Innovative Combustor for New Core Concepts

Lean combustion technology operates with an excess of air to significantly lower flame temperatures and consequently significantly reduce NO_X formation. Up to 70% of the total combustor air flow has to be premixed with the fuel before entering the reaction zone within the combustor module. Therefore, cooling flow has to be reduced accordingly to provide sufficient air for mixing.

Lean combustion comprises the lean direct injection of fuel, premixing with air and at least a partial pre-vaporisation of the fuel before initiating the combustion process. The optimisation of homogeneous fuel-air mixtures is the key to achieving lower flame temperatures and hence lower thermal NO_X formation. However, this homogenisation has a strongly adverse effect on combustion lean stability, drastically narrowing the operating and stability range. To overcome these stability drawbacks while maintaining good NO_X performance, fuel staging is required.

This can be made in a staged combustor architecture by multiple rows of injectors. A staged combustor is geometrically separated into at least two zones, so that each zone can be optimised for a particular requirement (regarding different parts of the flight envelope) and could thus offer good stability at low power. Alternatively, fuel staging can be achieved using internally staged injectors in SACs, thus creating a pilot and a main combustion zone downstream of a common fuel injector as figure 1 illustrates.

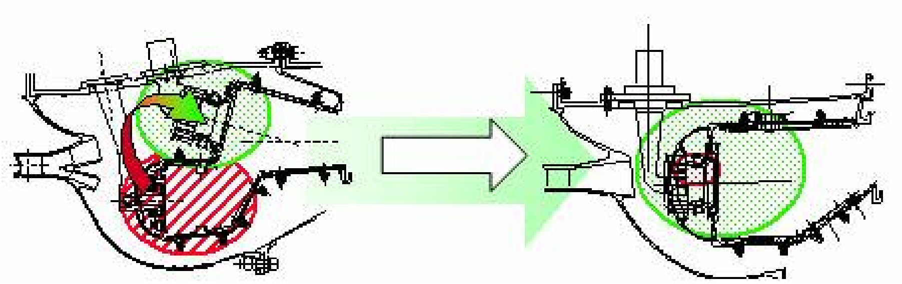

Fig. 1: Development towards a lean burn technology single annular combustor (SAC)

The SAC combustor geometries are much simpler and thus more advantageous with respect to unit cost, weight and cooling; cheaper to make, lighter and easier to cool. But even for the SAC, cost and weight reasons will demand that the total number of low emission injectors per annulus has to be minimised. As they are more complex compared to conventional air-blast fuel spray nozzles a significant proportion of the combustor cost will now be related to these advanced internally staged injectors.
In contrast to previous projects with several approaches to lean combustor architectures, NEWAC is concentrating on a SAC architecture with lean injectors.

The Ultra Low NO_X (ULN) combustor core technology is highly depending on the performance of the learn burn injection system. Air quantity needed for emission abatement is expected to be 60 to 70% of the combustion air. With this level of injector air-to fuel ratio, operability including ignition, altitude re-light, pull-away, weak extinction stability and thermo-acoustics will be a serious problem which needs to be carefully taken into consideration during ULN combustor development.

On this basis, the ULN lean premixed technology will require fuel-staging system to control the performance of the combustor through the entire engine cycle.
For the fuel injection system the current status of these techniques does not allow a down-select of injector technology. It would be too risky to make a selection before major performance parameters have been assessed and validated especially the characterisation of operability and thermo-acoustic behaviour. Thus, three different lean fuel injection systems will be investigated, based on previous EC and national funded projects:

- Lean Pre-Mixed Pre-vaporized (LPP)
- Partial Evaporation & Rapid Mixing (PERM)
- Lean Direct Injection (LDI)

They will be developed for applications in a wide range of engine OPR as shown by Figure 2.

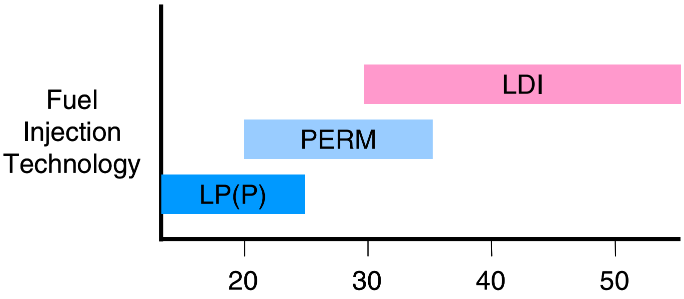

Fig. 2: Application of different fuel injector technologies depending on OPR

LP(P) injection - this concept is much more suited to low OPR engine cycles due to the fact that auto-ignition and flash-back constraints are much lower for this range of engines. It is based on the action of several air flows, one devoted to the fuel atomisation and the second dedicated to the mixing and fuel evaporation. The combination of the two acts also as a promoter for the flame stabilisation in the combustion chamber.

