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COMMON RAIL DIESEL-AUTOMOTIVE TO AERIAL VEHICLE CONVERSIONS: AN UPDATE (PART III)

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ABSTRACT

Back to the 1997 when this activity began, it was generally though that CRDIDs (Common Rail Direct Injection Diesel) would have completely replaced the piston gasoline engines used in aircrafts within a decade. This fact did not happen for several reasons. This paper tries to individuate these reasons. The more updated solutions to the many problems that almost stopped this application are also introduced. In this third part, maintenance and cost effectiveness related issues are introduced. Automotive OBD concept is described as a method to reduce maintenance costs and risks.

Keywords: common rail direct injection diesel, automotive and aerial-vehicle, On Board Diagnostic (OBD).

INTRODUCTION

In 1940, the Battle of Britain was lost also due to the lack of momentum. In fact the aircraft engine of the time had a very limited TBO (30h). In this condition, even the relative short flight over the channel toward London, took a big toll on the "black men" of the maintenance, as the highly specialized technicians of the Luftwaffe were called. This fact meant that despite the large number of aircrafts available to the Luftwaffe, the available number was much less. During WWII a large effort was made by the Allies to reduce the number of working hours necessary to keep the aircraft flying. The concept to keep the engine as closed as possible was fundamental. Oil, filters, spark plugs could be changed with relative ease, while the opening of engine covers was a totally different matter. In the fields, FOD (Foreign Object Damage) due to lack of cleanliness, is a major problem. Human errors are another important factor. The more extensive is the maintenance the easier is to "introduce" inside the engine new errors. Unnecessary maintenance operations are to be avoided. The third important factor is costs. Even in this high price fuel world, maintenance and spare parts costs (and availability) may be an important additional factor. The unavailability of an aerial vehicle may mean the necessity to purchase or to lease another one for the same task. The initial CRDID automotive-to-aircraft conversions use a much less severe maintenance than the old spark ignition piston engines they are meant to replace. However, their maintenance schedule is impressive when compared with their automotive counterparts. In fact, since the year 2000, the OBD (On Board Diagnostic=self diagnostic) systems are mandatory on cars. These systems are able to diagnose several problems in engines well before the problem reaches the critical level. In this paper the "typical" maintenance schedule of an aircraft CRDID and an automotive one are compared. A typical OBD or an automotive CRDID is introduced and the possible application on aerial vehicle is discussed.

Automotive and aerial-vehicle CRDID maintenance

A "typical" aircraft CRDID has the following scheduled maintenance (Tables 1, 2)

Table-1. Aircraft CRDID scheduled maintenance.

Hours	Activity
100	Perform visual inspection of the engine Exchange engine oil and oil filter Exchange gearbox oil and oil filter Test cooling system under pressure Perform cylinder leak down test Perform engine test run Download and e-mail Real Time Log Files and Event Logs
200	Replace air filter
600	Replace clutch Replace HPP (High Pressure Pump) Replace Pre feed pump (Fuel) Replace Rail Pressure Control Valve Replace Alternator
1200	Replace Coolant Replace Engine shock mounts Replace Flat belt Replace Shock mounts

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Table-2. Aircraft CRDID scheduled maintenance.

Time	Activity
12 months	Replace Excitation Battery of the Alternator
60 months	Replace all fuel, oil and cooling lines FADEC maintenance (to be carried out by engine manufacturer)

While, for an automotive CRDID the scheduled maintenance is summarized in Table 2, 3:

Table-3. Automotive CRDID scheduled maintenance.

km/hours	Activity
Every 36,000 km 1,285h	Check battery Visual check Replace engine lubricant Replace lubricant filter Download and e-mail Real Time Log Files and Event Logs
Every 72,000 km 2,571h	Air Filter Fuel Filter Replace Auxiliary polyV belt (polyV belt kit) Download and e-mail Real Time Log Files and Event Logs
Every 144,000 km 5,142 h	Replace timing belt (timing belt kit) Download and e-mail Real Time Log Files and Event Logs

The difference is impressive. In fact compared to the family trucksters of a generation ago, modern cars require about as much maintenance as a toaster. Curiously, many people haven't adjusted their thinking to keep pace with new car maintenance schedules. Over-achievers still fret about running synthetic oil more than 2,500 miles without a change.

