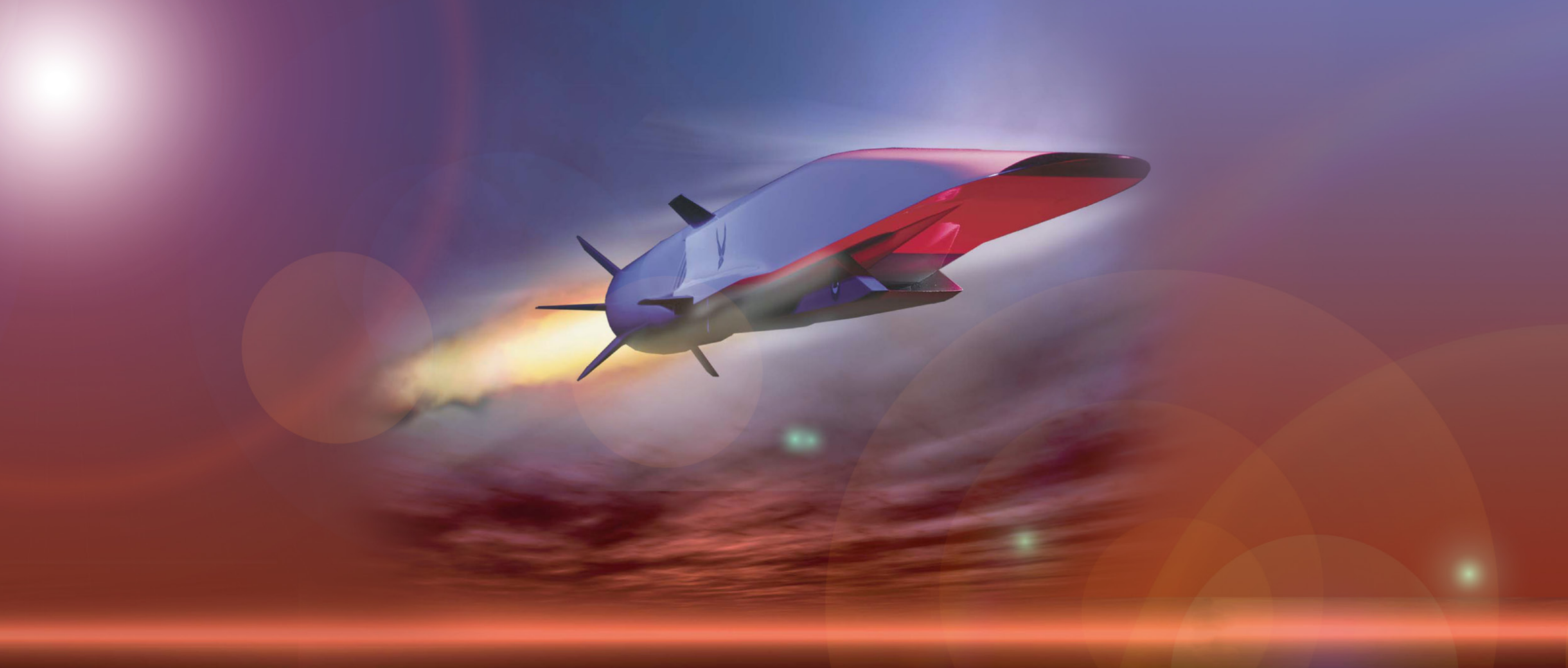

3rd Conference on

Propulsion Technologies for Unmanned Aerial Vehicles

Proceedings

Edited by: Dr L. Tartakovsky

Samuel Neaman Institute, Technion

Haifa, January 30, 2014

TECHNION
Israel Institute of Technology

מפא"ת/מר"פ/מעט"ר –
ענף הנעה

לשכת המהנדסים, האדריכלים
והאקדמאים במקצועות טכנולוגיים
בישראל

הטכניון – מכון טכנולוגי לישראל
הפקולטה להנדסת מכונות
המעבדה למנועי שריפה פנימית

טכנולוגיות הנעת כלי טייס בלתי מאוישים

הכנס הארצי השלישי

חוברת תקצירים

מוסד שמואל נאמן, הטכניון
חיפה
כ"ט שבט תשע"ד
30 בינואר 2014

Conference Program

3rd Conference on Propulsion Technologies for Unmanned Aerial Vehicles

Thursday, January 30, 2014
Auditorium Butler, Samuel Neaman Institute, Technion, Haifa

8:30 – 9:00	**Welcome and Registration**
Opening session	**Chairperson: Leonid Tartakovsky,** Technion
9:00 – 9:30	**Welcome:** **Oded Shmueli,** Vice President for Research, Technion **Pinhas Z. Bar-Yoseph,** Dean, Faculty of Mechanical Engineering, Technion **Uri Zvikel,** Head Propulsion Branch, Directorate of Defense Research & Development, MAFAT **Emanuel Liban,** Chairman, Israeli Society of Mechanical Engineers
9:30 – 10:00	**Keynote address:** **Future Fuels: Developing Tomorrow's Energy** **Rodica Baranescu,** University of Illinois at Chicago, US
Plenary session	**Chairperson: Yitzhak (Itche) Hochmann,** Edmatech
10:00 – 10:30	**The different failure modes of automotive and aircraft piston engines** **Luca Piancastelli,** University of Bologna, Italy
10:30 – 11:00	**Trends in UAV propulsion** **Emanuel Liban,** Edmatech Ltd. – CEO
11:00 – 11:30	**Coffee break**
Noon session	**Chairperson: Hemi Oron,** Elbit Systems
11:30 – 11:55	**Unusual threat to aircraft safety** **Tzippora Nusbaum, Konstantin Tartakovsky, Nir Goldin,** Analytical Lab, IAF
11:55 – 12:20	**Considerations in the design of UAV propulsion engine control systems** **Ehud David Silberstein,** UAS Division, Elbit Systems
12:20 – 12:45	**Improvement of Wankel engine performance at high altitudes** **Leonid Tartakovsky,** Technion
12:45 – 14:00	**Lunch**
Afternoon session "New Concepts"	**Chairperson: Kobi Feldman,** Israeli Aerospace Industries

