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

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Overview

WP 5
Project Management
Lead: RRD

WP 1
Smart Design Methodologies for Clean Combustion
Lead: SNM

T 1.1 Advanced KBE tool for low NOx combustor
T 1.2 Intelligent combustor design system
T 1.3 Quick design and rapid validation strategy
T 1.4 Multi-fidelity system for lean burn combustor design
T 1.5 LES models for emission prediction
T 1.6 NOx modeling for helicopter engines
T 1.7 Technology assessment (Lead: SNM)

WP 2
Modelling and Design of Advanced Combustor Wall Cooling Concepts
Lead: AVIO

T 2.1 Improved conjugate heat transfer modelling
T 2.2 Coupled heat transfer modelling for low NOx
T 2.3 Design & experimental validation of cooling schemes
T 2.4 Technology assessment (Lead: AVIO)

WP 3
Technology Validation by Detailed Flame Diagnostics
Lead: ONERA

T 3.1 Detailed measurements for low emission combustor
T 3.2 Pilot/ main and flames/ film cooling interactions
T 3.3 Effect of fuel temp. on spray characteristics
T 3.4 Fast response emissions sensor for lean burn
T 3.5 Technology assessment (Lead: ONERA)

WP 4
Design Methodology Demonstration for Efficient Low NOx Combustion
Lead: RRUUK

T 4.1 Improved fuel staging control laws
T 4.2 Combustion tests to validate new liner cooling
T 4.3 Demonstration of new combustor design concepts
T 4.4 Technology assessment (Lead: RRUUK)

IMPACT-AE
Coordinator: RRD

WP 6
Dissemination, communication & IPR management
Lead: RRD

Budget: 7.5 MEuro / Funding: 4.9 MEuro
Start date: 01/11/2011, Duration: 48 months
The road to ACARE

IMPACT-AE Objectives

IMPACT-AE Benefits

IMPACT-AE Goals

IMPACT-AE Structure

IMPACT-AE Integration

IMPACT-AE Workpackages
Main objective of the IMPACT-AE project is to develop and validate smart design systems for low NOx, highly efficient aero-engine combustors with focus on lean burn combustion.

The key features of the new combustor design systems are:

- a more comprehensive and realistic representation of a modern low emission combustion system
- flexibility of the design methods to scale the combustor to match the targeted engine architecture
- ability to more accurately optimize the combustor for low NOx emissions and high combustion efficiency

The IMPACT-AE project directly supports the reduction of NOx by 80% by 2020 set by ACARE.

Additionally the optimization of the NOx vs. combustion efficiency trade which is currently a technology gap will be addressed.
IMPACT-AE Objectives

- Automation of the combustion aero-design process: Coupling of different levels of combustor preliminary design tools from 1D combustor sizing models up to full 3D-CFD combustor simulations
- Improved parameterisation of the combustion system allowing scaling
- Increased accuracy of simulation tools through improved combustor wall cooling and NOx models
- Design and experimental validation of new combustor cooling schemes suitable for low emission combustion
- Generation of improved low NOx combustor designs based on optimisation techniques and improved knowledge based design rules
- Establishment of rapid-prototype design processes
- Generation of comprehensive design rules for low emission high efficient combustion via detailed non-intrusive and intrusive measurements inside the combustors as well as multi-sector and TRL 5 full-annular combustor tests to validate the design methods
IMPACT-AE Benefits

- 70% reduction versus CAEP/2 standards for NOx, this corresponds to 60% of current CAEP/6 standard
- Up to 50% reduction of combustor development time compared to state-of-the-art combustor aero-design processes
- 25% improvement for CO emissions compared to best lean burn technology currently under development
- Ability to perform combustion optimization at different stages within the combustor development due to automated combustor aero-design processes
- Improvement of the prediction accuracy of the combustion design process
- Development of combustor design methods suitable to scale combustor geometries for future aero-engine architectures
- Applicable for direct driven and geared turbofans and open rotor, driven by kerosene or alternative fuel
- Exploitation: wide and narrowbody aircraft with EIS: >2020
IMPACT-AE activities are split into four work packages:

