

ENGINE SCAVENGING OPTIMIZATION

D. DRECQ – A. du GARDIN
D2T, Drecq Daniel Technologies (France)

Abstract

Automotive pollutant emissions have been drastically restricted during the last ten years. These emission standards are now concerning small two-stroke engine.

In order to meet future emission standard, it is essential to improve the scavenging flow, and especially the trapping efficiency of the engines.

It is also interesting to have a tool for predicting the scavenging performances of an engine before the firing engine situation, which takes place late in the time scale of a development.

A special test stand has been developed by D2T Group to visualize and quantify the scavenging process. It was also modelled with CFD tools, and a good correlation was observed between calculations and experimentation.

This shows a good potential to reduce time and money spent in an engine development .

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 build and validate a test bench using liquids to simulate and visualize the scavenge flow behaviour of an engine. This scavenging machine will allow to improve the performances and emissions of the studied engines.

Experimental principle

The “scavenging machine” developed by D2T is based on a transparent cylinder engine, driven by an electrical motor. At the beginning of the test, the transfer port is filled with coloured water, representing the fresh air-fuel mixture. The cylinder and exhaust port are filled with clear water, representing the residual gas. The pressure difference between transfer and exhaust is generated by the water height difference. The beginning and the end of the test take place at the same piston position, between the transfer opening and

the exhaust opening. The low speed of the machine makes it possible to visualise the real scavenging flow with a high-speed video camera.

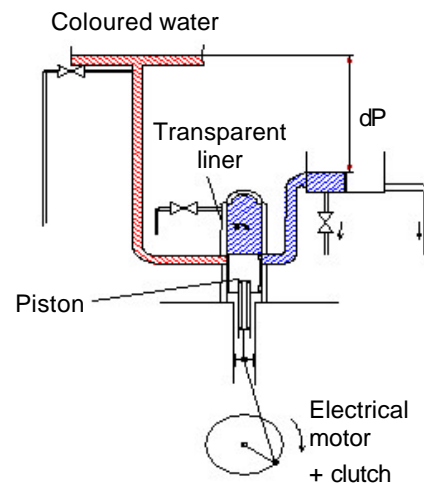


Fig1. Principle of the scavenging machine

With a purge of the water remaining in the cylinder after the test, and a measurement of its optical density, the trapping, scavenging and charging efficiencies are deduced as a function of the scavenge ratio. The scavenge ratio is regulated by changes of the pressure difference or of the motor speed, according to the similarity parameters.



Fig2. Scavenging machine

Similarity rules

In order to have a good correlation between the simulation and reality, several dimensionless quantities must be respected. The most important are Reynolds, Euler and Strouhal numbers, because inertial forces are more predominant in a scavenge process than the gravitational forces.

The Reynolds number determines the level of turbulence of the flow. The kinematic viscosities, densities of the fluids used in both conditions are fixed. The scale factor and speed of the tests must be adapted in order to respect the same Reynolds number between experience and reality.

The Euler similarity parameter gives the ratio between pressure forces and inertia forces. Since the densities of the fluids are fixed, we must adapt the difference of pressure between transfer and exhaust, and the velocity on the test bench to have an equivalent Euler number in each case.

The Strouhal number permits to respect the kinematic of the scavenging flow. As for the Reynolds, it is governed by the scale and the speed of the bench.

These three dimensionless numbers can't be exactly equivalent in simulation and reality, for all scavenging ratios. It is important to determine the accuracy

needed in order to keep a constant uncertainty on the measurements.

Experimental results

Scavenging measurement-validation

The optical density of the remaining water in the cylinder, combined with the optical density of the transfer port water give the scavenging efficiency as follows:

$$SE_v = \frac{O.D._{mixing}}{O.D._{transfer\ port.}}$$

The other efficiencies are deduced as for a conventional scavenging study, using the engine geometrical parameters, and the volume delivered through the transfer port.

The curves obtained with the scavenging machine are very close to the real engines. Fig.3 shows the trapping efficiency versus scavenge ratio measured on the same engine with the scavenging machine and with a test bench.

A specific installation has been developed by D2T for small, high speed engines. 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 the low frequency acquisitions, OSIRIS™ for the high frequency signal acquisition.