14:00 – 14:25	**Phase Change Materials (PCM) Energy Source for Micro Aerial Vehicles (MAV)** **Alon Lidor, Daniel Weihs, Eran Sher,** Technion
14:25 – 14:50	**Multidisciplinary Design Optimization of UAV with Solar Propulsion System** **Avi Ayele[1], Ohad Gur[1], Aviv Rosen[2]** 1- Israeli Aerospace Industries, 2 - Technion
14:50 – 15:15	**High efficiency split-cycle engine for UAV applications** **Oded Tour,** Tour Engine Inc.
15:15 – 15:40	**Development of a system for safety improvement of Li-Ion batteries for UAV applications** **Niles Fleisher & Alex Nimberger,** Analyzer – battery safety management systems Ltd
Afternoon session "Engine Design & Performance"	**Chairperson: Gil Finder,** Israel Defense Forces
14:00 – 14:25	**Adopting a UAV rotary engine to customer operational requirements** **Daniel Cohen,** UAS Division, Elbit Systems
14:25 – 14:50	**Two-stroke SI engine with direct injection of air-saturated fuel** **Yoav Heichal, Aviel Aloni,** Aeronautics Defense Systems Ltd.
14:50 – 15:15	**Mechano-chemical surface modification for reduction of friction losses: the path to decrease of fuel consumption and environmental pollution** **Michael Varenberg, Grigory Ryk and Alexander Yakhnis**, Technion
15:15 – 15:40	**Turbocharging of internal combustion engines – latest developments** **Erez Mosafi,** Ledico – Bosch Israel

Organizing Committee

- *Leonid Tartakovsky*, Faculty of Mechanical Engineering, Technion – Israel Institute of Technology, **Conference Chairman**
- *Kobi Feldman*, Israeli Aerospace Industries
- *Gil Finder*, Israel Defense Forces
- *Yitzhak (Itche) Hochmann*, Edmatech Advanced Engineering Consultants Ltd.
- *Emanuel Liban*, Chairman of Israeli Association of Mechanical Engineers
- *Hemi Oron*, Elbit Systems
- *Michael Shapiro*, Faculty of Mechanical Engineering, Technion – Israel Institute of Technology

Keynote address

Future Fuels: Developing Tomorrow's Energy

By Prof. Rodica A. Baranescu,
University of Illinois at Chicago

The issue of fuels for tomorrow is arguably one of the most important topics in connection with the future of energy on our planet. The world as we know it today is heading towards an unsustainable energy future. The present carbon based energy system is insecure, inefficient and certainly unsustainable. Bold change is required in direction of policies, in redirecting and increasing support in search of new energy responding to the escalating increase in energy demand worldwide.

According to the International Energy Agency (IEA) and its World Energy Outlook published yearly, between the present and the year 2035 the primary energy demand would increase by one-third. The share of fossil fuel in the global primary energy consumption may fall from around 81% today to 75 % in 2035. This forecast is based on the emergence of future fuels - alternatives that are not yet in the market today, but that show potential sometimes very significant in the decades to come. One significant characteristic of fuels and energy is that all the issues have become global and the interest in evolving the technologies crosses borders and continents.

An important evidence of global thinking in energy and fuels is the Worldwide Fuel Charter (WWFC). This unique document was issued for the first time in 1998 by four global automotive organizations from USA, Europe and Japan, plus 15 other national automotive organizations. The Charter aims to promote understanding of the fuel quality needs world-wide, to satisfy specific needs in accordance with technological development of vehicles. The Charter is not a standard, rather a high level global road map for fuels, a guiding document to help the development of standards and regulations in all parts of the world. As countries develop and apply new vehicle technology and enter a higher category, the Charter continues to guide the development of new fuels to match vehicle technology, maximize performance and satisfy emissions.

<u>BTL Biomass- to- Liquid.</u> Biofuels are growing steadily in their significance to the transportation fuel mix. In 2011, the International Energy Agency predicted in its Technology Roadmap for Biofuels in Transportation that by 2050 biofuels may constitute 27% of world's transportation fuels. This prediction did not refer to first generation biofuels, derived from edible feedstocks such as corn or soybeans and from residual greases: these biofuels are still affected by the "food vs. fuel" debate and their sustainability in terms of energy, emissions and indirect land use change are still controversial subjects. The prediction referred to next generation biofuels- processed from non- edible biomass, through advanced technology, exhibiting superior quality and most important, being drop-in replacements for petroleum derived fuels. Among biofuels of interest it is worth mentioning biobutanol and its isomers. Isobutanol is an ideal platform molecule, a more flexible and versatile renewable alternative to current biofuels. It can be used as a "drop in" gasoline blendstock; it converts readily to isobutylene, a precursor to a variety of transportation fuel products such as iso-octene (gasoline blendstock), iso-octane (alkylate — high-quality gasoline blendstock and/or avgas blendstock); it can generate iso-paraffinic kerosene (IPK, or renewable jet) and diesel fuel. Biobutanol can re-optimize the value chain with its ability to be shipped in pipelines, both inbound to and outbound

from a refining/blending facility. The versatility of isobutanol's properties as a blendstock for gasoline and its ability to be converted to other valuable products give the downstream industry great flexibility.

CTL; Coal- to- Liquid. Several technologies offer a great opportunity to use the abundant coal reserves in many parts of the world where petroleum is not available but liquid fuels are needed to satisfy the increasing demand for transportation fuels. The preferred technologies for conversion are coal gasification- synthesis gas production, and Fischer-Tropsch (FT) conversion, to produce superior synthetic fuels. These technologies are almost hundred years old, however they have a great appeal and potential especially in the Asia Pacific Region where coal reserves are huge and operating costs can be lower. CTL technologies can certainly provide an opportunity/cushion from crude oil volatility in the future; however, the technologies are complex, they require CCS (carbon capture and storage) and they have to be built at large scale for economic optimization. CTL have a long way to go before becoming an integral part of the energy mix in the future.