- **Development of smart design methodologies for clean combustion** as central work package will deliver the advanced tool for combustor design

- **Modelling and design of advanced combustor wall cooling concepts** for combustor liner design definition as key technology area

- **Technology validation by detailed flame diagnostics** will substantiate the fuel injector design rules to be implemented into the design methodology

- **Methodology demonstration for efficient low NOx combustors** will validate the overall combustor module design methodology and make recommendations for industrial application.
### Exploitation from other FP Projects

<table>
<thead>
<tr>
<th>TLC: optimisation methods applied to lean fuel injectors</th>
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<tbody>
<tr>
<td>KIAI: LES spray combustion</td>
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<td>TECC: prelim. design for low NOx comb. Liners</td>
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<td>INTELLECT: prelim. KBE model</td>
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<td>TECC: scaling laws for liner cooling at atmospheric conditions</td>
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<td>TECC/TLC: film cooling efficiency improvement</td>
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<td>INTELLECT: effusion cooling model &amp; design method for advanced cooling</td>
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<td>TLC: Enhancement of non-intrusive measurement techniques for lean burn</td>
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<tr>
<td>TECC/TLC/INTELLECT/KIAI/TIMECOP: detailed validation data for low emission combustors</td>
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<td>TLC/TECC/INTELLECT: Low NOx capability for various injection systems (TRL3-4)</td>
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<tr>
<td>INTELLECT: design rules for impr. LBO performance of lean burn combustion</td>
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<td>TECC: Basic design rules for compact comb. designs</td>
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### Expected key benefits from IMPACT-AE

<table>
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<th>WP1</th>
<th>WP2</th>
<th>WP3</th>
<th>WP4</th>
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<tr>
<td>50% faster, Improved prediction accuracy, Better representation, Multi-obj. optimisation, Scaleability</td>
<td>Validated heat transfer models, Optimised wall cooling design, Improved life cycle, Validation tests for advanced effusion cooling</td>
<td>Innovative emission sensors, Design rules for spray and vaporization, Design rules for low NOx high efficient combustors</td>
<td>Improved fuel staging strategy, Maturation of low NOx combustor concepts, Validation of WP1 design methods, Demo of new wall cooling</td>
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**Development and Validation of Smart Design Methodologies for Ultra Low NOx High Efficient Combustors Applicable to Future Engine Architectures**
IMPACT-AE Integration

Methods Development

**WP1**
Smart Design Methodology for Clean Combustion
- Technology Assessment

- Requirements for combustor wall cooling design features
- Improved heat transfer models & preliminary validation

**WP2**
- Technology Assessment

- Design and manufacture of new combustor cooling designs
- Validation data for thermal models

Experimental Validation

**WP3**
Technology Validation by Detailed Flame Diagnostics
- Technology Assessment

- Definition of low NOx high efficient injectors
- Multi-sector/ full annular validation data (exhaust emissions, efficiency, temperature traverse)

- Comprehensive test data to validate smart design methodologies

**WP4**
Methodology Demo. for Efficient low NOx Comb.
- Technology Assessment

- Definition of low NOx high efficient combustors
- Validation data for thermal models

Dissemination & exploitation of WP5 results

**WP5 & WP6**
Programme Management
Dissemination & Exploitation

- Dissemination & exploitation of WP2 results
- Dissemination & exploitation of WP4 results

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WP1 Objectives & Outcome

- Work done in WP1 is a step toward improved “numerical” combustor design industrial methodologies
- The development of intelligent numerical models for combustion systems from preliminary design to full 3D optimisation
- Two main areas: KBE tools/environments and Advanced CFD techniques
- Industrial KBE tools/environments for combustor design: integrating the recent advances in Low NOx technologies, integrating the most recent meshing techniques, securing the design process, allowing its use for optimisation purposes, applying optimisation techniques, including capabilities for rapid prototyping
  ➔ This result will contribute to halve the overall time for conception
- LES techniques with enhanced NOx prediction capabilities
  ➔ This result will contribute to prepare the next step in CFD modelling, the replacement of RANS by LES. The transition from one technique to the other is a clear objective for industry in general and for aeronautics in particular
The new KBE tools should integrate

