Publishable summary

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Summary description of project context and objectives

The optimal diesel engine designed for the light helicopter was assumed to reach an ideal helicopter characteristics and fulfill the environmental impact reduction expectations according to the ACARE goals for year 2020 as defined in the call.

The main goal of the project was to defined the optimal turbocharged diesel engine and the integration studies to make use of the engine for the ideal helicopter platform. The results of the project demonstrate a substantial potential for pollutant emission and fuel consumption reduction by powering the light single engine category helicopter with this advanced diesel engine instead of a conventional small turboshaft engine.

Hence, the research and development work in DELILAH was based on the following deliverables:

- Engine Specification – Engine General Description,
- Engine Specification – Subsystems,
- Engine Specification – Thermodynamic Analysis,
- Engine Specification – Engine Vibration Characteristics,
- Engine Specification – Engine Control System,
- Engine Specification – Interface Control Document,
- Environmental impact report.

The technical challenge has been to obtain the power-to-weight ratio taking into account helicopter requirements such as reliability and TBO. An optimal diesel engine has been chosen by selection procedure where ratings criteria will be based on performance, weight, size, fuel economy, emissions, multi-fuel capability, reliability, noise, technology, costs, integration, cooling, and drag.

The engine configuration has been selected from the several types of engines. Finally, the engine with the defined engine sub-systems has been designed. To solve the design problems designing tools to design aircraft and automotive piston engines have been applied. The project relates to the solution of problems like: vibration, noise, transmission chain coupling and torque oscillations, engine control and response. To solve these problems, the innovative ideas has been done to develop and analyze the high dimensional dynamics of the multi-body mechanical system and the original diesel engine adaptive control system.

The project of a full authority digital engine controller (FADEC) has been developed. The project includes the fuel injection system and takes into account the numerous variables of the engine with respect to exhaust gas emission, combustion pressure, EGT, torque, and engine speed limits. To establish the environmental benefits of the diesel engine technologies, mathematical models have been created and the performance and environmental impact of an advanced diesel engine light helicopter have been calculated, incorporating project technology developments. This phase is preceded by an analysis of the flight scenario. The performance of the helicopter is inseparably related to the load at the input to the propulsion system. With an increasing focus on reducing the use of fossil fuel to minimize climate change, there have been performed the calculations using not only usual diesel fuel but also biofuels and biomass-to-liquids (BTL) diesel fuel. The results have shown that the use of biofuels reduces nitrogen oxide emissions but increases soot emission.

Description of work performed and main results

Main goals of the project

The project defines the optimal turbocharged diesel engine and the integration studies to make use of the engine for the ideal helicopter platform.

The positive results of the project demonstrate a substantial potential for pollutant emission and fuel consumption reduction by powering a light single engine category helicopter with this advanced diesel engine instead of a conventional small turboshaft engine.

Technical Challenge

The technical challenge was tough concerning engine development in particular to reach the power-to-weight ratio taking into account helicopter needs such as reliability and TBO. The engine weight is the crux of the project.

The engine configuration has been selected from among several types of engines (in-line, V, opposed-piston, radial, Wankel) and cycle types (two-stroke or four-stroke). The V-8 engine has been defined as the optimal configuration.

Major project stages

I) Optimal Diesel Engine Specification

The optimal diesel engine design for the light helicopter was assumed to reach ideal helicopter characteristics and fulfill the environmental impact reduction expectations according to the Acare goals for year 2020 as defined in the call. This phase was preceded by an analysis of the flight scenario.

With the data base the engine performance was analysed for the selected representative group. The diesel engine Weight/power ratio for engines analysed were compared. The major engine construction assumptions were defined.

The calculations were done under the following ISA conditions: 0, 2500, 4000 and 6000 m. It was demonstrated that the engine power obtained is higher than required.

The engine main components were designed and tested in terms of their strength and fatigue. The input data necessary to analyse stress come from previous performance calculations. According to the project requirements, the engine components TBO, which was defined in call for proposal have been consider.

This study determined the geometry of the main components of the crank-piston engine under design, i.e. piston, connecting rod, and crankshaft. The generated structure of these elements and selected materials can ensure the engine to withdraw maximum load and provide safe, long-term, and efficient engine performance (within a given TBO for the engine for full engine service life).