GTL; Gas-to- Liquid. With a price of natural gas hovering at a ten years low and the significant increase of new reservoirs of natural gas found in the US as well as in remote areas of the world, much attention is devoted to Gas–to-Liquid Technology, to convert natural gas into "drop-in " liquid fuels for transportation. The traditional way centered around the known Fischer-Tropsch process, discovered in the 1920's and used by Germany to convert huge coal reserves into liquid fuels to support the war effort. Today the giant Sasol Corporation is producing FT fuels either from coal in South Africa or from natural gas in Qatar; more recent plans were announced to build a facility in Louisiana, processing gas reserves from the Gulf Coast region.

The traditional FT process generates mostly heavier components for diesel and jet fuel. Further cracking may produce lighter hydrocarbons such as in gasoline, albeit at increased processing cost and complexity.

A new approach developed by Mobil in the 70's achieved direct conversion of syngas into gasoline by producing methanol from syngas, and subsequently converting it directly to gasoline. A variation of this approach is embodied in a process called "Syngas–to-Gasoline plus" (STG plus) process. The "plus" stands for the fact that the process generates gasoline plus diesel, jet fuel, aromatics, and other praised chemicals. A pilot plant is operating in New Jersey US, and another demonstration plant is almost finished. The "STG plus" process includes proprietary improvements over the Mobil process, enabling multiple end products, higher degree of integration and flexibility. Due to its simpler process and lower cost, "STG plus", facilities can be built economically at smaller scale, allowing conversion of resources situated in close proximity geographically, within an area with a radius of only 50 miles.

In conclusion, I believe in a scenario where the picture of future global energy and fuels will rely on a combination of two categories of fuels: on one hand, the traditional fuels of today, but evolving in tune with new requirements and high quality; on the other hand, a growing proportion of new fuels; these will be produced either from low carbon feedstock such as advanced biofuels, or from fossil feedstock, that can be converted into syngas and further into superior liquid fuels. BTL, CTL, GTL are new acronyms that have entered in the vocabulary of refineries and fuel processing and the trend will continue.

Scientists, chemical engineers and researchers will continue to improve liquid fuels because of their excellent energy density, so well suited for internal combustion engines. These engines have served society and technology for over 150 years, and will continue to do so well in the 21st century.

THE DIFFERENT FAILURE MODES OF AUTOMOTIVE AND AIRCRAFT PISTON ENGINES

Prof. Luca Piankastelli
University of Bologna, viale Risorgimento 2, 40136 Bologna, Italy

Automotive piston engines are conceived for torque at low rpm. Fast, smooth and predictable response to throttle increase is required. FADEC maps are conceived to fulfill the perception of the driver, more throttle more torque as smoothly and quickly possible. In aircraft engines the propeller polar inertia smoothes automatically the throttle response with the engine becoming lazy. The flight follows the pilot's notes, with a proper throttle and rpm setting at taxiing, usually full throttle at takeoff, reduced throttle afterwards and a visual check to engine temperatures. At landing, "slow flight" attitude is checked, with proper flaps and nearly full throttle. In case of go around, flaps and closed and speed is regained, far before than the engine propeller or fan can reach full thrust. Aircraft engines run with settings, automotive engine runs with pilot's sensibility. Another main difference is that the automotive engines are commonly used in the first quarter of the power range, while aircraft usually flight with 50% of the power and usually take-off at full power. Helicopters are even worse, since they run at full rpm with power than varies from 75% to 100%. Aircraft normally are surrounded by "very fast air", usually over 100 km/h, this air not only cools down the engine, but also transforms this wasted energy in additional thrust by Meredith's effect. Not so for automotive engines. The "worst" cooling condition is the car at full throttle in an intermediate gear ratio, typically the III gear in a V speed gearbox. All this large differences determine very different failure modes in engines. Normally, in automotive engine it is the chain, or the belt that drives the camshaft that has problem. It is the weakest element in the engine. Camshaft is the next victim, typically, the blow-by and oil consumption increases and the oil pump is no more able fill the lubricating bath of the head. At this point the camshaft seizes, with deadly results for the whole engine. In some engines, due to different lubrication system the crankshaft bearings is the victim as the oil draining system is not more able to suck enough oil due to obstruction or low level in the wet sump. Aircraft engines are completely different. Usually head overheating is the first indication of problems. In old air cooled engines, a proper temperature sensor was embedded in the head cast. Now, in modern engines, the cooling liquid temperature is monitored. Another typical problem is overcooling, the piston seizure occurs when there is not enough play between the cylinder wall and the rings. Not so rare is valve spring failure with the valve that is stuck into the piston head. Fatigue in the flexible elements that brings the torque to the propeller is also common. In diesel this fatigue is due to shocks during engine stop. Thermal fatigue may induce cracks in aircraft components, especially when the aircraft is used for very short flights, like in paratrooper launching. It should be known than in old times cracks are commonplace. The author found cracks due to overload around bolt heads in a WWII Mosquito Merlin engine that crashed on the San Marino Mountain due to poor visibility. These cracks are now very difficult to be found in modern castings. However they can be found in thermally overloaded common rail turbo diesel engines. Excessive thermal load due to poor cooling is the cause. Failure analysis is the basis of engine development. Technical "bloodshed" during engine development is commonplace. The good engineer is the one that comes out of these problems that are "unluckily" unavoidable.

Trends in UAV Propulsion

Emanuel Liban

Edmatech Ltd. – CEO
And Chairman of the Israeli Society of Mechanical Engineers

The emerging technologies allow for design and usage of new and efficient propulsion systems that can assure the expected requirements of UAV's. Today, we are using many different types of power-plants: Electric, Hybrid's, I.C. engines and different versions of Turbo machines with excellent thermal efficiencies. At the same time, new energy sources, such as hydrogen in various configurations, high power density batteries, bio- fuels e.t.c., are introduced.

The majority of the new technologies stem from the huge investments in the development of efficient and clean propulsion for civil aviation and automotive systems as well as the enormous effort to build light-weight and powerful batteries and associated control systems.

In the lecture I shall define the operational domain of the different propulsion methods and try to suggest what we might expect to see in the future.