It is due to the self-diagnostic (OBD) system installed in every car. In fact in the car, even the lubricant replacement is controlled by the engine ECU and by the sensors. It limit is 36,000 km, but, if the service light turns on, it is done earlier. Usually on city cars it is done between 15,000 km (535h) and 20,000 km (714h) depending on the post injections and starting cycles. During starting a large amount of the fuel leaks down due to larger blow by, while in post-injection the lubricant is mixed with the unburned fuel on the cylinder walls. In both cases, the fuel dilutes the lubricant, ruining its performances.

Even the air filter, the fuel filter and the oil filter have a specific sensor for replacement. The scheduled time is the limit control time. As the car enters the maintenance shop, the fault and running data are collected and send to the manufacturer for statistical purposes. The corrective action required (if required) is then taken. The sensors/actuators are simply replaced and the ECU is recalibrated by introducing the sensors/actuators data. Due to the OBD the engines is kept controlled for emissions and working conditions by the engine ECU.

Only the most important automotive CRDID OBD functions are considered in the following paragraphs in order to discuss the OBD conversion to the aerial-vehicles.

Automotive self-diagnostic (On Board Diagnostic=OBD) systems.

The American Environmental Protection Agency and the European parliament have set targets for reducing the levels of emissions produced by passenger and commercial vehicles. The manufacturers should maintain these emission standards for the useful life of the vehicle. In order to meet and maintain these stiff standards all the new vehicles are fitted with On-Board Diagnostic systems which monitor the integrity and effectiveness of all emission related components.

Most vehicles now have multiple OBDs (e.g. Engine, Transmission, Body, Suspension, etc.) installed at different locations on the vehicle. The OBDs are usually integrated into the vehicle control ECUs (Electronic Control Units).

In 1988, the SAE (Society of Automotive Engineers) created a standard that defined a standard diagnostic socket and a set of diagnostic test signals. An OBD (On-Board Diagnostics) system was then produced. The OBD defined a universal inspection and diagnosis system to ensure that a vehicle is performing to Original Equipment manufacturer (OEM) specifications. The OBD system will store a DTC (Diagnostic Trouble Code) in the memory of the control module responsible for that component, in the event of an emissions related component fault. The OBD system will also illuminate a Malfunction Indicator Lamp (MIL) on the vehicle's instrument pack to alert the driver. The DTC can then be retrieved using diagnostic equipment to determine the type and status of the fault and a corrective action can be taken.

A brief description of a “typical” automotive CRDID OBD is described in the following paragraphs.

Basic types of engine ECUs

Basically, engine management systems are classified according to how operating in the intake manifold (air mass or intake manifold pressure) are determined. This classification is not referred to specific engine control unit manufacturers, because they usually supply both types.

The intake air quantity or intake manifold pressure are required to calculate the injections advance,

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the injection quantities and for OBD monitoring of almost all components.

Intake manifold pressure systems

In these engine management systems, intake air quantity is determined by the intake manifold pressure sensor. These systems may not have an air-mass flow meter (debimeter).

Air mass systems

The air-mass flow meter determines the intake air mass. CRDIDs maintain the intake manifold pressure sensors since it is required to measure the air charge pressure.

