Project Periodic Report

-Publishable Summary-

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1. Publishable summary

Low Emissions Core Engine Technologies

Background

LEMCOTEC is an initiative that integrates the interests of all European aero engine manufacturers of the Engine-IMG and Europe's leading research institutions and universities in the field of aeronautics providing innovative and sustainable technologies for the protection of the environment.

After laying the foundations for turbo-fan engines with very-high BPRs of up to 15 in VITAL and open-rotor configurations with ultra-high BPRs of 45 to 50 in DREAM, the development of core-engine technology with OPRs beyond 50 (up to 70 and higher), remains the only way, to increase the engine efficiency further, to expand the work commenced in NEWAC.

Global air traffic is forecast to grow at an average annual rate of around 5% in the next 20 years. This high level of growth makes the need to address the environmental penalties of air traffic all the more urgent. Consequently, Europe's aviation industry faces a massive challenge to satisfy the demand whilst ensuring economic, safe and more environmentally friendly air travel.

Current research is providing the technologies to improve the performance of existing engine components. However, even if these technologies enable improvements in emissions, their existing limitations (technology maturity and integration) might not allow the industry to reach the goals set by ACARE in the field of aeronautics research by 2020.

Overall objectives for the project (Month 1 – 48)

The main objective of LEMCOTEC will be to successfully validate, at component level (i.e up to TRL5), innovative ultra-high pressure-ratio core-engine technologies, to increase the thermal efficiency of the engine cycles relative to year 2000 in-service engines with

- **OPR of up to 70** (at max. condition) as an **enabler and key lever** of the core-engine technologies to exceed the ACARE 2020 targets on CO2, NOx and other pollutant emissions:
- **20 to 30 % CO2** reduction at the engine level, exceeding both, the ACARE 15 to 20% CO2 reduction target for the engine and subsequently the overall 50% committed CO2 and the fuel burn reduction target (including the contributions from operations and airframe improvements),
- **65 to 70 % NOx reduction** at the engine level (CAEP/2) to attain and exceed the ACARE objective of 80% overall NOx reduction (including the contributions from both, operational efficiency and airframe improvement),
- **Reduction of other emissions** (-50% CO, -50% UHC and -75% smoke/particulate matter at the engine level (CAEP/2), requiring that the minimum cruise combustion efficiency has to be higher than 99.8 %, exceeding the ACARE 2020 target for the reduction of other pollutants.
- **Reduction of the propulsion system weight** (engine including nacelle without pylon).

Most importantly, LEMCOTEC addresses the particular challenge in **delivering these benefits simultaneously**, hence contributing to the simultaneous attainment of the relevant ACARE targets described in their Strategic Research Agenda (SRA) and their Vision 2020.

Progress and main results achieved in first period (Month 1 – 18)

The following main achievements were made in the four LEMCOTEC RTD sub-projects:

Whole Engine specification and assessment on three study power plant concepts (SP1)

The subproject *Whole Engine specification and assessment* integrates the results for the LEMCOTEC technology development in SP2, SP3 and SP4 into three study power plants concepts. This has been done by defining the whole engine requirements for a Regional turbofan equipped, a Medium Range Open Rotor equipped and a Long Range turbofan equipped aircraft.

Based on this the subproject has developed the engine concepts in terms engine arrangements, cycles and dimensions to form overall specifications for three ultra high pressure ratio engines.

Additionally, concepts and evaluation methods for four innovative future cores aimed further into the future, i.e. 2030-2050 have been developed.

Ultra-high pressure ratio compressors (SP2)

The overall objective for the first 18 months of SP2 was to investigate and down select various concepts that would be tested on low and high speed aero rigs and mechanical/manufacture trails over the remaining 30 month period; this has been achieved. Of the 21 aero rig tests, 1 (Inter-duct test) has been completed and 10 more have been defined with many progressing through manufacture; this will enable the defined programmes to achieve their initial tests on or close to schedule. Subsequent designs that explore new technologies will be defined over the next 12 months through the progressive use of CFD and concept reviews. Good progress is being made on the IPC multi-stage high speed rig, a rig supplier has been chosen and detailed cost and timescales have been established that achieve the declared test date.

The 2 mechanical rigs are slightly behind schedule with their initial tests now taking place in the M18-24 period.