מכאן לאן – מגמות בהנעת כטב״מים

הטכנולוגיות החדשות מאפשרות לפתח מערכות הנעה חדשות, חסכוניות ובעלות ביצועים התואמים את הצרכים הגדלים והולכים של כלי הטיס.

כטב״מים משתמשים היום בין היתר בהנעה חשמלית, מערכות היברידיות מסוגים שונים, במנועי שריפה פנימית ונגזרות שונות של מנועי סילון. בו בזמן, גובר השימוש במקורות אנרגיה חדשים כמו מימן בצורות צבירה מגוונות, דלק על בסיס ״ביו״ תא -דלק וכו׳.

במרבית המקרים, פיתוח הטכנולוגי של מערכות ההנעה נהנה מהתוצרים של השקעות ענק לפיתוח מוצרים אזרחיים כגון מצברים עם צפיפות אנרגיה גבוהה, מנועי בוכנה משוכללים ומנועי טורבו-מניפה בעלי נצילות תרמודינמית מעולה.

ההרצאה תתייחס למקום הראוי לכל סוג הנעה תוך ניסיון לחזות מה יהיו פני הדברים בעתיד.

Unusual Threat to Aircraft Safety

<u>Tzippora Kanal</u>, *Analytical Lab., IAF, Israel*

Konstantin Tartakovsky, *Analytical Lab., IAF, Israel*

Zeev Amoyal, *Bruker Daltonics, Bruker Israel, Israel*

In the advent of an aircraft critical failure, all aircrafts in the fleet underwent general inspection. Within the oil systems of nearly every aircraft assessed, pools of an unknown, reddish-brown, highly viscous substance were discovered throughout the piping. In addition, in the areas of pooling, the piping itself was found to have taken on a reddish-brown hue in place of its original yellow color. According to the technical information received with the samples, the particular oil system in question is composed of flexible PVC piping, and uses synthetic oil grade 15W40. The substance was discovered both in systems that had been subject to regular usage for numerous years, as well as systems whose oil remained stagnant for extended periods of time.

Testing of both the suspicious substance and the affected piping using both FTIR ATR (with a diamond accessory) and GC/MS with a Chromatoprobe[1] accessory revealed that the unknown substance contains components from both the oil and the pipe. Notably, neither the oil nor the pipe was found in its original form within the substance or the affected pipe. We were able to successfully reproduce the unknown substance in an experimental setting, and verify that our reproduction is chemically similar to the unknown substance using GC/MS Chromatoprobe.

It was concluded that a mutual attraction was experienced between components of the PVC piping and those of the synthetic oil grade 15W40. As a result of this attraction, molecules in the PVC piping diffused towards the inner surface of the pipe, whereupon they extracted molecules from within the oil. The new mixture comprised of both piping and oil components is a new, highly viscous, liquid material.

In practice, this phenomenon can lead to clogging of the oil system. As a result, the customer was advised to avoid the use of flexible PVC in oil systems utilizing synthetic oil grade 15W40, and instead to use a different, nonreactive material for the oil system piping.

[1] The GC/MS Chromatoprobe accessory heats the sample to an intermediate temperature. Generally speaking, such temperatures allow for the evaporation of partially volatile and volatile additives.

Considerations in the design of UAV propulsion engine control systems

Ehud David Silberstein
UAS Division, Elbit Systems

Foreword:

Since the late 1960’s, the requirements for cleaner emissions and improved drivability have surpassed the ability of mechanical fuel and ignition delivery to satisfy those needs. As a result, the need arose to introduce electronic control into engine management in the form of fuel and ignition delivery. The contemporaneous development of computer technology allowed the use of electronic fuel injection.

In the expanding market for UAVs’, its evolving and ever increasing demands for performance, operation envelopes and reliability have become major catalysts for advancements in propulsion systems. The effect has been an introduction of Electronic Fuel Injection Management Systems to the propulsion system, replacing the traditional carburetor based fuel management.

Considerations in the design of an Electronic Fuel Injection Management Systems are the variety of internal combustion engines in use; piston engines (4-stroke / 2-stroke, SI / CI), rotary engines (Wankel), and the variety of fuel types in use (Mogas, Avgas, Diesel fuel and Jet fuel), whose unique characteristics require a dedicated management strategies.

The following is an introduction to various Electronic Fuel Injection management strategies widely in use throughout the world, and their suitability to each specific application.

The following discussion will be limited to SI engines.

Management strategies:

- Alpha/N
- Speed Density
- Mass Airflow
- Future strategies

Aspects discussed:

- Important parameters
- Sensors used
- Advantages and disadvantages

Engines reviewed:

- 4 strokes
- 2 strokes
- Rotary

אלביט מערכות
מערכי מל״ט

Improvement of Wankel engine performance at high altitudes

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The phenomenon of an UAV engine's power drop under high-altitude flight conditions is well known and studied in details. The reason of this power reduction is decrease of the atmospheric air density with altitude. Engine supercharging is the well-known method of this problem solution.

The main goal of the presented work was altitude performance improvement of Wankel engine by application a commercially available turbocharger. The aim was to keep the engine's brake power as close as possible to the rated value at sea level in the altitudes range between 0 and 15,000 feet.

The engine performance predictions were carried out using the GT-POWER software of the GT-SUITE package initially intended for modeling reciprocating piston engines. Since direct use of this software for simulation of the Wankel engine performance is impossible, the method of compiling a virtual piston engine was applied. This required definition of piston-to-Wankel engine similarity criteria and development of the algorithm taking into account peculiarities of Wankel engine combustion process, heat transfer and intake/exhaust ports discharge coefficients. This approach was applied in this work.

Altitude performance simulation of the naturally aspirated engine showed that at the flight altitude of 15,000 feet its power drops by more than 40% compared with a power at the sea level and BSFC increases by 4%.

Performance predictions of the turbocharged Wankel engine confirmed possibility of maintaining its power at all altitudes up to 15,000 feet, but revealed presence of a strong pressure wave process in the engine's intake manifold. This fact would increase significantly a risk of the compressor blades fatigue failure. In addition, instability of the air instantaneous flow rate provokes the compressor ingress into the surge zone under certain operation regimes. Two different methods for the compressor wheel protection from impact of the intake air pressure waves were suggested and simulated:

- throttling the intake manifold to screen the compressor wheel from the waves;

- suppressing the waves by including a damping volume into the intake manifold.

