VOL. 13, NO. 17, SEPTEMBER 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

INTAKE AND EXHAUST POSITION OPTIMIZATION IN THE COOLING DUCT OF DIESEL HELICOPTERS

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ABSTRACT

CRDID (Common Rail Direct Injection Diesel), automotive derived engine, main advantage is the enormous amount of experimental data. These engines are produced in millions of units and reliability data based trillions of hours are available. It is also possible to run automotive CRDIDs with jet fuel. It is also possible to mix the two fuels with a proper ECU (Electronic Central Unit) mapping. Therefore, the necessity to refuel in airports can be eliminated. Moreover, the additional mass of CRDIDs is largely compensated by the reduced fuel amount necessary to exploit the same mission/flight. However, an additional cooling system duct should be added. For this purpose, fans are replaced by ejector exhaust (augmenter) that does not need fan additional power. Solid Works Flow Simulation confirmed the feasibility of an ejector-exhaust-powered cooling. However, pressure fields around the helicopter varies in a very significant way in the different flight conditions. High cooling duct efficiency requires pressure and clean air at the intake port and negative pressure at the duct nozzle. Therefore, a optimization of the cooling duct positioning has been carried out on a common light helicopter (Eurocopter EC 120). Several different solutions have been simulated with Solid Works Flow Simulation. CFD confirms the ejector choice and the design criteria. The best configuration is a derivation of a Formula 1 intake duct. This solution proved to be the most effective for the CRDID-exhaust powered cooling duct. The result is that the ejector exhaust (augmenter) is extremely effective. With two small intakes at the side of the mast, the pressure differential between the intake and the nozzle of the duct proved to be extremely stable in every flight condition, even with crosswind.

Keywords: helicopter, diesel, cooling, efficiency, exhaust augmenter, CFD.

INTRODUCTION

Automotive CRDIDs are available from 100HP up to 1,000HP. The fixed point working point with high, steady rpm makes it possible to increase power output from the original automotive version of the engine. Crankshaft rpm up to 6000rpm can be easily achieved by modern common rail injectors. Furthermore, modern diesels are highly tolerant to high rpm, being throughout tested for the automotive use. Moreover, it is possible to increase original TBO (Time between Overhaul) four folds by implementing special treatments on engine parts and by replacing a few weak components. Apparently, the turboshafts have better power to weight ratio than CRDIDs (Common Rail Diesel Engine). Tturboshaft engines are the easiest choice for the helicopter power plants, being in use for more than 60 years (Aérospatiale Alouette II, 1955). However, the low efficiency in off-design conditions of turboshafts greatly reduces the turboshaft advantage over modern CRDIDs. CRDIDs have nearly-constant, high-efficiency at most of practical helicopter flight conditions. A typical helicopter duty cycle is depicted in Table-1. The most critical factor of helicopter is the very high number of cycles, nearly three times the classical automotive duty cycle (helicopter ICE TBO=3000h). The torque (load) for the helicopter is not very high for most of the time. Therefore, load is not the main issue of helicopter CRDIDs.

Table-1. Helicopter duty cycle.

No.	Load step	Crankshaft speed rpm	Load %	Time %
1	TO	6000	100	0.9
2	Hover-1	6000	108	1.9
3	Cruise-1	6000	75	40
4	Hover-2	6000	95	1.9
5	TO-2	6000	58	1.1
6	Cruise-2	6000	43	42
7	Cruise-3	6000	53	11.8
8	Hover-2	6000	51	0.4
-	Total	-	-	100

For a longer TBO several options have been tested in the racing field, where engine availability is extremely limited by regulations. Table-2 summarizes TBO increase starting from a commercial quality automotive engine.

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Table-2. TBO increase with surface improvements.

	Coatings	Roughness
Liner/ring	400%	5%
Journal and sliding bearings	20%	10%
Cams, valve…	2000%	10%

