Chalmers Ecomarathon Engine Design

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Summary

This report is written at Chalmers University of Technology as a part of the Ecomarathon project. The report covers suggestions and recommendations on what to change on a Honda GX25 to make it more suitable for an Ecomarathon car competing in the prototype class. The report is written before anything was built and all the thoughts and ideas are theoretical and have not yet been tested, only simulated. However, modifying the intake and exhaust valve timing , the intake port, and implementing a electronically controlled injection and spark timing system should be conducted in order to have a highly competitive Ecomarathon gasoline engine.

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Introduction

Background

"The Shell Eco-marathon is an educational project that integrates the sustainable development values with driving as far as possible using the least amount of energy." –Eco Marathon website.

In 2005 the School of Mechanical Engineering at Chalmers University of technology initiated an Ecomarathon project with the intention to give students experience and understanding of how complex engineering projects are carried out. One of the most important aspects with the work is to strengthen the connection between theory and practice. By this, better and more prepared engineers will be examined.
The project integrates students, PhDs, researchers and professors at Chalmers, and expertise from Swedish industry. A basis in the project is that all building and manufacturing work will be performed by the students themselves, although experienced engineers and project managers from the University and industry will be supervisors.
The engine is designed according to the Shell-Ecomarathon for the prototype class rules and the priority is lightweight an low BSFC.

Purpose

Designing and choosing an engine for a Ecomarathon car is a tough task and a lot of aspects need to be taken account for. This report explains why the 2007 Chalmers Ecomarathon team has decided to run a modified Honda mini 4-stroke. It also explains the reasons for investigating possible improvements of the engine. The design report is also a mandatory part of the Ecomarathon project.

Delimitations

At the time this report was written only the Honda GX25 was available for up close examination since Chalmers already had 2 complete GX25 and one split GX25 in stock. However the GX35 ,according to Honda's website, has a lower BSFC at certain rpm's therefore the 2 engines will be compared against each other, however this report will mostly focuses on the GX25.

Main Goals

- Fuel efficient
- Light
- Reliable
- Fairly quick to build

Choice of Engine

The market for small 4-stroke engines fairly small, and with the criteria of a 4-stroke, SI, 100 watt, highly efficient engine the market is non-existent. Since there is a limited amount of time the only reasonable thing to do, is to use a stock 4-stroke and modify it to fit the application needs as good as possible. The choice falls between the same engine as Chalmers used lased year, the Honda GX25, since it is light, already fairly efficient stock, and the team already has 2 spare engines of the same type and the Honda GX35, which is the next step in the Honda production line and is more efficient than the smaller GX25 in its original setup. At least over the rpms at which we intend to use the engine.

