Innovative Particle Trap System for Future Diesel Combustion Concepts

**Funding:** European (6th RTD Framework Programme)  
**Duration:** Jan 2007 - Dec 2009  
**Status:** Complete with results  
**Total project cost:** €1,795,556  
**EU contribution:** €988,257

**Call for proposal:** FP6-2005-TRANSPORT-4  
**CORDIS RCN:** 81511

**Background & policy context:**

Advanced diesel combustion processes for passenger car diesel engines, such as homogeneous charge compression ignition (HCCI), or partial homogeneous combustion, are developed for their potential to achieve near zero particulate and NOx emissions. One of the drawbacks of this technology is the difficult combustion control at medium and high loads and consequently a limited operating range where NOx and particulate emissions are at a very low level. For this purpose, novel exhaust cleaning devices are necessary to process the different loading areas with its specific emissions well below the Euro 5 emission level.

To ensure soot regeneration for the needed particulate trap at the low NO/NO2 and exhaust temperature levels resulting from efficient combustion, the project IPSY focused on a novel design of porous media and novel catalytic nanostructured materials in a compact unit, with tuneable soot particle collection that will accommodate multifunctional catalytic coatings.

**Objectives:**

The objectives of the project IPSY is to achieve in diesel combustion processes a global filtration efficiency, even on ultrafine particulates above 95% with a nearly constant fuel consumption at slightly increased back pressure and advanced regeneration strategies in the range of 580 °C in an acceptable time, therefore the focus lies on particulate and not only on CO and HC.

These means in detail:

- PM< 0.001 g/km NEDC (New European Driving Cycle);  
- NOx : 0.06 g/km NEDC;  
- applicability to passenger cars as well as adaptability to truck engines;  
- fuel consumption equivalent to the Euro 4 calibration including regeneration;  
- ability to run in all driving conditions.

One of the main pillars of the project is to design, develop, construct and test an innovative multifunctional filter reactor (MFR) for treating the particulate and gaseous pollutants from the exhaust streams of a HCCI, partial homogeneity and conventional combustion process of a diesel engine in the complete engine map.

The other main pillar is the development of advanced regeneration strategies to minimise active regeneration cases to avoid the risk of increasing the fuel consumption.

**Methodology:**
There were different key activities in the project:

Key activity 1
Development and construction of the multifunctional reactor divided in two tasks.

Task 1 - MFR development:
- catalyst synthesis and deposition on small-scale filters;
- construction of the MFR subunits;
- MFR prototype assembly and initial assessment;
- production of two fully-instrumented MFR prototypes for functional tests.

Task 2 - MFR evaluation with engine tests for loading and regeneration:
- testing the MFR on a conventional multi-cylinder engine on steady-state and transient operation (NEDC);
- testing the system with the HCCI engine under steady-state conditions;
- testing the system with applied control algorithms.

Key activity 2
Physical modelling of particulate morphology on particulate trapping and the setting-up of a 3D CFD (computerised fluid dynamics) simulation model including all necessary boundary conditions. Due to the fact that the thermomechanical interactions in the system must be taken into account, the model must include a gas phase as well as a solid wall structure of the DPF (diesel particulate filter) (conjugate heat transfer).

Following this activity, an algorithms for the power-train control unit using the 3D simulation real-time model of the complete exhaust system and different filter characteristics are developed. This takes into account thermal behaviour, coating, loading and soot oxidation for the new filter, as well as the engine out emissions and exhaust temperature of the HCCI diesel engine to integrate the real behaviour of the trap system in the entire vehicle environment.

Parent Programmes:
FP6-SUSTDEV-3 - Global Change and Ecosystems

Institute type: Public institution
Institute name: European Commission
Funding type: Public (EU)

Lead Organisation:

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Key Results:

The advanced features of the IPSY filter system were based on a higher soot-to-catalyst contact, which required deep-bed filtration in the catalyst layer, an increased soot reactivity resulting from a HCCI combustion system as well as an advanced operation strategy. A 3D-computational fluids dynamics (CFD) model of the IPSY filter has been setup with main focus on the prediction of deep-bed filtration mechanisms and influence of soot morphology on the reactivity. The model displays each filter channel by several computational cells to achieve very high accuracy. It contains a fluid and a solid part, which are connected by enthalpy source terms. Sub-routines for the filtration behaviour are derived from a 1D detailed physical pore model, which is directly parameterised by the physical properties of soot and filter substrate. The CFD model covered all physical effects, which are relevant for soot load and combustion. The calculation of the system performance and the development of a new operation strategy require a model that also covers the interaction between exhaust system and engine. Therefore, a 1D model was setup and extended. A new calculation methodology, which is based on the independent time discretisation of the ducts, has been developed at the beginning of this task. Subsequently, models for both HCCI and conventional diesel engine have been defined, and the optimum configuration of the exhaust line stressing emphasis on the influence of DPF position on engine performance has been determined.

Based on the first year results from the analysis of the internal heat recovery concepts and the developments on the multifunctional catalyst synthesis and application, a full-scale MFR prototype was built. During the first six months of the second year this prototype was evaluated against the project emission targets. The MFR internal heat recovery capability was verified via tests on a flow test bench and on the real engine exhaust under fast regeneration conditions.

During the second semester of the second year two MFR prototypes were manufactured. The prototypes were equipped with pressure and temperatures sensors for monitoring the filter operation during the testing on the real engine exhaust. A dedicated system was built for the data acquisition and storage during the MFR operation. The prototypes have been tested in the conventional diesel exhaust of the APTL and their performance has been evaluated.

In the third period the MFR was tested in both, conventional as well as HCCI opera

Technical Implications

The filtration efficiency of the filter was excellent and was retained after aging. The catalytic activity of the filter was significantly higher than the SA filters and was also retained after aging. The filter backpressure was comparable (or even better) than the SA filters. The effect of aging on the filter backpressure is either insignificant (UPVLC) or it causes a slight increase (APTL) mainly due to the accumulated ash particles originating from the engine oil consumption.

Readiness

The IPSY MFR showed huge potential to reduce the fuel penalty of today's DPF regeneration operation. Cycle simulations have shown the possibility of fuel penalty reduction by approximately 25% under real driving conditions. During the NEDC with a standard regeneration strategy over 45% of the fuel penalty could be saved. The IPSY coated filter is also able to regenerate during low load phases without HC conversion in the DOC. This is a big advantage in terms of avoiding oil dilution, as late post injection is no longer needed in many engine operating points. The new IPSY filter combined with an optimized operation strategy that are realised by adequate ECU functions form a complete and new diesel particulate filter concept. This will contribute to the future compliance with the particulate matter and number emission legislation and at the same time address today's open development challenges.

Documents:

IPSY_Final_Publishable_Executive_Summary.doc (Other project deliverable)

STRIA Roadmaps: Vehicle design and manufacturing, Low-emission alternative energy for transport
Transport mode: Road transport
Transport sectors: Passenger transport, Freight transport
Transport policies: Environmental/Emissions aspects
Geo-spatial type: Network corridors