For example, the application of the DLC (Diamond Like Carbon) treatment in the valve train on all contact surfaces improves twenty folds the TBO of this engine assembly. On top quality automotive CRDIDs, the improvement of the surface finish only and additional 10%. Therefore, the total obtainable on the valve train is 22. These values come from the Formula 1 engine experience. A slight increase in bearing TBO can be obtained with finish and coatings. Tests on the several Liners and piston rings improvement options showed that an acceptable value of blow-by is kept with four folds the original life (TBO). In the automotive field, continuous power plant downsizing is propelled by a continuous reduction of emissions. Automotive market practice requires a continuous increases of performance of modern car and truck. These updated engines may, in the lucky case of helicopter conversion, reach an efficiency of 52%. In this case the fixed rpm and the relatively high loading improves emissions. Therefore, modern CRDID are now good candidates for powering light to medium single/twin engine(s) helicopters. This solution contains costs, reduces emissions and hugely reduces fuel consumption. The lower operating costs and the growing public concern for environment protection are essential factors in future technical choices. An optimum CRDID-helicopter matching easily meets these objectives. The highly optimized matching process starts from helicopter expected performances. A primary advantage of CRDIDs is the multi fuel capability of jet fuel and of automotive diesel. Jet fuel should be tested for Cetane number, since the qualification tests for turboshaft are not suitable for CRDIDs. Fuel lubricity is not a big issue. In fact, poor diesel supply and water emulsions compelled the automotive manufacturers to apply extensive anti wear treatments on critical, high pressure fuel parts, like pumps and injectors. The automotive diesel fuel worldwide diffusion reduces the supply problems both for civilian and military helicopters. In fact, many private helicopter owners have their own landing sites, where diesel fuel storage can be readily installed. Not so for jet-fuel, that is available mostly in airports. Therefore, refuelling of turboshaft helicopters at the nearest local airport is common. Reduced fuel availability is an important limitation in private helicopter diffusion, increasing operating costs. However, the use of a CRDID with FADEC (Full Authority Electronic Control) poses a significant challenge to the designer, who should provide cooling with a specific duct. The main challenge is to keep air and coolant temperature acceptability low at take-off, when power output is at top and airspeed can be null. In this paper this problem is fully investigated and the optimal solution of ejector-exhaust cooling duct position is thoroughly searched for. As an example the optimum design of the cooling system for a diesel powered Eurocopter EC120 is introduced herein.

The original turboshaft powered helicopter and the CRDID replacement

The turboshaft powered Eurocopter EC120 data provided by the manufacturer is summarized in the Table-3.

Table-3. EC120 data.

Description	value	unit
EW	997	kg
Useful load	700	kg
MTOW	1,600	kg
MTOW ext. load	1,715	kg
TO power	376	kW
Cont. power	336	kW
Fuel capacity	390	lt
Best Arrius F2 SFC	295	g/kWh
Arrius F2 mass	105.5	kg
Generator	6	kW

Table-4 summarizes the CRDID data. In this case the starting engine is the PSA V8 CRDID installed on Land Rover cars. Several different modifications bring the power up to 380kW.

Table-4. CRDID data.

Displacement	3,630cc
Bore/stroke	81/88mm
Compression ratio	12:1
Mass	285kg
BSFC	160gr/kWh

The CRDID-helicopter-version has a single turbocharger due to the absence of the turbo lag problem and the necessity to have the maximum torque at the fixed rpm. Therefore, the single turbocharger is much larger than the automotive ones and it has the exhaust pointing to the helicopter tail. The exhaust passes a bulkhead and the radiator pack to discharge the hot gases in the augmenter.

CRDID installation

The better SFC (Specific Fuel Consumption) and the excellent off-design efficiency makes it possible to reduce helicopter fuel consumption of 60% for the cycle of Table-1. In order to obtain the same range, it is sufficient to reduce the fuel tanks fuel capacity down to 128kg (1):

 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

$$Capacity_{CRDID} = (1-0.6)Capacity_{turboshaft} = 168\,lt = 128\,kg \quad (1)$$

The total tank weight saving will be 211 kg (2) including an additional 10% of weight saving due to (smaller) fuel tank(s) structure and installation.

$$Capacity_{CRDID} = 0.6\,Capacity_{turboshaft}\,1.1 = 211\,kg \quad (2)$$

However, the additional mass of the CRDID is 120 kg

$$\Delta M_{CRDID} = M_{CRDID} - M_{Turboshaft} = 285 - 105 = 120 \quad (3)$$

Therefore, it is possible to use the additional 91 kg to install the cooling duct complete with pipings.