Two variants of the damping volume location were studied: the 1st - between the throttle and the intake manifold; the 2nd - between the compressor and the throttle. No substantial difference in the engine performance was revealed.

The throttling method allows reduction of the pressure/air flow waves swing, but this decrease is not sufficient, such as at the flight altitude of 15,000 feet and the engine low speeds (4500 - 5000 rpm) there is a risk of the compressor surge. An additional serious drawback of the throttling method is in the fact that at the flight altitude 15,000 feet and the engine rated speed 8100 rpm the compressor works very close to its maximal operation speed – 180,000 rpm, which can lead to problems of the turbocharger durability and reliability.

Iterative simulations with different values of the damping volume allowed us to find a volume optimal for effective suppression of the wave process and avoidance of the surge risk in the entire range of the flight altitudes and the engine operation regimes.

Comparison of the methods shows that the damping volume method is preferable since it ensures lower specific fuel consumption by about 1.5% practically under entire engine speed range (see Figure). In addition, the engine power under partial loads is up to 27% higher. Very important advantage of the damping volume method is a reduction of the turbocharger's speed by about 17% under maximal power. We recommend studying a potential of further efficiency increase of this method with a possibility of the damping volume decrease by designing it in a similar way as an exhaust muffler.

The results of these predictions have to be verified experimentally in an altitude chamber and during flight tests.

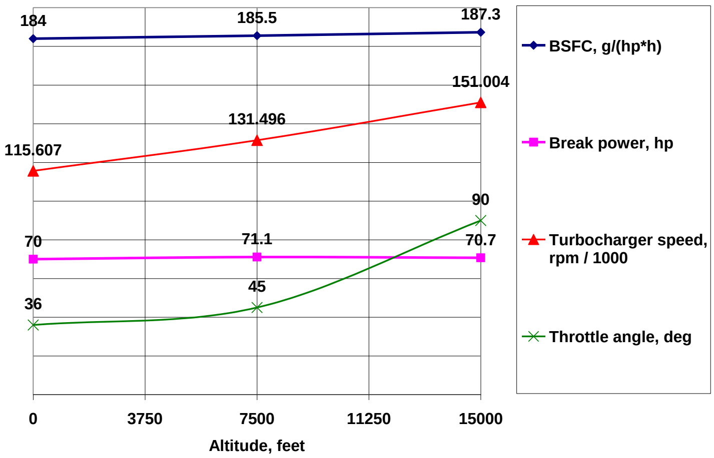


Figure. Altitude performance of the turbocharged Wankel engine: suppressing intake pressure waves by the damping volume

Phase Change Materials (PCM) Energy Source for Micro Aerial Vehicles (MAV)

Alon Lidor, Daniel Weihs, Eran Sher
Faculty of Aerospace Engineering, Technion – Israel Institute of Technology

Recent years have seen an increased effort in research and development of remotely-controlled and autonomous micro aerial vehicles (MAV). While there are many different challenges in the development of MAVs, one of the severe limiting factors in terms of weight is the energy source/storage. Most of the MAVs developed to date are based on electrochemical batteries, with limited endurance (operational time) of less than 30 minutes. In the present study, several potential alternative energy storage systems are compared: carbon nano-tubes (CNT), fuel cells, shape memory alloys (SMA), synthetic muscles, flywheels, elastic elements, pneumatics, thermal systems, radioisotope thermoelectric generators, and phase change materials (PCM). The potential alternatives are compared to electrical batteries and hydrocarbon fuel storage for miniature internal combustion engines (ICE). The results are then applied to typical fixed wing and rotary wing MAV configurations with several mission profiles. A novel PCM open cycle in which the environment is the warm reservoir is suggested and analyzed, revealing promising results in terms of specific power and thermodynamic efficiency. For a nitrogen based PCM open cycle with a 20W microturbine as the power generating device, a specific power of 45-140W/kg with an open-cycle thermodynamic efficiency of 22-54% is achieved. The specific energy of the system is 20-45W-h/kg, under different ambient conditions, with temperature ranging from -17.5°C to 45°C and pressure of 50kPa to 101.325kPa. We conclude that for the near future, a promising alternative energy storage method for MAVs will be based on phase-change materials.

תכן ראשוני, אופטימלי רב-תחומי (MDO), למל"ט בעל מערכת הנעה סולארית

אבי איילה, אוהד גור – תיכון מוקדם, תעשייה אוירית לישראל
אביב רוזן – הפקולטה להנדסת אוירונוטיקה, הטכניון מכון טכנולוגי לישראל

המצגת תעסוק בתכן ראשוני של מטוס ללא טייס (מל"ט) בעל מערכת הנעה סולארית. מל"ט זה מיועד לשמש כ"לווין נמוך", תיאורטית בעל יכולת שהייה אין סופית. בשעות היום כלי הטיס נוסק לגובה רב, שם הוא שוהה ואוגר את אנרגית הקרינה של השמש ובשעות הלילה יורד לגובה נמוך יותר בו צריכת ההספק קטנה יחסית.

בהרצאה יוצגו הדיסציפלינות השונות המרכיבות את סביבת התכן. תחומי הידע הללו מיוצגים על ידי סימולציות נומריות לחיזוי קרינת השמש, יכולת האגירה של אנרגיה זו על ידי מערך סוללות, תכונותיו האווירודינמיות של הכלי הכוללות גם את מערכת ההנעה, הערכת משקלו העצמי וחישוב ביצועי המשימה שלו.

האתגר העיקרי בתכן כלי שכזה הוא מציאת האיזון בין צריכת ההספק על ידי מערכת ההנעה והמטען המועיל, לבין ההספק המצוי מקרינת השמש. הספק זה משמש להנעת הכלי במהלך שעות היום וחלקו נאגר במצברים לצורך השהייה בשעות הלילה.