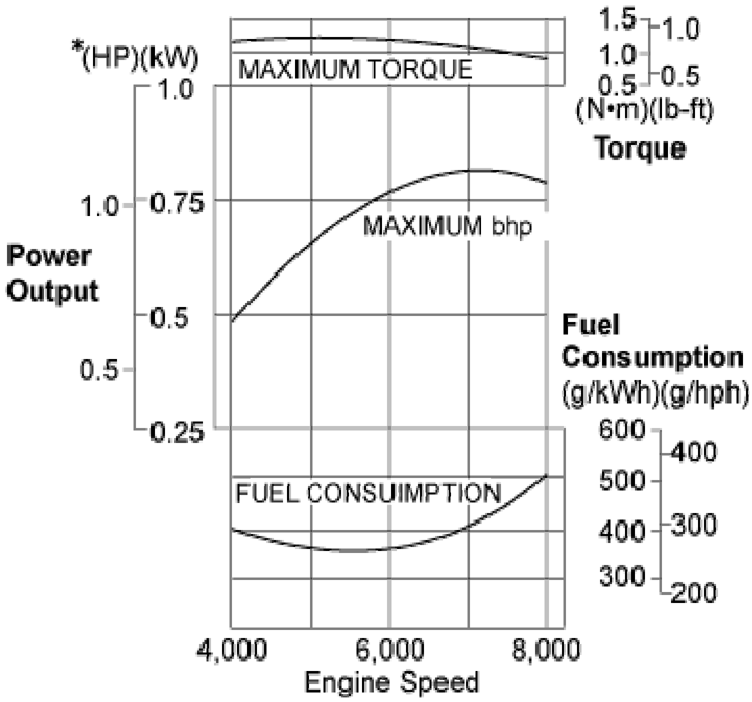

Figure 1 *Honda GX35*

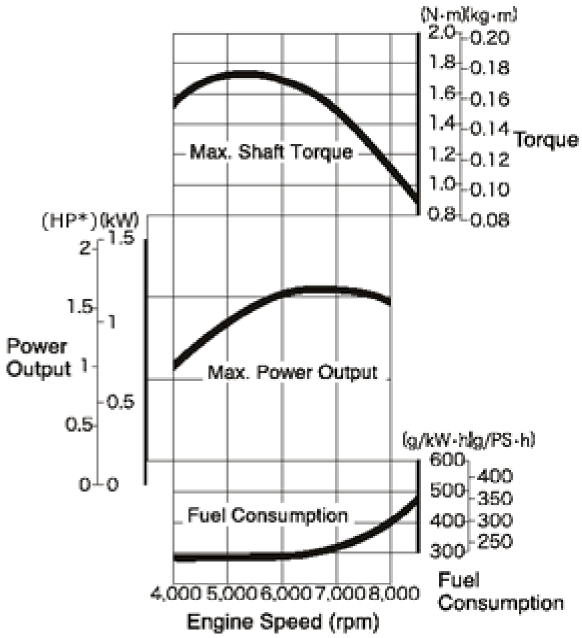

Figure 2 *Honda GX25*

In order to truly investigate which engine is more suitable the both engine models have been ordered so a comparative study can be carried out in order to chose the most suitable engine for the car.

Theory

Intake valve timing

The original engine's valve timing is completely designed for WOT at high rpm's. It is most likely tuned to take advantage of intake and exhaust pulses at around 7000rpm. To achieve a favorable gas exchange at high rpm's IVO should occur significantly before TDC, however it is quite insensitive to when, the important thing is that the cylinder pressure should not dip early in the intake stroke. The timing of the IVC is more crucial since it basically determines the high speed volumetric efficiency, which in return highly effects the low speed efficiency due to a backflow slightly before IVC. Therefore this will is be an area of focus during simulations and engine testing.

Port design

Volumetric efficiency partly depends on flow friction and restrictions in the intake and exhaust system, pressure losses in an intake system depends on the speed of air squared. (Heywood) Therefore lowering the amount of air flow through the intake system will lower the air speed and also increase the efficiency. However high air speed at the intake valve is also very important for the mixing of fuel and air in the cylinder and a complete combustion. There are 3 basic configurations of the cylinder head, 2- 3- and 4-valves.

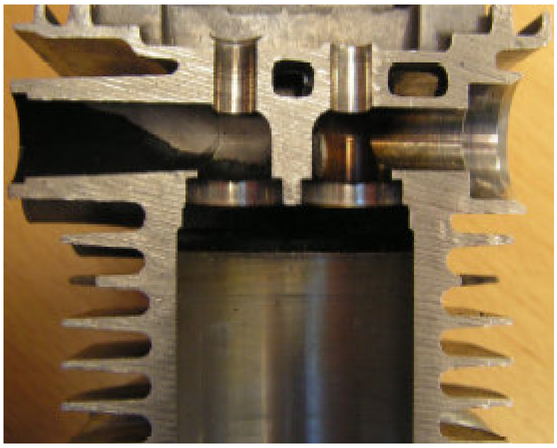

Figure 3 *Sliced view of the GX25*

The advantages of a 2-valve engine are:
• smaller number of parts
• less friction in cylinder-head
• better torque at lower rpm due to smaller ports
• simple structure of valve train
There are also some disadvantages:
• intake area not as large as in 3- or 4-valve cylinder head
• not suitable for high rpm because of big mass of valves
• unfavorable position of spark plug

Fortunately the GX25 originally has a 2-valve setup. 3- and 4-valve setups are superior for running at high rpm's with a large mass flow. For the ecomarathon application of the engine, a 2-valve setup is possibly the best.

