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טכנולוגיות הנעת כלי טייס בלתי מאוישים

הכנס הארצי החמישי

חוברת תקצירים

הפקולטה להנדסת מכונות, הטכניון
חיפה
יח' שבט תשע"ו
28 בינואר 2016

Conference Program

5th Conference on Propulsion Technologies for Unmanned Aerial Vehicles

Thursday, January 28, 2016
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:** **Small Internal Combustion Engine Technology – State of the Art and Future Trends** ***Helmut Eichelseder***, Director, Institute of Internal Combustion Engines and Thermodynamics, Graz University of Technology, Austria
Morning plenary session	**Chairman: Yitzhak (Itche) Hochmann,** Edmatech
10:00 – 10:25	**Conceptual Trends in Development of Future Unmanned Aerial Systems and their Propulsion Derivatives** ***Ariel Dvorjetski***, Head of Concepts & Unmanned Systems Branch, Directorate of Defense Research & Development, MAFAT
10:25 – 10:50	**HALE Piston Propulsion Systems Optimization** ***Luca Piancastelli***, Aerospace division, Faculty of Mechanical and Aerospace Engineering, University of Bologna, Italy
10:50 – 11:35 **Coffee break**	**Posters Session**, Chairman: Emanuel Liban,** Israel Society of Mechanical Engineers
Noon plenary session	**Chairman: Hemi Oron,** Elbit Systems
11:35 – 12:00	**Requirements of future diesel propulsion system for MALE UAVs** ***Jacob Feldman, Yehuda Fass***, Israel Aerospace Industries
12:00 – 12:25	**Investigation of engine coolant system in UAV** ***Ofer Levy***, IAF, IDF

12:25 – 12:50	**Operational Perspective of Internal Combustion Engines Usage in MALE UAV Fleet** ***A. Gil***, IDF
12:50 – 13:00	**Best Student Poster Award Ceremony**
13:00 – 14:00 **Lunch**	**Posters session** - continuation
Afternoon session "New Concepts"	**Chairman: Jacob Feldman,** Israel Aerospace Industries
14:00 – 14:25	**Knock prevention in UAV engines – theoretical considerations** ***Ran Amiel, Leonid Tartakovsky***, Technion
14:25 – 14:50	**The cryogenic miniature propulsion system - initial test results** ***Eran Sher***, Technion
14:50 – 15:15	**Energy management system for high fuel economy and low pollutants emission of a vehicle** ***Erez Mosafi***, Ledico – Bosch Israel
15:15 – 15:40	**Micro-Turbine Generators – prospect for compact power source** ***B. Arav, R. Shulman***, TurboGEN Technology Ltd
Afternoon session "Engine Design & Performance"	**Chairman: Gil Finder,** Israel Defense Forces
14:00 – 14:25	**Engineering design considerations in UAV engine liquid cooling systems** ***Ron Raz***, Elbit Systems
14:25 – 14:50	**Civil certification of UAS propulsion systems** ***Tamir Bar-Am***, Civil Aviation Authority of Israel
14:50 – 15:15	**The challenges of UAV propulsion system testing** ***Menachem Lerer***, Elbit Systems
15:15 – 15:40	**Flow Simulation for Internal Combustion Engines** ***Roy Honig***, Tenzor Ltd.
Closing remarks 15:40 – 15:50	**Leonid Tartakovsky**, Chairman Organizing Committee

Posters session

1. **Optimization of propulsion system for UAV**
   V. Kliatzkin, E. Shalem, Winflex

2. **Improvement of Plug-in Hybrid Electric Vehicles (PHEV) by using Micro-Turbine Generators (MTG)**
   B. Arav, R. Shulman, TurboGEN Technology Ltd.

3. **Analysis and danger assessment of UAV flight conditions at low altitude**
   E. Shalem, V. Kliatzkin, Winflex

4. **Surface Modification by Shot-Peening for Friction and Wear Reduction**
   H. Kasem and G. Ryk, Tribology Laboratories, Technion

5. **Combustion mechanisms validation at fuel rich conditions using Laser diagnostics**
   A. Fomin, T. Zavlev, V.A. Alekseev, A.A. Konnov, V. Tsionsky, I. Rahinov, S. Cheskis, Tel-Aviv University

6. **Spray Combustion in Vortical Flows**
   Y. Dagan[1], David Katoshevski[2], Barry Greenberg[1], 1 – Technion, 2 – Ben-Gurion University of the Negev, Beer-Sheva

7. **Dry sump and Cooling system of the SAE Formula-Student engine**
   H. Bombigher, O. Gryzman, Technion

8. **Fuel and Power Delivery in the SAE Formula-Student engine**
   O. Avni, Y. Dadon, Technion

9. **Manifolds design & Engine Performance Analysis**
   R. Mizrahi, T. Bashan, D. Diskin, Technion

10. **High-pressure methanol steam reformer for waste heat recovery of an internal combustion engine**
    A. Poran, L. Tartakovsky, Technion

11. **Management of the HCCI Combustion Process with Thermo-Chemical Recuperation by Control of the Reforming Products Composition**
    A. Eyal, L. Tartakovsky, Technion

12. **Mitigation of nanoparticles emission from diesel buses by retrofitting diesel particle filters**
    R. Fleischman, R. Amiel, L. Tartakovsky, Technion

13. **Hybrid propulsion system for Unmanned Aerial Vehicles – simulation results**
    I. Biner, Technion

14. **Propulsion system for the 2016 SAE Formula-Student car**
    N. Dabush, I. Greenberg, D. Ganon, A. Asraf, T. Lipshitz, D. Brudner, A. Sacks, Technion

15. **Spray flame dynamics in an oscillating flow field – computational study**
    I.Moshe, D.Katoshevski, G.Ziskind, Ben-Gurion University of the Negev, Beer-Sheva

Organizing Committee

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- *Uri Zvikel,* MAFAT, Ministry of Defense

Conference Secretary:

Mrs. Ruthie Bouscher, meruthi@tx.technion.ac.il *Phone: +972-4-8292065, Fax: +972-4-8295711*

Best Student Poster Selection Committee:

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- *Jacob Feldman,* Israel Aerospace Industries
- *Yitzhak (Itche) Hochmann,* Edmatech
- *Hemi Oron,* Elbit Systems
- *Michael Shapiro,* Technion

Oral presentations

Keynote address

Small IC Engine Technology – State of the Art and Future Trends

Helmut Eichlseder

Institute of Internal Combustion Engines and Thermodynamics, Graz University of Technology,
8010 Graz, Austria
eichlseder@ivt.tugraz.at

Keywords: small engine, two stroke, hand held engines, power products, engine control

Today small engines are used in a wide range of applications. They reach from hand-held power tools to motorcycles, power sport products and different stationary and aerial applications. Within each of the applications the engines have to be developed for different specific tasks: Hand-held tools, for example, are used for garden/landscape maintenance, in the construction industry and in forestry; motorcycles exist as low cost transport tools as well as high-tech supersport "toy". The situation is quite similar for power sport applications, snowmobiles and different aerial and water applications. For all of these engines, fuel efficiency, power density, emissions, costs and reliability play important roles - but partly with completely different weighting. Therefore there is not the "one ideal technology" for small IC engines, but depending on specific boundary conditions, different technological solutions and trends could be successful (Kirchberger, 2015). Describing the state of the art, motorcycle engines and handheld engines can serve as good examples.

Motorcycle engines are produced in incredible production figures (forecast for 2020: around 100 Million per year) and, as mentioned, cover two different main applications. With much more than 90 % of the produced figures, low cost engines are mostly based on simple four-stroke technology without lambda-control. Until now, beside the key properties as low production costs, robustness, ease of maintenance and low fuel consumption , the specific power and emission characteristics played a less important role. This is changing at the moment as emission regulations get more stringent. The technologies enabling these new emission levels are already available. However, the research and development task is to find cost effective solutions for low-emission combustion systems, engine control algorithms (without additional sensors) and exhaust aftertreatment (Kirchberger et al., 2007). On the contrary, for recreational motorcycle engines, specific power and power/weight are strong arguments for the European and US markets. The dominating engine concepts are based on the four stroke, naturally aspirated MPI principle. Although the power figures of more than 200 HP in the supersport class come close to pure racing motorcycles, no end of the power-orientated trend is foreseeable. An additional (and not easy to fulfil) requirement is and will be the emissions: not only are the future limits of harmful gaseous emissions tailored to passenger cars, but also On-Board Diagnosis and Real Drive Emissions as well as CO_2 emissions will be a topic in the near future (Eichlseder I, 2014). A massive technological step in engine control devices, driven and supported by variabilities of engine components and parameters, will be necessary. Approaches using passenger car technology are probable: Variabilities in the valvetrain (different valve lift curves, cam-phasing, valve deactivation) (Eichlseder II, 2014), super- and turbocharging (Hirz 2005, Zinner 2014), direct injection (Schmidt, 2009) etc. are being investigated or even in development. It has to be mentioned that many of these technologies have been applied for motorcycle engines even before their use in passenger cars, but disappeared for different reasons. Two stroke motorcycle engines with their excellent power density are, due to emissions reasons, only applied in some specific niches as mopeds and competition (Enduro and Trial) bikes (Winkler et al., 2015). Within the next years a significant technology step, probably with electronically controlled direct injection, is necessary to fulfil the upcoming legislation and keep them in production at least in their niches.

Handheld tools, on the other hand, are using two-stroke engines equipped with a carburettor in most of the cases. High power density, low weight and costs as well as simplicity are the convincing advantages of this concept. Today's concepts are operating with quite rich mixture settings in order to achieve high performance, robustness and good transient behaviour. As their emission behaviour is quite poor compared to passenger car engines, and the user is exposed to the exhaust gas most of the time, the engine technology had and has to be developed further in order to keep the two stroke specific advantages in combination with environmental compatibility. As primary successful steps stratified scavenging systems and first electronic control functions were introduced in the last years. Key technologies such as advanced control functionalities (lambda, ignition) compensating different fuel qualities, temperatures, altitude etc., as well as simple fuel injection systems (Trattner, 2016), have to be investigated in the future.

For different power products as snowmobiles, personal watercraft, side-by-side vehicles, outboards etc., four stroke as well as two stroke engines are applied. Challenges are similar to these of motorcycle engines, but according to different boundary conditions and weighting of properties the design slightly differs; nevertheless, in principle the technologies applied and under investigation for future solutions are similar.

Small Diesel engines are widely used for stationary applications, agriculture and construction machinery where their benefit in fuel consumption is worth the higher costs and, at least as naturally aspirated units, clearly lower power density. Unconventional drive systems as rotary engines, Stirling engines and small gas turbines are applied in special niches and are, as well as fuel cells, not discussed in the presentation.

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Conceptual Trends in Development of Future Unmanned Aerial Systems and their Propulsion Derivatives

A. Dvorjetski*

Head of Concepts and Unmanned Systems Branch, Aeronautical Division,
Directorate of Defense Research and Development, Ministry of Defence, Israel
* Presenting author email: ariel_dvorjetski@mod.gov.il

Keywords: Unmanned Aerial Vehicles; ICE; Fuel Cells; Drones; Civil Market

In recent years, there has been a tremendous growth in the unmanned aerial system market, for various operational requirements and scenarios. Moreover, in recent years the demands are also derived in from the civil market, which brings new requirements which were not familiar to the classical military industries.

When dealing with Unmanned Aerial Vehicles propulsion systems, it is commonly known to address the MTBL (Mean time between losses) of the platform. Usually, 60-70% of the safety events of those platforms are driven from propulsion system failures, malfunctions, etc, mainly for the ICE propelled platforms. Statistically (based on field operation data [1]), the reliability of the platform is related quasi-linearly to the size of platforms, in the log chart, as one could be seen in figure #1:

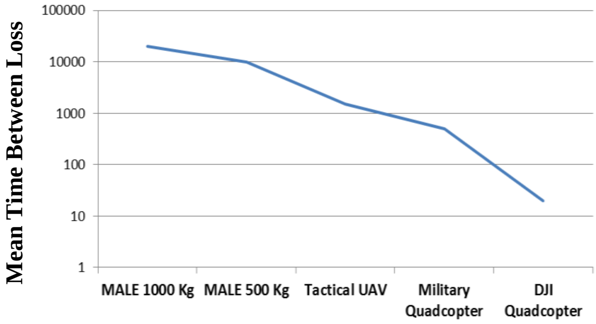

Figure 1. Mean time between loss and Platform size

When looking in such figure, we understand that there are new players of platforms, that originally were not part of the mainstream business of the classical aeronautical industries, such as tactical Drones, multi-rotors vehicles etc. Therefore, when we discuss conceptual Trends in Development of Future Unmanned Aerial Systems, we should delineate between the UAV tiers – HALE, MALE, and near Terrain.

Future MALE systems

In general, we believe that the Thrust to weight ratio will be always limited due to the MTCR limitations, thus the focus from the platform side would be in the "2nd derivative" of the propulsion system. Therefore, the MALE (Medium altitude Long Endurance) platforms main propulsion requirements rely on three main contributors: Capability of retaining Power in higher altitudes (30-40 Kft), power of auxiliary systems (i.e. advanced Payloads) and emergency batteries.

Retaining power in higher altitudes bring the need for turbo-charging to the table. Several researches have been conducted in recent year in that direction. However, the classical MALE UAV Workhorses around the world still use a basic turbocharger system. We believe that the conservatism in the aeronautical arena should provide a space for a learning process of the advances in automotive world which could be an attractive solution (twin/triple parallel charging, hybrid charging, etc.).

Power of auxiliary systems is an emerging need, where future payloads of MALE systems require much larger power, for much longer flights. Advanced SAR and future standoff capabilities bonded together with advanced communication suites bring the need of future single alternator that could achieve up to 10KW for MALE systems in the next 5-10 years, with MTBR (mean time between overhaul) of above 2000 Hours, in compact design.

Emergency Batteries is a basic requirement for the MALE platforms. However, the majority of them utilize today basic technology (Ni-Cd or Lithium-Ion Batteries), which encapsulates energy density between 30 to 100 Watt*Hour/Kg. We believe that the need of reduction of batteries weight and enhancement of the batteries operation time is crucial in the MALE family, where longer flights are becoming a regular flight profile.

