HCCI Engine ignition time detection

Advancement report.

Objectives and definitions.

The purpose of this paper is to show the methods we have found in order to detect the different interesting point required to characterize the combustion inside the engine. For this we received 5 series of curves, from 5 different series of measurements. The in-cylinder pressure, the net heat release, the heat flux and the in-cylinder temperature can be observed thanks to sensors.

The difference with previous research on this subject is that there exists a heat flux sensor inside the engine. We can use the data of the sensor to try new kinds of detection methods. We have tried many detection methods, most of them were not useful or had just given us erroneous results. This paper explains which methods were chosen, shows the results and perspectives.

Summary

I/ Methods of detection.

In order to get the best performances from the engine, we will detect the CA50. This variable characterize the best the combustion. The detection of CA50 will allow us later to realize a control of this value to improve engine's performances. To do this we work under Matlab.

1) Detection by using an approximate integral.

This is the conventional "reference" method used to detect the CA50, CA10 or others.

It consists of performing a cumulative sum of the HRR, as an approximation of an integral, the resulting curve (fig. 1) can be used to determine the searched points. Once the maximum and minimum value have been found and the value of the interval between them has been computed, the CA50 is located at 50% of this interval and the CA10 at 10%.

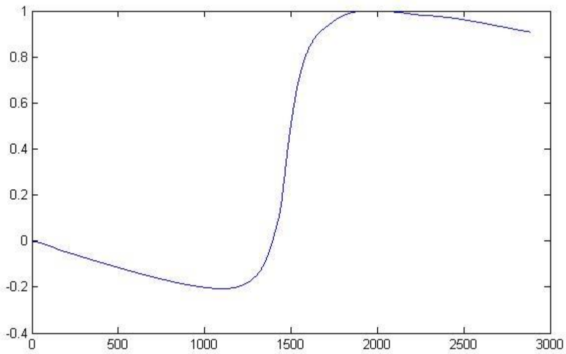

Fig 1. Cumulative sum of the heat flux (normalized) vs CA

axes libélle

2) Other methods to detect CA50.

Our research has led us to explore other detection methods for the CA50 point. The following are extracted from the literature and provide us different result witch would be compared in the second part of this report.

CA50 based on the maximum pressure: The CA50 point can be determined when the pressure in the cylinder reaches his maximum value. This method is based on the assumptions that the combustion behaved in a good way. [1]

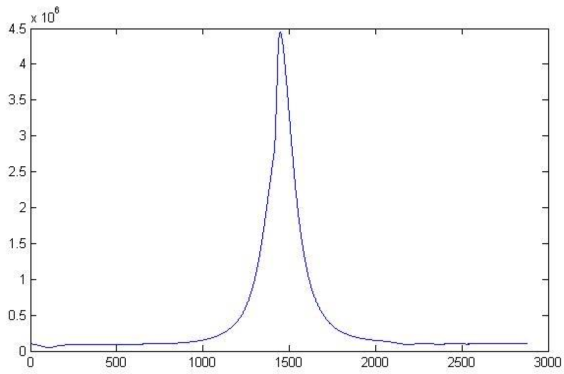

Fig 2. Pressure (Pa) vs CA

CA50 based on net heat release: The CA50 point can be determined when the net energy per crank angle reaches his maximum value. [1]

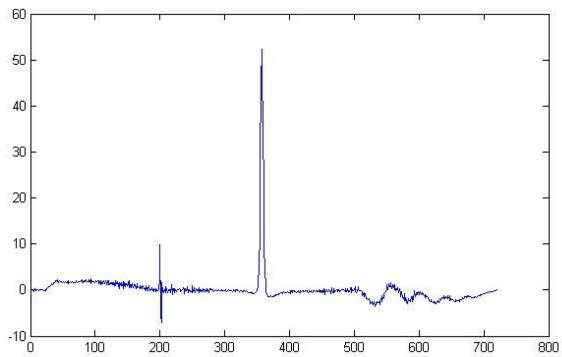

Fig 3. dQ/dϑ vs CA

We have also tried to find other metrics and scale like logarithmic scale, second derivation or other cumulative sum but none of them have given us exploitable results.

3) <u>Detection of CA10.</u>

The CA10 is used in order to have a point near the beginning of the combustion, while robust to noise and misfire. It can be detected, like the CA50, by using the cumulative sum method. The method is exactly the same except that one has to take 10% of the interval between the minimum and the maximum value.

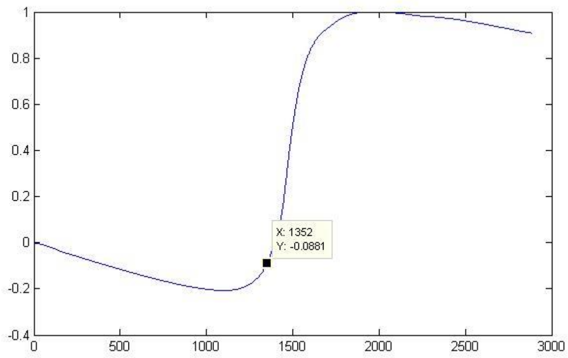

Fig 4. CA10

The CA10 location, just after the beginning of the combustion, could provide a good information about the combustion timing, before the CA50, and is used in a lot of publications in order to create a control model. Its potential use will be discussed further.

4) <u>Threshold method.</u>

The last method we used was to create a threshold to detect the start of combustion (or ignition point) as it can't be clearly seen. This method had been applied on the dQ/dθ (net heat release) curve (fig.5)

The first step of the work is to use a median filter to reduce the noise, as indeed this curve is very noisy due to differentiation.