The original port design of the GX25 very poor since there very sharp 90 degree bend just before the inlet valve and just after the exhaust valve. This geometry is extremely bad, the optimum would be not to have a bend at all which

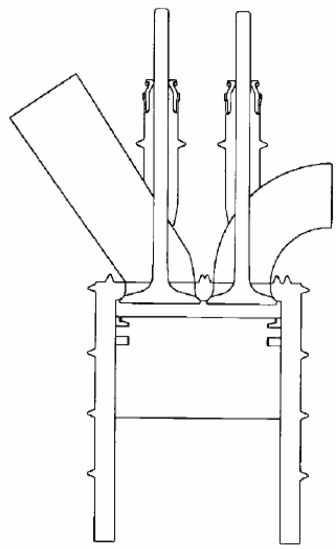

Figure 4 *Principal sketch of a 2-valve intake design*

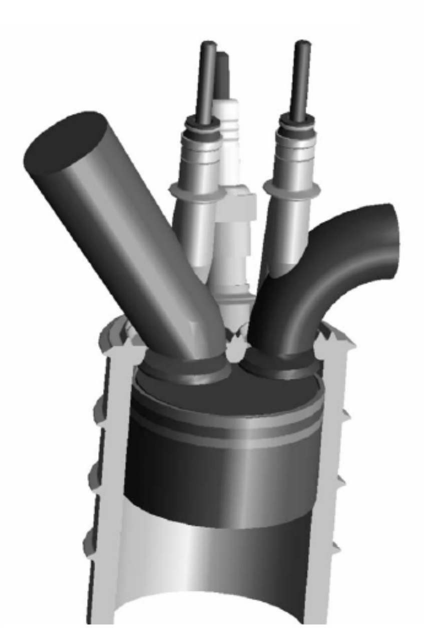

Figure 5 *3D model view of a 2-valve intake design*

is impossible, but there should be a strive to have an as small bend as possible and the bend should have a big radius as possible leading to less flow friction and better flow profile.

According to a study carried out at Graz Technical University in 1999 there is a lot of research still to be done on small 4-stroke engines. They tried 3 different port cylinder head-, port- and combustion chamber layouts, comparing the cylinder-head 3 types in a flow from stereo lithography models, and also simulating the engines in AVL's Boost predicting a potential of each configuration. The interesting findings for the ecomarathon engine is that the 2-valve port design gives the best low rpm characteristics and by far the best tumble number which is the key for good low rpm characteristics. In fig.** the engine designs are compared to a CB50 and a Honda GX31 which is basically the same engine as the GX25 but