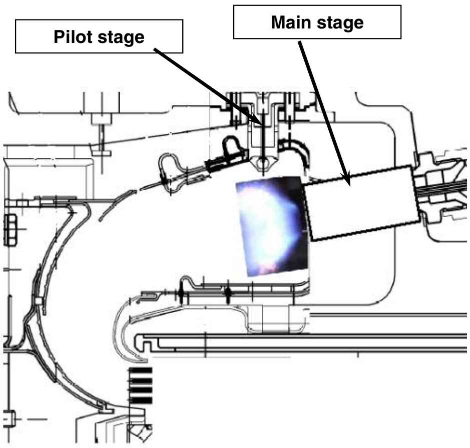

Fig. 3: LP(P) Combustor

PERM - the concept is based on swirler technology development and is addressed to achieve partial evaporation inside the inner duct and a rapid mixing within the combustor, optimising the location of the flame and the stability of the Lean System.

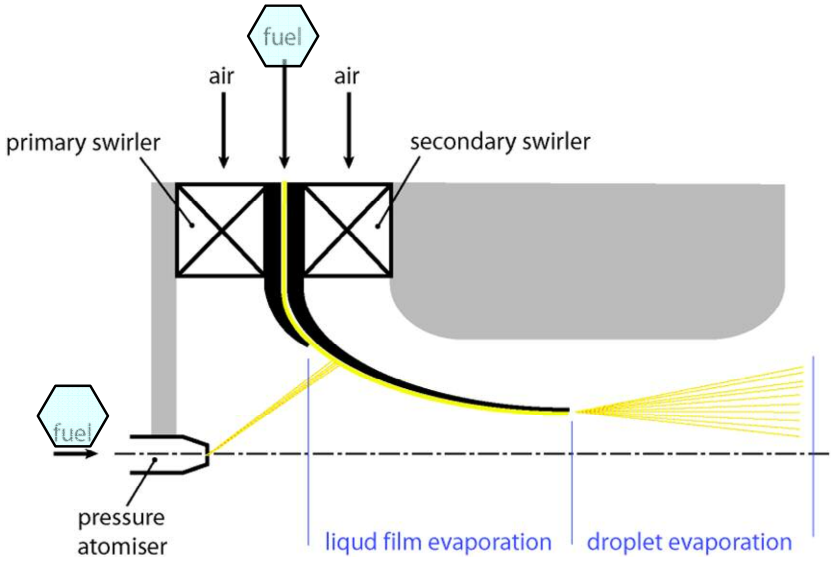

Fig. 4: PERM Combustor

LDI – This concept has a controlled premixing: concentric internally staged fuel injection with optimised pilot and main stage flame structure to control their interaction for low NOx and weak extinction stability.

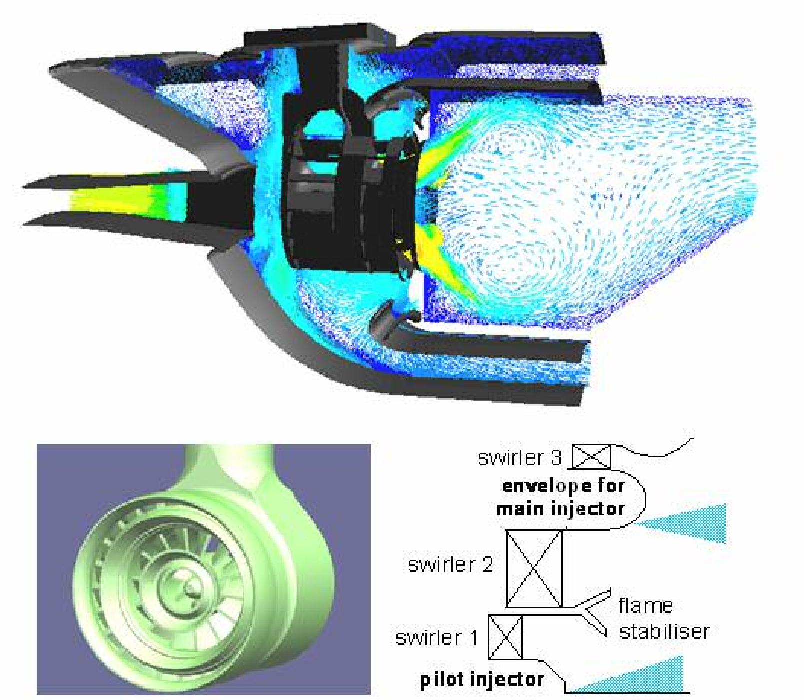

Fig. 5: LDI Combustor

Advanced measurement techniques will give insight into the fuel preparation, fuel placement, the initial combustion flame front of both pilot and main combustion zones. They support the identification of problem areas and help to define necessary modifications. The sequence of CFD, sector testing and detailed measurement campaigns will be an iteration process feeding in results into a modified fuel injector layout. Full annular testing will finally validate the new derived fuel injector technologies simulating real engine conditions within a full combustor scale.