Overview of OBD

With a well defined time schedule, the Engine ECU performs the diagnostic operations automatically. The OBD checks the functioning of all vehicle systems which have a bearing on exhaust gas quality (e.g. lambda probes, secondary air system), the functioning of the catalyst and the misfiring. The last check is the self-diagnosis fault of the warning lamp. If a fault impairing exhaust gas quality occurs, the fault is saved into the fault memory and the fault warning lamp is activated. The only visible elements of OBD to the driver is (are) the self-diagnosis fault warning lamp(s) MIL(s). If there is a risk of catalyst damage due to misfiring, the self-diagnosis fault warning lamp flashes.

After the checks a corrective action is taken on the exhaust control system. This action may reduce output power or even (in an extremely rare case) stop the car.

At the maintenance shop, the stored OBD fault-data can be read out via the diagnosis interface. The fault codes are standardised so that data can be acquired using any Generic Scan Tool. The OBD stores the "on" period of the self-diagnosis fault warning lamp (in terms of kilometres travelled).

A new generation of sensors has been developed since the mandatory introduction of the OBD on car is 1998.

The broadband lambda probe

With these sensors it is possible to measure the lambda value over a large measurement area. The output is a near-linear rises in current, and not only an abruptly rising voltage curve (which is the case with the step-type lambda probe). This sensor is usually installed before the main catalyst. The broadband lambda probe and the engine ECU are a single system. It is important that the lambda probe matches the engine control unit in order to have the best emission performance (lambda feedback). A step-type lambda probe around the predefined optimal value of lambda is sufficient after the catalyst to perform its monitoring function on emissions.

The broadband lambda probe has a self diagnosis system. If the signal from the lambda probe fails, no lambda control takes place and lambda feedback is disabled. A recovery system is then adopted.

The fuel tank purging system enters the emergency running mode. The engine ECU uses a mapped (fixed) control as an emergency function. The maximum power output is reduced. The secondary air and catalyst diagnoses are disabled. The fault warning lamp is activated and the fault is saved into the fault memory. The broadband lambda probe should be replaced. The office shop should enter the calibration curve of this probe into the engine ECU.

Electrical exhaust gas recirculation system

The exhaust gas recirculation system is primarily used to reduce emissions at low loads. As a result of the recirculating exhaust gases, the engine induces less air. This valve is activated directly by the engine ECU and electromagnetically adjusts the opening stroke for exhaust gas recirculation.

The integrated exhaust gas recirculation potentiometer signals the actual opening stroke of the valve to the ECU. If the valve fails in the open position, the engine shuts down at idling speed and can no longer be started. If the valve remains closed, the failure has no effects on vehicle operation. An alternative map is used for injection and the fault will nevertheless be detected and saved. Power output at low loads is reduced. This means that the driver has to use more throttle to obtain the same torque.

When the vehicle is taken to the maintenance site the failure will be detected and corrected (EGR valve substitution).

Electric throttle drive

The electrical throttle control enables the engine control unit to adapt the throttle valve position to the given basic conditions in any driving situation. The signals from the accelerator pedal module are transferred to the engine ECU. From the throttle and the auxiliary signals, the engine ECU then determines how the torque requirement can best be obtained.

For example, auxiliary signals are supplied by: the cruise control system, the air conditioning system, the idle speed control, the lambda control, the transmission and the traction/brake and stability systems. The torque requirement is implemented via the electronic throttle valve, the ignition system and the fuel injection system. The failure diagnosis of the electric control valve is complex since also linearity should be checked and diagnosed. Several different recovery strategies are used for this sensor/control system.

The accelerator pedal module has two position sensors and two dedicated channels to the ECU. The two position sensors have different HardWare (HW) and

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SoftWare (SW) for reliability. Also diagnostic procedures are completely different and separated. Throttle is a critical safety item.

Integrated shaft sealing ring sensor

In several engines, a new generation of engine speed sensor is used. The sensor is mounted in sealing flanges for the crankshaft and the camshaft. The camshaft one (hall type) is used at engine starting, while the crankshaft one is used for normal operation. In case of failure detection from the engine ECU, the maximum engine speed is reduced and the engine control unit calculates a default value for engine speed from the signal supplied by the back-up hall sensor. The fault warning lamp is activated and the fault is saved into the fault memory. The sensor should be replaced.

