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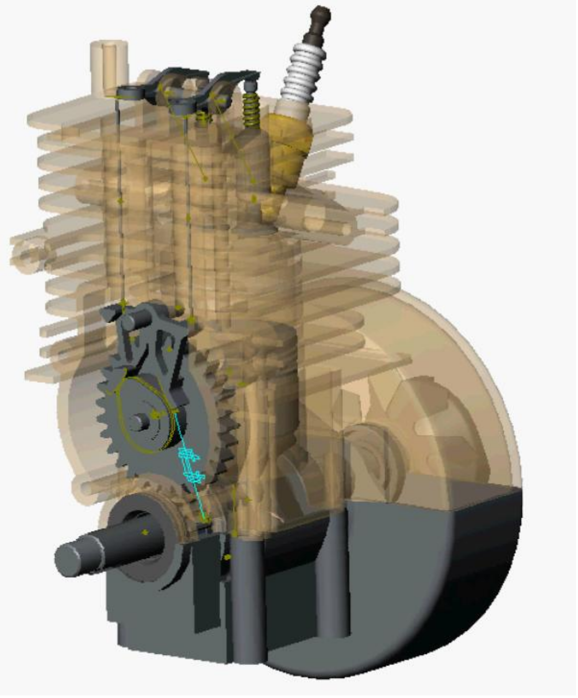
Industrial Placement report:
Improvement of the distribution system for the Shell Eco Marathon



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Lefort Isaline GTE2S06
April - June 2008

Abstract

I did my industrial placement at NEWI University, in Wrexham, Wales, from April 7th to June 13th 2008. My subject was the improvement of the Shell eco Marathon engine.

The main activity I realised was the etude concerning the improvement of the distribution system.

I had to determine the best valve timing for the special running conditions we wanted for the engine, 1500 – 1800 rpm. I made researches on how the system valve-cam runs. I also studied the possibility to improve the performances of the engine by using the acoustic supercharging that is to say the use of the wave pressure created when the valve closes to fill the cylinder. I also studied the Atkinson cycle to see if it would be interesting to apply on our engine but it wouldn't have brought a lot of gain in performances.

I also had to design two new cams to replace the only one cam of the engine. I studied the motion of the piston and the valves so that the profile of the cams which fitted the best for the valve timing could be determined.

Apart from these studies, I also participated in smaller projects.

I had to create two mocks-up of the bodies of the Shell Eco Marathon and the vélo couché another team was realising. During two weeks, we looked for the best streamlined profile and then created the body to be able to manufacture it on the Computer Numerical Control Machine.

I also participated in the realisation of parts of the chassis of the Shell Eco Marathon car.

Key words:

NEWI; Shell Eco Marathon; improvement of the distribution system; valves; acoustic supercharging; Atkinson cycle; cams; streamlined mocks-up of the bodies; chassis.

Acknowledgements

First, I would like to thank Mr Le Ny, my French supervisor, and Mr Royon, the head of the mechanical and thermal engineering department of the IUT for having put me in touch with NEWI and helped me to find this placement.

I also would like to acknowledge Mrs Mitkova, who helped me to obtain the regional bursary. I also thank Conseil Regional Ile-de-France for its financial help.

At NEWI, I would like to thank very much Mr Olivier Durieux, who is in charge of the industrial placement, for his attention and his appreciated advices during my internship.

I also would like to gratefully acknowledge Dr Graham Sparey-Taylor for his supervision, his availability and for his kindness and attention as taking care that everything was okay during my placement.

Summary

Introduction

Within the framework of my two-year degree, an industrial placement of ten weeks is necessary at the end of the second year, to complete and to put my acquired knowledge into practise.

When the IUT proposed me to do this placement abroad, at NEWI, in Wales, I thought it would be a great opportunity to improve my English spoken and discover a new foreign country. I could also have a good placement subject that interested me, as I knew that NEWI offers mechanical placements and subjects such as the Shell Eco Marathon, the Formula Student or the creation of a vélo couché . . .
So, after having sent a Curriculum vitae and a covering letter, I was accepted provided that I find an accommodation in Wrexham. I sent lots of email to find somewhere to stay and at last, I found a house at 20 min on foot from NEWI.

When I arrived there, Olivier Durieux, my supervisor in NEWI, described the different projects proposed. I chose the Shell Eco Marathon project, as I am interested in environmental technology in car industry.

Then, I chose to work more especially on the improvement of the engine of the car, which fitted the best to my knowledge. Finally, I chose to work on the adjusting of the valves opening and closing and the conception of two new cams which would replace the only one cam of the engine.