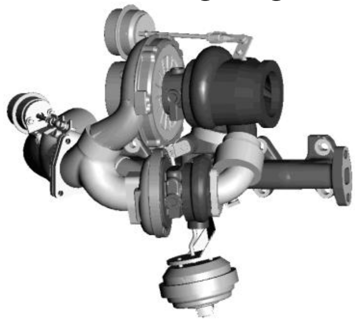

Figure 2. Future concepts of Turbo Charging

Future Tactical UAV systems

Tactical UAVs is a rapid growing market, where the capabilities are endless. Due to the miniaturization of Payloads and navigation systems, we believe that several DDD (Dull, danger, dangerous) missions will migrate from the MALE systems in to the tactical UAV systems in the future, on top of the utilization of such Tactical UAV systems by the sole soldier. Most of the current tactical UAV systems utilize electric motors as the sole source for the propulsion. Therefore, the Tactical UAV systems main propulsion requirements rely on three main contributors: prominent enhanced endurance time, propulsion system volume reduction and reliability enhancement by utilizing hybrid systems. All requirements should adhere to the tactical world budget – low cost, simplicity in usage and logistics.

Prominent enhanced endurance time brings the need for advanced propulsion systems which will enable two-digits flight time (in hours) for the tactical (~50 Kg Gross weight of Platform). A relevant technology for such requirement could be solar cells and fuel cells. In the aeronautical field, we aim for a PEM fuel cell which provide up to 800 Watt*Hour/Kg in the next 5 years.

Propulsion system volume reduction

The introduction of future prolusion systems in the tactical UAVs brings a new challenge of volume. Therefore, a need of a compact propulsion system, utilizing On-Demand energy storage is critical. Conformal hydrides tanks of is a future concept we should explore to wisely implement relevant volume of the future tactical vehicle.

Reliability enhancement by utilizing hybrid systems

Although tactical UAV systems today use mostly electrical motors, we believe that near future will incorporate ICE engine in the tactical world as well. Due to the long reliability learning curve of small ICE engine, a hybrid solution of propulsion shall be perused. Such solution could provide benefits of ICE world and future electrical technology, both for safety and operational needs.

Figure 3. Tactical UAV in operational usage

Future Multi-Rotors Systems

The Multi-Rotors system is the most emerging UAV system in the civil market. In winter 2015, it was the most notable present for Christmas in USA. Due to the low cost for entry level systems, it became a tool that enable vast amount of users (civil) and relevant operational scenarios in the militarized world. The military world is just in the first phase of understanding the potential of Multi-Rotors, and to decide which the benefits of the emerging civil market should be absorbed in the military systems. We currently see three main contributors in the propulsion need of such platforms: Reliability, Acoustics and rotors optimization, endurance time in hovering.

Reliability brings the need for electric motors that should be cheap on one hand, and mission-reliable from other hand. That would elevate the need for introducing endurance tests for such motors, at a relevant volume, for the mission profile required.

Acoustics and rotors optimization address fundamental aspects for multi-rotors. The optimization tools for rotors geometries for performance vs. acoustics is still not in appropriate phase of utilization by industries, and relies heavily on academia. A change in that direction is required.

Endurance time in hovering is essential operational requirement, as most Multi-Rotors of today's world could achieve up to 1 hours (regardless of size), using electrical batteries up to 240 Watt*Hour/Kg. Future technologies, such as fuel cells is a key player for breaking that limit.

In general, in the field of Multi-Rotors systems, we should selectively decide which technology we develop in the military world, and which technology we absorb from civil market. Such decisions are relevant also for the propulsion system selected.

Figure 4. Multi Rotor UAVs

Conclusions

The demand of unmanned aerial system both for the military and civil market keep growing, and the propulsion systems making continuous upgrades for achieving the new platforms requirements. Relevant focus items in future propulsion requirements in the MALE, tactical and Low Terrain UAS systems were presented. We believe that the propulsion industry should pursue the relevant platform trends to keep being relevant today and in the future.

HALE Piston Propulsion Systems Optimization

L. Piancastelli*, L.Frizziero

DIN (Aerospace Div.), University of Bologna, viale Risorgimento 2, 40136 Bologna - Italy
* Presenting author email: luca.piancastelli@unibo.it

Keywords: HALE, MALE, UAV, piston engine, supercharging, installation, cooling, thrusters

Diesel and spark-ignition piston engines are an ideal choice for long endurance, high altitude operations (10,000m/33,000ft) and extremely high altitude operations (20,000m-65,000ft). These systems are more complex than traditional applications that are normally limited to 5,000-7,000m (16,000-23,000ft). In fact, the air propulsion system (propeller or fan), the air intake, the fuel system, the turbocharging, the exhaust and the cooling system take part to the design optimization process. An integrated design is strictly necessary. Since prop-fan is currently under development, the design should start from the choice between propeller and fan. This choice will influence optimum cruise speed, critical altitude and aircraft design as a whole. The air induction system is extremely important to improve efficiency, endurance and critical altitude. At low altitude, a filtered induction system is used for takeoff. At high altitudes, the intake air is taken from high-pressure areas into an alternate, extremely optimized, path. This induction system recovers as much pressure as possible, air kinetic energy at cruise speed. In propeller systems, the intake is usually positioned in the lower part of the aircraft. On fan systems, a little amount of "high pressure" air is taken from the high-pressure area of the fan. The exhaust system is also critical with the choice between pressure recovery and thrust. Exhaust-pressure-recovery reduces backpressure and temperature at exhaust. This is important, since propeller efficiency is reduced with Reynolds number at altitude. However, the improvement in critical altitude is marginal. In more common, thrust driven exhaust systems, the exhaust energy is converted into speed and thrust. At the relatively high speed of high altitude cruise, also the cooling system adds a small amount of thrust through the Meredith's effect. The piston engine power plant design is then extremely critical. Many different components should find the correct position for maximum performance. The power-plants of WWII water-cooled fighters and bombers are good examples, even if their design cruise altitude is below 10,000m (33,000ft). Modern turbofan and turbojet air intakes are also of help. Commercial turbochargers and intercoolers derived from the automotive field can be used for HALE powerplants. However, Reynolds and Mach number differ from ground based applications. Therefore the compressor and turbine map supplied by the manufacturers should be corrected. Turbomatching equations should be adapted to the new extremely high altitude environment. Compressor impeller and turbine housing should be remanufactured to suit to the new requirements. Also intercoolers should be converted to the new application. In any case, the requirements of low weight, high reliability and long endurance HALE (High Altitude Long Endurance) UAVs (Unmanned Aerial Vehicle) requires further work on this specific subject.

Requirements of future diesel propulsion system for MALE UAVs

J. Feldman[1]*, Y. Fass[1]
[1]Israel Aerospace Industries, Ben-Gurion Airport, Israel
* Presenting author email: Jfeldman@iai.co.il

Keywords: Engine; UAV; Diesel

The new trend in aircraft piston engines is the diesel engine. Modern diesel engines are starting to be used in light aircraft. The main reasons for this trend are reduced availability of Avgas (aviation gasoline) and newly developed automotive diesel engines. The reduced availability of Avgas has created a need for engines working on other types of fuel. Engine manufacturers have identified this need and have started to develop aviation diesel engines either from scratch or as automotive engine conversions. The new automotive diesel engines provide higher reliability and lower operating costs. The diesel engine also has lower specific fuel consumption than a gasoline engine (Figure 1). This is beneficial influence on the aircraft by increasing range and endurance. Although the spark-ignition engines, which require high-octane fuels such as gasoline (Avgas) and methanol, have been the predominant choice among light aircraft, there is a growing trend to incorporate diesel engines in UAVs.

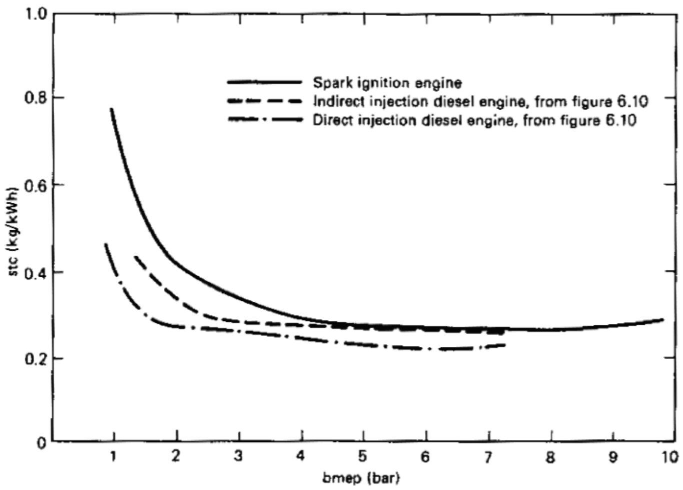

Figure 1 SI and CI SFC comparison (Stone, 2012)

There is a difference between requirements for UAV propulsion systems and for automotive drive systems. Some flight time of UAVs is performed while flying at loiter speed as the engine runs at low throttle setting. On the other hand, some flight time is performed with take-offs and climbs as the engine is set to maximum power settings or close, which take their toll of the engine life. Engines for light UAVs are designed for prolonged flight at a relatively high 75% throttle setting. When considering converted car engines, they have not been designed for operation near full power for prolonged periods.

Some diesel engines for aircraft applications have been certified for operation and are already available in the market. Among these engines are the Wilksch WAM-12, the SMA SR-305, and the Thielert TAE-125, but others, like the Delta Hawk, the Zoche ZO-01A and the Airship A-Tech 100, are already in demonstration stage.

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Investigation of engine coolant system in UAV

Ofer Levy
[1]IAF, IDF

Keywords: Engine; UAV; Cooling system; Failure

The steady advance of the world into composite materials leads to the need for deep understanding of failures in composite and non-metallic materials.
Failure Analysis Department has the capabilities that allow it to undergo thorough research as will be presented in the process of a failure investigation of a UAV engine coolant system.

The failure occurred during flight. It was noticed that the engine coolant temperature increased to dangerous levels and simultaneously, the cylinders temperature began to rise. The aircraft landed safely. Visual examination of the engine revealed that one of the pipes that supply coolant liquid to the engine is torn.

In the past similar failures occurred and led to a design revision in the pipes. This revision did not prevent the current failure. Furthermore, an additional failure of a pipe from the new design occurred to a foreign operator.

The scope of the investigation included:
-Documentation and disassembly of the engine.
-Visual and Macroscopic examination of the failed pipe, pipes for comparison (used and new) and the failed pipe from the foreign operator.
-Testing pipes in different environments and temperatures, Mechanical testing, Temperature measurement of engine area.
-Various chemical analyses of the materials in the system (pipes, coolant, motor oil.(
-Examination of additional engines and aircrafts.

Analyzing the fractographic, analytic and experimantal results led to determining the failure cause of the current event – and subsequently, the past events.

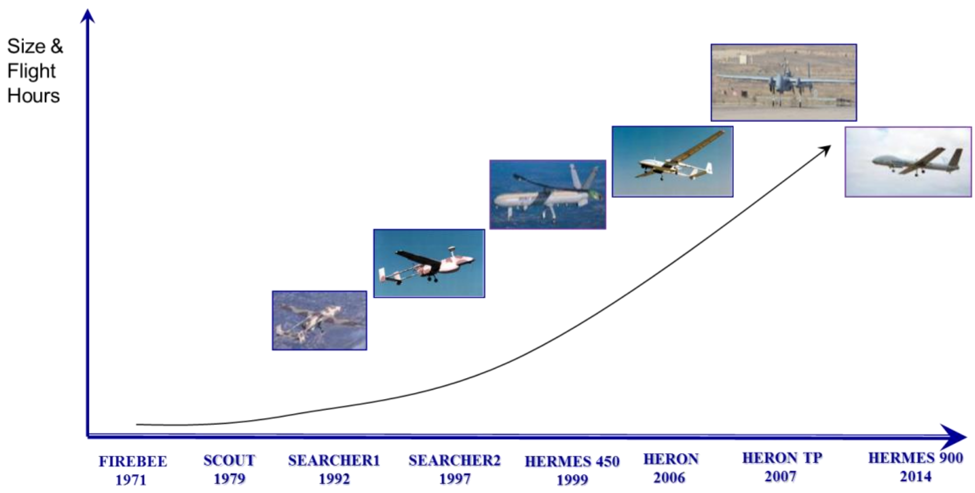
Operational Perspective of Internal Combustion Engines Usage in MALE UAV Fleet

A. Gil

Israel Defense Forces, Israel

Keywords: Unmanned Aerial Vehicles; ICE; Operational Lessons

UAV usage in Israeli Air Force has legacy of more than 40 years. Since the early days, the operational requirements and the advance in technology joined forces to bring to the battlefield more capable unmanned systems.



In Recent years, there has been a tremendous growth in the unmanned aerial system market, for various operational requirements and scenarios. This rapid growth in demands shows it way in the variety of missions: ISTAR – the main mission (24/7), JTAC, Close Air Support (CAS), Maritime patrol mission, Hunting rocket/mortar launchers, BDA, S&R, Police, Fire fighters, etc.

Operating Massive UAV fleets flying enormous amount of flight hours requires comprehensive understanding of the air vehicle , and especially the its propulsion system. it is commonly known to address the MTBL (Mean time between losses) of the platform. Usually, 60-70% of the safety events of those platforms are driven from propulsion system failures, malfunctions, etc., mainly for the ICE (Internal Combustion Engines) propelled platforms.

Main issues that attract the operator are Engines failures that might cancel the mission, or even cancel the sortie. Such cancellations are key factors of the reliability of the air-systems. In general terms, elevating the engine reliability would reduce dramatically mission cancellation rate.

Major items of focus to the operator would be rpm fluctuations. Such fluctuations could be severe, and still not to be identified by an operator. That because of the fact that engine behavior tend to be deteriorating during the mission, and due to the replacement of operator between shift, this deterioration sometimes could be "covered" by other factors.

Another item of importance to the operator is severe engine malfunctions that can be caused in surprise. One key item of the ICE propulsion systems is detonation. Such incidents could cause catastrophic instances of loss of control of the vehicle, and incapability of the operator to understand properly the situation.

Usually, as majority of flights are operational, the operator is lack of training of variety of engine problems. He would be trained by "real time" problems that we withstand in the real world, and usually will not have a specified "engine problems" simulator.

Looking in to the future, from the operator eyes, one would like to absorb new technology that would reduce that attention and the need of the operator to look on the engine operation during mission. Main idea would include:

1) Automation of control on the engine RPM / Throttle for various condition and malfunctions.
2) Improved algorithms to reduce chances of engine detonation
3) Improved algorithms to change engine performance and deterioration identification early enough, based on neural networks and system autonomous learning.
4) Condition based maintenance for engines rather hourly based maintenance for the engines – that would give the operator much more flexibility to utilize the available operational fleet.
5) Integrate propulsion – driven scenarios in real-time simulators to enhance the operator capabilities to withstand such problems in real world scenarios.