הן ההספק המצוי והן ההספק הדרוש מושפעים מתכן הכלי. לפיכך, נעשה שימוש בכלי אופטימיזציה נומרית לצורך ביצוע תכן מיטבי רב-תחומי (MDO – Multidisciplinary Design Optimization). בתהליך תכן זה נמצאו השפעות הגומלין בין הפרמטרים השונים ורגישויות התכן לאילוצי התכן שיוצגו באמצעות הזיתות פרטו.

במחקר זה גם בוצע חקר רגישות לשתי טכנולוגיות עיקריות המאפיינות כלי טיס סולארי – נצילות המצברים ונצילות הפאנלים הסולאריים. מתוך תוצאות התכן ניתן לראות בבירור שהטכנולוגיה שלה יש את מירב הפוטנציאל לשיפור היא טכנולוגית אגירת האנרגיה. בנוסף, התוצאות מדגישות את החשיבות של שימוש בסביבות תכן מבוססות MDO בתכן ראשוני של כלי טיס. בתכן ראשוני של כלי סולארי החשיבות גבוהה יותר בשל השפעות הגומלין החזקות בין דיסציפלינות שונות ורגישות התכן להשפעות גומלין אלו.

High efficiency split-cycle engine for UAV applications

Hugo Tour, Oded Tour
TOUR ENGINE, Inc.

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 Spool Shuttle* that serves as a combustion chamber as well as a gating mechanism. A second cylinder (denoted Hot-Cylinder), serves as a power cylinder. The first Tour engine prototype (Prototype I) has successfully demonstrated the engines mechanical feasibility. The recently completed Prototype II was built in such a way that different compression to expansion ratios can be tested (e.g., implementation of an Atkinson cycle) as well as testing of various *crossover mechanical designs*.

Theoretically, splitting the four stroke cycle of the internal combustion engine between two cylinders, rather than executing the complete cycle within a single cylinder, has the potential for significant efficiency gain due to:

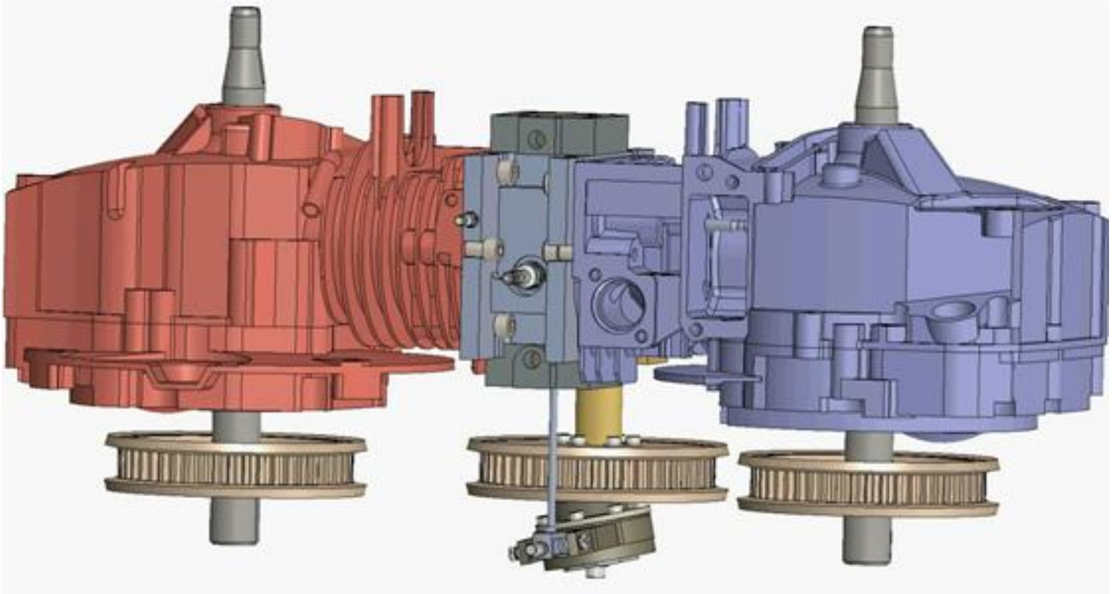
- Keeping colder temperatures at the Cold-Cylinder (as it does not host combustion) while maintaining common compression ratios.
- Increasing the Hot-Cylinder (power cylinder) expansion ratio, this increases the conversion of thermal energy to kinetic energy. A larger expansion ratio also permits less deliberate heat rejection (active cooling) as the larger expansion acts as a cooling mechanism.

However, over the years several other split-cycle designs have been proposed, but none have matured. The challenges that were not overcome were inadequate working fluid transfer between the two cylinders that led to poor combustion and thermodynamic losses. Those engineering efforts also failed in designing a reliable, properly sealed and none-restrictive inter-cylinder crossover valve.

Lately, Tour Engine Inc. has developed a unique inter-cylinders gas exchange mechanism which has the potential to fully address and resolve the above mentioned shortcomings of other split-cycle designs. This mechanism utilizes a synchronous reciprocating spool shuttle valve that contains the combustion chamber and serves as a gating mechanism for the transfer of the charge from the Cold-Cylinder to the Hot-Cylinder.

Two computer simulations, predict considerable performance gains over current state of the art engines (above 50% BTE at conventional gasoline operating conditions). In addition, the design utilizes existing state of the art engine hardware and components and hence will be easy to adopt by the industry.

The newly patented, recently prototyped Tour Engine's internal combustion (IC) engine is a platform technology that may revolutionize the way IC engines are used in numerous transportation and stationary power generation applications. Specifically, the Tour Engine design is well suited for UAV applications, due to its high efficiency and potentially high power density.



SolidWorks drawing showing the TourEngine prototype II design**.**

פיתוח מערכת לשיפור רמת הבטיחות במצברי Li-ion לכטב"מ

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ANALYZER – Battery Safety Management Systems Inc.

