

## EMISSION AND CONSUMPTION REDUCTION FOR SMALL TWO-STROKE GASOLINE ENGINES

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### Abstract

Automotive pollutant emissions have been drastically restricted during the last ten years. These emission standards are now concerning small two-stroke engine. A Lot of technologies are offered to automotive engine manufacturers, such as direct injection or catalyst converter, but needs for low production price do not allow small two-stroke engine designers to use such evolutions.

So, despite its high weight and complex mechanic, today's trend is towards four-stroke cycle.

In order to meet future emission standard, different concepts have been implemented on a small two-stroke engine. An optimum combination between boost pressure and port timing has been found, using CFD, connected with results from hydraulic simulation, in correlation with tests on engine. The intake required conditions are reached through an external device, which is giving the right in-cylinder scavenging flow.

Significant gains have been observed, concerning pollutant emissions as well as fuel consumption. These concepts allows small two-stroke engine to meet future regulations, keeping its advantages in price and weight.

### Introduction

The HC emissions of a small 2-stroke engine mainly come from a short-circuit between the transfer- and exhaust-ports: more than 25% of the fresh air-fuel mixture entering into the cylinder exits before the exhaust valve closes.

The aim of this research is to show how an apparent dissymmetrical port timing diagram obtained by an auto-charging system can lead to a major reduction of the HC emissions and fuel consumption.

### 1-Physical principle and application

On a port timing diagram, the period between the transfer-ports and the exhaust-port closing doesn't introduce anymore fresh air-fuel mixture into the cylinder and is responsible for a large part of the HC emissions. Furthermore, the simple reduction of this period duration could avoid this major short-circuiting but also reduce the blow-down and so the quality of the whole scavenging process. The idea of this research is to have a longer blow-down and a shorter duration between transfer-ports and exhaust-port closing through a fictive dissymmetrical port timing diagram. The total delivered mass will remain the same thanks to an adapted pressure profile in the transfer-ports.

In order to keep a cylinder with simple symmetrical ports, the pressure profile in the transfer-ports has been modified so that it leads to this apparent later opening of these ports. The way to get this new pressure profile has just been patented by D2T and won't be explained here in

details. Combined with an optimal port geometry, it avoids a rapid short circuit with fresh mixture. This experimental engine will now be called “modified engine”.

The figure below explains the new apparent port timing for the transfer-ports.

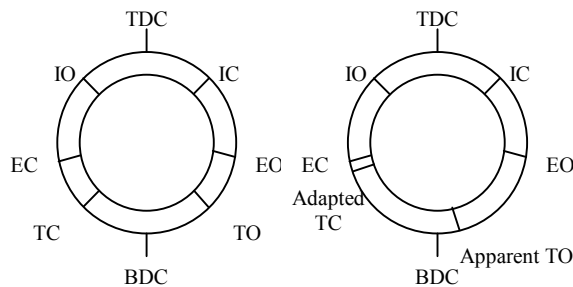
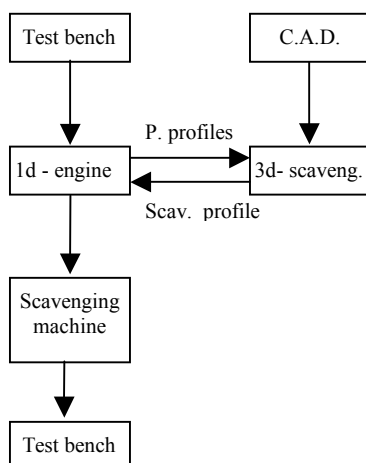


Fig1. Symmetrical and dissymmetrical diagrams

The 2-stroke engine chosen for the experimentations has 41,6 cm<sup>3</sup> with a carburettor and gives a maximal torque at 9000 rpm.

## 2- The steps of the research

The methodology to follow is based on results coming from test bench measures and on a CAD cylinder model.



First, a one-dimensional model of the modified engine has been created with an assumed scavenging process. Based on test bench measurements, this gives a first

pressure profile in the exhaust port and above the piston. Then, a correlation with a three-dimensional model of the cylinder, running with these pressure profiles leads to a more accurate scavenging profile which is introduced into the one-dimensional model; after some iterations, we got a good predictive model of the engine and his scavenging, showing a large reduction of the HC emissions.

The accurate scavenging profile given by this numerical way can be verified by a test on the scavenging machine specially developed by D2T for two-stroke engine cylinders.

A last measure on a test bench will validate the performance predictions of the modified engine.

## 3 -Numerical models for scavenging analysis

### 3.1- Preliminaries: test- and flow-bench

To adjust a one-dimensional numerical model based on a real engine, many characteristics have to be experimentally determined.

The discharge coefficients of the different ports and the pressure losses of the different pipes, exhaust muffler and carburettor, have been measured on a special flow bench.

A very small test bench has been specially developed for this application. The performances of the standard engine have been determined: torque, crankcase-cylinder- and exhaust- instantaneous pressure profiles, temperatures, consumption, exhaust gas emissions ...