Conclusions

The demand of unmanned aerial system keeps growing, and the propulsion systems making continuous upgrades for achieving the new platforms requirements. In the paper we addressed key items in the future requirements in the reliability enhancements of the UAV ICE engines.

Knock Prevention in UAV engines – Theoretical Considerations

R.AMIEL. *, L. TARTAKOVSKY.[1]

[1]Faculty of Mechanical Engineering, Technion – Israel Institute of Technology, Haifa, 32000, Israel
* Presenting author email: Ran@amiel.biz

The knock phenomenon in spark ignition (SI) internal combustion engines (ICE) has been a limiting factor in power generation since its invention in the mid-19th century. Knock (or detonation) is an abnormal combustion in the ICE cylinder, caused by an undesired ignition of the unburned mixture inside the cylinder in addition to the flame initiated from the spark ignition. Two main phenomena that cause this are surface ignition and mixture ignition due to the increased pressure and temperature during the progress of the flame through the cylinder. Abnormal combustion is called "knock" due to the noise generated by the collision of the multiple flame fronts and the increased cylinder pressure that causes the piston, connecting rod and bearings to resonate. The presence of multiple flame fronts can have serious effects on the ICE: decrease in engine power output and longevity, increase in pollutant emissions and total destruction of the engine in the worst cases (Heywood, 1988; Zhen *et al, 2011*). The main goal of this research is to study the causes of knocks in the Rotax 914 engine, to find the methods to identify their start and to prevent them.

At the first step of the research, a computer model of the engine in the GT-SUITE software was built. The reached accuracy on the main parameters of the engine (power, BSFC and air flow) is up to 2% deviation from the test bench measured values. After achieving that, the potential treatments available in the research were evaluated. The criteria for the desirable ways for knock prevention and mitigation were simplicity, cost, availability, time needed for implementation and low weight. All considerations were made based on GT-SUITE analysis of the engine model that has been developed. The chosen solutions were:

- Optimization of the cooling system (intercooler)
- EGR
- Spark advance
- Water injection

The GT- SUITE experiments were performed at 5510 rpm, 1.212 bar air box target boost pressure, altitude of 4500 feet and temperature (air box + ambient) and pressure which have recorded as conditions causing knocks. Reduction of air box temperature by 5-10 degrees is not expected to entirely solve the problem, but to cause it to happen in a less dangerous region of amplitudes (Figure 2).

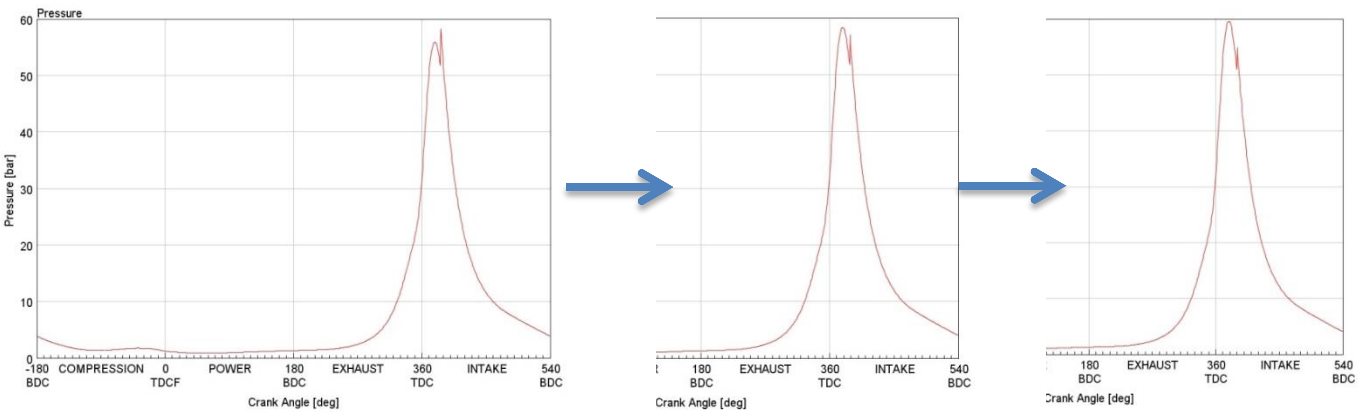


Figure 2. Indicator diagrams of Cylinder 1 at 330, 310 and 300 deg. Kelvin

The knock problem can be completely eliminated by using EGR at rates of 0-10%. Already at rates of 5% the phenomenon becomes insignificant (Figure 3). This comes with a cost of higher BSFC and lower engine power.

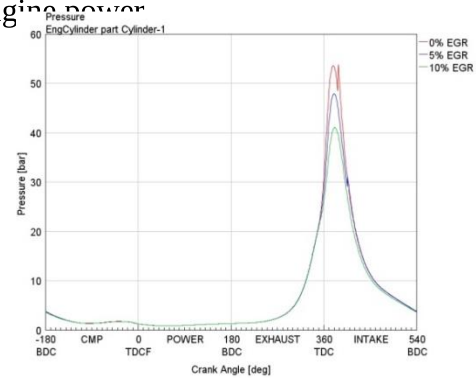


Figure 3. Indicator diagrams of Cylinder 1 with EGR

By using water injection at rates of 0-10% of the total fuel injection mass, knocks can be eliminated (Figure 5) with no significant influence on the BSFC and brake power (Figure 4).

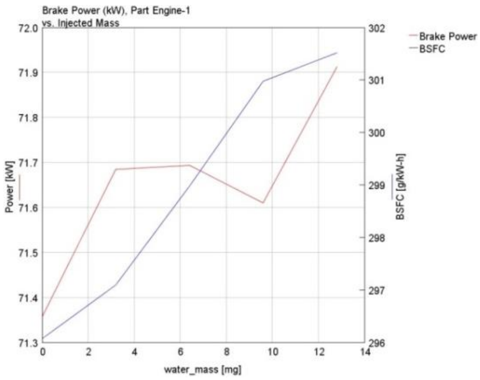


Figure 4. BSFC and brake power with water injection.

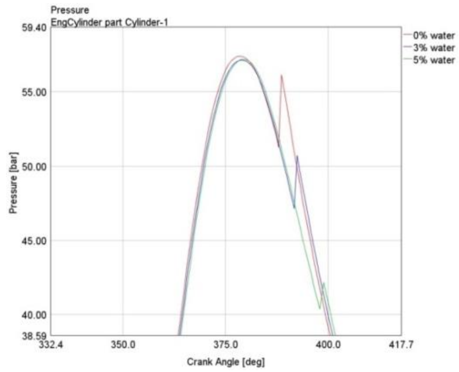


Figure 5. Peak pressures with 0, 3 and 5% mass water injection.

By using retarded ignition timing of 3° the amplitude of knocks can be reduced out of the dangerous area (Figure 6).

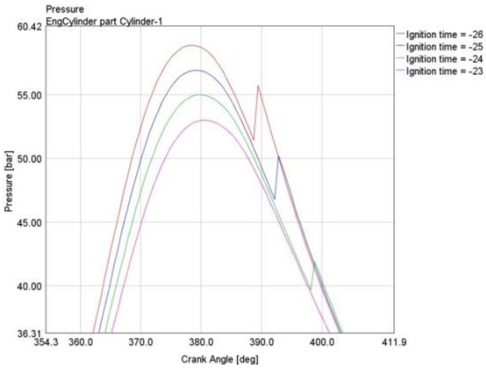


Figure 6. Peak pressures with -26 to -23 BTDC ignition timing.

Acknowledgement

This work is supported by MAFAT.

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The Cryogenic Miniature Propulsion System - Initial Test Results

E. Sher*, Y. Fuchs, A. Lidor and D. Weihs

Faculty of Aerospace Engineering, Technion, Haifa, 32000, Israel
* Presenting author email: sher@technion.ac.il

Keywords: MAV Propulsion; Cryogenic propulsion system

A cryogenic miniature propulsion system for micro aerial vehicles MAV) has been developed, constructed and tested. In this unique system, the energy source is a phase-change-material (PCM) that is initially at saturated liquid conditions. In our specific system we used saturated nitrogen at a pressure of 1MPa. During operation, the nitrogen is heated by a heat exchanger that is constructed inside the container. The warmer fluid in the heat exchanger is a superheated nitrogen at atmospheric temperature that was delivered by the same container and then allowed to absorb heat from the surrounding at the same pressure. Part of the superheated nitrogen is redirected to heat the container to provide the proper amount of heat to vaporize the required amount of nitrogen, and the other part is directed to drive a miniature turbine. The superheated nitrogen flow that is used to vaporize the nitrogen is then allow again to absorb heat from the atmosphere and then the two nitrogen parts are mixed prior to the turbine entrance. The nitrogen is expanded in the turbine to the atmospheric pressure and then exhausted to the atmosphere. The nitrogen container contains initially the needed amount of liquid hydrogen as required for the pre-specified mission (mainly a derivative of the flying time).

In the present presentation, we will outline the principles, dimensions and show the optimization considerations of the cryogenic propulsion system. Some initial yet promising results will be presented and analysed. For a nitrogen based PCM open cycle with a 20W micro-turbine 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 10okPa.

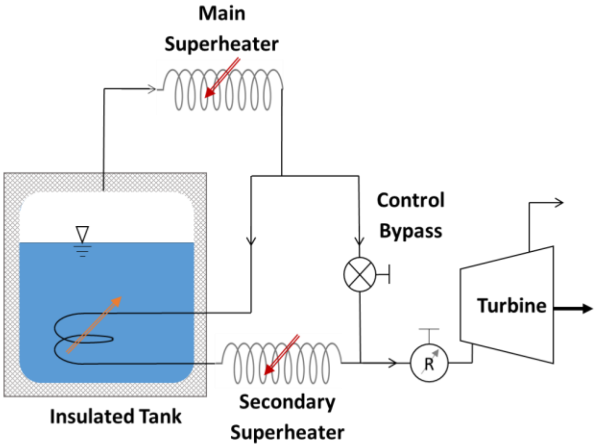

Figure 1. Schematic of the PCM engine concept

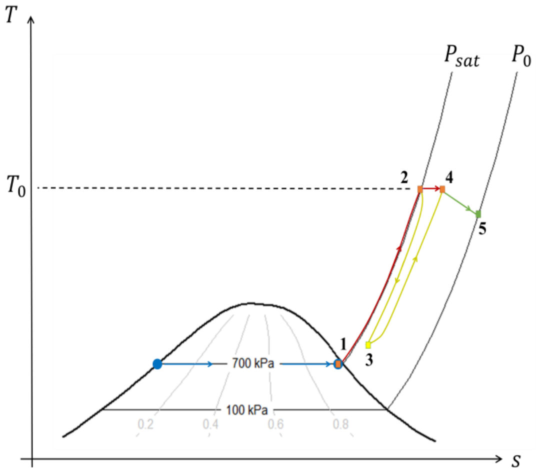

Figure 2. T-s diagram of the proposed cycle

Acknowledgement

The support of Mr. Tal Yehoshua is greatly appreciated.

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Energy management system for high fuel economy and low pollutants emission of a vehicle

Erez Mosafi

Ledico – Bosch Israel
* Presenting author email: mosafie@zahav.net.il

Keywords: Intelligent alternator control; Battery charging strategy; Cyclic stability

The core principle of the intelligent alternator control is an expanded charging strategy for the vehicle battery. Accordingly, the battery is no longer fully charged but charged to a defined level depending on various environmental/ambient conditions (outside temperature, battery age, etc.). In contrast to conventional charging strategies, energy recuperation now takes place only during the overrun (coasting) phases of vehicle operation. Alternator excitation is at a maximum during these phases, electrical energy is generated and fed to the vehicle battery. Fuel is not consumed and the kinetic energy produced by the vehicle in coasting mode acts on the alternator via the wheels and engine so that electrical energy is generated. The alternator is not excited during the acceleration phases of the vehicle. Consequently, no energy is generated and therefore no fuel is used for the purpose of generating electrical energy – Fig.1. Fuel consumption is reduced by way of energy recuperation in favorable vehicle operating modes (overrun phases) based on a request to increase the alternator voltage (target value). This energy recovered without the use of fuel is stored in a "receptive battery". The charge status of the battery must be within certain levels that permit charging. A fully charged battery (100 % charged) cannot accept energy and is therefore avoided as part of the intelligent alternator control strategy.

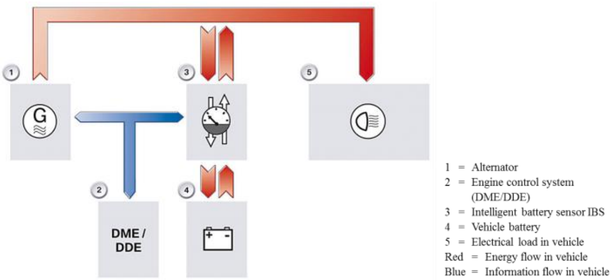

Figure 1. Energy and information flow.

The engine-control system communicates with the intelligent battery sensor and with the alternator via the bit-serial interface (shown in blue). The information from the intelligent battery sensor is used to calculate the charge and ageing status of the vehicle battery in the power management. The power management is the software that is responsible for all energy management calculations. On vehicles equipped with intelligent alternator control, the application is additionally responsible for the control processes of the intelligent alternator control. The control units connected to the overall bus system represent further sources of information. General conditions that influence the charging procedure are derived from the acquired information. This control process results in precisely coordinated charging of the vehicle battery using the least possible energy from the engine.

In contrast to conventional charge control, the intelligent battery control avoids a 100 % charge. The charge level of the battery reaches about 70 - 80 % of the maximum possible charge. The intelligent alternator control is suppressed cyclically in order to allow 100 % battery charge to maintain the full capacity of the battery over time (regeneration) – Fig.2. In the intelligent alternator control system, the alternator voltage is correspondingly more often in the lower voltage range in order to achieve more effective charge intake by the vehicle battery.

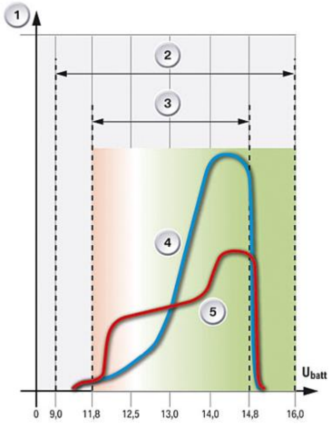

Figure 2. Charge level and voltage control.