The cooling duct

CRDID suffers both from overcooling and overheating. To have a good combustion it is vital to keep the head, the piston and the liner at optimum temperature. Long idling periods, even at tropical temperatures, may conduct to engine overcooling due to high engine efficiency even at minimal loads. Overcooling increases the play between the liners and the piston rings. The following blow-by tends to contaminate the lubricant with the fuel and to increase liner wear. Maximum temperature should also be kept under control for engine durability. If maximum allowed temperatures are exceeded, CRDIDs tend to fail very rapidly. At first the blow-by is again increased, reducing the power output. In this case lubricant is consumed at an accelerated rate. Then a major failure takes place, normally the piston or the exhaust valves fail. In a few cases the head may crack if a weak spot is present due to design or manufacturing flaws. Liner/ring seizure is possible but it is far less common than spark ignition engines. Also lubricant temperature is normally controlled by coolant through a liquid-to-liquid heat exchanger. Therefore, the cooling system should adequately keep coolant temperature within optimum range in every flight phase. Normally coolant temperature within the engine is controlled by a thermostatic valve or a variable velocity coolant pump. Due to emissions requirements automotive engines should have an extremely rapid heating phase after cold starting. Heat is taken where possible also by cooling accessories (like the generator). Coolant temperature control is extremely accurate and it is monitored and controlled by the FADEC. For this reason, overcooling can be easily kept under control even in helicopter application. On the contrary heating should be controlled by providing adequate heat removal in every flight phase. As discussed before, the use of fans is possible but encounters several limitations. From the duty cycle of Table-1, power output over 90% with zero airspeed is encountered only for 5% of the flight. In this case, it is possible to install batteries to energize the cooling fans. In this way it is possible to avoid engine overload. In fact, 380kW is the net engine power output. However, battery additional weight should be taken into account for the installation. Cooling drag is also of concern. In aircrafts, the Meredith ramjet duct increases net thrust. This solution is not equally efficient on helicopters. TO (Take Off), Hover-1 and Hover-2 are very demanding conditions, with nearly maximum power and no useful airflow from the main rotor. In fact, the swirl impairs the possibility to use rotor induced velocity for the cooling system. Engine coolant and air from the intercooler are cooled at full power, zero airspeed for several minutes. Correct positioning of inlet outlets ports of the cooling ducts is critical in helicopters. Efficient heating is only possible with adequate, forced airflow [1-15].

Theoretically in cruise it is possible to obtain additional thrust from a Meredith cooling duct. However, in most helicopters, cooling duct cannot be optimized for cruise at the expense of TO and hover due to excessive weight. The best way obtain a high reliability level is to simplify of the cooling system. Therefore, the ejector exhaust extractor (augmenter) reduces both the additional energy requirements and the size of inlet and outlet ports. Ejector exhaust works only at relatively high power settings where the air digested by the engine is nearly maximum. That is the case of the helicopter engine that always runs at the same speed. Since cooling power is a function of efficiency, CRDIDs are the less demanding among ICEs (Internal Combustion Engine). The ideal cooling system regulates cooling airflow as a function of engine power setting and temperatures. The ejector exhaust solution minimizes the cooling drag due to the relatively high pressure difference. The absences of fans and batteries greatly increases the reliability of the system. The possibility to use carbon ceramic composites for the exhaust and CFRP (Carbon Fiber Reinforced Plastic) for the duct reduces the overall mass of the exhaust/cooling duct. The exhaust augmenter aspires the air the outside air into the cooling duct. As common in automotive application, the fresh air cools the intercooler and then the coolant radiator. The two radiators are packed together in a serial arrangement. The intercooler should keep the air temperature at CRDID intake below 50 DEG C with OAT=35 C (Outside Air Temperature). This is due to the fact that the intake air is used to cool piston top surface. The bottom piston surface is cooled by the lubricant. A coolant-to-lubricant heat-exchanger is installed on the engine after the lubrication pump. For our V8 engine, maximum coolant temperature is 120 DEG C and maximum lubricant temperature is 130 DEG C. The cooling circuit is pressurized at 4.5 bar. Coolant temperature inside the cylinder block should not drop below 60 DEG C during normal operations.

For the radiator design, a reasonable volumetric coefficient for modern CRDID is cv=25,000 mm^3/kW. This cv is valid for racing quality finned “standard radiator cores” with 2.75” thickness and 25 fpi (fin per inch). This cv is “calculated” for a “radiator pack” that includes a suitable air-to-air intercooler installed in front the main coolant radiator. Therefore, the radiator area "frontal area" $S_{radiator}$

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$$S_{radiator} = \frac{P_{CRDID}cv}{w} = \frac{380 \times 25 \times 10^3}{70} = 135 \times 10^3\,[mm^3] \tag{4}$$