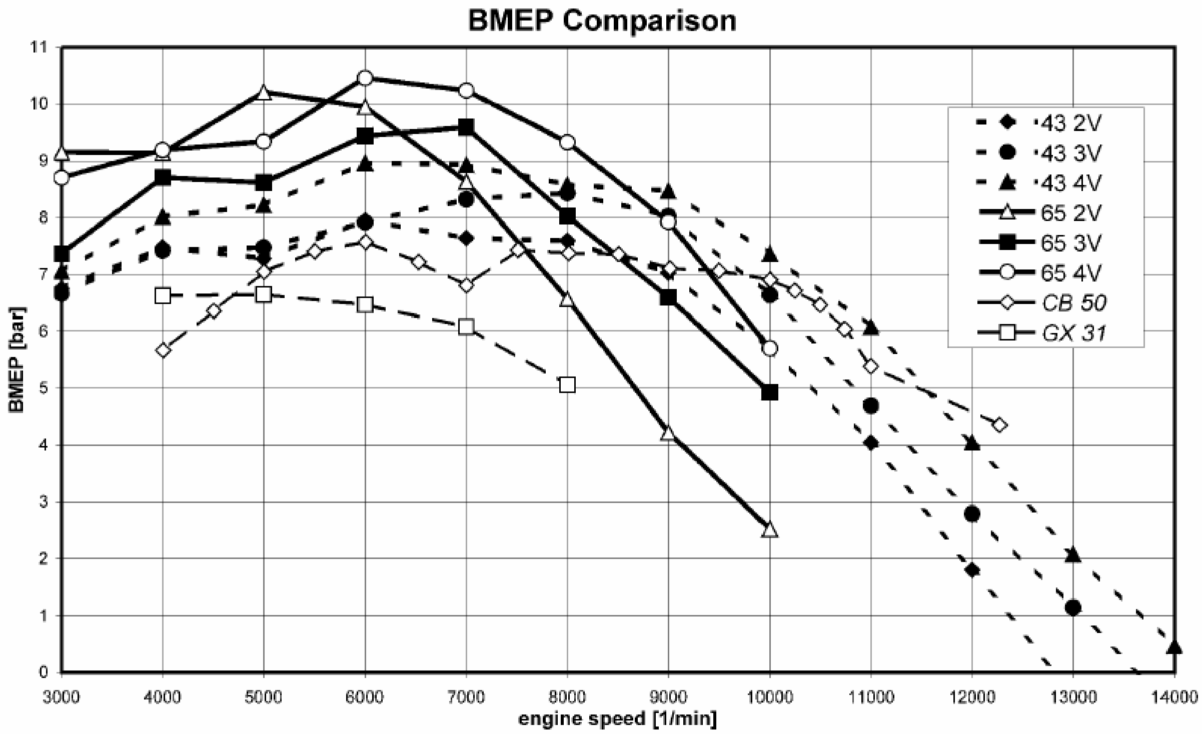

Figure 6 *Comparison chart of BMEP vs. engine speed*

with a bigger bore and stroke. The comparison shows that there is a great possibility of improving the BMEP of the GX25 by changing the intake and exhaust port geometry.

Methodology

In order to increase the efficiency of the engine several design improvements were considered. First of all raising the compression ratio was considered since it is usually by far the easiest way of increasing the efficiency of an engine. However the task to achieve a higher compression ratio on the GX25 is difficult since the cylinder head, the cylinder, and the half the crank case is one solid piece. The task of raising the compression ratio suddenly becomes more difficult because of this. The only feasible means of changing the compression ratio was considered to be changing the piston, the con-rod length or the geometry of the combustion chamber. Therefore the idea was dropped.

Instead the focus is aimed at improving the gas exchange, especially at low rpm's. Since the engine originally is designed for high power at high rpm's, around 7000rpm, the margin for improvement is considered to be quite large at low rpm's.

The aim at running the engine at lower rpm's is based on the facts that the efficiency of SI engines almost always is the highest at full throttle around low-mid engine speeds. This is due to several phenomenon, such as, the volumetric efficiency which severely deteriorates due to the airflow gets chocked during at least part of the intake process. (Heywod) Another great loss comes from the friction, which increases substantially with engine speed. Therefore lowering the target operating speed and optimizing the engine for low rpms will improve the efficiency of the engine at these engine speeds, however the maximum power output will be lowered since the gas exchange process for high rpm's will become substantially worse due to a different intake and exhaust valve timing compared to the original cam timing.

Simulation

All engine simulations are done using a 1-D thermodynamic simulation software from AVL called BOOST. A model of the engine had already been created last year of the GX35 however it was not complete, therefore the model was refined and improved implementing data from similar tests conducted at AVL and published as an SAE paper. The model is still not accurate but simulations using it can show trends and therefore greatly aid in the design process.

Valve timing

In fig XXXX there is a large backflow at the intake port during the end of the intake phase. This obviously is something that is not wanted. By just changing the intake cam profile by -8 degrees the backflow is reduced, however not completely. The problem with changing anything regarding the intake cam curve is that it will also effect the exhaust cam curve since both rocker arms are gliding on the same cam-lobe. However there is a possibility to re-grind the cam with a offset on half the cam since the 2 rocker arms are offset. However due to the time restraint this will most likely not be tested.