1- Frequency of alternator voltage; 2 - Maximum permissible voltage range in vehicle; 3 - Alternator control range; 4 - Charging voltage, conventional alternator control - the charging alternator charging voltage is predominantly in the range between 13 V and 15 V; 5 - Charging voltage, intelligent alternator control - the charging voltage is predominantly in the range between 12 V and 15 V. It is possible to charge the battery while the vehicle is in overrun (coasting) mode.

The IGR function is subdivided into three operating statuses:

• IGR-Low: The alternator voltage is increased during overrun phases and the battery is charged (energy recuperation)

• IGR-Medium: Battery discharge is not permitted in the phase between IGR-Low and IGR- High so that the current charge status is maintained (partial relief of alternator load)

• IGR-High: Energy returned from the battery into the vehicle electrical system (relief of alternator load)

In the IGR-Low mode the alternator voltage is increased during the overrun (coasting) phases (this alternator load status occurs only at engines speeds above 1000 rpm and at vehicle speeds of 10 km/h). The IGR increases the alternator voltage during the vehicle overrun phases. The increased voltage facilitates increased battery charging. The battery charge level increases with increasing number and duration of overrun phases (the state of charge can reach up to 100 % during the IGR-Low phase). In the IGR-Medium mode a request to partially relieve the alternator load is triggered during vehicle operating phases where fuel is used. The battery is no longer actively charged but rather only the state of charge is maintained at a sufficient level. This takes place when the state of battery has reached a certain level (approx. 70 - 80 %). Intelligent alternator control takes place when a certain minimum battery charge is reached. At sufficient battery charge level, the alternator voltage is controlled such that the state of charge remains virtually constant outside the overrun (coasting) phases. The alternator then only supplies the vehicle electrical system. In the IGR-High mode at sufficient battery charge level, the alternator voltage is controlled such that the battery is discharged at an acceptable rate. In this phase, the vehicle electrical system is partly supported by the battery. The load on the alternator is at a minimum in this phase, however, it only has a stabilizing effect for the vehicle electrical system. The required IGR voltage level is limited by the power management to a voltage compatible for the electrical system.

Micro Turbine Generators – prospect for compact power source

B. Arav*, R. Shulman

TurboGEN Technology, Tel-Aviv, Israel
* Presenting author email: borisarav@gmail.com

Keywords: Plug-in Hybrid Electric Vehicles, range extender generator, microturbines, ICR Cycle.

Advantages of Micro Turbine Generator (MTG) (in addition to weight and dimensions): multi-fuel; excellent environmental friendliness, low noise and vibration; high reliability and low operating costs; the possibility of unification, modular design, and others. [4,5,6,7]. Modern possibilities increase the electrical efficiency of MTG to the level of diesel generators [6,7]. Those advantages possible due to the simplicity design of MTG.

The MTG is based on a rotor, consisting of compressor, turbine and rotor generator. Therefore, the market of MTG is much wider then PHEV's market [5,6,7]. MTG demand: a) mini power stations and systems, distributed generation Combined Heat (Cooling) and Power (CHP and CCHP), compatible for alternative energy sources; b) - in the Auxiliary Power Unit (APU) combat vehicles; c) - as a waste heat energy, including for fuel cells and others. There is enough experience with the MTG systems CHP (30-200 kW), and others. [5,6,7]. However, there is no mass production and the price is unacceptable for use in the PHEV.

"TurboGEN Technology" company performed the analysis of structures and simulation cycle of MTG. In the result of research is justified the efficiency of the Brayton cycle with intermediate cooling and regeneration (ICR). Defined a rational scheme and parameters of ICR and possibility of unification with turbochargers, coolers and other mass production on-shelf automotive aggregates .[4] On this base, designed a family of multipurpose and unified MTG (2.5-25 kW output, prices to $ 300-400 / kW) for use in REG, mini electric plant , CHP, APU and other sources of energy.

Currently undergoing bench testing concept MTG REG (Brayton cycle, NREG to 1.9 kW; n to 120,000 RPM, propane fuel) Unified with automotive turbocharger "Garrett", Fig.1. Using the permanent magnet alternator "Bental Motion Systems" company. Achieved meet the requirements for overall dimensions.

The authors share the view that the development of unified MTG is relevant, and the organization of their production in the coming years is real and economically feasible [4,7].

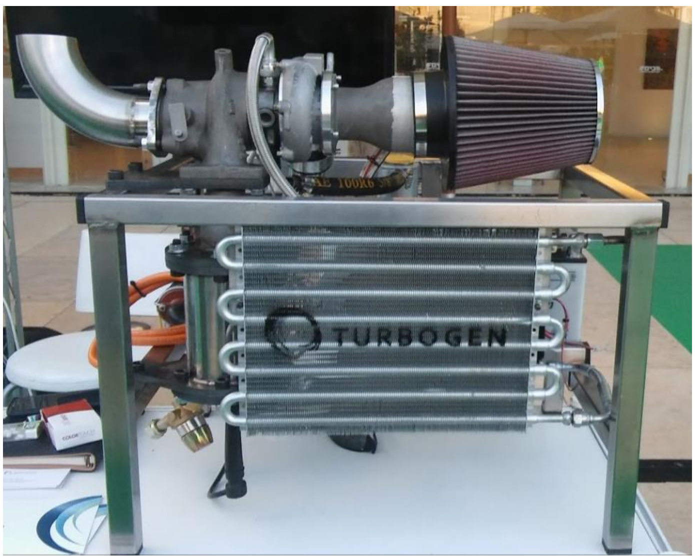

Figure 1. MTG concept by "TurboGEN Technology"

Acknowledgement

This work was supported by the EcoMotion Smart Transportation Accelerator, Bental Motion Systems and TurboTech.

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Engineering design considerations in UAV engine liquid cooling systems

Ron Raz
Engineer, UAV engines Plant Elbit systems, Nes Ziona, Israel
Presenting author email: Ron.Raz@elbitsystes.com

Keywords: UAV engines, Engine cooling system

Unmanned Air Vehicles (UAV) require engines of high power, low weight, good specific fuel consumption and reliability. In a lot of UAV's the choice for the engine is Internal Combustion Engine (ICE). As such engine and such requirements the management of the engine temperature is very important. The talk gives an overview of the engineering consideration while designing a coolant fluid cooling system for an UAV engine. The compromise between a perfect cooling solution and the weight/drag does not leave the designer table and accompany the cooling system main components and system architecture. The unique of the cooling system in a UAV root is that the platform mission different from other platforms using ICE

- The operational temperature amplitude is wide
- The operational altitude is high
- In most platforms the engine is pusher and not tractor as in most piloted air vehicles
- The weight and the drag are very important

The talk will cover main components in the system and relevant design questions

- Engine coolant channels (Parallel/in a row)
- Radiator
    - Air flow
    - Coolant flow
    - Tank contour and size
    - Weight
- Thermostat
    - one/two way
- Coolant fluid
    - Percentage of coolant fluid
    - Type of coolant fluid
- Pump
    - Place in the architecture
    - System pressure
    - Size
- Coolant tank
    - Size
    - Close system/with expansion tank
- Tubing
    - Diameter & size
    - Material – heat transfer, elasticity and the time constant
- Air duct
    - To use air from the platform boundary layer?
    - Covering the radiator thank and pipes connection?

To make a real study of the system a lot of tests have to be taken. In the engineering life we can neglect some tests and short the project duration.

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Civil Certification of UAS Propulsion Systems

Tamir Bar-Am

Civil Aviation Authority of Israel, Department of Transportation
* Presenting author email: baramt@mot.gov.il

Keywords: UAS, Propulsion System, Certification

The demand for civil applications of unmanned aerial systems in recent years has brought up the need for a set of criteria for airworthiness civil certification. Within the general certification of the complete system (i.e. airframe, ground control station and communication), a separate subject is the certification of the propulsion system, both as a standalone system and its integration in the airframe.

Civil Aviation Authorities around the world are still in the process of a preliminary definition of such airworthiness standards which will enable civil operations and to date none of the leading aviation authorities have come up with a comprehensive set of regulations for UAS which addresses the unique aspects of unmanned systems. The introduction of new types of propulsion systems such as hybrid, electric and fuel cell systems present new challenges for defining relevant airworthiness standards.

The presentation provides an overview of the existing regulations applicable to civil certification of UAS propulsion systems and the unique aspects that need to be addressed in the process.

The challenges of UAV propulsion system testing - production vs. development requirements

Menachem Lerer

Elbit Systems LTD - ISTAR – UEP
* Presenting author email: **menachem.lerer@elbitsystems.com**

Keywords: Engine Testing; Dynamometer; Data Acquisition; LabView;

Engine plants for UAV engines are facing constant constraints of testing facilities performance and availability due to the opposing requirements for routine production testing vs. highly demanding and flexible development testing. The engine test cells and all other propulsion testing facilities are therefore designed to be readily adapted for short turnaround time of configuration modifications.

UAV engine testing facilities are usually designed to support a variety of internal combustion engines, ranging from small rotary engine models, 2-stroke models, and also 4-stroke SI and CI models. The power range can be from 5 to 500 HP with up to 4 different fuel types.

The UAV propulsion testing industry segment is usually small-scale compared to other aerospace and automotive testing industry segments. This presentation describes the challenges of UAV engine testing in an environment of limited budgets, small operating production and engineering teams, and the opposing requirements of routine production testing vs. the constant changing needs of engine development efforts.

A typical UAV engine plant may operate several test cells. Some of the UAV propulsion test facilities should be designed to run engines with propeller loading or a dynamometer. The turnaround time between loading systems should be less than one day.

One important aspect of a UAV engine testing environment is that all test cells should be controlled and monitored by using the same software application and HMI. The test cell operators are all trained to use the facilities, while the engineering teams should also be capable to perform data acquisition modifications and data reduction procedures.

In addition to the main engine production testing environment, there may be also the enhancements of mainstream testing applications as LabView, Matlab, ATI Vision, and INCA. Most of the current testing environments do not require programming skills.

Engine development testing instrumentation modifications are usually performed by adding distributed data acquisition modules from National Instruments, Kistler, Advantech, Baumer and others. This presentation describes the efforts to provide a uniform database that accumulates several digital and analog I/O channels, and also communication with CAN or Ethenet data sources. The additional instrumentation modifications are always verified by using field calibrators on-site. The propulsion engineering team may also support fuel systems instrumentation, flight testing and remote site engine testing.

An important key factor for an efficient engine testing environment is the production plant organizational structure. This presentation also suggests several insights for maintenance and engineering teams training and responsibility allocation.

Flow Simulations for Internal Combustion Engines

Roey Honig

TenZor M.E.D.A. Ltd., Rehovot, 74114, Israel
* Presenting author email: roey@tenzor.co.il

Keywords: Internal Combustion Engine; Numerical Simulation; Multi-Physics; Ansys

Internal Combustion Engines (ICE) are vastly used in a variety of industries such as Automotive, Agriculture, Construction, Transportation & Aerial Vehicles. ICE's continue to dominate in the foreseeable future. In 2035, approximately 60% of engines will still use combustion. Federal Regulation (reduction of CO_2 emission), New Technologies (hybridization, light-weight materials) & Alternative fuels (rise of natural gas in ICE) are some of the global trends faced by engines manufactures.

Traditional CAD, Prototypes & Benchmark Testing alone, do not satisfy the growing need to design new and improved engines while reducing TTM. The usage of Numerical Simulations is necessary. The challenges, confronted by the FEA & CFD engineers, when simulating the ICE, arouse mainly from the highly coupled Multi-Physics nature of the system. Some of the phenomena include: Fully\Partially Premixed Regimes, Exhaust Gas Recirculation, Knock, Conjugate Heat Transfer, Spray Wall interaction, Evaporation, Charge Motion, Flame-front tracking, Flame-Wall Interaction, Spark-ignition, Chemical Species Evaluation, Fuel Injection & Cyclic Variance.

Ansys provides a complete tool for numerical simulations which is fully automated, scalable & robust as well as accurately describing the flow physics and chemistry. Dynamic-Mesh, which enables simulating the changes in the control volume as well as matching the desired fuel properties with the new ANSYS-CHEMKIN-PRO Reaction workbench to provide a numerical Fuel Model, are some of the advantages for using Ansys software for ICE simulations.

Poster presentations

Optimization of propulsion system for UAV

V. Kliatzkin[1*], E. Shalem[1]
[1] Winflex
* Presenting author email: vk@winflex.co.il

Keywords: Optimization of UAV propulsion system; Optimal parameter of optimal systems; Optimal plane parameters.

While selecting a Unmanned Aerial Vehicle (UAV) propulsion system various solutions are available (electrical engine, solar energy, internal combustion engine (ICE), gas turbine, etc.) and deciding on one could be a complex matter that takes into account the design of the vehicle, The required payload, the flight time, designation and other elements. The goal of this paper is to present a scheme for choosing an optimal propulsion system and its components.

The designed system will gather specific input from the customer such as the required payload, the flight profile, the aerodynamic parameters (CL and CD vs. angle of attack) acceleration operational envelope in every axis and others and will couple these with the optimal propulsion system.

The propulsion system will be divided into four sections and the optimal parameters of the optimal combination will be selected.

1. Energy storage:
a. On-Board storage:
i. Fuel tank with various fuel options: gasoline, metanols, kerosene, diesel.
ii. Electrical storage: battery, chemical battery, capacitors.
b. Non On-Board storage:
i. Sun energy.
ii. High frequency transmission.
iii. Laser transmission.

2. Energy inverter system:
a. Internal Combustion Engine (ICE) – Otto or Diesel.
b. Gas Turbine.
c. Electric motor.
d. Jet engine.

3. Transmission:
a. Gear between the ICE or electric motor to the propulsion system
b. Ejector to the jet system in order to increase the propulsive efficiency.

4. Propulsion:
a. Propeller:
i. Constant pitch.
ii. Controlled pitch.
iii. Vertical axis.
iv. Horizontal axis.

v. Variable orientation axis.
b. Jet.
i. Vertical axis.
ii. Horizontal axis.
iii. Variable orientation axis.
iv. Bypass jet
v. Ejector jet

Here is an example of a process for an ICE engine:
1. Thermodynamic Cycle:
a. Brayton cycle
b. Otto cycle.
c. Diesel cycle.
d. Free pumping
e. Turbocharger
f. Super charger
g. 2 stroke engine.
i. Direct air trajectory
ii. Loop air trajectory
h. Membrane spring valve distribution
i. Cylinder windows piston distribution
j. Outer mixture prepare (carburetor or injection in the inlet)
k. Internal fuel injection
l. Cylinder number choice.
m. Cylinder disposition choice.
2. Preliminary weight and strength calculation.
3. Engine parameter equation
a. Weight vs. RPM function
b. Finding the maximum load on the engine.
c. Heat transfer from the engine.
d. Propeller efficiency vs. RPM function.
e. Preliminary gear ratio calculation
f. Finding the Optimal set of the optimal parameters of the engine, gear, propulsor, fuel type, storage type etc. at predetermined parameters of fuselage, wing, TOW etc.