### 3.2- One-dimensional numerical model

This analysis has been made with the codes WAVE™ and GT-Power™. The main advantage in using a one-dimensional code consists in the very fast calculation (about one minute with a PC 1,2 GHz and

512 Mo RAM) compared to a CFD simulation where one would simulate both the scavenging and the combustion.

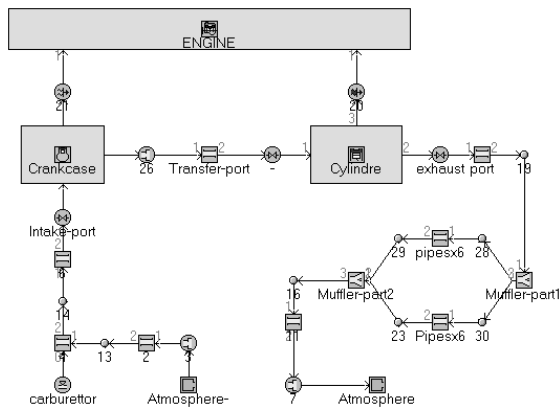


Fig2. One-dimensional model of the standard engine

Both models use the flow bench results and correlate the test bench measurement with a high accuracy. For the first iteration, the correlation has been established by adjusting the scavenging profile in order to match the global performances of the engine.

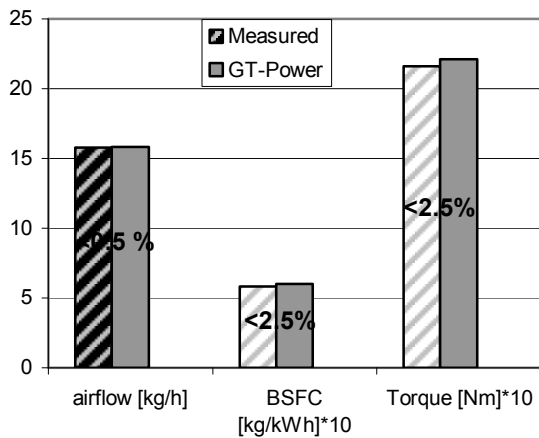


Fig3. Correlation one-dimensional model with Test-bench

These one-dimensional codes offer a performance prediction feature which will allow to estimate the benefit of the modified engine versus the standard engine.

Two sensors installed on this model will supply the needed pressure profiles into the crankcase and the exhaust muffler to run the following iteration of the CFD scavenging simulation.

A comparison of these profiles with the test bench measures shows the accuracy:

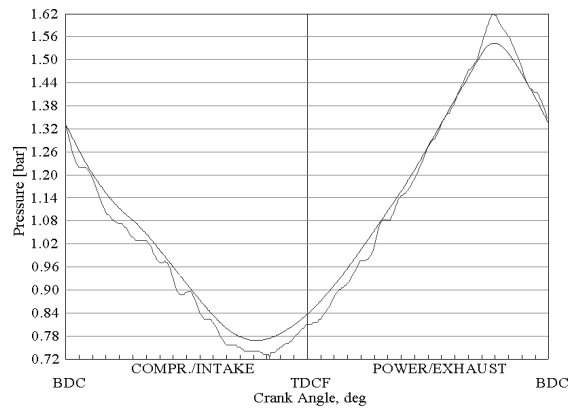


Fig4. Comparison of the measured pressure profile into the crankcase with the simulation.

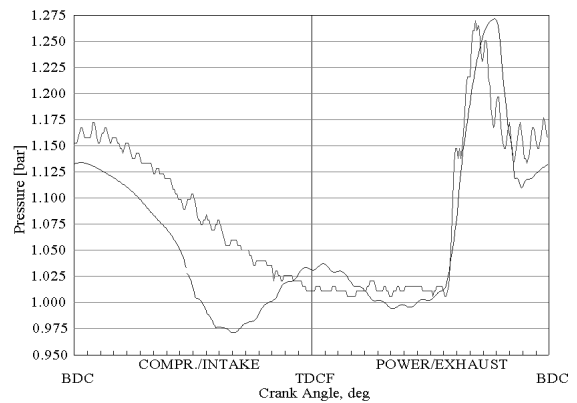


Fig5. Comparison of the measured pressure profile into the exhaust muffler (above on the left) with the simulation.

With the 1d-simulation, one can easily see the effect of the dissymmetrical apparent port timing: The pressure comes later in the transfer-port and so the mass flow too.

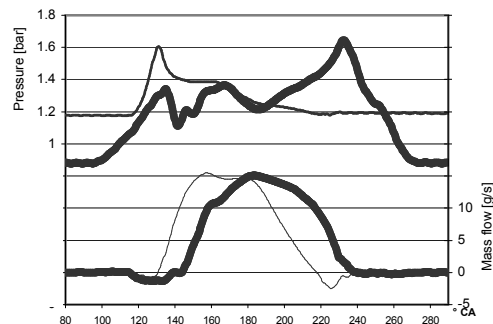


Fig6. Comparison between the standard engine (small line) vs. modified engine (large line): pressure into the transfer-ports and mass flow rate through the transfer.

