed at investigation of air pollution by ultrafine particles (UFP) inside passenger trains and providing a basis for assessment of passengers' exposure to this pollutant.

Concentrations of UFP inside the carriages of push-pull trains are found to be dramatically higher when the train operates in the pull mode. Minimal average UFP number concentrations (NC) measured in a train operating in the pull mode are higher by a factor of two and by a factor of 2.4 than the average UFP NC value reported for car cabins and for buses, respectively. The highest levels of air pollution by UFP are observed inside the carriages of pull trains close to the locomotive, whereas average UFP NC in these wagons are found to be higher by up to order of magnitude than in car cabins. UFP concentrations are substantially lower in diesel multiple-unit trains as compared to those measured in trains operating in the pull mode. Significant influence of the train movement regime on UFP NC inside a carriage is found.

Reforming-controlled HCCI process

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Keywords: HCCI engine; thermochemical recuperation; methanol steam reforming; dehydration of methanol

A computer model was built and a theoretical analysis was performed to predict the behavior of a system containing Homogenous charge compression ignition (HCCI) engine and a methanol reformer. The reformer utilizes the waste heat of the exhaust gases to sustain the two subsequent processes: dehydration of methanol to dimethyl ether (DME) and water, and methanol steam reforming (SRM) where methanol and water react to mainly hydrogen, CO and CO2. Eventually, a gaseous mixture of DME, H2, CO, CO2, water (reused) and some other species is created in these processes. This mixture is used for the engine feeding. By adding water to the methanol and fixing the vaporized fuel's temperature, it is possible to manage the kinetics of chemical processes, and thus to control the products' composition. This allows controlling the HCCI combustion. By a magnification of H2/DME ratio the ignition delay is increased and so it is possible to synchronize the ignition timing and also to control combustion duration. The simulation results prove feasibility of the suggested approach and a possibility of achieving substantially higher energy efficiency together with zero-impact NOx emissions in a wide range of engine operating modes.

Optimization of Extinguishing Powder Dispersal

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In this study we examine the dynamics of extinguishing powder in a reacting flow.
The purpose of the study is to find ways to minimize the amount of extinguishing powder needed, using better locations for the sprinklers or using better features for the powder dispersal (i.e. pulses, dispersing velocities, powder particle diameter distribution etc.).
The aim of the first phase of the study, which is presented here, was to develop a theoretical method to simulate the dynamics of particles in a flow field utilizing the GDE equation. We reformulated the equation so it can regard particles having mass, temperature and velocity distributions. The equation also takes into account the spatial movement of the powder. Further, a simple general solution for the equation is presented.
The solution is demonstrated for simple case of two phase flow.
This method can be used in problems other than the dynamic of extinguishing powder, such problem can be the dynamics of fuel droplet in a combustion chamber.