This process could be performed for any configuration or any flight input. Any additional information supplied by the client will only improve the system performance.

Improvement Plug-in Hybrid Electric Vehicles (PHEV) by using Micro Turbine Generators (MTG).

B. Arav*, R. Shulman

TurboGEN Technology, Tel-Aviv, Israel
* Presenting author email: borisarav@gmail.com

Keywords: Plug-in Hybrid Electric Vehicles, range extender generator, micro-turbines, ICR cycle.

The Advantages of Mini Electric Vehicles: Mini City Vehicles (MCV), Unmanned Ground Vehicles (UGV), UAV is obvious. The main drawback, limited cruising range, is overcome in PHEV [1, 2, 3]. Their specific feature is charging the battery from an external source, and, if necessary, from the range extender generator (REG), Fig.1. However energy consumption $N_{M,}$ required for movement PHEV is higher, as their total mass M_V is 15-20% higher than the weight of the Internal Combustion Engine Vehicles [2]. For the required range S and the mass of the payload M_U, reserves for reduce $M_V$and improving energy consumption N_M are limited by the reason that vehicle weight close to minimal possible, due to aerodynamic perfect construction and maximum possibility of today's power units.

In this case, the unused reserves to reduce M_V is reducing a REG mass (M_{REG}) and volume (V_{reg}). [3,4]. They consist of mass and volume of the engine, generator, fuel tank and power electronics.

For Mini PHEV, mass M_{REG} does not exceed 60-90 kg (about 10-15% M_V) with the electric power N_{reg} = 5-15 kW. Mass reduction of M_V by reduction in M_{REG} depend on engine compartment. It is estimated to MCV: ΔM_V to 1,4 ΔM_{REG} , cabinet for Mini UGV: ΔM_V to 2,0 ΔM_{REG} .

The actual effect of weight reduction is achieved by M_{REG} with: specific electric power (N_{EM}) is not less than 0.3-0.5 kW / kg, volume power (N_{EV}) of at least 140-160 kW / m3. The top concepts REG, based on internal combustion (ICE REG) achieved: N_{EM} to 0.1 kW / kg, N_{EV} to 40-60 kW / m3. The main season for those low parameters it is limit speed (n) motors and generators up to 12000-15000 RPM. To reduce the MPEG is suitable: the integration of the engine and the generator into a single unit and to increase rotation n to 120000-150000 RPM (reduce the weight of engine generator up to 8-10 times). This is achievable only by Micro Turbine Generators (MTG) [4, 5, 6, and 7].

The effect of weight reduction M_V in Mini PHEV, by using MTG REG, modeled with MCV and UGV (weight: M_V = 500 kg payload M_U = 140 kg). For modeling used Parametric Analytical Model (PAMVEC) [8] while driving: MCV (Urban Driving Cycle); UGV (Off-road Driving Cycle).

Application of MTG REG provides: 1) - during the design phase - the reduction of weight ΔM_{REG} with required reserve S and mass M_U. This reduces energy consumption ΔN_M by dependencies (Fig. 2): a) - close to proportional (MCV); b) - by increasing (UGV). Perhaps an additional proportional reduction in energy consumption, weight and cost of the batteries, simplify assembly and provide greater stability PHEV performance in difficult conditions. Thus, improving the PHEV by using MTG REG is appropriate.

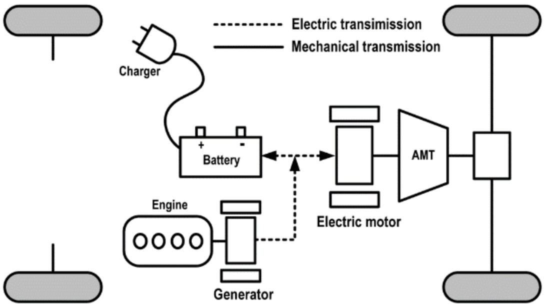

Fig.1: PHEV scheme.

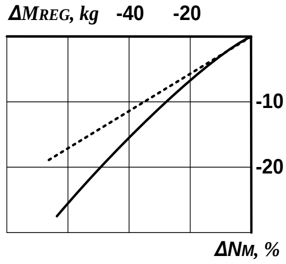

Fig. 2: Effect of reducing M_{REG}: --- MCC, ___UGV

Acknowledgement

This work was supported by the Ecomotion Smart Transportation Accelerator, Bental Motion Systems and TurboTech.

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Analysis and danger assessment of UAV flight conditions at low altitude

E. Shalem[1], V. Kliatzkin[1*]

[1] Winflex, Israel
* Presenting author email: vk@winflex.co.il

Keywords: Turbulent flow; low altitude flight; UAV accidents.

According to US army, navy and air force reports the human factor is a key contributor in UAV accidents and could amount up to 67% of all accidents in certain models. Within the human factor the majority of incidents involve take-off and landing.
UAVs regularly experience turbulent wind conditions during flight, as such; turbulent wind exhibit drastic variations in both temporal and spatial aspects. Naturally this is common for every aerial vehicle, however since a UAV's size and weight creates a smaller inertial energy it is much more susceptible to these variations.
The influence turbulent flow has on the flight of the UAV's has to be evaluated, in order to do that the flow itself needs to be evaluated. Since turbulent flow has little value for singular data points a massive database of wind measurements was collected.
An analysis of the database shows the distribution of wind speed at different times and the fact that the wind can change its speed at up to double its value in as little as a second from its former average speed, which in turn will change the aerodynamic forces at up to 4 times so in order to maintain constant speed the propulsion system need to increase its output by a factor of 8 to compensate, these compensation are impossible for a jet engine or gas turbine with constant propeller pitch, however for an Internal Combustion Engine (IEC) with direct fuel injection it might be obtainable using a specialized control loop.
These facts lead us to believe that UAVs takeoff and landing speeds might fall well within the range of atmospheric wind speed, which will elevate the importance of these measurements.
The experimental part was consisted of 3D, high (20 Hz) frequency wind measurements performed at a height of 20 m taken at different times of the year and different hours of the day, and the database itself is comprised of over 1.1 million data points.
By displaying and analyzing the complicated wind conditions UAVs have to face at low altitude it is possible to better evaluate the risk and the requirements that need to be met in order to improve safety and reduce accidents that occur in low altitude flight.

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Surface Modification by Shot-Peening for Friction and Wear Reduction

H. Kasem*, and G. Ryk

Tribology Laboratories, Israel Metals Institute Technion, Haifa Israel
* Presenting author email: mehaytam@technion.ac.il

Keywords: Surface modification; mechano-chemichal treatment; friction reduction; wear reduction

Considered as a key part of defense strategy, UAV systems place a high priority on reliability. Ensuring that reliability involves that certain critical factors, including friction, wear and leakage must be addressed in the design of the UAV. Besides, it is well known that the topmost surface layers govern frictional performance, and modifying their physiochemical properties is implemented to reduce frictional losses. Modifying physic-chemical properties of these layers is an obvious choice in trying to reduce friction losses. Known solutions to the problem are focused on the use of oil additives that react with working surfaces under extreme loading conditions to form low-shear-strength surface films. However, most materials, added into lubricant oil, such as chlorides, sulfides, and phosphates, offer only a limited life expectancy and limited reduction of friction for engines that causes the fuel consumption and frictional losses of many industries to be far from optimal.

Besides, extensive plastic deformation of near-surface regions achieved during finishing manufacturing processes is known to thermally activate the surface and generate channels for easy diffusion of foreign atoms into the topmost layers of the metal. We took advantage of this phenomenon to introduce lubricant-bonding films to the samples surfaces made of Cast-Iron. This is done by supplying sulfur-containing compounds during finishing shot-peening cold-working processes. Tribological tests were performed on a “Roller-Block” experimental device under heated lubricated contact using SAE-20 oil. The first results show that this technology allows decreasing friction manifold under lubricated conditions including oil starvation (see Fig. 1), increases surface hardness and allows controlling surface roughness.

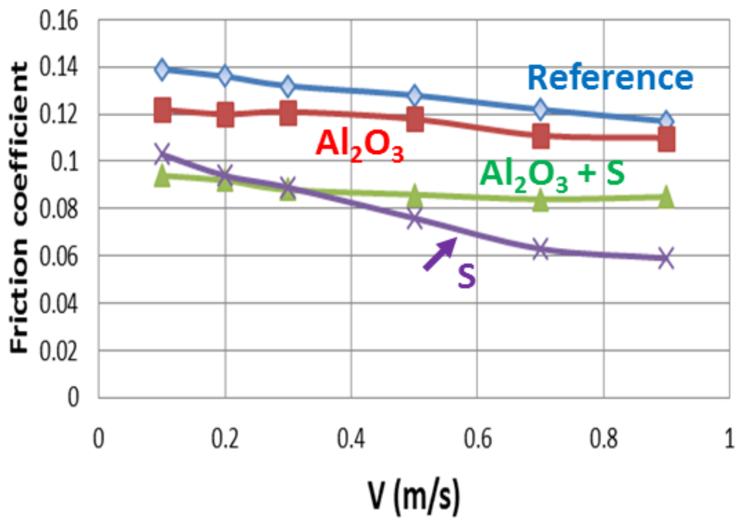

Figure 1. Comparison of friction between different treatments and a reference surface

Acknowledgement

This work was supported by the Technion Technology Transfer T3 fund.

Combustion mechanisms validation at fuel rich conditions using Laser diagnostics.

Alexey Fomin[1], Tatyana Zavlev[1], Vladimir A. Alekseev[3], Alexander A. Konnov[3], Vladimir Tsionsky[1], Igor Rahinov[2], Sergey Cheskis[1]

[1]School of Chemistry, Raymond and Beverly Sackler Faculty of exact Sciences, Tel-Aviv University, Tel-Aviv, Israel

[2]Department of Natural Sciences, The Open University of Israel, Raanana, Israel

[3]Division of Combustion Physics, Lund University, P.O. Box 118, SE-221 00 Lund, Sweden

Presenting author email: alexeyfo@post.tau.ac.il

Keywords: Laser Diagnostic, ICLAS, FLICAS

Laser-based diagnostic measurements provide a rigorous test of our understanding of combustion chemistry. Intracavity Laser Absorption Spectroscopy (ICLAS) technique used for absolute concentration measurements of HCO and $^1CH_2$ radicals, playing an important role in combustion mechanism. HCO radical reactions have a strong influence on the chemistry of the chain reactions of oxidation or combustion, since the concentration of the H atom is strongly dependent on the presence of HCO. The $^1CH_2$ radical is also important intermediate molecule in hydrocarbon oxidation. Methylene has been involved in the buildup of higher hydrocarbons in flames and in formation of soot (Homann, K. H. 1983, Homann, K. H. 1981).

The experimental spectra of the HCO and $^1CH_2$ radicals were recorded for different equivalence ratios. The interpretation of the spectral data is presented and its potential for the combustion model development is discussed. [see Fig.1]

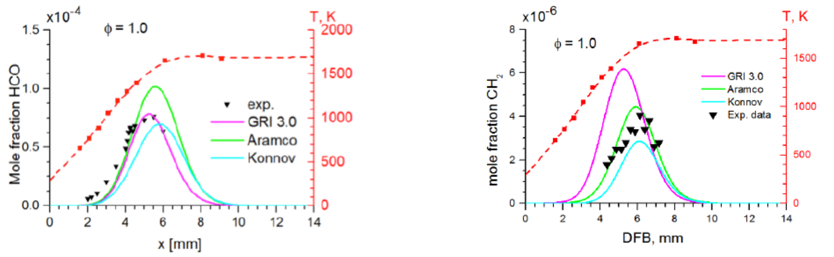

Fig.1 Experimental HCO(left) and CH_2(right) profiles (filled triangles) and those calculated using the GRI mechanism (solid magenta line), Aramco mechanism (solid green line) and Konnov mechanism(solid blue line). Equivalence ratio is φ =1.0. Red diamond: temperatures measured by LIF.

However, the possibilities of the mechanism modification were limited since the concentrations of the final products were measured in the experiment (Zhu, J. 2001) using gas chromatography. New methodology for in-situ concentration measurements of CO, CO_2, CH_4, and H_2O and thermometry based on broadband detection of these species, using Fiber Laser Intracavity Absorption Spectroscopy (FLICAS) was developed and verified. The experiments were performed in a temperature-controlled flow-cell, which allowed evaluating the feasibility of the FLICAS technique for temperature and concentration diagnostics.

We have found that CO and CO_2 spectra are well described by HITRAN database allowing for accurate and simultaneous determination of temperature and concentration. Our study demonstrates that for CH_4 and H_2O the deficiencies of HITRAN database (especially for high temperature conditions) somewhat limit the use of these molecules as candidates for thermometry in combustion related devices. [see Fig.2]

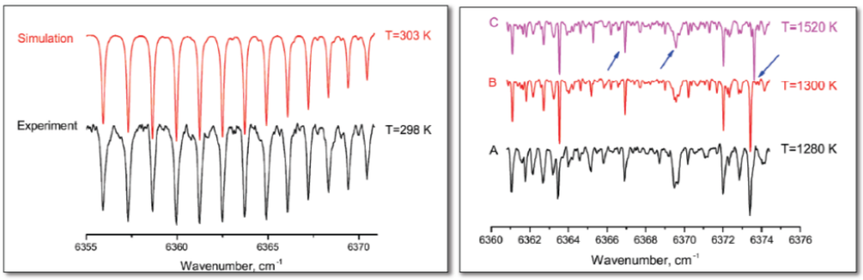

Fig.2 Left panel: FLICAS spectrum of CO_2 at room temperature along with simulation; Right panel: FLICAS spectrum of water vapors (A) at 1280 K along with simulation using original HITEMP database (C) and the modified one (B) (shifted lines shown with arrows), indicating the deficiencies of the spectral database.

Acknowledgement

This work was supported by the IME fund.

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Spray Combustion in Vortical Flows

Yuval Dagan[1], David Katoshevski[2], Barry Greenberg[1]

[1] Faculty of Aerospace Engineering, Technion - Israel Institute of Technology, Haifa, 32000, Israel.
[2] Environmental Engineering Unit, Ben-Gurion University of the Negev, P.O.B 653, Beer-Sheva, 84105, Israel.