The most efficient shape for an ejector augmenter is the circular one. However, for manufacturing reasons, a square or rectangular radiator should be adopted. In the case of the square radiator the side is 0.37 m. The augmenter is a jet compressor that uses the small high-speed exhaust-gas-jet to suck a larger mass of cooling air through the radiator pack. The engine exhaust is positioned in a hole at the center of the radiators. This solution is simple to manufacture in aluminum alloy radiators that are TIG (Tungsten Inert Gas) welded. The CFD (Computational Fluid Dynamics) model assimilates the radiator to an equivalent porous media. The augmenter has the convergent inlet, the constant (straight or mixing) and the diffuser sections (Figure 1). From old NACA reports, the optimum inlet area is 15% larger than that of the radiator frontal area. This optimum convergent inlet is trumpet shaped with a Diameter to Length ratio of 5.However, since the convergent section is not critical it will be kept as small as reasonable. On the contrary, the diffuser shape is extremely critical. The most stringent design requirement in dimensioning the diffuser is to maximize the pressure recovery by minimizing the internal losses. Diffuser has distributed loss, caused by the friction on the walls and the concentrated loss caused by misguiding of the air flow. About a century ago it was found that the semi-angle opening of the duct of about 7° is acceptable for straight ducts. However, the best diffuser is the streamline one that was widely used for Meredith's duct during WWII. This is the best design to minimize the friction losses. In fact, in a streamline diffuser the walls follow the "natural shape" of the airflow, guiding it with the most possible efficiency. The trumpet profile of the streamline diffuser is long 1.5 times the larger side of the radiator. In this critical application, the geometry of the diffuser causes an increase in the radiator drag and a reduction of the heat-rejection, because of the reduction in the airflow. In fact, a deviated flow hits the parallel fins of the radiator increasing the pressure drop. However, as it will be shown in the following, it is possible even to avoid the diffuser section of the cooling duct, if the inlet and outlet ports are carefully positioned.

NACA augmenter design

The CRDID of Table-4, with an air-to-fuel ratio of 20 will output 0.38 kg/s (5)

$$M_{exhaust} = \frac{BSFC * P_{CRDID}r}{1000 \times 3600} = 0.38 \tag{5}$$

With an exhaust temperature of $T_{exhaust}$=923.15 K and a gas velocity of $v_{exhaust}$=0.8 Mach, the exhaust diameter $d_{exhaust}$ is 96 mm (6).

$$d_{exhaust} = \sqrt{4\frac{M_{exaust}}{\pi \frac{Patm}{T_{exhaust}R} v_{exhaust}}} = 0.096 \tag{6}$$

The straight section area has to be 8 times the exhaust area, therefore the side of the square duct will be $l_{straight}$=242mm (7).

$$l_{straight} = \sqrt{\frac{d^2_{exhaust}\,\pi \times 8}{4}} = 0.242 \tag{7}$$

The optimum length of the mixing (straight) section is six times the side, while the best final diameter for the diffuser is 1.45 times the mixing side with an angle of divergence lower than 12 DEG (Figure-1).

Cooling duct port optimization

The first tentative design was to position a circular grid after the engine bulkhead. In this way the fresh cooling air should enter radially into the duct to be sucked into the convergent port of the ejector exhaust. As it can be seen from Figure-1 the best position of the engine exhaust port is just at the beginning of the straight mixing section.

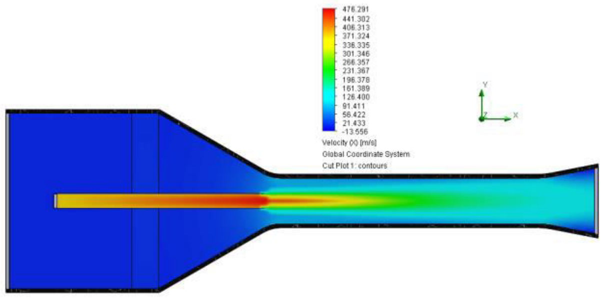

Figure-1. Engine exhaust port is positioned at the beginning of the mixing (straight) section (best position).

Unfortunately, in hover and TO, CFD simulation showed that the area in which the exhaust augmenter should discharge (ejector duct exhaust port) is placed at a higher pressure than the one in which aspires air from the outside (ejector duct inlet port), with a reduction of cooling efficiency (Figures 2 and 3).

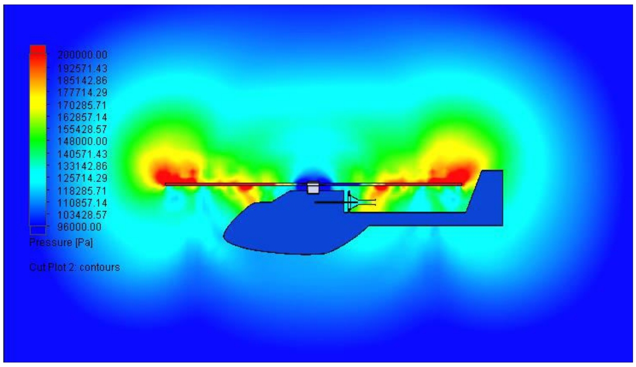

Figure-2. CFD of the helicopter in hover with the first cooling duct (pressures).