I will begin this report with a small presentation of the place where I did my industrial placement, NEWI. Then, I will present the Shell Eco Marathon and the Solar Event, the two races the car should have competed. On the next part, I will describe my researches on the improvement of the engine and the others works I realised on the car. I will finish this report by the assessment of this placement.

I. Presentation of NEWI

1. Wales and Wrexham

Situated in the South West of Great Britain, Wales is one of the four parts of the United Kingdom. It is one of the few places in the world where Welsh is still spoken. Its capital is Cardiff, an ancient Roman city, located in the south coast of Wales.

Wrexham (Wrecsam in Welsh), with its 43 000 inhabitants, is the largest town in North Wales. Located near the English border, it is usually surnamed the Capital of North Wales, as it is a commercial, educational and cultural centre of this part of Wales.

The main economy of Wrexham has been transformed in the past twenty years: from a heavy and traditional industry, it became a high tech manufacturing, technology and services hub. Wrexham is also known as the home of the newest University of Wales College, the North East Wales Institute of Higher Education (NEWI).

2. NEWI

I did my training course in North East Wales Institute of Higher Education, located on Plas Coch campus, in Mold Road, Wrexham.

The origin of NEWI dates back to the opening of Wrexham School of Science and Art in 1887. This school was funded by “Whisky Money”, a tax on beer and spirits, as one of Wrexham’s major industries is based on Wrexham Lager. Many of the courses reflected the industrial nature of Wrexham, in particular the mining industry. The original school became part of a new technical institute founded by the Miners’ Welfare Found, in 1927.

Then, the school began run out of space, as the demand of places grew. After the Second Wold War, the problems of space became even worse with the increased demand for technical education. The college was amended. But as it was not enough compared to the continuing demand for high quality education, the main three colleges of the country (Denbighshire Technical College, Cartrefle Teacher Training College and Kelsterton College in Deeside) had to be joined: Newi was born.

Then, it became one of the largest colleges of its kind in Britain with over 9000 students and an annual budget of £5 million in 1975. The College grew both in the number of students and in reputation.

Now, the university teaches in several and various field and is composed of numerous schools, such as Art and design, Business, Computing and Technology, Education and Community, Health, Social care, Sport and exercise sciences, Humanities or Science and technology schools.

This is the reason why, in 2004, NEWI was formally invited to become a full member of the University of Wales.

II. The Shell Eco Marathon and the Solar Event

1. The Shell Eco Marathon

The Shell Eco Marathon is a race organised by the oil company Shell and held every year in Europe, America and United Kingdom. The car we had to create would have participated to the race at Rockingham Motor Speedway, the 2^{nd} and 3^{rd} of July 2008.

The origin of this race was a friendly wager between scientists from the American Shell research laboratory, in 1939, to see who could get the most miles per gallon from their vehicles.
A that time, the best that could be achieved was 17.7 km/L. Then, it became an organized competition that moved to Europe and attracts more and more competitors, coming from engineering schools and universities, and spectators.

The principle of this race is to design and build a vehicle that uses the least amount of fuel to travel the farthest distance. Before the race, the vehicles have to be controlled to check there are no cheating or dangerous and not allowed equipment. Then, the competitors have four tests to manage to do their best performance.

In each test, the vehicle has to do seven circuit laps of 3.61 km, (25.272 km sum-total) with a minimum average speed of 30 kilometres per hour. At the end, the amount of fuel consummated is measured and converted into the number of kilometres the vehicle would have done with an equivalent litre of Unleaded 95. The winner is the one who cover the most kilometres with only one litre of gasoline.

There are two categories of vehicles: the Prototypes and the Urban Concepts. Each group has its own restrictions.

The Prototypes are vehicles in which the security of the pilot, the other competitors and the spectators is pushing forward.
The Urban Concepts have to have the appearance of a car that could be used in the road traffic.

The energy sources are various. The vehicles can use Petrol, Gasoline or Diesel, but also Liquefied Petroleum Gas, Bio fuels, hydrogen or solar power.

The record of the number of kilometres covered with the equivalent of a single litre of fuel is improved each year, and now peaks at 10 227 miles per gallon for a combustion engine (3 638 km/l).

2. The Solar Event Challenge

The Solar Event Challenge occurs in Chambéry (Savoie) from the 27th to the 29th of June 2008. It is part of a bigger event as, during these days, exhibitions and activities about the solar power are held there. As the Shell Eco Marathon, the competitors come mostly from schools or universities.