Lean combustion for ultra-high OPR engines (SP3)

The injection systems concepts issued from past projects have been analysed in order to identify the changes that must be brought to the design in order to meet the objectives in terms of Nox emissions and operability. 3D RANS and LES computations of several new designs have been performed to assess their capabilities and performance before manufacturing and tests in mono sector or multi-sector combustors. Because lean combustion is prone to combustion instabilities an innovative device for flame monitoring has been designed. A plasma ignition system is also considered and the corresponding test rig has been defined.

In parallel to the work devoted to the injection system, the design of the combustion chamber has begun, as the injection system details are not needed at this step. Analyses of the cooling scheme and the external aerodynamics have been performed, preliminary design of the three combustors has been undertaken and for some partners the first corresponding mechanical design achieved. LES and pure acoustics computations have been performed in order to determine the minimum number of injection system for which the flame till propagate circumferentially after ignition and to identify the influence of fuel split against combustion instabilities. The overhaul sensitivity of the combustor to combustion instabilities one integrated into the engine, thus taking into account realistic boundary conditions at the high-pressure compressor exit and at the inlet of the high pressure turbine has been investigated. Moreover the design of the test rig aiming at the investigation by mean of optical and intrusive methods of the interface between the combustor outlet and the high-pressure turbine inlet has been completed.

Finally, several architectures for the fuel control system that will be required in order to operate lean combustors into a real engine have been assessed and the specification for the ones that will be developed up to TRL5 within LEMCOTEC have been consolidated.

Advanced structures and thermal management (SP4)

The sub-project *Advanced structures and thermal management* is working on developing 11 technology areas towards a medium TRL (4-5) demonstration level.

In the first 18 months specifications have been prepared for the technologies and equipment for tests and manufacturing trials. These specifications give major dimension and/or other essential parameters for the test objects, and have been used for concept development. For *High stiffness compressor structures* specifications have been provided for each of the three LEMCOTEC study engines. Engine cycles and heat exchanger specifications for *inter-cooled* as well as for r*ecuperated engines* have been delivered. Further specifications have been provided for Innovative sheet forming process for hot section components as well as *Intermediate and high pressure turbine test designs*.

Designs for the test components and systems are under development. Finished designs are available for the *High performance light weight HPC guide vane* and the *Cooled HPC exit cone designs* are ready and manufacturing is underway. Cast test components using an *Extended temperature material for hot section structures* have been produced. A concept for a *Low leakage liner* to proceed to manufacturing and aero-thermal tests has been described.

LEMCOTEC partners

The LEMCOTEC is composed of the following partner organisations:

- Rolls-Royce Deutschland Ltd & Co KG (RRD)
- MTU Aero Engines GmbH (MTU)
- Rolls-Royce plc (RR)
- Snecma – Safran Group (SN)
- GKN Aerospace Engine Systems Sweden (GKN former VOLVO)
- Avio S.p.A. (AVIO)
- Industria de Turbo Propulsores, S.A (ITP)
- První brněnská strojírna, a.s. (PBS)
- Turbomeca – Safran Group (TM)
- WSK "PZL-RZESZÓW" S. A (WSK)
- ARTTIC (ART)
- Aristotle University of Thessaloniki (AUTH)
- Bauhaus Luftfahrt e.V.(BHL)
- Cambridge University (UCAM)
- CERFACS (CERFACS)
- Chalmers University (CHALM)
- Central Institute of Aviation Motors (CIAM)
- CNRS CORIA (CNRS)
- Cranfield University (CU)
- CTA Fundacion Centro Tecnologias Aeronauticas (CTA)
- Deutsches Zentrum für Luft- und Raumfahrt e.V.(DLR)
- Fraunhofer Gesellschaft – Institut für Produktionstechnologie (IPT)
- Karlsruhe Institute of Technology (KIT)
- Loughborough University (LOUGH)
- ONERA (ONERA)
- PCA Engineers Ltd. (PCA)
- Aachen University of Technology (RWTH)
- TU Braunschweig (TUB)
- TU Dresden (TUD)
- Universidad Politecnica de Madrid (UPM)
- Università degli Studi di Firenze (UNIFI)
- University of Oxford (UOXF)
- University of Stuttgart (USTUTT)
- Von Karman Institute for Fluid Dynamics, INPA (VKI)
- VÝZKUMNÝ A ZKUŠEBNÍ LETECKÝ ÚSTAV, A.S. (VZLU)
- ERGON research (ER)

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