New analytical solutions for the dynamics and combustion of fuel sprays is presented in this study. The case of a spray diffusion flame in an unsteady axisymmetric vortex flow field is considered. Similarity equations are presented for polydisperse spray dynamics and spray flames, where the unsteady flame location and combustion properties are obtained by using two Schvab-Zeldovich type decoupling parameters.

Analytical solutions for an Oseen-type vortex flow field and mono-sectional droplet distributions are presented and compared to numerical results. Initially, at t=0, a cloud of droplets is suspended in the vortical flow. A small mass fraction of fuel vapor, methanol in this case, is initially introduced to the outer boundary and air is introduced as an inner boundary condition. The effects of vortex magnitude and droplet evaporation on the droplet mass fraction distribution, flame location and temperature is presented here in Figure 1a as a function of the similarity coordinate η, where $\eta = \frac{r^2}{4\nu t}$, r is the radial coordinate, ν is the kinematic viscosity and t is the time.

Vortex magnitude significantly changes the droplet mass fraction distribution, "pushing" it outwards from the center due to centrifugal forces. Increasing the evaporation coefficient has a similar effect since droplets evaporate as time goes by (lower values of η). The solution for the flame location is shown in Figure 1b via the Schvab-Zeldovich parameter β for different evaporation coefficients and vortex magnitudes.

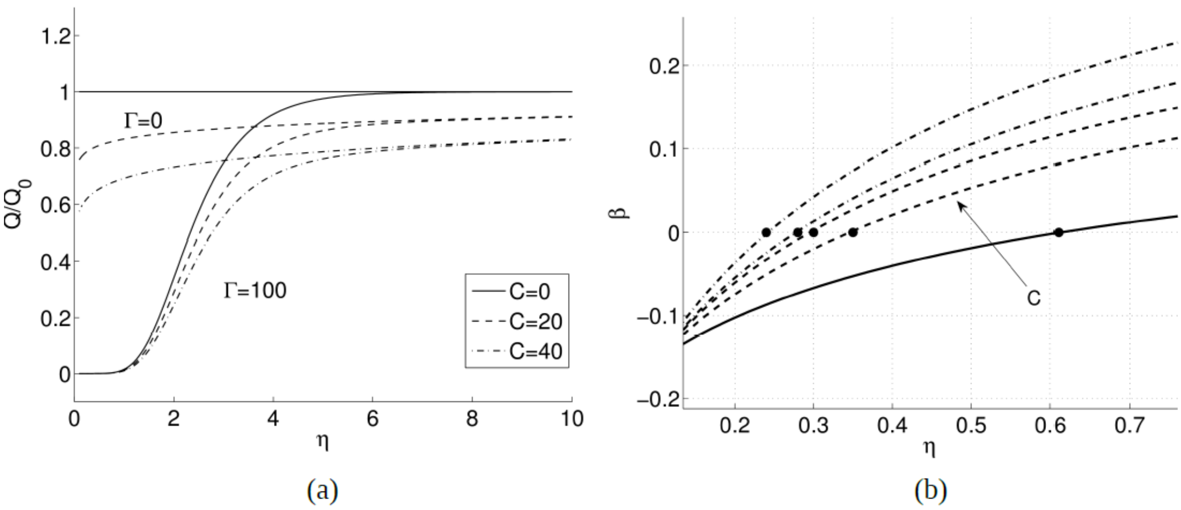

Figure 1: (a) Droplet mass fraction distribution as a function of the similarity coordinate for different values of the evaporation coefficient, C, and the vortex strength, Γ. (b) Schvab Zeldovich parameter shows the flame location where $\beta = 0$.

Despite the simplicity of the current model, its predictions provide fundamental insight into the driving mechanisms behind doplet distribution and diffusion flame dynamics in vortical flow environments.

Direct-injection internal combustion engine with high pressure methanol steam reforming

A. Poran[1]* and L. Tartakovsky[2]

[1]Grand Technion Energy Program, Technion – I.I.T, Haifa, 3200003, Israel
[2]Faculty of Mechanical Engineering, Technion – I.I.T, Haifa, 3200003, Israel
* Presenting author email: arnonp@campus.technion.ac.il

Keywords: Waste heat recovery; Thermo-chemical recuperation; Steam reforming of methanol; High-pressure reforming; Direct-injection

It is well known that in an internal combustion engine (ICE) about 30% of the energy introduced with the fuel is wasted along with the hot exhaust gases. Utilizing a part of this energy can lead to a significant increase in the overall ICE efficiency. One of the ways to utilize this energy is by promoting endothermic fuel reactions that increase the primary fuel energy and improve its combustion properties. This method is often referred to as thermochemical recuperation (TCR). In this project we focused our attention in TCR through steam reforming of methanol (SRM) (Eq. 1) since methanol can be reformed at low temperature (~573K) and be produced from abundant and widely available sources such as coal and natural gas, as well as from renewable sources such as bio-mass.

$$CH_3OH_{(g)} + H_2O_{(g)} \rightarrow CO_2 + 3H_2 \quad \Delta H = 50 kJ/mol \qquad (1)$$

Previous research of different TCR schemes in which the reforming products were introduced to the engine by fumigation encountered problems of uncontrolled ignition and reduced maximal power. That is due to high flammability and high partial volume of reformate in the fuel-air mixture at the intake manifold. Hence, Tartakovsky *et al* (2013) offered to direct-inject the reformate into the cylinder to mitigate these problems. However, in the case of onboard reforming the energy required to compress the gas prior to its injection to the engine's cylinder has to be taken into account. The main goal of the reported study was to analyze the concept of ICE with SRM and direct reformate injection and to discuss a method that might allow substantial improvement of the efficiency of a direct-injection (DI) engine with TCR.

For the purpose of a comprehensive analysis of the ICE-SRM system, a model of a DI-ICE with a chemical reformer was developed and applied. A flow chart of the ICE-SRM system is shown in Fig. 1.

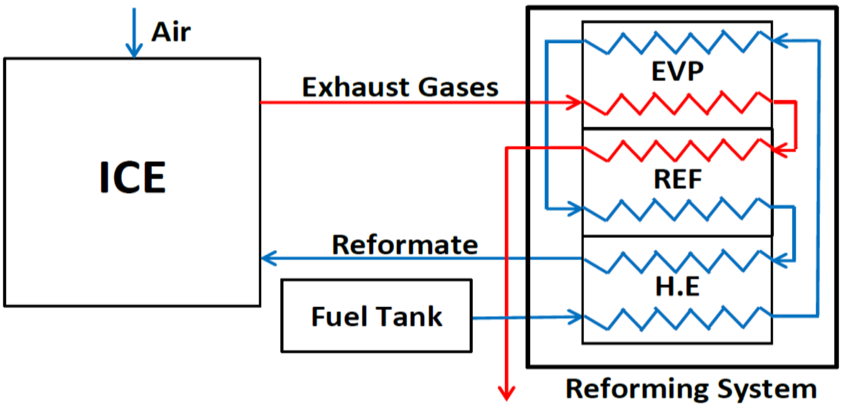

Figure 7. Flow chart of the ICE-SRM system. EVP-evaporator & super-heater, H.E-heat exchanger, REF-reformer

GT-Power, validated engine development software was used to model the ICE and the reformer. The chemical reactions kinetics were based on Langmuir-Hinshelwood model adopted from Peppley (1997). The energy necessary for reformate compression before its injection was also taken into account.

Firstly, the brake thermal efficiency (BTE) was calculated as function of injector reference flow dimeter (IRFD, injector area available for reformate flow), and start of injection timing (Fig. 2).

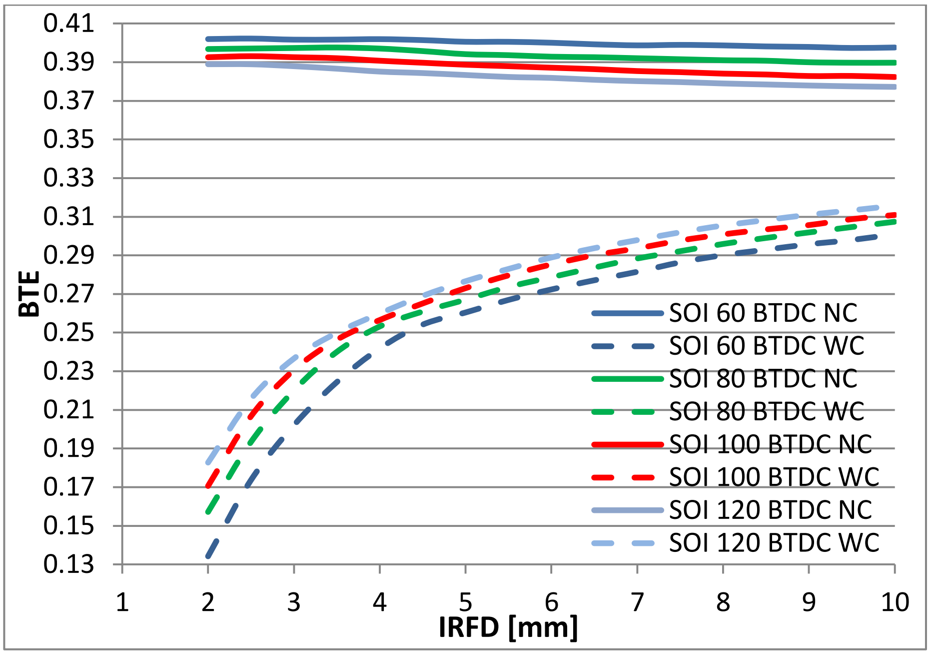

Figure 2. Dependence of BTE on IRFD and SOI values. SRM mixture (75% H_2, 25% CO_2), P_b =75 kW, n=4,000 rpm, injection temperature =350K, reforming pressure 1 bar NC-compression power consumption not accounted for, WC-compression power accounted for (Poran, 2015).

As anticipated, when the compression work was not taken into account, retarded injection and small IRFD lead to BTE increase, because the fuel entered the cylinder later in the compression stroke, thus reducing the negative compression work of the piston. Of course, retarded fuel injection would require higher injection pressure. When energy investment for gaseous fuel compression is considered, increase of the IRFD and injection advancement has a positive effect on the BTE. Results presented in Fig. 2 show that gaseous fuel compression to high pressures in order to enable late injection would be unprofitable. The results of the simulations shown above allow us to conclude that when the reforming process is performed under atmospheric pressure, DI method in ICE with TCR would be unviable due to low BTE caused by the need to compress the reformate prior to its injection. Thus, we suggest to perform the reforming at high pressure and consequently reduce the work required to compress the reformate.

Analysis of a high-pressure SRM DI-ICE system shows a possibility of engine's efficiency improvement by 12-14% compared with a DI-gasoline-fuelled counterpart (Fig. 3).

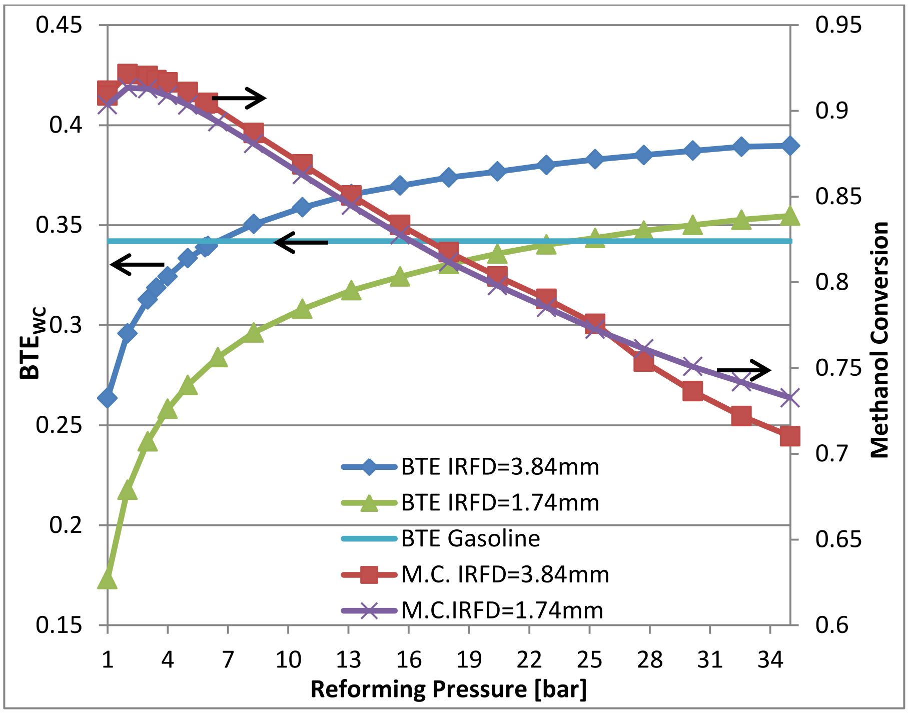

Figure 3. Dependence of BTE and methanol conversion (M.C.) on reforming pressure. P_b=75 kW, n=4,000 rpm, WOT, λ=1.2, reformer heat transfer area=1.78 m^2 (Poran, 2015).

This work examined the concept of direct-injection ICE with TCR and found that compressing the reformate-gas to high pressures that enable late fuel injection is not energetically efficient. It also proved that DI-ICE with TCR is unviable, if reforming is carried out at atmospheric pressure. It is possible to tremendously reduce the energy required for fuel compression in a DI-ICE with TCR by compressing the liquid methanol-water mixture prior to its evaporation. This can be done by applying high-pressure methanol reforming. Available literature data prove the feasibility of high-pressure SRM. Computational analysis performed in this work shows a possibility of engine's efficiency improvement by 12-14% compared with a DI-gasoline-fuelled counterpart by applying a DI-ICE with TCR and high-pressure methanol reforming.

Acknowledgement

This work was supported by the Nancy and Stephen Grand Technion Energy Program (GTEP), Ministry of Science Technology and Space, Ministry of Transport and Road Safety, Israel Science Foundation and Israel Ministry of National Infrastructures, Energy and Water Resources.