- The advances achieved in meshing software (automatisation process, structured and unstructured meshes, robust, high quality)
- Prepare to managed the CFD calculations (preventing errors and reduced required time to design a combustor)
- In view of optimisation (geometric variants, operating conditions), the KBE tools will enable the industrials to rapidly generate CFD meshes and to set up the parameters defining the different calculations
- Rapid prototyping of combustion liners which will reduce time and cost of the product development process
Advanced CFD techniques

- The ability of LES techniques to predict NOx emissions will be analysed.
- This work is a step toward the replacement of RANS by LES in the industry (combustion instabilities, combustion stability Domain, high altitude relight prediction as well as the classical area covered by the RANS techniques)
To increase the accuracy and reliability of models that predict the behaviour of wall cooling devices in Low NOx combustor applications

Development of accurate numerical tools for CFD code in order to predict wall cooling combustor configuration, keeping into consideration;

- Modelling of the effusion cooling
- Heat load under the effect of pressure oscillation

Development of numerical modelling to be used into a robust design methodology (QDRV) in order to predict:

- Heat load, due to the mixing process obtained in ULN combustor
- Influence of the turbulence on the heat transfer by radiation
Within task 2.1 and 2.2, the use of a particular model of wall heat transfer will be tested with LES and URANS methods in the complex conditions of an aero-engine combustor. In one study using DNS methods, the CFD tools are focused on simulating jets in cross flow under the effect pressure fluctuation.

A second approach will take into consideration the effect of air mixing and combustion radiation in the design of classical configurations and exploring innovative configuration of cooling system obtained by rapid prototyping technology.

A validation phase is planned to experimentally compare the cooling effect in a Low NOx combustor and to assess the design parameters of the proposed new methodology.
WP3 Objectives & Outcome

- Improve optical techniques for combustion measurements
- Apply these optical techniques at realistic operating conditions of aeronautical gas turbines
- Generate a robust experimental database to be used to validate CFD tools
- Derive design rules for fuel injectors and low emission combustors
- Experimental database helpful to improve understanding of parameters influencing combustor efficiency
  - Fuel distribution, flowfield
  - CO formation in multipoint injector
  - Effect of fuel temperature on fuel vaporization and air/fuel mixing
- Development and application of a fast response sensor for lean burn combustor
WP3 Description of Work

- Development & utilisation of new optical techniques
  - Measurements of CO in a multipoint injector
  - Design, manufacture and validate a fast response sensor for lean burn combustors
- Utilisation of optical techniques
  - Determination of flame structure, fuel distribution, flow velocity
  - Effect of fuel temperature on fuel vaporization and air/fuel mixing
WP4 Objectives & Outcome

- Demonstration of the performance improvements achievable with low NOx combustor designs
- Designs to be tested mainly developed within IMPACT-AE or previous EU programmes
- Accounting for trade off in terms of emissions, operability and durability
- Up to TRL 4-5
- Validation rules implemented into KBE systems will be validated and reviewed
WP4 Description of Work

- Improved fuel staging control laws by multi-sector testing of staged injector at mid-power conditions
- Control laws of low NOx combustor with LPP injectors by full annular testing of LPP injectors (LBO, emissions, traverse)
- Low pressure (Idle) sector combustion validation by multi-sector rig testing (stability limits)
- High temperature (MTO) combustion validation by multi-sector testing (traverse, metal temperature)
- Operability study of an innovative low NOx combustor by Low pressure full annular testing of TVC-like combustor (emissions, PIV, OH PLIF)
- Full annular high pressure emissions testing of a low emission combustor with lean burn injector to validate KBE methods
- Experiments on cooled cooling air duct systems by full annular isothermal testing of novel CCA configurations (pressure and velocity)
Thank you for your attention!

Visit the IMPACT-AE website:

http://www.impact-ae.eu/