<u>הקדמה</u>

פיתוח מצברי ליתיום יון (**Li-ion**) עתירי אנרגיה והספק הינה אחת האתגרים החשובים באלקטרוכימיה המודרנית מזה כשני העשורים האחרונים.
מצברי ליתיום מהווים היום מקור מתח עיקרי למגוון יישומים לרבות מחשבים ניידים, מכשירי הסלולר, פיתוח רכב חשמלי, הפעלת כטב"מ ו"רשת חכמה". שוק המכירות של מצברי **Li-ion** הגיע בשנת-2012 ל <u>11.7 ביליון $ לשנה</u>, עם צפי גידול במכירות בקצב דו ספרתי בשנה.
לטכנולוגיית מצברי **Li-ion** מספר יתרונות על פני מצברים האחרים לרבות: משקל ונפח קטנים יותר, צפיפות אנרגיה והספק (פי 2 עד 5) גבוהים יותר; מספר מחזורים (טעינה/פריקה) רב, השתמרות מטען טובה יותר ותחום טמפרטורת עבודה רחב.

<u>הבעיה</u>

אחת המגבלות העיקריות של מצברי ליתיום יון - הינה בעיית הבטיחות, המונעת את הרחבת השימוש של מצברי הליתיום עבור רכבים חשמליים וכלי טייס. מדי שנה מתרחשים כמה מאות אירועי התלקחות של מצברי ליתיום, ידוע על עשרות נפגעים ואף אנשים שקיפחו את חייהם.
לאחרונה, (2013) התפרסמו מספר אירועי בטיחות עם מעורבות של מצברי ליתיום יון , בעת שימוש/נסיעה/טיסה, טעינה, כגון שריפות ב עת טיסה של **Boeing Dreamliner's** והתלקחות של רכבים חשמליים של **TESLA EV**. גם במערכות כטב"מ אירעו תקלות והתלקחויות בסוללות. למעשה אין כיום יצרן של כטב"מ שלא נתקל באירוע בטיחותי או תקלה בשלבי הפיתוח או השימוש בכלי טיס.
בדיוק למטרה זו, ועל מנת לפתור את בעיות הבטיחות ברמת התא והמצבר **Li-ion** לפני מספר חדשים הוקמה חברת הזנק **Analyzer** . בכוונתנו לפתח אלגוריתם אקטיבי (בניגוד לאמצעים פסיביים הקיימים במערכת מצבר-מטען היום), זאת לצורך זיהוי מוקדם של סיכונים פוטנציאליים – כמו- קצר פנימי בתא ליתיום יון או כל תקלה אחרת ומניעת התלקחות/פיצוץ המצבר. לנו ניסיון קודם במערכות ליתיום אחרות , חברת **Analyzer** נמצאת בשלבי התארגנות ראשוניים וגיוס שותפים.

בהרצאה נסקור ונציג את הנושאים הבאים:

א. סוגי טכנולוגיית מצברי ליתיום יון בחתך של יישומים.
ב. מהי בעיית הבטיחות?
ג. כיצד ניתן לצמצם הסיכונים בשימוש במצברי ליתיום בהפעלת הכטב"מ וכיצד אנו מתכוונים לפתור את הבעיה בעתיד.
ד. שלבי פיתוח האלגוריתם ושילובו בתוך מערכות הנטענות

*****Dr. Niles Fleisher & Dr. Alex Nimberger Co-founders Analyzer.

Adapting a UAV rotary engine to customer operational requirements

Daniel Cohen

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UAV engine design is challenging today more than ever. Apart from the growing market, UAV engine design needs to take into consideration diverse requirements.

The modern UAV engine has to withstand the challenges listed below alongside the demands for increased performance and operational capabilities. Examples for the leading customer operational requirements and the technical challenges they impose:

A wide range of operational requirements: The UAV is expected to operate in a variety of environmental conditions – from wide range of temperature extremes, rain, icing and F.O.D such as dust. A handful of engine subsystems have been developed to meet these environmental requirements: A module is mounted on the engine air inlet acts as a centrifugal filter. Blade tips and leading edges have been covered with a special tape to protect against dust and rain erosion. Two different systems have been developed to allow engine operation in cold weather: engine core heating before startup, and a system for heating engine oil during flight.

Personnel requirements: The never ending quest for reduced operational costs dictates the requirement for minimal and 'incorporated' air and ground crews. The number of personnel is limited, and training level is relatively basic. Starter-alternator eases the engine start-up on ground and even during flight if needed. Automated procedures have been developed such as the engine ground run script. The procedures which *do* need to be performed by the personnel are minimal and relatively simple. The UAV maneuvers in flight are performed without direct commands to the engine by the operators, such as RPM or fuel mixture.

Flight zone regulations: Homeland security applications requiring the use of civil aviation routs demands that the engine be certified to meet civil safety regulations. During combat UAVS often require take-off and landing to and from undesignated semi-prepared runways.

Ecological issues: Engine design must be designed to take into consideration modern ecological requirements such as exclusion of hazardous materials and pollution limitations.

Two-stroke SI engine with direct injection of air-saturated fuel

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Two strokes reciprocating engines have been used for many applications for more than 100 years now. The simple engine design, high power to weight ratio and low number of engine parts made those engines suitable for various applications starting from tiny garden tool engines to huge ship engines. However, one of the most obvious disadvantages of two strokes engines is their low specific fuel consumption and high Hydrocarbons emissions. In some countries and some applications, two strokes engines have been banned for use due to their emissions.

In one specific industry in particular, two strokes engines still dominate the sky, this is the small UAV segment. The light reliable engine with high power to weight ratio holds irreplaceable advantages for UAV manufacturers. However as no human beings are flying in UAVs, long flight endurance is required, thus low fuel consumption is needed to maintain the system light weight advantages.

The only way for two strokes engines to survive in the 21st century is by eliminating their HC emissions and reducing their fuel consumption. Those two requirements can only be achieved by injecting the fuel directly into the combustion chambers as the piston is approaching the top dead center. Such direct fuel injection architecture requires very fast and efficient fuel atomization during times the pressure in the combustion chamber is very high.

Specifically in the UAV industry, the usage of heavy fuels (such as diesel and kerosene based fuels) and the implementation of spark ignition design are very important, unlike in conventional heavy fuel engines where compression ignition can be used.

A novel design, based on saturation of air in the heavy fuel, was tested. The atomization of fuel as function of injection pressure and air content was investigated. A complete two strokes UAV DI engine assembly was built and tested with air saturated heavy fuels. Results of this study and testing is presented and explained in details.