OBD diagnosis strategies: comprehensive components monitoring

This diagnostic routine monitors the functioning of all sensors, actuators and output stages.

All the components are tested for input and output signals plausibility, short circuit to earth, and short circuit to positive and open circuit.

OBD diagnosis: lambda probe

Ageing or poisoning can cause a shift in the voltage (on/off) or current (broadband) curve of the probe. This shift is detected by the engine ECU with the engine working in well defined conditions. The shift be compensated (adapted) within defined bounds. At first, by measuring the probe heating resistance, the engine ECU checks the correctness of the heat output of the lambda probe heater. Then, the reaction time of the probe is measured. For this purpose the ECU induces artificially a slight fluctuation around the "set point". This is easily obtained since the catalyst requires the mixture composition to fluctuate slightly for optimal operation. Therefore, the engine control unit modulates this mixture with the broadband lambda probe. The curve "read" by the sensor is then checked by the ECU. If the sensor is aging, the ECU will read a more "rounded" oscillation. This is indicative of aging. By evaluating the two probes before and after the catalyst in transient operation is possible to check the health of both.

OBD diagnosis: catalytic conversion diagnosis

The engine control unit compares the outputs of the lambda probes before and after the catalyst. In this way, the degree of efficiency of the catalyst is determined.

OBD diagnosis: cylinder-selective misfiring detection system: irregular running method

The engine speed sensor can detect irregularities in engine speed caused by misfiring with the aid of the crankshaft teethed disk. In combination with the signal from the Hall sensor (camshaft position), the engine ECU can locate the misfiring injector (cylinder), save the fault to fault memory and activate self diagnosis fault warning lamp K83.

OBD diagnosis: cylinder-selective misfiring detection system: torque analysis method

As with the irregular running method, the torque analysis method detects misfiring from the signal supplied by the engine speed sensor and the Hall sensor. The difference between these two methods lies in the way the engine speed signal is evaluated. The moment analysis method correlates the irregular engine speed caused by ignition and compression with reference data calculated by the engine ECU. These calculations are based on the engine load and speed. Torque is calculated. The Newton's law outputs the crankshaft-speed-reference-curve given the inertia moment. The fluctuation in engine torque calculated in this way gives the same results of the irregular running method, but the engine speed characteristic is required to be stored in the engine ECU. During the compression cycle, the kinetic energy of the engine is used to compress the air charge. The engine speed then decreases. The compression cycle is followed by the injection, and engine speed is increased. In this way, engine speed is made to fluctuate by compression and expansion during each combustion cycle. When all the cylinders are examined, the individual engine speed fluctuations are superposed to produce a resulting torque-speed curve. This curve can be measured by the engine speed sensor and checked by the engine ECU against a calculation made with stored engine data. If there is a risk of misfiring the self diagnosis fault warning lamp initially flashes and the fuel charge to the corresponding cylinder is shut off.

OBD diagnosis: electrical exhaust gas recirculation, pressure diagnosis

When exhaust gas enters into the intake manifold, the intake manifold pressure sensor must register a rise in pressure. The engine ECU can then compare the pressure rise in the intake manifold with the supplied exhaust gas quantity and can thus determine whether the EGR is functioning properly. This diagnosis is only carried when injection is deactivated as a disturbing influence for measurement and the intake capacity of the engine is very high (overrun mode).

OBD diagnosis: electric throttle drive

The OBD uses the electrical throttle control diagnostic functions which indicate a fault via the electric throttle control fault lamp. The electric throttle OBD checks: the accelerator position sensor, the angle sensors for throttle valve, the brake light switch, the brake and clutch pedal switch, the vehicle road speed signal.

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Basically, through the vehicle motion laws, the ECU evaluates the congruence of the received signal.