II) Engine/Rotorcraft Integration Study

This study was conducted to evaluate the integration of the proposed optimal diesel engines into helicopter. The engine and its subsystems were built on the ideal platform which requires the following connections:

a) thermodynamic,

b) mechanic,

c) electronic,

d) hydraulic and pneumatic.

Finally, the design of each sub-system, i.e. a fuel system, cooling system, oil system, electrical system, air inlet system, anti-icing system was determined.

III) Environmental Impact Analysis

To establish the environmental benefits of the diesel engine technologies, mathematical models have been created to predict the performance and environmental impact of an advanced diesel engine light helicopter, incorporating project technology developments. Some parts of models were used to determine the effect of the engine on its operating costs. The results were then compared with the corresponding data for the currently produced turboshaft engine to power light rotorcraft. This model has been used in the Technology Evaluator, along with fleet forecasts for the Year 2020+, so that the Technology Evaluator can assess the environmental benefits of the project technological breakthroughs.

In the calculations of the emission of toxic compounds of exhaust gases, a similar method as in the case of the calculations of the fuel consumption was applied. For the thermodynamical model of the engine, the emission of toxic compounds of exhaust gases such as: CO, NOx has been calculated.

Final results and potential impacts

When helicopter designing was significantly developed in the second half of the 20th century, the turboshaft engine for its better power-to-weight ratio (kg/kW) became a dominant driving unit in this type of aircraft. In the past century, the Diesel engine was not so competitive in terms of this ratio as compared to the turboshaft engine. The fact that Diesel engines have their mass much larger than turboshaft engines is the most serious problem. If this type of engine is installed in the helicopter, the following technical requirements need to be satisfied:

a) high priority criterion: engine performance, fuel economy, emission of toxic exhaust gases, etc;

b) medium priority criterion: capability of using varied types of fuels, reliability, etc;

c) low priority criterion: production costs, operating costs, etc.

This project Diesel engine design had to meet certain requirements. A helicopter with this innovative Diesel engine uses at least twice less fuel than the one with a turbine engine. The emission of toxiccompounds from our engine in one-hour flight is lower (CO - 20 times, soot - 229 times, CO_2 - twice).

Additionally, this engine design enables alternative fuels such as B100 to be supplied, which will contribute to a lower consumption of conventional fuels and a lower emission of greenhouse gases. This innovative technology will contribute to the improvement of the environment, which corresponds to the EU horizontal policy. The project has a neutral impact on the policy of equality as specified in Art. 17 of Council Regulation (EC) No 1083/2006. The results of this project will lead to the improvement of the environment as specified in Art. 16 of Council Regulation No 1083/2006. The EU policy aims to protect and improve the environment. The development scenario by the EC Directorate-General for Energy and

Transport assumes a 23% share of substitution of petrol and diesel oil in 2020. As specified in the EU strategic documents (Corinne Hermant-de Callataÿ, Christian Svanfeldt: Cities of tomorrow - Challenges, visions, ways forward, European Union, 2011) related to the plans of EU programmes for 2014-2020, it is necessary to reduce energy sensitivity and CO_2 emissions by programmes that could launch new technologies capable of a significant reduction of greenhouse gas emissions. Nowadays, there are too many examples of public transport infrastructure that has caused urban spatial segregation and uncontrolled urban development, increased traffic in city centers and thus CO_2 emissions and pollution, and consequently deteriorated the quality of life.

This solution can significantly lower the cost of helicopter flight per hour because fuel consumption is much lower. Significantly reduced transport costs will be reflected in household savings as prices of any products are closely related to costs of transport. Russia as the second largest global exporter of helicopters after the United States exports 99 helicopters per year, worth € 2.5 billion. In 2012, Eurocopter sold 475 helicopters and its turnover reached € 6.3 billion. This type of helicopters is 33% of the global fleet of helicopters of civil use and public organizations.

Concluding, the helicopter industry can depend on Diesel engines in the future, which can be supported by the availability of increasingly lighter structural materials of similar or even better strength than those used today. In addition, some environmental activities to reduce pollution by aircraft and economic benefits from Diesel engine in helicopter can contribute to the applicability of this type of driving unit.

PhD students' involvement in this project has also contributed to the development of European young scientists (human resources rejuvenation criterion). While implementing the project, a doctoral dissertation has been started. The project involved 25 people with a total of 224 person-months, which has reduced the unemployment rate to some extent and helped develop the R&D sector.