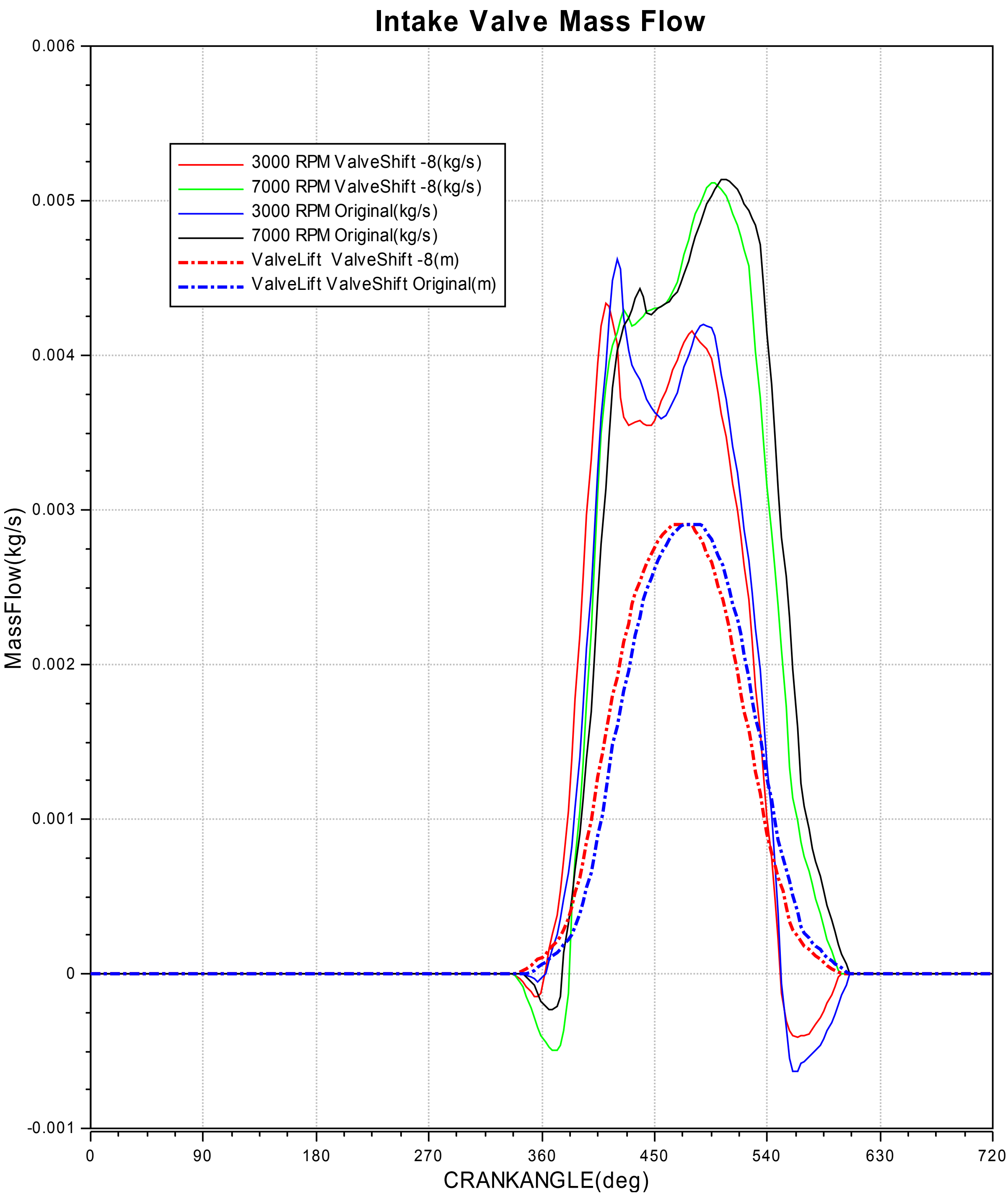

Figure 7 *Mass flow over the intake valve vs. engine speed*

The simplest change to increase the efficiency of the engine at low rpm's would therefore be to just change valve timing by setting the camshaft at an earlier opening of the intake and exhaust valves. The effects of this can be seen on the torque curve and BSFC curve in fig XXXX and fig XXXX respectively.