### 3.3- Three-dimensional scavenging model

The CFD model uses a CAD structure of the engine. A first simulation has been made with FLOWWORKS™ to get fast an idea of the scavenging process. Then, STAR-CD™ allowed a very accurate calculation.

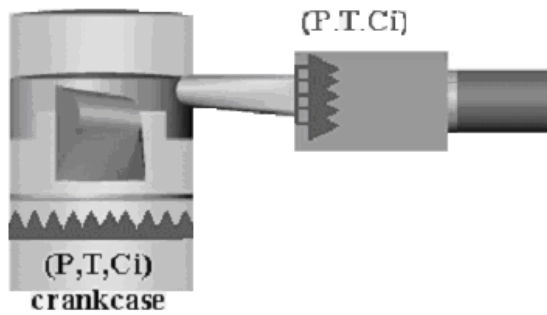


Fig7. Cylinder three-dimensional model

The instantaneous pressure profiles are imported and placed as shown on the fig7. The values for the initialisation of the cylinder state are taken from the one-dimensional model too. The calculation made with about 300.000 cells supplies the residual ratio vs. the scavenging ratio which will be used as new scavenging profile in the one-dimensional model for the next iteration.

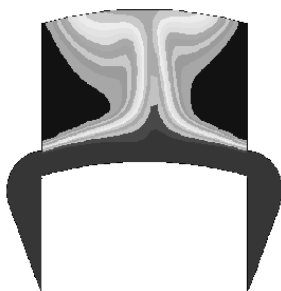


Fig8. Scavenging with CFD.

The convergence between both models has been established after a few iterations. Furthermore, the numerical visualisation of the flow inside the cylinder will made it possible to find some useful modifications of the transfer-ports geometry.

## 4-Experimental tools to validate the numerical models.

### 4.1- Hydraulic scavenging machine

The theoretical improvement of the transfer-ports obtained through the CFD calculation will be first compared to the standard version on a "scavenging machine" developed by D2T and using some laws of similitude in term of speed and pressures.

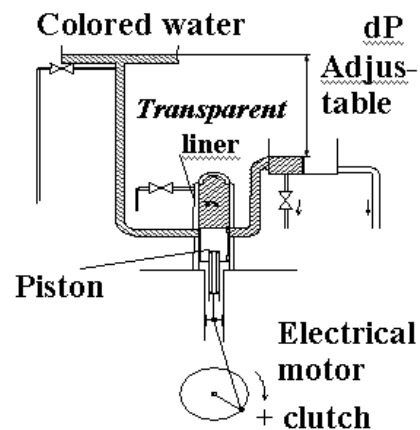


Fig9. Principle of the scavenging machine

One simulates the real scavenging with two liquids of different optical densities in a fast-prototyped and cost-efficient transparent cylinder. The first liquid represents the fresh mixture, the second one the residual gas. With this experimentation, different cylinders can be compared.

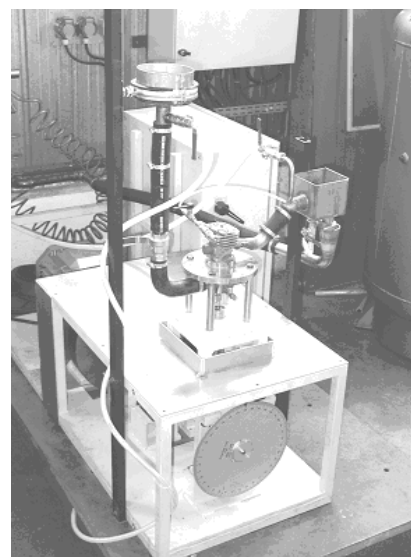


Fig10. Scavenging machine

#### 4.2- Specific test-bench

A specific installation has been developed by D2T for small capacity, high speed engine. The test bench set-up includes an Eddy current brake with a 0-6 Nm torque measurement range and a 0-18000 rpm speed range, MORPHEE™ for test bench management and low frequency acquisitions, OSIRIS™ for high speed signal acquisition.

An engine has been adapted and instrumented in order to test the different solutions coming from the calculation approach. The dissymmetrical boost pressure shapes is obtained by a simple device, installed outside the engine for the experimentation phase.

The main analyses from the test results concerns the effect of the concept on the combustion profile, the impact of the device on the friction losses generated by the low pressure profile, and the interest of a new compression ratio better adapted. Some more tests have to be conducted to optimise the boost pressure timing.

#### Conclusion

The first step of the study has been to validate our research process from calculations to tests, thought simulations. The gain coming from this method concerns the reduction in time and cost of a new engine development, using specific tools for each steps.

The main goal of this research has been to explore the potential of the dissymmetrical port timing diagram obtained by an auto-charging device. The results from calculations has confirmed the interest of this concept, and the high gain that could be obtained in the reduction of fuel consumption as well as HC emissions. Today, we are still working on the optimisation of the boost pressure delivered to the engine.