Project Periodic Report

- Publishable Summary -

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Project acronym: IMPACT-AE

Project title: Intelligent Design Methodologies for Low Pollutant Combustors for Aero-Engines

Funding Scheme: Small or medium-scale focused research project (STREP)

Date of latest version of Annex I against which the assessment will be made: 21-06-2011

Periodic report 1st X 2nd ☐ 3rd ☐

Period covered From 01/11/2011 to 30/04/2013

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1. Publishable summary

IMPACT-AE
Intelligent Design Methodologies
for Low Pollutant Combustors
for Aero-Engines

Background and overall objectives for the project (Month 1 – 48)

The environmental benefits of low emissions lean burn technology in reducing NOx emissions up to 80% will only be effective when these are deployed to a large range of new aero-engine applications. While integrating and developing low emission combustion design rules, IMPACT-AE delivers novel combustor design methodologies for advanced engine architectures and thermodynamic cycles. It supports European engine manufacturers picking up and keeping pace with the US competitors, who are already able to exploit their new low emission combustion technology to various engine applications with short turn-around times.

Key element of the project is the development and validation of design methods for low emissions combustors to reduce NOx and CO emissions by an optimization of the combustor aero-design process. Preliminary combustor design tools are coupled with advanced parameterisation and automation tools. Improved heat transfer and NOx models increase the accuracy of the numerical prediction. The advanced representation of low emission combustors and the capability to investigate combustor scaling effects aims at an efficient optimisation of future combustors targeting a cut of combustor development time by 50%.

IMPACT-AE is split into four technical work packages:

- WP1 Development of smart design methodologies for clean combustion' as central WP to deliver the new methodology for combustor design,
- WP2 Modelling and design of advanced combustor wall cooling concepts' for combustor liner design definition as key technology area,
- WP3 Technology validation by detailed flame diagnostics' to substantiate fuel injector design rules implemented into the design methodology and
- WP4 Methodology demonstration for efficient low NOx combustors' will validate the combustor design.

The consortium consists of all major aero-engine manufactures in Europe, 7 universities and 3 research establishments with recognised experience in low emission combustion research and 10 SME.

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

Within the first 18 months of the project key building blocks of low emissions combustor design systems have been developed:

- Parametric combustor models have been created and the generation of meshes for subsequent CFD computations has been automated.
- The design process is being automated and linked to preliminary design methods.
- The prediction accuracy of the numerical models has been enhanced through the development and application of improved heat transfer and NOx models.

Based on a more comprehensive and realistic representation of low emission combustors and the possibility to investigate combustor scaling effects a bespoke optimisation of low emission combustors for future aero-engine architectures is possible. A significant reduction of the development time for low emission aero-engine combustors of up to 50% is targeted. Furthermore, progress has been made on the assessment of fast manufacturing technologies for combustor components, such as fuel injectors. To assess new combustion technology architectures, detailed flame diagnostics are being performed. Additionally test rigs have been set up to validate the low emission combustor design methodology.

In the four research fields covered by IMPACT-AE the following achievements are reported in Period I:

Smart Design Methodologies for Clean Combustion

(1) Tools automating repetitive and time consuming tasks: Automation aims at halving the time from the preliminary design tools to the numerical simulations. An integrated tool has been developed. It automates the construction of a combustion chamber through the assembly of basic individual combustion chamber features, the mesh generation, the launching of CFD simulation and the post processing. Another tool automatically optimizes the design of a combustion chamber through an optimization loop which integrates the modification of the geometry of the combustor, the meshing, and the launching of the post processing of the simulations.
(2) Developing rapid prototyping of combustion liners which will reduce time and cost of the product development process: From the definition of numerical sketch up of basic geometries, different pieces have been manufactured. Then the influences of the geometry and of the manufacturing process parameters on the quality of the pieces have been studied.
(3) Developing thermal models to optimize the thermal management: These models predict the efficiency of the effusion cooling technique thanks to numerical simulations and experiments
(4) Developing different models for advanced unsteady computational fluid simulations: NOx model and sub-grid scale combustion models have been developed in order to predict pollutant emissions in low NOx combustors. Their validation is ongoing.

Modelling and Design of Advanced Combustor Wall Cooling Concepts

(1) Simulation approaches have been developed and implemented to improve the prediction of the heat transfer of combustor walls. The modeling approach takes into account the unsteady energy transport in near wall regions, the influence of turbulence on radiation load, the mixing and compressibility effects.
(2) A numerical code has been developed to model effusion cooling combustor walls in details. The parallel efficiency of the code has been assessed.
(3) An experimental approach was implemented concerning the design of a three sector test rig that will allow the rapid turn round of different liners configurations.

Technology Validation by detailed Flame Diagnostics

(1) Development of optical diagnostics for applications in combustion environments: Spectroscopic studies of laser-induced fluorescence of the CO molecule were carried out for various thermodynamic conditions. Experimental results allow defining a measurement strategy for probing CO within a combustor operating at realistic conditions; which will be used in the second period. Technical specifications of a fast emissions sensor for probing CO and CH2O at the outlet of a real combustor were defined. The sensor was designed and manufacturing is engaged.
(2) Design of an innovative fuel injection system: An injection system was designed together with the modifications of a test rig for studying the effects of multi-perforation on pollutant emissions.
(3) Design and manufacturing of a test rig have been carried out, which will be used for investigating entropy waves.

Measurements using the different optical techniques developed in the first period will be performed in the second period on test rigs which have been designed and/or upgraded during the first period.

Design Methodology Demonstration for Efficient Low NOx Combustion

(1) A novel trapped-vortex combustor concept has been tested and optimised based on its emissions and thermo-acoustic performance. The detailed diagnostics applied has enabled gaining a good understanding of the combustion process.
(2) The approach for definition of a novel cooled cooling air system has been defined through design of two separate rigs. One of them will allow investigating the impact of a down-selected cooled cooling air system on a lean combustor aerodynamics. Another will allow assessing the aerodynamics of the ducting design within the constraints imposed by the engine. Both rigs have been designed and manufactured. Eventually, preliminary activities have been undertaken in preparation for a lean burn test campaign aimed to characterise the cruise emissions of a lean burn combustor.

IMPACT-AE partners

The IMPACT-AE consortium is composed of the following partner organisations:

(1) ROLLS-ROYCE DEUTSCHLAND LTD & CO KG (RRD)
(2) SNECMA SA (SNM)
(3) ROLLS-ROYCE PLC (RRUK)
(4) AVIO S.P.A (AVIO)
(5) TURBOMECA SA (TM)
(6) MTU AERO ENGINES GMBH (MTU)
(7) OFFICE NATIONAL D'ETUDES ET DE RECHERCHES AEROSPATIALES (ONERA)
(8) DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV (DLR)
(9) UNIVERSITE DE PAU ET DES PAYS DE L'ADOUR (UPPA)
(10) KARLSRUHER INSTITUT FUER TECHNOLOGIE (KIT-U)
(11) UNIVERSITAET DER BUNDESWEHR MUENCHEN (UBWM)
(12) IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE (IC)
(13) THE CHANCELLOR, MASTERS AND SCHOLARS OF THE UNIVERSITYOF CAMBRIDGE(UCAM)
(14) LOUGHBOROUGH UNIVERSITY (LU)
(15) UNIVERSITA DEGLI STUDI DI FIRENZE (UNIFI)
(16) CAMBRIDGE FLOW SOLUTIONS LTD (CFS)
(17) AVIOPROP SRL (APROP)
(18) INSTITUT NATIONAL DES SCIENCES APPLIQUEES DE ROUEN (INSA-CORIA)
(19) ARTTIC (ART)

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