

Key Parameters for Startability Improvement Applied to Ethanol Engines

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ABSTRACT

It is well known that high ethanol content fuels have to face poor quality regarding startability in cold conditions on a spark ignited engine.

This paper will show test results when using E0, E85 and E100 fuels led on a single cylinder engine equipped with an active valve train research system. In order to improve engine behavior in severe thermal conditions, influence of several parameters was investigated. Injection strategies (timing, split injection, flow rate), valve train laws (delayed intake opening, valve lift...), ignition parameters (timing, multi-spark, strong energy coil...) as well as intake pressure were analyzed thanks to cylinder pressure analysis and specific test procedure. CFD investigations (influence of fuel, wall wetting) helped us to confirm some hypothesis on physical phenomenon. Those simulations were correlated with spray and wall film visualizations in the inlet port on an optical engine.

To conclude, it has been clearly shown that valve lift and valve timing optimization are the most efficient strategies as well as injection timing and low intake pressure to minimize start duration. Fruitful CFD results were also found on wall wetting process and underline some guidelines to optimize settings. This work provides a useful help to get efficient tuning on flex fuel engines.

INTRODUCTION

EXPERIMENTAL PROCEDURE

ENGINE FEATURES

This study was led using a single cylinder engine, Table 1 shows the main specifications of this engine.

Table 1 : Engine Specifications.

Number of cylinders	1
Bore X Stroke	76 X 80.5
Compression Ratio	10.75
Displacement	365 cc
Fuel Injection	PFI
Number of valves	4
Intake Valve Open	0deg. BTDC
Intake Valve Close	20deg. ABTC
Exhaust Valve open	20deg. BBDC
Exhaust Valve Close	-7deg. ATDC

This engine was also equipped with an active valvetrain research system which allows, on the exhaust and intake valves, for a continuous variability of the valve lift, lift duration, and phasing.

GASOLINE

Table 2 shows the properties of the test fuels. The first to be tested is 95 RON gasoline (EN228), the second one is a blend of 85% Ethanol and 15% RON 95 called E85, and finally the third one is 100% ethanol called E100. Ethanol has higher latent heat of evaporation than gasoline and boils at 78.5°C; this is why it has an influence on cold startability [1-4], [6].

Table 2 Gasoline Fuel properties

	E0	E85	E100
RON	94.7	>100	>100
MON	85	>90	>100
Density (kg/m ³)	745	785.8	806
Low Heating Value (kcal/kg)	10279	6987	6020
T10 (°C)	59	75	78
T30 (°C)	81	77	78
T50 (°C)	107	78	78
T70 (°C)	122	78	78
T90 (°C)	153	79	78
EP (°C)	185	166	78
Aromatics (%)	33.9		
Ethanol		84.26	91.2
Water content (%vol)		0.2	6

TEST PROCEDURE

The engine speed is 500rpm (as close as possible to engine speed under starter conditions), fluids temperature are regulated at 15°C (intake air, cooling fluid and oil). Intake manifold pressure is 80 kPa. The following procedure is repeated 6 times for each engine setting and the result is the average value of the 6 tests.

Progress of a test

Time second	
0	Start of the test, motoring the engine at 500 rpm. Intake air, coolant and oil temperature = 15°C. Spark ignition on.
	Thermal stabilization
540	Start data recording of slow tracking channels.
550	Start data recording of fast tracking channels.
560	Start of fuel injection.
	Transient IMEP evolution.
620	End of fuel injection
660	End of data recording, immediate start of a new test (6 times).

Figure 1 shows the IMEP evolution for different injection durations. For each case, the results of the six tests are plotted, so that we can see a good reproducibility of the results, except for the very short injection duration where combustion becomes very difficult to occur. Real trends can be seen without any curve overlapping.

A threshold value of 200 kPa IMEP was chosen to compare the efficiency of engine settings. All along this paper, number of cycle is for 200kPa IMEP level.

E85 Gasoline, 500 rpm, Fluids temperature: 15°C,
Intake Air Temperature: 15°C. Intake Manifold Pressure:
80 kPa, Ignition Timing: 20° BTDC.

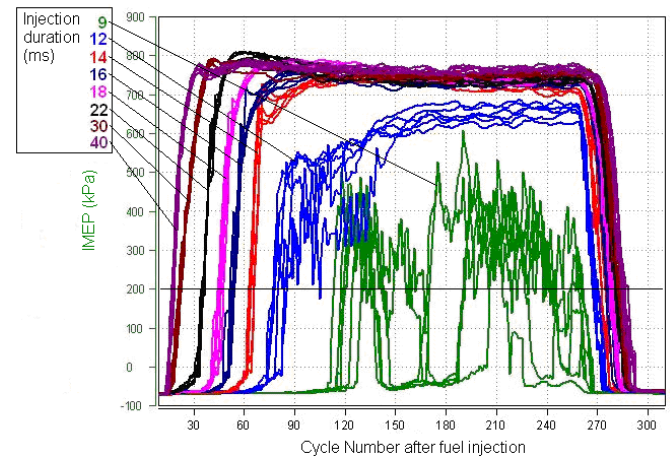


Figure 1 Comparison of Combustion for different Injection Durations.

COMPUTATION PROCEDURE

The CFD code STAR CD V3.26 has been used for the simulation of the PFI gasoline engine considered. The calculation domain includes combustion chamber, intake and exhaust ports (figure 2). Cell number is varying from 110000 to 155000 depending on the crank angle. A 180° engine model was used because symmetry conditions are satisfied. The average cell size is 1.0 mm in intake port (figure 3) while it is 2.0 mm elsewhere. This can be explained by the fact that evaporation takes place almost exclusively in the intake port or near the intake valve.