OBD diagnosis: intake pressure limits diagnosis

The check also serves to protect the engine, which must not be overloaded by excessively high intake pressure. The maximum permissible charge pressure is exceeded due to a fault in the charge pressure control. In this case, it is not enough to indicate and save the fault. The exhaust gas turbocharger has to be deactivated in order to avoid damaging the engine. For this purpose, the "waste gate" of the turbocharger is opened.

Trained pilot/driver OBD

In traditional aerial vehicle engines a "human" OBD is made both by the maintenance operators and the pilots. The maintenance operator keep log of the lubricant added and of the fuel consumed during operations. Should "acceptable" limits be surpassed, a more important check is made. Piston engines and turbines are periodically boroscope inspected by trained personnel. Even pilots, reading their checklists, check the "green area" of most instruments. Undue oscillations are also carefully observed and reported for controls. The pilot is trained to calculate mentally the fuel consumption since telelevels are notoriously not to be trusted. Excessive lubricant or fuel consumption is a clear sign of something not working properly in the engines. On the automotive side, the common driver never opens the engine hood, limiting his activity to drive and refuel. The difference is the "service light", when it turns on the drivers takes his car to the shop.

Maintenance errors

Maintenance errors are the second most common problem in aircraft crashes after the PF (Pilot Flying error. Negligent maintenance such as not performing scheduled operation, incorrect part replacement, wrong installation or failure to tighten all the parts can easily cause an accident. Listed below are the top seven causes of 276 in-flight engine shutdowns.

- Incomplete installation (33%)
- Damaged on installation (14.5%)
- Improper installation (11%)
- Equipment not installed or missing (11%)
- Foreign object damage (6.5%)
- Improper fault isolation, inspection, test (6%)
- Equipment not activated or deactivated (4%)

These data show that various forms of faulty installation were the top four most frequent causal categories, together comprising over 70 per cent of all contributing factors. Comparable findings were obtained by Pratt and Whitney in their 1992 survey of 120 in-flight shutdowns occurring on Boeing 747s in 1991.

Reliability Centered Maintenance (RCM)

RCM methodology deals with some key issues not dealt with by other maintenance programs. It recognizes that all equipment in a vehicle is not of equal importance to either the operational availability or the safety. It recognizes that equipment design and operation differs and that different equipment will have a higher probability to undergo failures from different degradation mechanisms than others. It also approaches the structuring of a maintenance program. It recognize that a maintenance facility does not have unlimited financial and personnel resources and that the use of both need to be prioritized and optimized. Basically, RCM is a systematic approach to evaluate a facility’s equipment and resources to best mate the two and result in a high degree of vehicle reliability and cost-effectiveness. RCM should be highly reliant. It lowers the costs by eliminating unnecessary maintenance or overhauls. It minimizes the frequency of overhauls. RCM reduces the probability of sudden equipment failures. It reduces the probability of human errors by focusing maintenance activities on critical components. It incorporates system monitoring. However it has significant start-up cost, training, equipment, etc.

Cost considerations

RCM is not the best solution from the direct maintenance cost point of view. In fact the typical maintenance cost of complex system is shown in Figure-1. RCM is not the least expensive solution, since the correction is predictive from continuous monitoring.

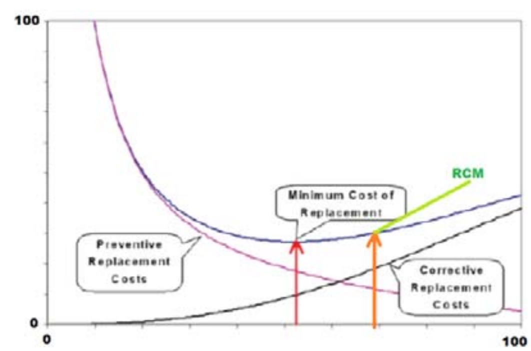

Figure-1. minimum maintenance cost (Y-axis cost % - Y axis time %).