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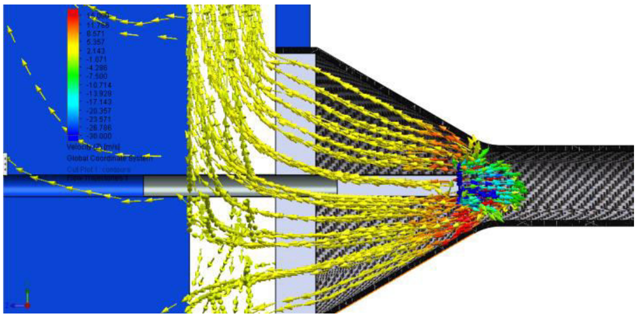

Figure-3. CFD of the helicopter in hover with the first cooling duct (velocity vectors).

The substantial failure of the first design, lead to a second “improved” version.

The intake port of the cooling duct was moved on the front of the helicopter, with a shorter augmenter. This means a shorter mixing section (Figure-4).

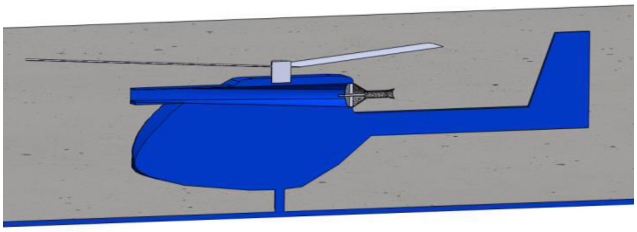

Figure-4. Second design with front port and shorter mixing section (TO)

This solution was simulated without the hot engine exhaust jet.

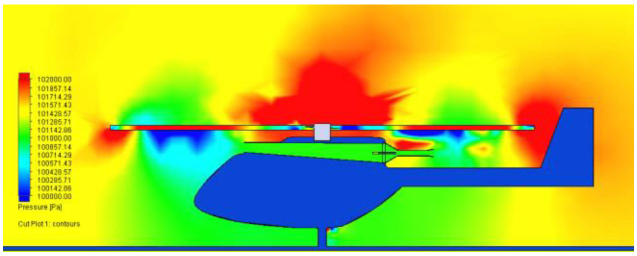

Figure-5. CFD simulation of the second design with front port and shorter mixing section without the exhaust gas jet (pressures at TO)

Figure-5 shows that the intake and exhaust ports are substantially correct. Figures 6 and 7 show the II design with the exhaust gas jet.

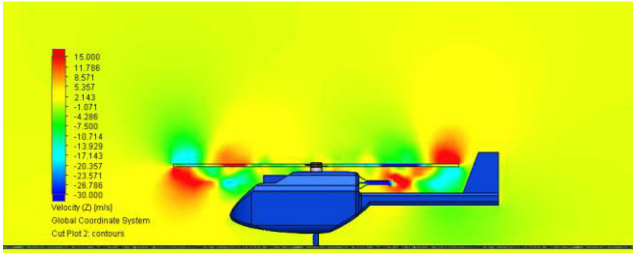

Figure-6. CFD simulation of the second design with front port and shorter mixing section with the exhaust gas jet (horizontal velocity at TO)

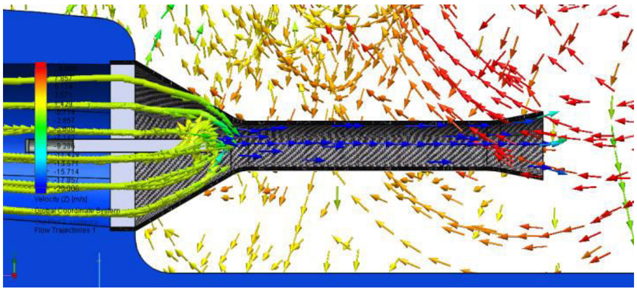

Figure-7. CFD simulation of the second design with front port and shorter mixing section with the exhaust gas jet (velocity vectors at TO)

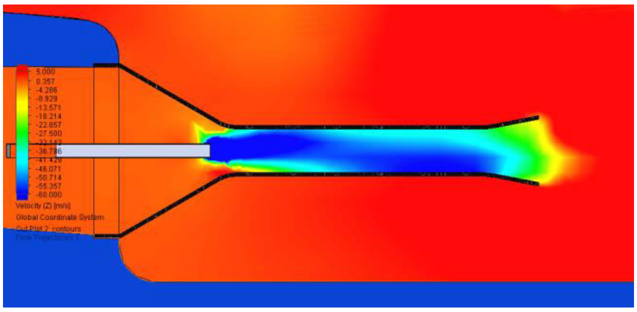

Figure-8. CFD simulation of the second design with front port and shorter mixing section with the exhaust gas jet (velocity at TO)

These second set of simulations show of a frontal zone of high pressure and a rear area of low pressure, which may suggest the possibility of obtaining an adequate cooling without exhaust augmenter. The pressure difference can be theoretically obtained by placing the intake and the exhaust ports in the right positions. Unfortunately, this solution would not ensure an adequate cooling in every flight condition. This second configuration seems to be acceptable for an adequate cooling of the engine. However, the presence of the rotor mast and reduction gearings will reduce its efficiency.

