ESTIMATION OF THE LOCAL AIR/FUEL RATIO BY A CATALYTIC HOT WIRE FOR A LEAN MIXTURE OF PROPANE AND AIR

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Introduction:

Cycle-to-cycle variations in the gasoline engine combustion process interest to the engine designer for many reasons including performance, emissions, and the researcher for the understanding of the physical phenomena (e.g.[1,2]).

The cycle-to-cycle fluctuation in combustion is generally due to three primary causes

-the variation of the velocity field (swirl and tumble) in the cylinder during combustion [cycle by cycle]

-the variation in the amounts of fuel/air and recycled exhaust gas supplied to the cylinder each cycle.

-the variations in the mixture composition within the cylinder in each cycle (especially near the spark plug) due to variations in mixture preparation including completeness fuel vaporization and mixing between air, fuel residual gases and recycled gases.

The principal interest of this work was to develop a device to estimate the variation in the mixture composition near the spark plug, mainly at the critical time of ignition and early flame development.

Many techniques have been yet used, there are the non intrusive methods: Schileren photography, Raman techniques (e.g. [3]), Laser Induced Fluorescence (e. g. [4]).

There are many advantages to use these techniques but they require a research laboratory environment For example the LIF (e. g. [4]) was applied with an optical accesses engine. The laser used for the LIF (tripled YAG laser) requires an optical bench around of experimental engine The visualization of concentration field near of spark plug is obtained by camera who collects the fluorescence image through a quartz piston

And the gasoline must be seeded by for example biacetyl to get a sufficient fluorescence excitation.

There is evenly the intrusive methods, they require a direct sample and use for gas analysis the Infra Red (IR) or the Flame Ionisation Detector (e. g. [5]) for example.

All these techniques have a minimum time resolution for the analysis (~ 2 ms for the FID), this is an important parameter for the measurement.

The aim of our experiment is to use the hot wire technology for propane concentration measurements in the mixture in a Spark Ignition engine. This technique is applied with the air fuel ratios range between 0.5 and 1.1.

The Probe Device

The main advantage is:
With the catalytic hot wire probe, all gasoline engines can be used. The measure device

inserts near the spark plug.
The hot wire is maintained at a high temperature (T>800 K) with a Constant Temperature Anemometer (e. g. [6]). So when a chemical reaction occurs on the catalytic wire (Pt/Ir) the electric current who heats the wire changes (e. g. [7]).
These variations of the electric current can be linked to the variation of concentration (propane in air) with few precautions. The special sample at constant pressure is used to eliminate the influence of pressure variation in the measurement, the hot wire is placed at atmospheric pressure. The calibration probe with air is necessary to get a reference signal.
A small tube (0.3 mm ID and 40 mm large, Figure 1), placed between the spark plug and the electric valve, was to ensure a small sample flow, so that the measurement did not significantly affect the ignition process.
The probe is connected to the electric valve, this valve takes from few crankshaft degree (10 at 50) before the ignition then the sample is analysed by the probe.
In the test device, we use one hot wire because the pressure curve is very repetitive Then we
assume that the curve of speed cyclic evolution near the hot wire is constant.
Two hot wires could be used in a "real" engine with combustion: one of wires should be sensible at the mixture flow (velocity variation) and the second one should be sensible at the
mixture flow and at the variation of concentration by the catalysis process.
The difference between these both informations gives the sample local concentration.

	Catalytic hot wire	Hot wire
Materials	Platinum / Iridium (80/20)	Tungsten
Diameter (µm)	10	10
Long (mm)	1	1
Range average running temperature (°C)	400-800	100-300

Table 1

In order to validate these measurements, this technique is applied for one experimental set up before the use in an engine.
The device is a miniature engine driven by a speed regulated electric motor *(Figure* 1)
This engine was a single-cylinder, the engine specifications used are given below.