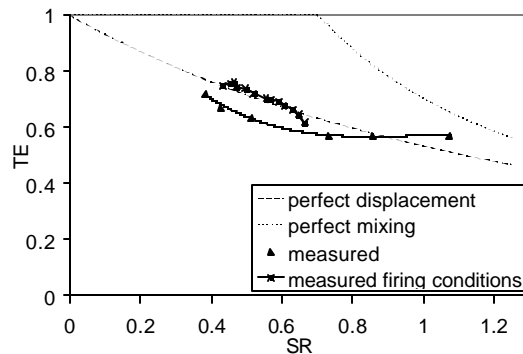


Fig3. Trapping efficiency measured on a 42 cm³ 2-stroke engine

Scavenging measurement as a tool to compare different cylinders

The scavenging machine is very useful to compare the performances of different cylinder shapes, as we can see on the following measurements results. Two 36 cm^3 loop-scavenged engines with a slight transfer design difference have been tested. The results clearly predict the better one. Using the scavenging machine is the best way to spare time and money in a new cylinder development.

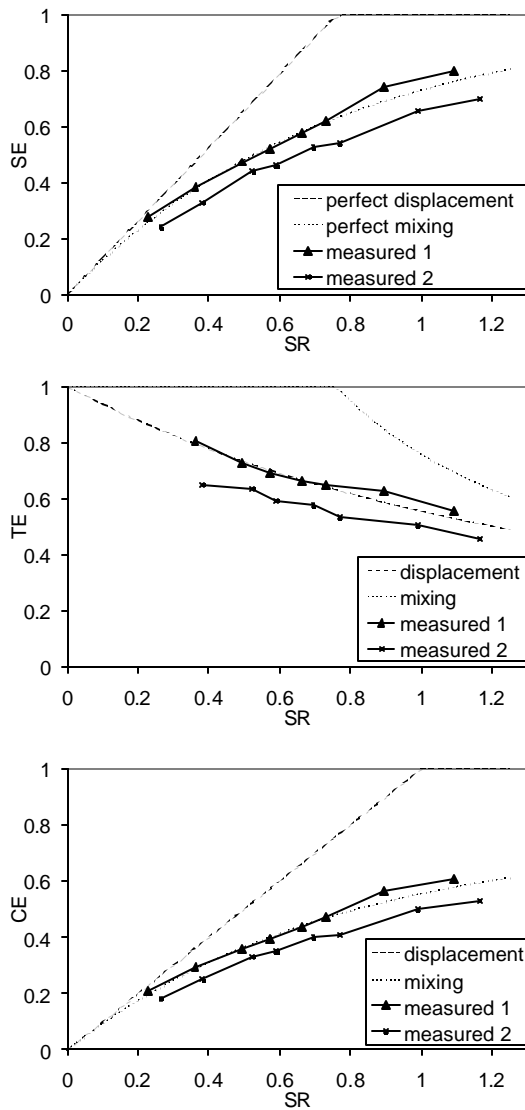


Fig4. Scavenging, trapping and charging efficiencies measured on two different 36 cm^3 engines

Scavenging visualisation

The scavenging flow can clearly be visualized on the movies made during the tests. It is a helpful tool to adjust CFD simulations. The short-circuiting mechanism of the fresh charge is also clearly showed by this way.