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Figure-9. Forghieri's Ferrari 312 T2 (1977) is the starting point for the third design solution.

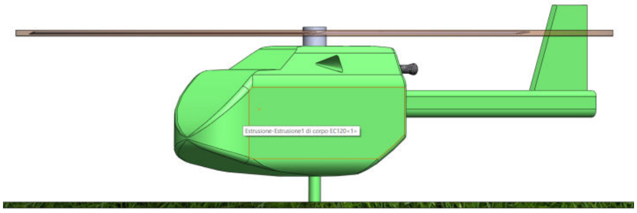

Figure-10. Third design solution inspired to Ferrari 312 T2 (lateral view, TO simulation).

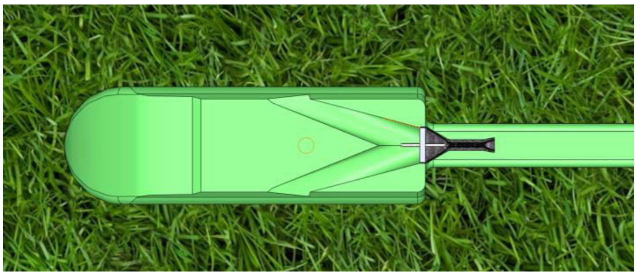

Figure-11. Third design solution inspired to Ferrari 312 T2 (plan/transparent view, TO simulation).

A third design solution uses two symmetrical NACA air intakes on the side of the helicopter. These intakes are slightly inclined to achieve a sufficient air flow. This solution is similar to the air inlets of Niki Lauda's Ferrari 312 T2 designed by Mauro Forghieri in 1977 (Figure-9). The CAD model used for the CFD simulations is shown in figures 10 and 11. The slightly inclined intake ports are clearly visible in the transparent view of Figure-11. As shown in figures 12, 13 and 14, a marked improvement is obtained by this configuration, especially observing the results relating to the speed, in which it was necessary to modify the scale to show the larger values. In cruise the advantage is even more relevant. Therefore, this is the best configuration for cooling and drag. Moreover, this solution is easier to implement on the helicopter [16-20].

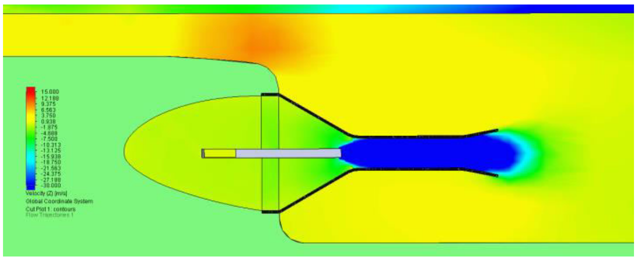

Figure-12. CFD of third design (velocity inside the augmenter, TO simulation).

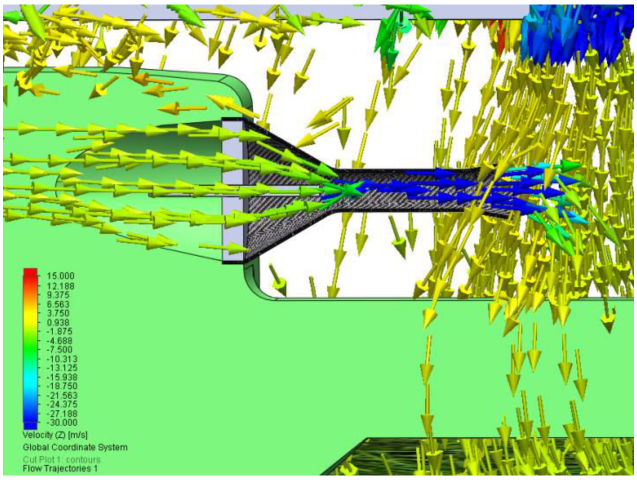

Figure-13. CFD of third design (velocity vectors inside the augmenter, TO simulation).

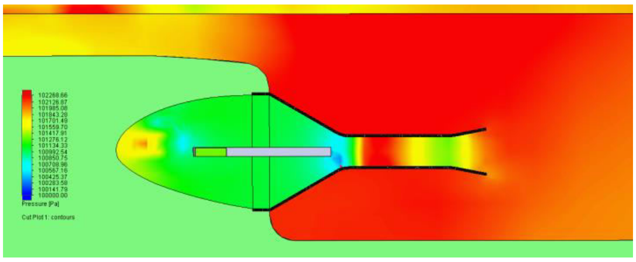

Figure-14. CFD of third design (pressures inside the augmenter, TO simulation).