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Management of the HCCI Combustion Process with Thermo-Chemical Recuperation by Control of the Reforming Products Composition

A. Eyal[1]*, and L. Tartakovsky[1]

[1]Faculty of Mechanical Engineering, Technion Israel Inst. of Technology, Haifa, 32000, Israel
* Presenting author email: amnone@tx.technion.ac.il

Keywords: HCCI Engine; Controllability; Thermo-Chemical Recuperation; Methanol Reforming

This study examines the possibility of using reforming products of methanol to feed a Homogenous charge compression ignition (HCCI) engine (see Figure 8), while by the changing of these products to manage the HCCI combustion process. These products are produced in an on-board reformer, which utilizes the energy of the exhaust gases to sustain endothermic reactions. These reactions include first dehydration of methanol to Dimethyl-Ether (DME) and H_2O with support of γ-Al_2O_3 catalyst and then a methanol steam reforming (SRM) process with support of $CuO/ZnO/Al_2O_3$ catalyst. Eventually a gas mixture of DME, H_2, CO_2, CO, H_2O, and methanol is created during this process. By changing the ratio between H_2 to DME one can manage the mixture's octane number (ON), burning velocity, and as a result the HCCI combustion process. This paper presents first results of GT-Power simulations. A model considering joint operation of the reformer and the HCCI engine was developed to predict performance of the HCCI engine with thermo-chemical recuperation. The reformer part of the model was developed by (Poran & Tartakovsky, 2015) and is adapted to this model.

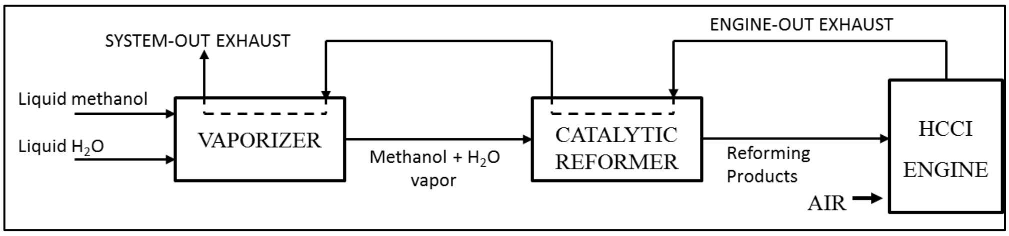

Figure 8. HCCI engine with thermo-chemical recuperation of the exhaust gas energy

HCCI combustion in internal combustion engines has been proposed to improve the thermal efficiency and to reduce the emission of nitrogen oxides (NOx) and particles, as compared with conventional combustion process. HCCI process combines homogenous air-fuel mixture as in Otto cycle and compression ignition as in Diesel engine. The ignition occurs simultaneously in the entire space of the cylinder and therefore the combustion period is very short (constant volume combustion). Usually, HCCI engines are operated with lean mixture and at low temperatures. The low temperature is a result of burning lean mixtures, which lead to lower heat transfer losses to the cylinder walls. Additionally, HCCI process is fuel-tolerant and allows engine operating with variety of different fuels.

However, there are some challenges which have to be solved, in order to make the HCCI engine suitable for commercial use. The main challenges are: the process controllability, noise, HC and CO formation, operating range, cold start, homogenous mixture preparation, etc. HCCI combustion process is a kinetics-controlled process, which depends on the chemical and physical properties of the fuel-air mixture and the cylinder's history, without any external control tool, like ignition timing in a gasoline engine or injection timing in a diesel engine. Therefore, it is necessary to develop alternative process control methods. Some control methods were proposed. One can divide these methods to two main groups: change of time-temperature's history of the mixture by tools like EGR, variable compression ratio, variable valve timing etc. and reactivity-controlled compression ignition (RCCI), which means controlling the fuel properties to achieve optimal mixture for each operating mode of the engine.

The main goal of this study is to solve the controllability problem of the HCCI engine, to improve the engine's performance and the operating range by keeping the ultra-low NO_x and particle emissions. The controllability problem is suggested to be solved by changing the reformate composition according to the engine operating regime, namely adaption of reformate fuel composition to the engine's demand, while each mode has its optimal composition. The engine performance supposed to be improved relative to regular HCCI process due to the waste heat recovery and burning the hydrogen-rich gaseous fuel. In addition, the mixture is injected to the cylinder by direct gas injector.

The model uses two kinetic models to calculate the chemical reactions' rate. The first kinetic model, which proposed by (Bercic & Levec, 1993), describes the methanol dehydration to DME and H_2O. The chemical equation of this reaction is:

$$2CH_3OH \rightarrow CH_3OCH_3 + H_2O, \Delta H = 51.8[\text{kJ}]$$

By adding water to the methanol fuel, one can change the composition of the reaction products. Namely, as more water is added, less DME and more hydrogen is produced. Eventually the unreformed water can be recycled.

The SRM kinetic model was proposed by (Peppley, Amphlett, Kearns, & Mann, 1999). The chemical equations of this SRM process are:

$$CH_3OH + H_2O \rightarrow CO_2 + 3H_2$$
$$H_2O + CO \rightarrow H_2 + CO_2$$
$$CH_3OH \rightarrow 2H_2 + CO$$

In this process the mixture after the dehydration reacts to receive mainly CO_2 and H_2. In general the ratio between the methanol and the water which is obtained from the dehydration is approximately optimal for this process. In Figure 9 one can see variation in composition of the methanol reforming products, after the outlay of unreformed water, depending on the fraction of the water in the primary fuel. One can see that adding water to the fuel leads to changing the obtained H_2/DME ratio from 2.7 to 6. This graph is a representative case and reformate composition can be a little different depending on the fuel mass rate, the combustion temperature, and the design of the reformer.

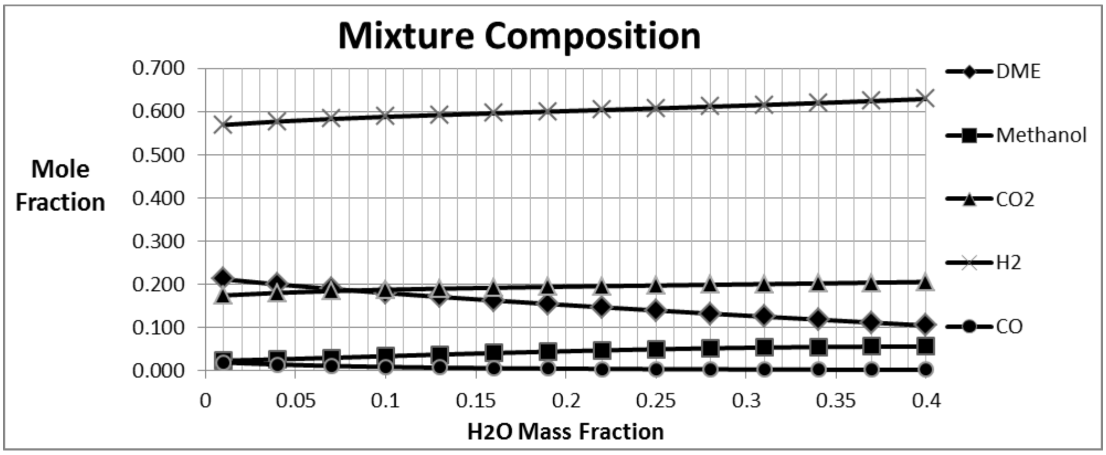

Figure 9. Reformate composition vs water mass fraction in the primary fuel

Control on the HCCI combustion is achieved by a few tools. The first is the adaption of the reformate fuel composition to the engine's operating mode. The second is using EGR to influence the ignition timing. The EGR rises the mean temperature in the cylinder during the compression stroke, and therefore can reduce the ignition delay of the auto-ignition process. Furthermore, the EGR is not burned and then it can absorb the heat of the combustion and by that reduce the mean temperature during the combustion. In addition, EGR can be used to control air mass in the cylinder. Other tools which can be used are: changing the compression ratio, valve timing, and IEGR. In this study the last two tools have not been examined.

Table 1 shows the HCCI engine performance at several studied operating regimes. One can see that as expected, there is almost zero NO_x emission when the maximal temperature is lower than 2350 K. Further the research on optimization of each operating mode will be done to further improve the engine efficiency. Higher H_2O fraction should be adapted for high load regimes. However, under high speed this should be restricted because of the limited time available for combustion process. Higher H_2O fraction leads to higher ON and longer ignition delay. In addition, it is necessary to make sure that there is sufficient thermal energy in the exhaust gases to sustain endothermic reactions in the reformer.

	high speed, high load	high speed, med load	med-high speed, high load	med-high speed, med load	med speed, high load	med speed, med load	med-low speed, med load
RPM	3500	3500	3000	3000	2500	2500	2000
Power(i) [kW]	7.2	6.6	6.7	5.7	5.2	4.6	3.4
Power(b) [kW]	5.3	4.7	5	4.2	3.9	3.5	2.5
impe [bar]	6.7	6.2	7.3	6.2	6.8	6	5.5
H2O_fraction	0.2	0.1	0.2	0.2	0.2	0.1	0.1
EGR	0.05	0.1	0.05	0.05	0.3	0.4	0.4
CR	18.8	18.8	18.8	18.8	18.8	18.8	18.8
max_Temp [K]	2423	2368	2395	2095	2184	1924	1898
Engine Eff. [%]	45.1	44.6	41.3	47.1	43.2	47.5	45.8
Bsfc [g/KW-h]	253.6	288.3	269.6	239.9	263.8	248.6	262.1
Nox [ppm]	46.6	49.4	8.2	0.2	11	0.2	0.1
lambda	1.4	1.4	1.5	1.8	1.4	1.4	1.5

Table 1. Performance of HCCI engine with thermochemical recuperation at various operating modes.

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Reduction of nanoparticle emissions by retrofitting in-service buses with diesel particulate filters

R. Fleischman*, R. Amiel and L. Tartakovsky

Faculty of Mechanical Engineering, Technion–Israel Institute of Technology, Haifa, 32000, Israel
* Presenting author email: rf@technion.ac.il

Keywords: Nanoparticles; Diesel engine; Diesel particulate filter; Retrofitting

Introduction

The fact that inhalation of particulate matter leads to adverse health effects is known for centuries (Brimblecombe, 1987), but only relatively recent studies have established the connection with particulate size, suggesting that the smaller the particles, the greater the toxicity (Dellinger et al., 2008). Road transport vehicles had long been identified as one of the main sources of nanoparticles, and its reduction accounts for one of the biggest challenges modern societies face.

New vehicles are subjected to regulation that imposes strict limitation for particle emissions. Nonetheless, due to the long service life of heavy-duty diesel engine vehicles, their emission control technologies become obsolete and they turn into a major source of particulate emissions. Retrofitting in-use buses with recently developed technologies appears as a cost effective measure to reduce particulate matter emissions.

The objective of this study is to evaluate what is the most suitable Diesel Particulate Filter (DPF) to be incorporated for intercity and urban buses, in order to cope up with the regulation imposed by the Israel Ministry of Environmental Protection.

Methodology

In order to choose appropriate DPFs, it was needed to obtain data about the temperature profiles in the exhaust manifold, where the filters are mounted. For this purpose, thermocouples were installed in previously selected buses. Figure 10 shows the temperature profile obtained with an urban bus from the Jerusalem area.

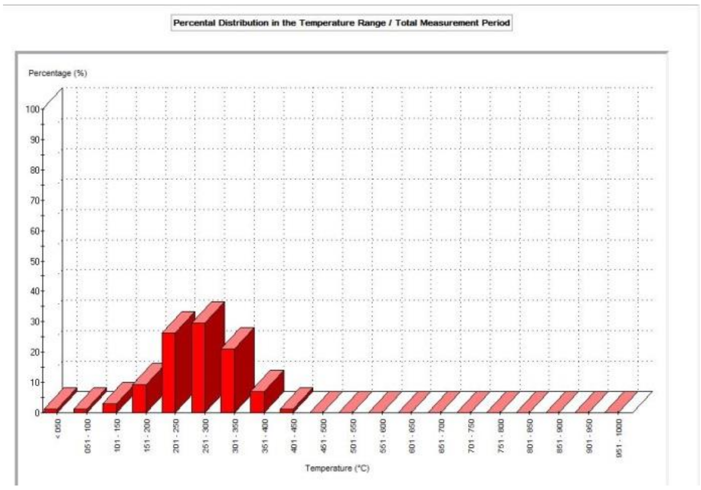

Figure 10: Temperature profile example

Based on the obtained temperature profiles, DPFs from three different manufactures were selected. 18 in-use buses were selected for DPFs retrofitting: 6 from the Jerusalem area, 6 from the Center area and 6 from the North area, being 3 urban and 3 intercity buses for every area.

Each vehicle was tested at four different operating regimes that reflect in some way real conditions of buses usage (Tartakovsky et al., 2015): low idle, high idle, 85% load and free acceleration. Exhaust gases were sampled both upstream and downstream the DPFs for every bus at each operating mode. The experiments were performed in Egged central garages. Chassis dynamometers were used to impose load to the buses.

TSI-made particle sizer EEPS 3090 was used for nanoparticle measurements. TSI 379020A-30 Thermodiluter and Thermal conditioning device was used to provide a two-stage dilution and heating to $300^{\circ}C$. Particle size distribution from 5.6 nm up to 560 nm with sizing resolution of 32 channels and frequency of 10Hz was measured.

Current Particle Measurement Program procedure prescribes PN measurement for particles with diameter greater than 23 nm. Thus, all data regarding smaller particles was not included in the provided analysis results. The number weighted concentration per channel, n_i was used to estimate particle mass weighted concentration per channel, m_i, with two different methods. The first method, which assumes spherical particle shape and is used also by EEPS 3090 internal software, is described by the equation:

$$m_i = \rho \frac{\pi d_i^3}{6} n_i$$

Here ρ is the particle density and d_i is the particle diameter (channel midpoint). The second method (referred to as Maricq method), calculates the particle mass in terms of the mobility volume and effective density, as suggested by (Maricq, Xu, & Chase, 2006):

$$m_i = n_i \frac{\pi}{6} \rho d_i^{(3-d_f)} \mu_g^{d_f} \exp\left(\frac{d_f^2 \left(\ln \sigma_g\right)^2}{2} \right)$$

Here d_f represents the fractal dimension, μ_g is the geometric mean diameter and σ_g the geometric standard deviation. It was found that $d_f = 2.3$ is the best fit for the fractal dimension (Maricq et al., 2006). Total particle number concentration N and mass concentration M were calculated, respectively, by:

$$N = \sum_{i=l}^{u} n_i$$

$$M = \sum_{i=l}^{u} m_i$$

Here i is the channel, l and u are the lower and upper channel boundaries, respectively. DPFs efficiencies, in terms of particle number and mass, $PNFE$ and $PMFE$, were respectively calculated by the following equations, where the subscripts (W/O) and (F) stand for without and with the DPF.

$$PNFE = \frac{(N_{W/O} - N_F)}{N_{W/O}} \cdot 100$$

$$PMFE = \frac{(M_{W/O} - M_F)}{M_{W/O}} \cdot 100$$

Results and Discussion

It was found that both PNFE and PMFE are very high (usually greater than 95%), with few exceptions. Nonetheless, at low idle, filtration efficiencies were found to be the smallest, possibly because of the lower emissions level. Figure 11 presents the particle size distribution, PFNE and PFME during 85% load of the same bus whose temperature profile is presented in Figure 10, for exemplification.