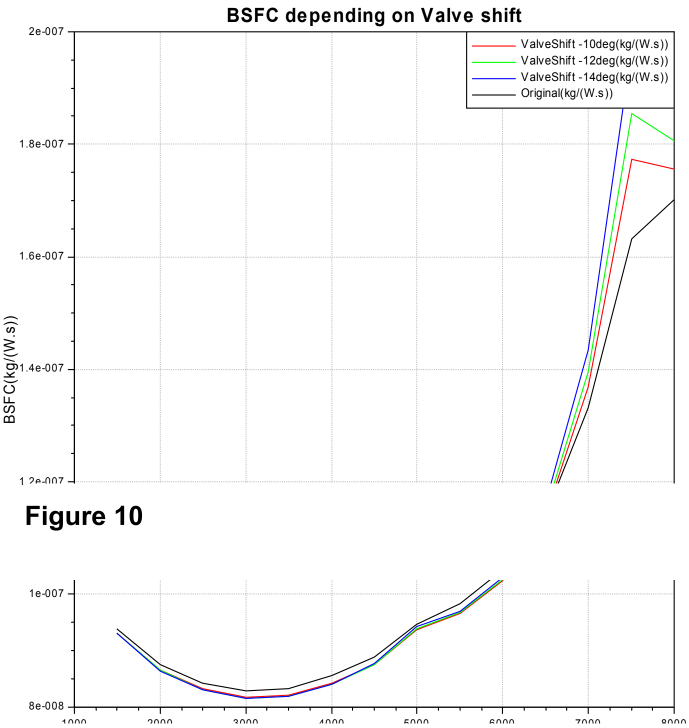

Figure 10

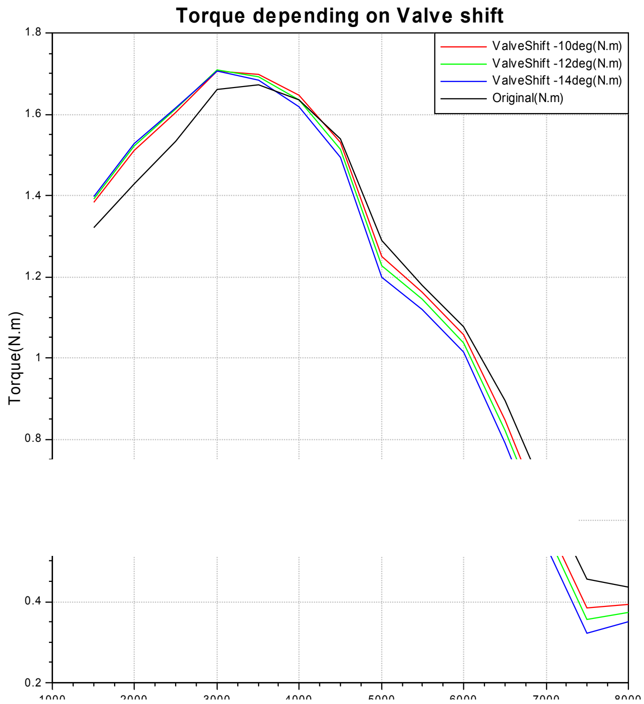

Figure 8 *BSFC vs. engine speed for different valve timing*

Figure 9 *Torque vs. engine speed for different valve timing*

The most favorable is around a –10 degree shift.

Another effects that increases the BSFC is blow by due to valve overlapping. The overlap can be seen in figure 10. The only way of reducing this on the GX25 is to re-grind the camshaft lobe so the lobe becomes "sharper". This operation is simpler then making 2 offsets on one lobe and has been done with success by last years engine guy Mikael Persson using a NC mill.