	General
Manufacturer	O.S.(Japan)
Model	FS 120
Number of Cylinder	1
Capacity (cc)	19 96
Bore (mm)	30.4
Stroke (mm)	27.5
Rate Speed (rpm)	2000

Compression ratio	8 4:1
Connecting rode long/crankshaft diameter (1/r)	3 12

	Intake	Exhaust
Valve opens	~ 37° BTDC	~ 65° BBDC
Valve closes	~ 103° ABDC	~ 66° ATDC

Table 2

A Kistler piezoelectric pressure sensor is located in the cylinder of the engine. The frequency generator allows the regulation of engine speed by the electric motor. During these experiments, there is no combustion in the engine.

Results and Discussion

Figure 2 shows three consecutive cycles, the curves 1,2 and 3 are obtained for different mixtures : the sampled gas of a known concentration (realised in a tank) is analysed by the catalytic hot wire and his response is very different versus air/fuel ratio.
More the C_3H_8 is present in the mixture more the catalytic reaction will be exothermic then the electric power which allows to maintain constant the hot wire temperature will decrease (e. g. [8,9]).

This method will be used to know the engine cyclic evolution of C_3H_8 concentration near the spark plug.

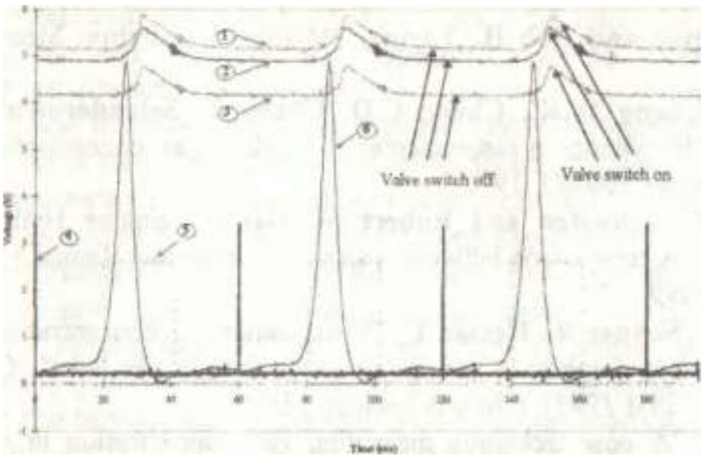

Figure 2:

1: equivalence ratio = 0; 2: equivalence ratio = 0,5
3: equivalence ratio = 1; 4,5: drive signals; 6: pressure curve

The optical rotary encoder pip (Cf Figure 2, curve 4) triggers off the sample with an electrically - operated valve (Cf Figure 2, curve 5 the command signal of electrically valve). This triggering off can be adjustable.

We can noted that the curves 1,2 and 3 are not at the same level from 40 ms to 80 ms (when the electric valve is switch off). This fact can be explained like that: near the hot wire a mixture of propane air is kept so this reactant mixture reacts with the catalytic hot

wire. So the hot wire signal is not equal to the one obtained with the air.
The study in the test device has allowed to check the validity of this type of measurements and led to the definition of a new probe.
This probe was also improved on a Renault monocylindre J4S engine, without combustion. The mechanical resistance has been checked as well in combustion situations.
These experimental sets up allow to reach a 0.1 air/fuel ratio precision, in the case of a propane / air mixture.

Conclusions

A minimally intrusive and easy method for evaluating, in real time, the preparation of a cylinder mixture in a spark ignition engine at the most critical time (without combustion) and location, has been demonstrated. This technique allows the measurement a little variation of equivalence ratio at 0.1 ratio precision.

Future work

Shortly the catalytic hot wire was applied with the spark ignition engine with combustion. This method will be compare with an another one : the visualization by Laser Induced Fluorescence of the unbumed mixture seeded with biacetyl (IFP, *Baritaud, 1994).*
We must also find out the relationship between the local equivalence ratio and the mixture inflammability. This work gave more information about the critical time of ignition.

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