The simulation of the mixture formation requires an accurate prediction of spray dynamics, so experimental spray characterizations were used to fit the injector model and the model of film was activated in the entire domain. The simulation was launched on 5 engine cycles to take into account the dynamics of establishment of the fuel film (wall wetting).

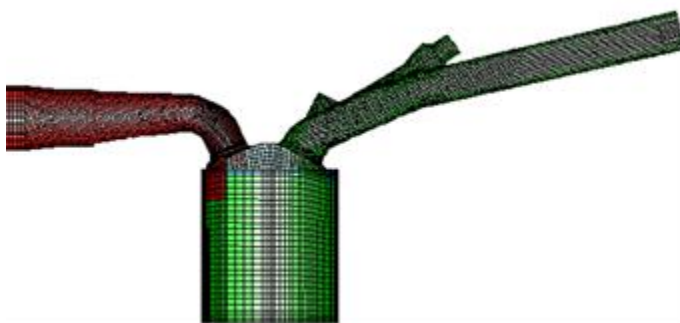


Figure 2 : Global Mesh

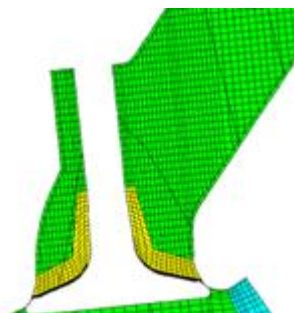


Figure 3 : Intake Port Mesh

RESULTS AND DISCUSSION

EFFECT OF INJECTION DURATION

It is well known that increasing the injected fuel amount improves the startability. But it is necessary to know precisely the efficiency of this strategy because a too large amount of injected fuel can lead to oil dilution and obviously to a non respect of the pollution requirement. A compromise has to be found to set the right start time staying within pollution requirements and preventing from oil dilution[5].

Figure 4 shows the effect of injection duration for E0, E85 and E100 Gasoline. Ignition timing is 13° BTDC for E0 and 20° BTDC for E85 and E100. Lambda 1 could not be used for E100 to start the engine within a reasonable duration. The enrichment needed to start the engine increases as the fuel concentration of ethanol increases. It is also interesting to know that whatever the injection duration, the engine requires more than 15 cycles with E100 fuel to start. During the first cycles where no combustion occurs, a part of the injected fuel leaves the combustion chamber via the exhaust valve while complementary part stays inside the combustion chamber therefore trapped quantity of fuel increases cycle to cycle.

Ignition phasing: E0/13°BTDC, E85 and E100/20° BTDC. E0, Lambda from 1.1 to 0.74. E85, Lambda from 1.05 to 0.42. E100, Lambda from 0.63 to 0.12.

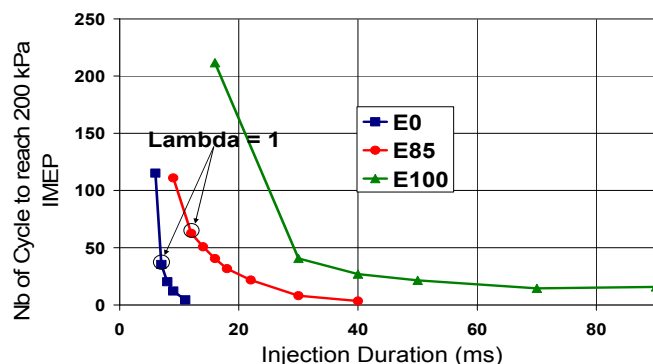


Figure 4 Effect of Injection Duration on startability.

EFFECT OF IGNITION TIMING

As the combustion slows down in cold condition, it is expected to anticipate ignition timing compared to warm condition. Figure 5 shows the effect of ignition timing on startability. The effect is more important for E0 than for E85 and E100 fuels. But these three fuels need ignition timing anticipation to improve startability. It is also possible to slightly improve startability by applying a multiple spark ignition as described by figure 6.

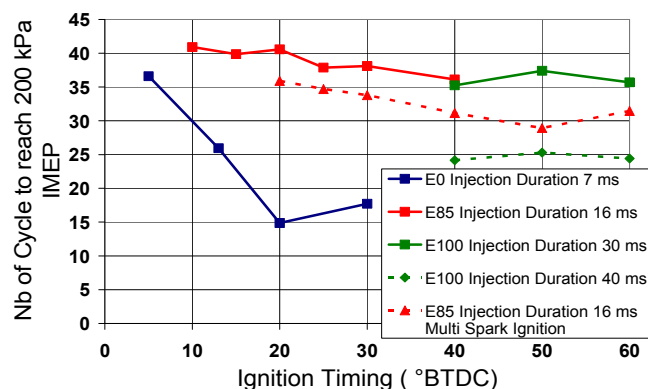


Figure 5 Effect of Ignition timing on startability.

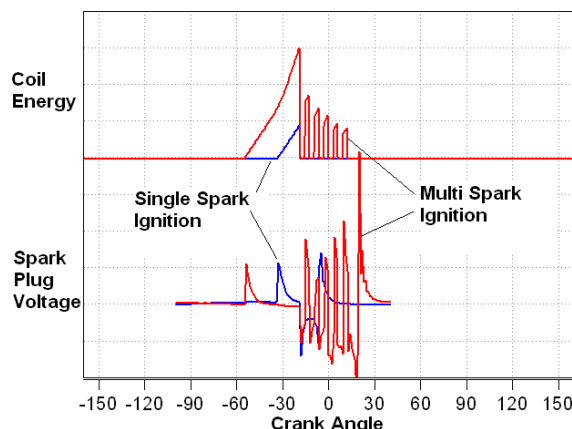


Figure 6 Description of multi-spark ignition.