CONCLUSIONS

CRDID (Common Rail Direct Injection Diesel), automotive derived engine, main advantage is the enormous amount of experimental data. These engines are produced in millions of units and reliability data based trillions of hours are available. It is also possible and easy to run automotive CRDIDs with jet fuel. However, diesel fuel is safer and easier to find. It is possible to mix the two fuels with a proper ECU (Electronic Central Unit) mapping. Therefore, the necessity to refuel in airports can be eliminated. Moreover, the additional mass of CRDIDs is largely compensated by the reduced fuel amount necessary to exploit the same mission/flight. However, an additional cooling system duct should be added. For this purpose, fans are replaced by ejector exhaust that does not need fan additional power. Solid Works Flow Simulation confirmed the feasibility of an ejector-exhaust-powered cooling. However, pressure fields around the helicopter varies in a very significant way in the different flight condition. High cooling duct efficiency requires pressure and clean air at the intake and negative pressure at the duct nozzle. Therefore, a feasibility optimization of the cooling duct positioning has been carried out on a common light helicopter (Eurocopter EC 120). Several different solutions have been simulated with Solid Works Flow Simulation. CFD confirms the ejector choice and the design criteria. The total mass is not varied being the increased mass of the engine compensated by fuel weight saving. Finally, a derivation of a 1977 Formula 1 cooling duct proved to be the most effective for the CRDID-exhaust powered cooling duct. The result is that the ejector exhaust (augmenter) is extremely effective. With two small intakes at the side of the mast, the pressure differential between the intake and the nozzle of the duct proved to be extremely stable in every flight condition, even with crosswind [21-27].

Symbols

Symbol	Description	Unit
$Capacity_{turboshaft}$	Fuel capacity turboshaft helicopter	kg
$Capacity_{CRDID}$	Fuel capacity CRDID helicopter	kg
$Mass_{turboshaft}$	Mass turboshaft	kg
$Mass_{CRDID}$	Mass CRDID	kg
P_{CRDID}	Max Power CRDID	kW
cv	Radiator volumetric factor	mm^3/kW
$S_{radiator}$	Radiator frontal area	mm^2
w	Radiator thickness	mm
$M_{exhaust}$	Exhaust Mass flow rate	kg/s
$T_{exhaust}$	Exhaust gas Temperature	K
R	Air specific gas constant	J/(kg K)
r	Air to fuel ratio	-
$v_{exhaust}$	Exhaust gas velocity	m/s
$d_{exhaust}$	Exhaust pipe diameter	m
p_{atm}	Atmospheric pressure	Pa
$l_{straight}$	Side of square mixing duct	m

REFERENCES

[1] L. Piancastelli, L. Frizziero, S. Marcoppido, E. Pezzuti. 2012. Methodology to evaluate aircraft piston engine durability edizioni ETS. International Journal of Heat & Technology. ISSN 0392-8764, Volume 30, n.1, pp. 89-92, Bologna.

[2] L. Piancastelli, L. Frizziero, G. Donnici. 2015. The Meredith ramjet: An efficient way to recover the heat wasted in piston engine cooling. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608, Volume 10, Issue 12, pp. 5327-5333, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[3] L. Piancastelli, A. Gatti, L. Frizziero, L. Ragazzi, M. Cremonini. 2015. CFD analysis of the Zimmerman's V173 stol aircraft. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608, 10(18): 8063-8070, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[4] L. Piancastelli, L. Frizziero. 2014. Turbocharging and turbocompounding 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.

[5] L. Piancastelli, L. Frizziero, G. Donnici. 2014. The common-rail fuel injection technique in turbocharged di-diesel-engines for aircraft applications. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608, 9(12): 2493-2499, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[6] L. Piancastelli, L. Frizziero, G. Donnici. 2015. Turbomatching of small aircraft diesel common rail engines derived from the automotive field. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608, 10(1): 172-178, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA

[7] L. Piancastelli, L. Frizziero. 2015. Supercharging systems in small aircraft diesel common rail engines derived from the automotive field. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608, 10(1): 20-26, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA

[8] P.P. Valentini, E. Pezzuti E. Computer-aided tolerance allocation of compliant ortho-planar spring mechanism. International Journal of Computer Applications in Technology, 53: 369-374, ISSN: 0952-8091, doi: 10.1504/IJCAT.2016.076801.