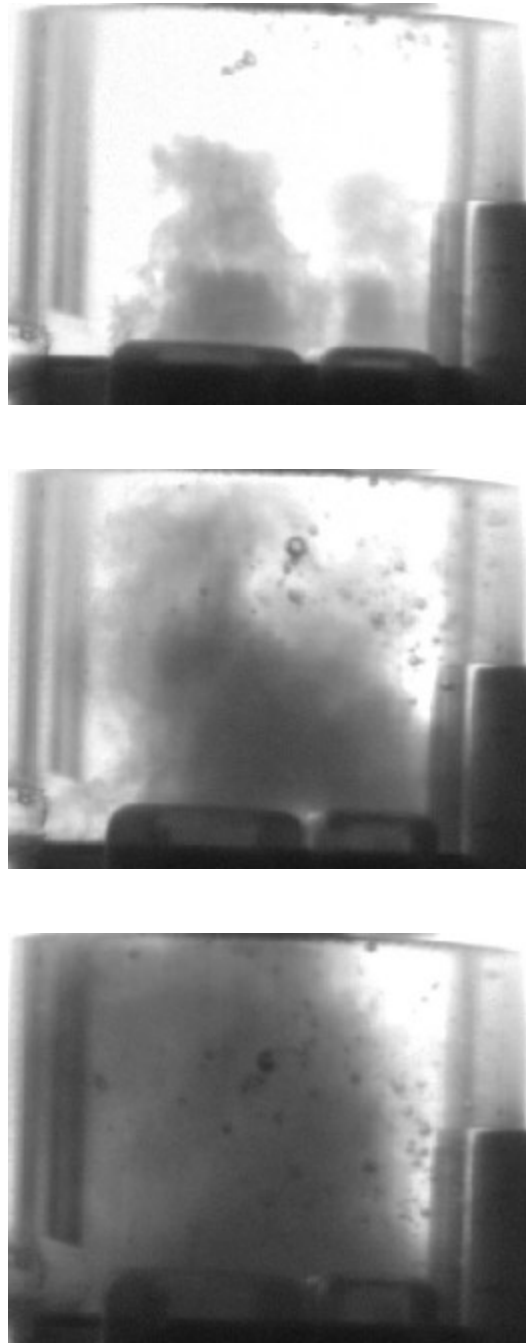


Fig5. Scavenging visualization examples

Three-dimensional numerical models for scavenging analysis

A CFD model has been created to study the validity of the hypothesis made concerning the similarity rules. 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.

Two sensors installed on a GT-Power™ one-dimensional model supply the needed pressure profiles into the crankcase and the exhaust muffler.

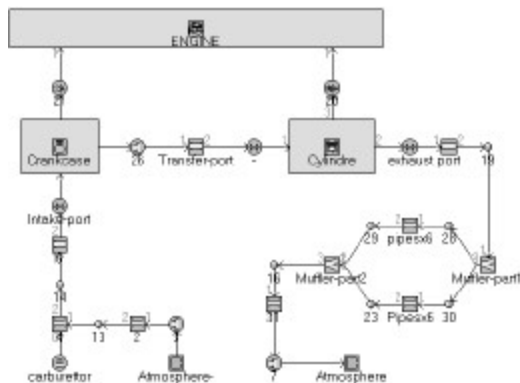


Fig6. One-dimensional model of the engine

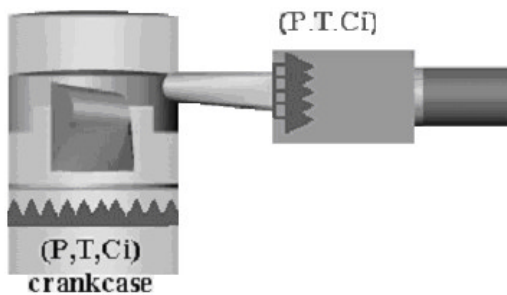


Fig7. Cylinder three-dimensional model

The instantaneous pressure profiles are imported and placed as shown on fig7. The initial values of the cylinder state are taken from the one-dimensional model too. The scavenging flows obtained by CFD confirm the visualisation done with the scavenging machine.

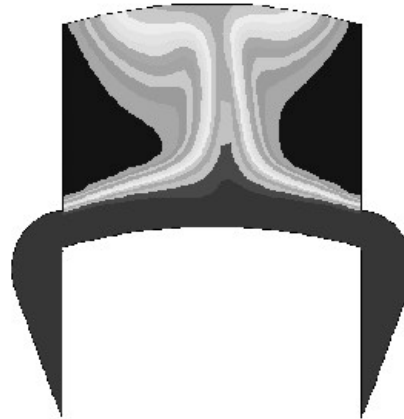


Fig8. Scavenging with CFD.

Conclusion

The D2T scavenging machine gives a simple way to measure the scavenging flow performances of a 2 stroke engine. There is a double interest in using the machine:

- get rapidly the scavenging efficiencies of an engine geometry
- visualise the scavenging process.

These results can be obtained without any new expensive casting, and the cylinder shape can be easily modified, when using a fast-prototyped and cost-efficient transparent cylinder.

The gain coming from this method concerns the reduction in time and cost of a new engine development, and can also be applied for the study of a stratified 4 stroke engine.

References

- [1] G.P. Blair "Design and Simulation of Two-Stroke Engines", Society of Automotive Engineers, February 1996
- [2] P.E. BENTEYN, "Conception d'une machine de balayage hydraulique pour petits moteurs", Internal report, D2T, March 2000
- [3] A. Du GARDIN, "Simulation CFD d'une machine de balayage hydraulique", Internal report, D2T, December 2001