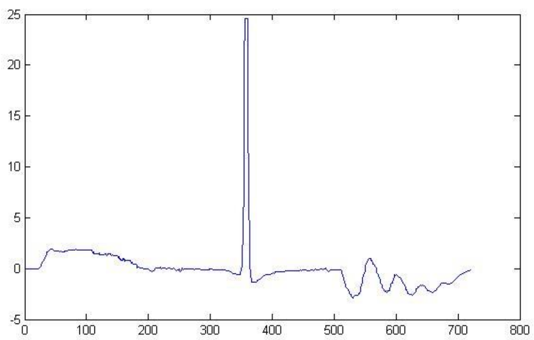

Fig 5. Median filter on dQ/dϑ

Once this is done, we calculate the standard deviation of the curve and create the threshold by multiplying it by 3. [10] This allows us to estimate the moment when the phenomenon appears, and so to find a point very close from the CA1.

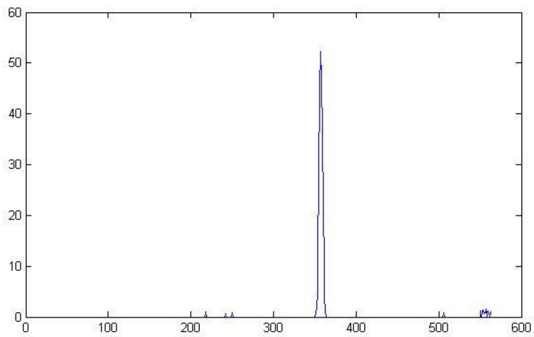

Fig 6. Threshold results.

II/ Results.

1) CA50 measurements and estimates.

We have three different methods to estimate the CA50, we applied those methods to our experimental curves to obtain eventually the following results:

	Curve 1	Curve 2	Curve 3	Curve 4	Curve 5
Pressure method	1.75	3.5	5	7.5	9.75
dQ/dθ method	-3	-1	0	3	6
Cumulative sum method	9,75°	10°	9,25°	14,75°	20,5°

Table 1. CA50 real and estimated values

The results obtained by the maximum pressure method and maximum of dQ/dθ method are close to each other and lie between 0° and 10°. In the literature we have found that the CA50 point should be located between those two values.

The results obtained by using the cumulative sum method are way different, the CA50 values are higher from almost 10°. We assume this gap is due to the approximation in the measurements and calculus. There is a seminal difference, though, between max detection methods and cumulative sum methods. In the max-based methods, one looks for an inflexion point, which is assumed to be located at 50 % of the combustion; while this is true is not really shown by this study.

2) <u>CA10 results.</u>

	Curve 1	Curve 2	Curve 3	Curve 4	Curve 5
Cumulative Sum method	-22°	-24°	-28°	-18°	-15°

Table 2. CA10 measures

This is the best method we know to detect the CA10, it correlate with the CA50 detection methods.

3) <u>CA1 results.</u>

The following results are, once again, an approximation of the CA1.

	Curve 1	Curve 2	Curve 3	Curve 4	Curve 5
Pressure	-10	-8	-6.25	-3	0
dQ/dθ	-9	-11.25	-5	-0.75	-0.75
Threshold	-19	-17	-16	-13	-11

Table 3.

In this case, we assume that the good result is given by the threshold method, as the two previous methods weren't very documented or square. Moreover those results are in accordance with the CA50 results: when the CA1 happens later, then the CA50 follows.

The threshold method gives an estimate that is not too far from the reality.

III/ Perspective of control.

In our system, there are the following variables.

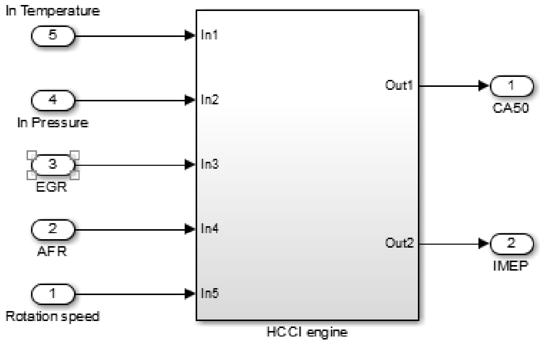

Fig. 7 Inputs and Outputs of the system

Input variables:

There are different input variables to control the CA50. This variables are:

- the intake temperature
- the intake pressure
- the EGR
- the rotation speed
- the AFR

It's also possible to control the CA50 by using the variable valve actuation [11] [12].

Measured values:

With the sensors present on the engine, we can measure:

- the in-cylinder pressure
- the in-cylinder temperature
- the net heat release rate
- the heat flux.

Output variables:

The controller's objective is to keep the system's combustion phasing (CA_{50}) at a desired set point to ensure stability and optimal efficiency. It is also possible to control the IMEP (Indicative Mean Effective Pressure).

To do this, there are different control methods.

Cycle to cycle control: this method consists of controlling the CA_{50} by using the data outcome from precedents cycles [13].

For the cycle-to-cycle control, we can use a nonlinear control model. This model use thermo-dynamical equations to represent the system [14].

For the cycle-to-cycle control, it's also possible to use an Iterative Feedback Tunning. This method consists of tuning an initial controller by using initial data then to use the data from the previous cycles to control the system. [15]

Intra cycle control: this method consists of measuring pressure deviations and correct them within the same cycle [16].

Question: we don't have access to this publication. Do you have access to the SAE publications?

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