The maintenance cost can be calculated from (1) [rrr]:

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$$Cost(t) = \sum_{i=1}^{N} \frac{Cost_{pi} R_i(t) + Cost_{ci}(1 - R_i(t))}{R_i(t)} \qquad (1)$$

Where Cost (t) is the cost per hour, $Cost_{pi}$ is the cost of the preventive replacement of component i, $Cost_{ci}$ is the cost the corrective replacement, $R_i(t)$ is the reliability function for the single component and t is the scheduled preventive maintenance time. N is the number of items. The problem is complex since the costs used for this model can be due to a variety of causes, which include monetary cost to replace the component, cost of diminished company reputation and cost of lawsuits associated with failures. In (1) the numerator represents the average cost for a single replacement. It is the costs of preventive and corrective maintenance actions weighted by the probabilities that the component will survive until the preventive maintenance replacement time.

The minimum can be found with (2)

$$\frac{\partial \left[\sum_{i=1}^{N} \frac{Cost_{pi} R_i(t) + Cost_{ci}(1 - R_i(t))}{R_i(t)} \right]}{\partial t} = 0 \qquad (2)$$

This is a very difficult equation to use in the practical world, even with automotive CRDID conversions. The data retrieval is very difficult, since the reliability data are a well kept secret of the manufacturer and the aerial vehicle conversion is a totally different application with different use and several "new" components. The reliability is also installation critical, being the use very different from general aviation aircraft application, to UAVs (Unmanned Aerial Vehicle) and helicopters. In any case the RCM (green) in Figure-1, hast higher costs than the minimum.

The reason of the cost superior to the minimum is the time of diagnosis. Once the monitoring system has diagnosed a "going to be" defective component, the maintenance is called. The operator connects the computer to the OBD port that in cars is a standard, and reads the diagnosis. The defective components are then substituted.

This time can be minimized by IoT (Internet of Things also Cloud of Things or CoT) or M2M (Machine To Machine) approach. This technique includes capturing Sensor Data. This data can then be correlated with a simplified engine/vehicle/operator model. Those data that falls outside standard ranges trigger alerts and formulate diagnostics. The diagnostic may indicate a reason to undertake maintenance. This monitoring procedure may be realized inside the Engine ECU or the data flowing off these sensors are connected to a central processing facility using some WAN (Wireless Area Network) or LAN (Local Area Network) connectivity platform. The aerial vehicle may be permanently connected to a Ground Station (UAV) or may be connected at refuelling or every morning. The choice of connectivity technology is dependent on several factors including security requirements and expected integrations with other assets.

The captured data is evaluated and the enterprise need not over-invest in maintenance labour and parts. Vehicle availability is also optimized, since the part failure is evaluated on reliability and cost basis. As maintenance is scheduled the parts are sent directly to the maintenance facility along with the vehicle.

Aerial application OBD

A major problem of automotive OBD is reliability. These highly sophisticated diagnosis system are not as reliable as they should be. However their reliability is progressively increasing, so the problem is coming to a solution. What is really a problem is the software, both for the on-board and the maintenance facility. Increasingly sophisticated SW increasingly answer with unknown errors, compelling the maintainer to change components in a try-and-see way. Also the OBD port and the GPS/bluetooth/wifi ports are open accesses to the hacker that are increasingly interested to the automotive market.

The OBD of an aerial vehicle should be separated from the very basic diagnostic of the FADEC. This concept may help to avoid that the OBD SW and HD problems have a direct influence on safety. This will also make it possible for the OBD to operate at a different rate from the control system. In this way it is possible to increase OBD complexity and to update the system without directly affecting the engine control system. However a very simplified OBD is already performed by any CRDID FADEC on its main sensor, and on the master and slave arrangement of the ECUs. This part should be kept as simply as possible for reliability reasons.