[9] E. Pezzuti, PP. Valentini PP. Accuracy in fingertip tracking using Leap Motion Controller for interactive virtual applications. International Journal on Interactive Design And Manufacturing, pp. 1-10, ISSN: 1955-2513, doi: 10.1007/s12008-016-0339-y

[10] E.Pezzuti E, PP. Valentini P. Design and interactive simulation of cross-axis compliant pivot using dynamic spline. Int. Jour. On Interactive Design And Manufacturing, 7: 261-269, ISSN: 1955-2513, doi: 10.1007/s12008-012-0180-x

[11] L. Piancastelli, S. Cassani. 2017. Maximum peak pressure evaluation of an automotive common rail diesel piston engine head. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608, 12(1): 212-218, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[12] S. Cassani. 2017. AIRPLANE DESIGN: THE SUPERIORITY OF FSW Aluminum-Alloy Pure Monocoque Over CFRP “BLACK” Constructions. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608, 12(2): 377-361, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[13] L. Piancastelli, S. Cassani. 2017. Power Speed Reduction Units For General Aviation Part 2: General Design, Optimum Bearing Selection For Propeller Driven Aircrafts With Piston Engines. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608, 12(2): 544-550, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[14] L. Piancastelli, S. Cassani. 2017. Power Speed Reduction Units For General Aviation Part 5: Housing/Casing Optimized Design For Propeller-Driven Aircrafts AND HELICOPTERS. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608, 12(2): 602-608, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[15] L. Piancastelli, S. Cassani. 2017. Power Speed Reduction Units For General Aviation Part 3: Simplified Gear Design Piston-Powered, Propeller-Driven General Aviation Aircrafts. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608, 12(3): 870-874, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[16] L. Piancastelli, S. Cassani. 2017. Power Speed Reduction Units For General Aviation Part 4: Simplified Gear Design For Piston-Powered, Propeller-Driven Heavy Duty Aircrafts And Helicopters. Journal of Engineering and Applied Sciences. ISSN 1819-6608, 12(5): 1533-1539, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[17] L. Piancastelli, S. Migliano, S. Cassani. 2017. An Extremely Compact, High Torque Continuously Variable Power Transmission For Large Hybrid Terrain Vehicles. Journal of Engineering and Applied Sciences. ISSN 1819-6608, 12(6): 1796-1800, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[18] L. Piancastelli, S. Cassani. 2017. Mapping Optimization For Partial Loads Of Common Rail Diesel Piston Engines. Journal of Engineering and Applied Sciences. ISSN 1819-6608, 12(7): 2223-2229, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[19] L. Piancastelli, S. Cassani. 2017. High Altitude Operations with Piston Engines Power Plant Design Optimization Part V: Nozzle Design And Ramjet General Considerations. Journal of Engineering and Applied Sciences. ISSN 1819-6608, 12(7): 2242-2247, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[20] L. Piancastelli, R. V. Clarke, S. Cassani. 2017. Diffuser Augmented Run The River And Tidal Picohydropower Generation System. Journal of Engineering and Applied Sciences. ISSN 1819-6608, 12(8): 2678-2688, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[21] L. Piancastelli, M. Gardella, S. Cassani. 2017. Cooling System Optimization For Light Diesel Helicopters. Journal of Engineering and Applied Sciences. ISSN 1819-6608, 12(9): 2803-2808, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[22] L. Piancastelli, S. Cassani. 2017. Study And Optimization Of A Contra-Rotating Propeller Hub For Convertiplanes. Part 1: Vto And Hovering. Journal of Engineering and Applied Sciences. ISSN 1819-6608, 12(11): 3451-3457, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[23] L. Piancastelli, S. Cassani. 2017. On The Conversion Of Automotive Engines For General Aviation. Journal of Engineering and Applied Sciences. ISSN 1819-6608, 12(13): 4196-4203, EBSCO Publishing, 10

Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[24] L. Piancastelli, S. Cassani. 2017. Convertiplane Cruise Performance With Contra-Rotating Propeller. Journal of Engineering and Applied Sciences. ISSN 1819-6608, 12(19): 5554-5559, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[25] L. Piancastelli, S. Cassani. 2017. Tribological Problem Solving In Medium Heavy Duty Marine Diesel Engine Part 1: Journal Bearings. Journal of Engineering and Applied Sciences. ISSN 1819-6608, 12(22): 6533-6541, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[26] A. Ceruti, T. Bombardi, T., L. Piancastelli. 2016. Visual Flight Rules Pilots Into Instrumental Meteorological Conditions: a Proposal for a Mobile Application to Increase In-flight Survivability. International Review of Aerospace Engineering (IREASE). 9(5).

[27] L. Piancastelli, A. Burnelli A., S. Cassani. 2017. Validation of a simplified method for the evaluation of pressure and temperature on a RR Merlin XX head, International Journal of Heat and Technology, 35(1): 549558. DOI: 10.18280/ijht.350311.