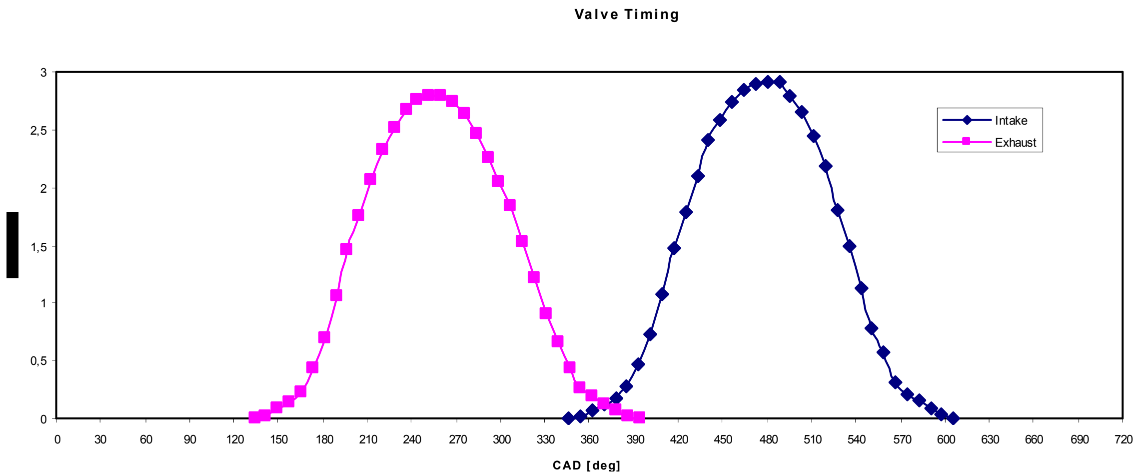

Figure 10 *Lift profiles of the intake and exhaust valve*

Intake and exhaust port modification

In order to increase the volumetric efficiency and to improve the flow field the port design has to be changed. However changing the port design is a big and difficult task since the original design of the head does not leave any room for changing the port design without adding material. Therefore the idea is to mill out and insert a new intake port, a new angle and placement is suggested be the red lines in figure 11. Also the same idea can be implemented for the exhaust port in order to lower the pumping losses. However the exhaust port flow is less sensitive to performance gains or losses. Also the design of the port including the valve guide location is of more importance in the exhaust port since the gases are extremely hot and can lead to failure of the exhaust valve if configured incorrectly.

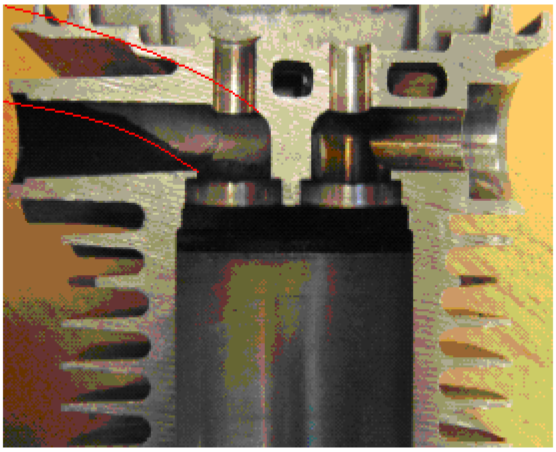

Figure 11 *The red lines show the location of the new suggested intake port*

Implementation of a electronically controlled injection and timing system

In order to control the amount of fuel the engine gets in every load case the engine will converted from using a carburetor to using an injection system. This will also enable the use of different ignition timing during different loads and rpms. These are the most obvious reasons and why all car engine manufacturers use it today. However there are more great advantages, such as the ability to record all the engine data and also switching from different engine strategies can be changed with a few clicks on a computer.
The main disadvantages are weight and it adds complexity. However the advantages outweighs the disadvantages.

Results and discussion

So far there are no results of improvement since neither of the engines have been tested, only figures from simulations show significant improvements of the BSFC. If this is true in reality will be evaluated at a later stage in the project.

Conclusion

Modifying the intake and exhaust valve timing , the intake port, and implementing a electronically controlled injection and spark timing system should be conducted in order to have a highly competitive Ecomarathon gasoline engine. The big drawback is that every modification takes time. Since the Ecomarathon project at Chalmers only has around 3 months to build test and evaluate the engine, the lack of time will be the biggest reason not to test or implement certain design improvements.

References

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