The closed hood concept

An important choice of car manufacturer is the closed hood concept. The maintenance should be kept as long as possible into the hand of the facility and the engine should be kept as closed as possible to avoid FOD (Foreign Object Digestion). Automotive engines are opened only on overhauls. Any other maintenance operation is made without opening the engine. Injectors, sensors. etc. are changed from the outside of the engine. Filters, lubricant, cooling liquid are changed in a way that avoid the contamination of the engine by foreign objects. For aircraft FADEC, this concept that comes from the piston engines of WWII should be kept. Even boroscope inspection should be avoided, since many data can be directly retrieved from the OBD. It is perfectly possible to refuel, add lubricant, cooling liquid and change filters without even turning off the engine. This fact will reduce the CRDID thermal cycling that is deleterious for engine life. In this way aerial vehicle availability is increased. Lubricant can be changed at 500h or on condition (OBD).

500h continuous operation is perfectly possible for a modern CRDID with OBD. Maintenance should be avoided, since it introduces the possibility of human errors. For this reason the maintenance facilities should be kept as clean and specialized as possible. Maintenance is not only a cost but also a risk.

CONCLUSIONS

Scheduled preventive maintenance is a surpassed concept, modern up-to-date predictive maintenance, automotive-derived OBD should be used instead. Automotive OBD is very effective and advanced but still has and will have increasing SW problems. To avoid them and to exploit fully the possibility of automotive OBD, a system fully separated from the FADEC should be used. Maintenance errors are the second most common problem in aircraft crashes after the PF error. So, in order to reduce risks and to increase availability a scheduled maintenance interval of 500h is perfectly possible. Predictive OBD technology should be used for un-scheduled maintenance. The monitoring procedure diagnostics data flowing off the ODB can be to a central processing facility using some WAN (Wireless Area Network) or LAN (Local Area Network) connectivity platform. The captured data can then be evaluated and the enterprise need not over-invest in maintenance labour and parts. Aerial vehicle availability can also be optimized, since the part failure is evaluated on a reliability and cost basis. Finally, the "closed hood" concept should be adopted also for CRDIDs in order to reduce FOD risk to a minimum.

REFERENCES

[1] Pratt and Whitney. 1992. Open Cowl.

[2] Reliability Hotwire, Issue 96, February 2009. http://www.weibull.com/hotwire/issue96/relbasics96.htm.

[3] L. Piancastelli, L. Frizziero, N.E. Daidzic, I. Rocchi. 2013. Analysis of automotive diesel conversions with KERS for future aerospace applications. International Journal of Heat and Technology. 31(1): 143-154.

[4] L. Piancastelli, L. Frizziero, I. Rocchi. 2012. An innovative method to speed up the finite element analysis of critical engine components. International Journal of Heat and Technology. 30(2): 127-132.

[5] L. Piancastelli, L. Frizziero, I. Rocchi. 2012. Feasible optimum design of a turbocompound Diesel Brayton cycle for diesel-turbo-fan aircraft propulsion. International Journal of Heat and Technology. 30(2): 121-126.

[6] L. Piancastelli, L. Frizziero, S. Marcoppido, A. Donnarumma, E. Pezzuti. 2011. Fuzzy control system for recovering direction after spinning. International Journal of Heat and Technology. 29(2): 87-93.

[7] L. Piancastelli, L. Frizziero, S. Marcoppido, A. Donnarumma, E. Pezzuti. 2011. Active antiskid system for handling improvement in motorbikes controlled by fuzzy logic. International Journal of Heat and Technology. 29(2): 95-101.

[8] L. Piancastelli, L. Frizziero, E. Morganti, E. Pezzuti: 2012. Method for evaluating the durability of aircraft piston engines. Published by Walailak Journal of Science and Technology The Walailak Journal of Science and Technology, Institute of Research and Development, Walailak University, ISSN: 1686-3933, Thasala, Nakhon Si Thammarat 80161. 9(4): 425-431, Thailand.