Aeronautics

Mechano-chemical surface modification for reduction of friction losses: the path to decrease of fuel consumption and environmental pollution

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One of the two major approaches to bridging the gap between consumption and production of energy is to seek solutions for more efficient energy use. The reduction in energy consumption through reduced friction is the most straightforward one as about one-third of the world energy resources is expended by frictional losses, with internal combustion engines being the most prominent example. Frictional performance is governed by the topmost surface layers restricted to a few hundred nanometers underneath the contact interface. Thus, modifying physico-chemical properties of these layers is an obvious choice in trying to reduce friction and, hence, energy losses. This can be achieved by having surface films containing metal salts known for their ability to facilitate lubrication. Therefore, one of the most effective current solutions for improving frictional performance is the use of such elements as chlorine, sulfur, phosphorus and other nonmetals as oil additives that react with working surfaces under extreme loading conditions to form low-shear-strength surface films.

Extensive plastic deformation of near-surface region achieved during abrasive and cold-working mechanical processes is known to activate the surface by heat and generate numerous defects that provide channels for easy diffusion of foreign atoms into the metal. Based on this, we develop a novel technology, whose core idea consists of synthesizing intentionally low-shear-strength surface films by supplying chlorine, sulfur or phosphorus *during* a finishing mechanical treatment. This should result in early formation of self-regenerating surface films, which are currently known to appear only under extreme loading conditions if the above-mentioned reactive substances are used as oil additives. The advantage of this technology consists in that the low-friction surface is manufactured in a direct controlled way before the actual use and hence, the mechanical system can benefit from more efficient energy consumption during the whole life of its frictional components. Moreover, due to its self-regenerating property this thin low-friction layer may stay on the surface for extensive period of time in spite of progressive surface wear.

We believe that this technology may lead to a dramatic enhancement of tribological performance of mechanical elements used in a wide number of sectors such as high-tech, tool, automotive, aerospace, etc. For instance, it may significantly improve energy efficiency in transportation sector, which is almost exclusively built around internal combustion engines, where nearly half of the mechanical energy losses results from the piston assembly friction. Moreover, this technology is expected to increase the engine's ecological efficiency by reduction of fuel and oil consumption, and mitigation of harmful pollutants in the exhaust gases.

The results of preliminary friction tests obtained on the surfaces treated abrasively in sulfur-containing environment will be presented.

Turbocharging of internal combustion engines – latest developments

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Latest developments in the engine turbocharging field are overviewed, including various twin-charging schemes and methods of boost pressure control.

The series arrangement, the more common arrangement of twin-chargers, is set up such that one compressor's (turbo or supercharger) output feeds the inlet of another. A sequentially-organized Roots type supercharger is connected to a medium- to large-sized turbocharger. The supercharger provides near-instant manifold pressure (eliminating turbo lag, which would otherwise result when the turbocharger is not up to its operating speed). Once the turbocharger has reached operating speed, the supercharger can either continue compounding the pressurized air to the turbocharger inlet (yielding elevated intake pressures), or it can be bypassed and/or mechanically decoupled from the drivetrain via an electromagnetic clutch and bypass valve (increasing efficiency of the induction system).

Other series configurations exist where no bypass system is employed and both compressors are in continuous duty. As a result, compounded boost is always produced as the pressure ratios of the two compressors are multiplied, not added. In other words, if a supercharger which produced 10 psi (0.7 bar) (pressure ratio = 1.7) alone blew into a turbocharger which also produced 10psi alone, the resultant manifold pressure would be 27 psi (1.9 bar) (PR=2.8) rather than 20 psi (1.4 bar) (PR=2.3). This form of series twin-charging allows for the production of boost pressures that would otherwise be unachievable with other compressor arrangements and would be inefficient.

However, the efficiencies of the turbo and supercharger are also multiplied, and since the efficiency of the supercharger is often much lower than that of large turbochargers, this can lead to extremely high manifold temperatures unless very powerful charge cooling is employed. For example, if a turbocharger with an efficiency of 70% blew into a Roots blower with an efficiency of 60%, the overall compression efficiency would be only 42% -- at 2.8 pressure ratio as shown above and 20 °C (68 °F) ambient temperature, this would mean air exiting the turbocharger would be 263 °C (505 °F), which is enough to melt most rubber couplers and nearly enough to melt expensive silicone couplers. A large turbocharger producing 27 psi (1.9 bar) by itself, with an adiabatic efficiency around 70%, would only produce 166 °C (331 °F). Additionally, the energy cost to drive a supercharger is higher than that of a turbocharger; if it is bypassed, the load of performing compression is removed, leaving only slight parasitic losses from spinning the working parts of the supercharger. The supercharger can further be disconnected electrically (using an electromagnetic clutch such as those used on the VW 1.4TSI or Toyota's 4A-GZE) which eliminates this small parasitic loss.

With series twin-charging, the turbocharger can be of a less expensive and more durable journal bearing variety, and the sacrifice in boost response is more than made up for by the instant-on nature of displacement superchargers. While the weight and cost of the supercharger assembly are always a factor, the inefficiency and power consumption of the supercharger are almost totally eliminated as the turbocharger reaches operating rpm and the supercharger is effectively disconnected by the bypass valve.

Parallel arrangements typically always require the use of a bypass or diverter valve to allow one or both compressors to feed the engine. If no valve were employed and both compressors were merely routed directly to the intake manifold, the supercharger would blow backwards through the turbocharger compressor rather than pressurize the intake manifold, as that would be the path of least resistance. Thus a diverter valve must be employed to vent turbocharger air until it has reached the pressure in the intake manifold. Complex or expensive electronic controls are usually necessary to ensure smooth power delivery.

The main disadvantage of twin-charging is the complexity and expense of components. Usually, to provide acceptable response, smoothness of power delivery, and adequate power gain over a single-compressor system, expensive electronic and/or mechanical controls must be used. In a spark-ignition engine, a low compression ratio must also be used if the supercharger produces high boost levels, negating some of the efficiency benefit of low displacement.

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