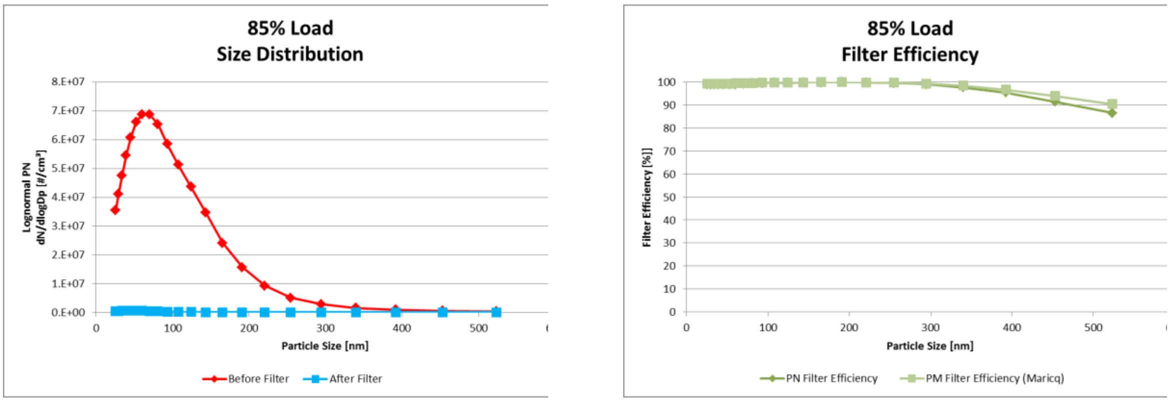

Figure 11: Particle Size Distribution and DPF Efficiency example

Acknowledgments

The authors appreciate the financial support of the Egged bus company and the fruitful collaboration of the Israel Ministry of Environmental Protection.

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Hybrid propulsion system for Unmanned Aerial Vehicles Computer Model & Simulation

I.Biner*

Internal Combustion Laboratory, Faculty of Mechanical Engineering, Technion Institute of Technology, Haifa 3200003, Israel
* Presenting author email: ibiner@gmail.com

Keywords: UAV; Hybrid; Propulsion; GT-Suite; Simulation

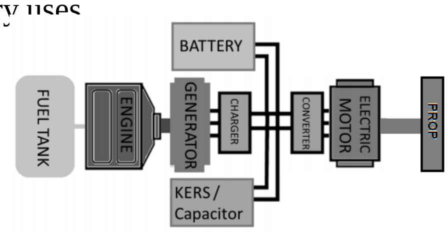
The goal of this research project was to examine the main characteristics of an UAV (Unmanned Aerial Vehicle) powered by a conventional ICE (Internal Combustion Engine) in order to design an alternative hybrid propulsion system with the following properties; smaller ICE, lower acoustic and thermal signatures for desired period of time, and lower fuel consumption.

The project contains a general overview of a UAV's mission and the demands from the propulsion system ensuring success in its mission. An approximate calculation of the power demands was conducted for every section of the mission.

Several possible configurations for the hybrid system were considered and their advantages and disadvantages regarding UAVs mission were listed. The main parts of the hybrid system were outlined and their governing equations were presented. The propeller and its driving motor were emphasized particularly as their adjustment is one of the main challenges of the design.

Finally, a Series Hybrid System has been proposed and a GT-Suite model has been created to simulate the propulsion system performance on a typical mission. The main characteristics of the simulation can be controlled by the user such as; Take Off time, Battery Capacity, ICE speed [rpm]. In order to compensate for the added weight (relatively to the original propulsion system) the power demand is controlled as well.

A well-known UAV- Heron1 was chosen for redesign of its propulsion system. Its original 1200cc ICE was reduced to a smaller one, EM (electrical motor) and Generator were added alongside a battery package. The new platform was shaped numerous times to achieve comparable fuel consumption and in a specific working point it even consumed less fuel than the original platform. Moreover, a section of flight with the ICE turned off was achieved. These few minutes with lower thermal and acoustic signature can be highly valuable for military uses



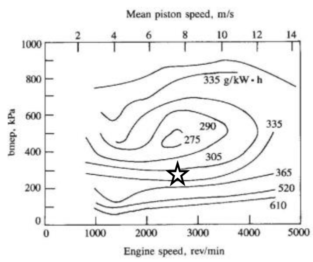


Figure 12. Schematic Series Hybrid Propulsion System

Figure 13. Specific fuel consumption

Prima facie, higher rate of fuel consumption is mandatory for the propulsion system presented in Figure 1 relatively to the original propulsion system including only an ICE and Propeller. However, by running the ICE in its Efficiency Island (marked with star in figure 2) fuel consumption can be reduced.

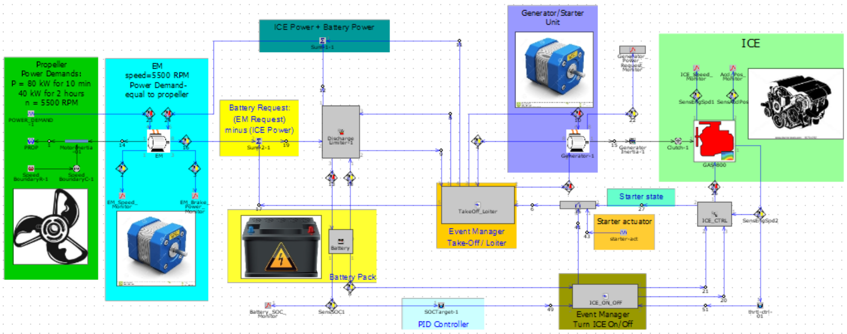


Figure 14. GT-Suite model of the system in Figure 1

The model runs over several cases. In Each case a different set of parameters is checked. During the model run the EM speed, Propeller speed and required power, ICE power, Generator Power, Battery SOC (State of Charge) are all monitored and visible on screen.

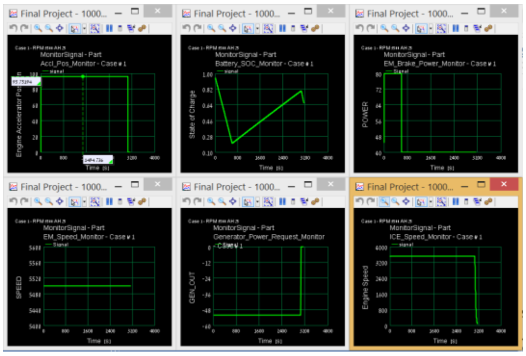


Figure 15. Monitors during model run

The simulation stops in every failure to provide the required power to the propeller. After the simulation terminate the important data is collected and examine. Fuel consumption, charging and discharging time and other performance parameters are presented.

The project includes the author’s conclusions for the Heron1 hybrid system approach; it requires a smaller ICE than the original 1200cc, but not smaller than analogous 800cc ICE, fuel consumption reduction of ~5% is achieved for a hybrid system of 30Ah battery capacity, 800cc ICE running in 4500rpm.

The Model is the first step in creating a design tool for Hybrid Propulsion System Design which allows the engineer to examine the trends and sensitiveness of its system to changes at minimal costs and in a very short time. Further work is being done in the Internal Combustion Engines Laboratory towards this goal.

Acknowledgement

This work was supervised by Dr. Leonid Tartakovsky, Faculty of Mechanical Engineering, Technion, Haifa, Israel.

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Spray flame dynamics in an oscillating flow field – computational study

I.Moshe[1*], *D.Katoshevski*[2], *G.Ziskind*[1]

[1]*Department of Mechanical engineering, Ben-Gurion University of the Negev, Beer-Sheva, Israel*

[2] *Unit of Environmental Engineering, Ben-Gurion University of the Negev, Beer-Sheva, Israel*

**itaymo@post.bgu.ac.il*

Keywords: *Spray flame dynamics, CFD, Burke-Schumann, droplet grouping*

The Burke-Schumann laminar spray flame configuration (Figure 1) is investigated. The velocities of the streams in the inner and outer ducts are taken to be identical, but, unlike in Burke–Schumann's original gas flame analysis, they are not constant and taking an oscillating form.

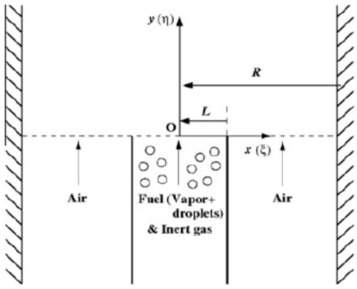

Fig. 1. Configuration for formation of Burke-Schumann spray diffusion flame.

Droplet grouping (Katoshevski et al.) induced by the host gas flow oscillations is accounted for and its effect on the flame front shape is demonstrated.

A computational fluid dynamics (CFD) framework has been established, considering an Eulerian-Lagrangian approach, in which droplets are introduced as discrete entities into a continuous oscillating flow field and a coupling is performed between the two phases. The non-premixed combustion reaction is simplified to a mixture problem, in which species concentrations are derived from a predicted mixture fraction fields (preprocessed).

This work is a natural continuation to previous works (Greenberg J.B, Katoshevski D., Ziskind G.,), which offer an insight into the mechanism prevalent in more complex spray-combustion systems involving fluctuating flow fields.

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Powertrain for the 2016 SAE Student Car

N. Dabush*, I. Hirsh, T. Lipshitz, D. Brudner, D. Ganon, A. Asraf, I. Greenberg, A. Sacks

Faculty of Mechanical Engineering, Technion - Israel Institute of Technology, Haifa, Israel 3200003
* Presenting author email: ndabush@gmail.com

Keywords: Formula; SAE; Engine; Optimization;

The Technion Formula SAE team is designing the fourth iteration of its vehicle. The approach of the team this year is to optimize the previous year's design with a primary focus on reliability, especially within the engine team. The engine team is responsible for the engine's performance as well as the all the surrounding systems: manifolds, dry sump, cooling, fuel and drivetrain.

The manifolds team spent a lot of time analysing the design of last year's intake and exhaust systems to ensure that the team is taking advantage of the engine's maximum performance and also cut the weight of the systems to meet the overall requirement for the entire car to cut weight. A total of 1.8 kilograms were cut from the manifolds alone.

In order to level the playing field at the competition, an intake restrictor is required for each team. This restrictor reduces the intake to 20mm prior to entering the manifold itself. As this restrictor significantly hinders the performance of the engine, a flow analysis (CFD) was done to find the optimal length and design of this restrictor. The restrictor will be manufactured of aluminium to ensure optimal air flow, and with the following dimensions:

Parameter	Chosen Value
Intake runners length	220mm
Intake runners diameter	38mm
Intake valve opening angle	41º BTDC

Table 1. Final values chosen for the geometry of the intake manifold

The SAE rules also specify a maximum noise level for the vehicle during driving. Last year this was an issue for the team. As a result, an additional muffler, which can be disassembled, will be added before the standard muffler to ensure that the vehicle will meet the noise requirements. To design the exhaust, a Design of Experiment (DOE) analysis was done using GT Suite Engine simulation software. Using these simulations, the optimal length of the runners was determined, with the average between them being 275mm.

Since the 2014 iteration of the vehicle, the team has used a dry sump system for increased engine performance. At the 2015 competition, the team ran into issues with oil pressure that eventually caused the stripping of a crankshaft bearing. As a result, a strong emphasis was put on the dry sump system this year to ensure that there is sufficient pressure at all times. Tests were done on the 2014 oil system, which did not yield any engine problems, to compare it to the pressures of the manufacturer wet sump system at various RPM ranges. The dry sump system came close to the pressure values of the wet sump, but a lack of pressure (roughly 10%) still exists. A new oil pan and tank are being designed with an emphasis on the flow of the oil throughout the system. The hose that the oil travels through when going from the tank to the oil plan was increased from AN12 to AN16. Also, the hose connecting the oil pan to the oil scavenge pump was changed from rubber to metal to guarantee improved oil flow.

Functioning systems on the vehicle were not changed except for optimization of weight and changes to increase reliability. In order to ensure that the cooling system will always work to its maximum potential, flow (CFD) analyses on the distance between the fan and the radiator were done to determine the distance that would yield optimal air flow. In addition, the heat transfer in the radiator was analysed and through calculations, the cooling team determined that the coolant mass flow rate should be increased by 40% from last year, specifically from 22kW to 35kW at 8000rpm.

The fuel system incurred some changes in the tank geometry as well as the inside of it. The geometry was changed to ensure optimal flow of fuel from the tank to the pump. In addition, the bottom of the tank was given a trapezoid shape for less sensitivity to sloshing at the point where the gasoline is pumped from. Inside the tank, anti-sloshing foam will be added to prevent lack of fuel pressure during turns and accelerations. The weight of this system was reduced from 4kg to 2.5kg, mainly by changing the thickness of the material used to manufacture the tank as well as the mounting mechanism of the pump and filter to the tank.

The transfer of power from the engine to the wheels is achieved using a differential connected to the rear axle. Last year the team encountered integration issues between the differential mounts and the engine as well as a lack of strength. As a result, analyses were done using SolidThinking software to determine the optimal geometry while accounting for all forces that the mounts would encounter during competition driving. Not only was the strength of the mounts increased, but the weight of the system was decreased by 1.7 kilograms, fulfilling the optimization requirements for weight and reliability determined by the team at the beginning of the year.

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. The battery was changed from a Lead-acid battery to a new lithium-ion battery, providing more cranking amps while being 2.1 kilograms lighter than the previous battery. Also, multiple sensors were added to allow for better analysis of all engine systems while driving. Due to the oil pressure issues, a temperature sensor was added to the oil tank and a digital oil pressure sensor will replace the pressostat in the engine. These values will be recorded to the engine's ECU (engine control unit) for remote viewing while driving as well as analysis afterwards.

Since the beginning of the design process for the 2016 Technion Formula Student car, the team is confident in the increased reliability of the engine and its systems, as well as increased performance of the engine due to careful analysis of these systems. With each component being analysed both isolated from the rest of the vehicle and then checked for integration with the rest of the car's design, all goals set for the design of the engine systems have been fulfilled.

Acknowledgement

We would like to thank the Faculty of Mechanical Engineering at the Technion - Israel Institute of Technology for their continued support of our project, as well as Dr. Leonid Tartakovsky for his knowledge and guidance which he has generously shared with us throughout the design process.