[9] L. Piancastelli, L. Frizziero, E. Morganti, A. Canaparo: 2012. Embodiment of an innovative system design in a sportscar factory. Published by Pushpa Publishing House. Far East Journal of Electronics and Communications. ISSN: 0973-7006, 9(2): 69-98, Allahabad, India.

[10] L. Piancastelli, L. Frizziero, E. Morganti, A. Canaparo. 2012. The Electronic Stability Program controlled by a Fuzzy Algorithm tuned for tyre burst issues. Published by Pushpa Publishing House. Far East Journal of Electronics and Communications. ISSN: 0973-7006, 9(1): 49-68, Allahabad, India.

[11] L. Piancastelli, L. Frizziero, I. Rocchi, G. Zanuccoli, N.E. Daidzic. 2013. The "C-triplex" approach to design of CFRP transport-category airplane structures. International Journal of Heat and Technology, ISSN 0392-8764. 31(2): 51-59.

[12] L. Frizziero, I. Rocchi. 2013. New finite element analysis approach. Published by Pushpa Publishing House. Far East Journal of Electronics and Communications. ISSN: 0973-7006. 11(2): 85-100, Allahabad, India.

[13] L. Piancastelli, L. Frizziero, E. Pezzuti. 2014. Aircraft diesel engines controlled by fuzzy logic. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608,

9(1): 30-34, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[14] L. Piancastelli, L. Frizziero, E. Pezzuti. 2014. Kers applications to aerospace diesel propulsion. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608, 9(5): 807-818, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[15] L. Piancastelli, L. Frizziero, G. Donnici. 2014. A highly constrained geometric problem: The inside-outhuman-based approach for the automotive vehicles design. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608, 9(6): 901-906, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[16] L. Frizziero, F. R. Curbastro. 2014. Innovative methodologies in mechanical design: QFD vs TRIZ to develop an innovative pressure control system. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608, 9(6): 966-970, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[17] L. Piancastelli, L. Frizziero. 2014. How to adopt innovative design in a sportscar factory. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608, 9(6): 859-870, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[18] L. Piancastelli, L. Frizziero, I. Rocchi: 2014. A low-cost, mass-producible, wheeled wind turbine for easy production of renewableenergy. Published by Pushpa Publishing House. Far East Journal of Electronics and Communications. ISSN: 0973-7006, 12(1): 19-37, Allahabad, India.

[19] L. Piancastelli, L. Frizziero, E. Morganti, A. Canaparo. 2012. Fuzzy control system for aircraft diesel engines edizioni ETS. International journal of heat and technology. ISSN 0392-8764, 30(1): 131-135.

[20] L. Piancastelli, L. Frizziero, T. Bombardi. 2014. Bézier based shape parameterization in high speed mandrel design. International Journal of Heat and Technology. 32(1-2): 57-63.

[21] L. Frizziero. 2014. A coffee machine design project through innovative methods: QFD, value analysis and design for assembly. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608. 9(7): 1134-1139, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[22] E. Pezzuti, P.P. Valentini, L. Piancastelli, L. Frizziero. 2014. Development of a modular system for drilling aid for the installation of dental implants. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608, 9(9): 1527-1534, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[23] L. Piancastelli, L. Frizziero, G. Donnici. 2014. Study and optimization of an innovative CVT concept for bikes. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608, 9(8): 1289-1296, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[24] L. Piancastelli, L. Frizziero, G. Donnici. 2014. Learning by failures: The "Astura II" concept car design process. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608, 9(10): 2009-2015, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[25] L. Piancastelli, L. Frizziero. 2014. Turbocharging and turbo compounding optimization in automotive racing. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608, 9(11): 2192-2199, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[26] L. Piancastelli, L. Frizziero, G. Zanuccoli, N.E. Daidzic, I. Rocchi. 2013. A comparison between CFRP and 2195-FSW for aircraft structural designs. International Journal of Heat and Technology. 31(1): 17-24.