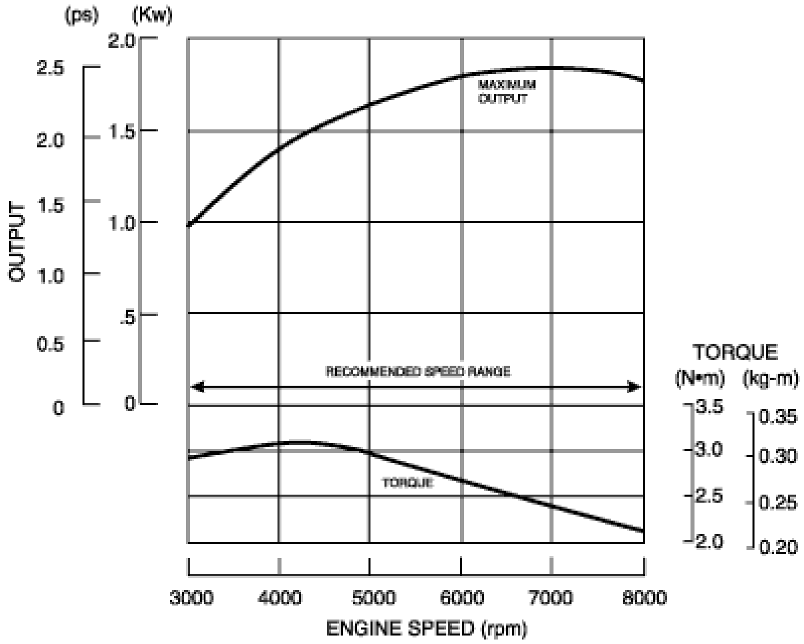
The dozen of cars that will participate will compete on a closed circuit of more than 4 kilometres. The competition will be in several rounds one of which will even happen during the night. At the end of the race, several awards will be bestowed on different references, such as the performance, the technical innovation, the vehicle aesthetic or the dynamism of the teams. A special award will also be bestowed on by the audience.

III. Improvement of the engine

The car I have worked on during my placement is called Carlingue. We were 13 French students from different universities to work on it. The team had to design and then create it in 13 weeks, as it would participate to the Solar Event Challenge and then the Shell Eco Marathon in Rockingham. So we had to deal with an electrical engine with batteries and a thermal engine. Smaller internal teams were created, according to our knowledge and our interest, so that each one could work on a special part of the car. I decided to work on the thermal engine of the car.

1. <u>The Engine Honda GX31</u>

The engine chosen for the car is a Honda GX-31. It is one of the most used engines for Shell Eco Marathon cars, as it is small, light and doesn't consume lots of fuel.
Here are its Output and Torque graph and its characteristics:



Stroke 39 mm
Bore 26 mm
Maximum Output 1.1 kW at 7000 rpm
Maximum Torque 1.64 Nm at 4500 rpm
Maximum speed 10 000 rpm
Consumption 340 g/kWh
Weight 3.4 kg

The engine was almost assembled but it needed improvements to reduce its consumption.

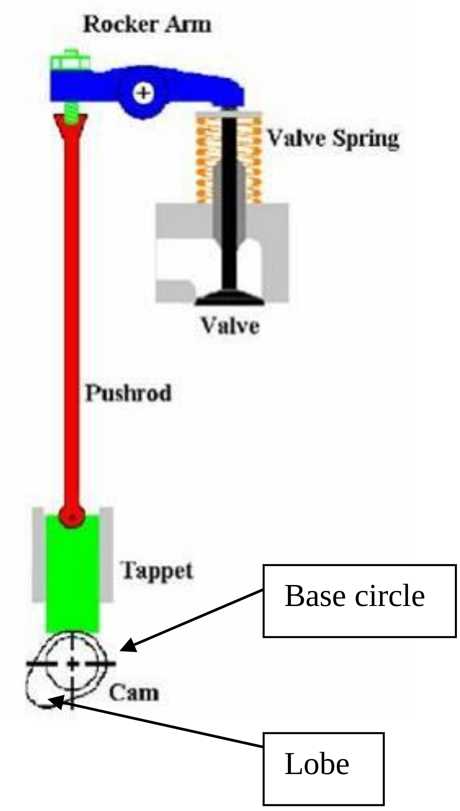
Two students had already worked on how to improve the engine, few months ago but only in theory. They underlined that its performances could be improved and its consumption decreased by increasing the compression ratio, improving the valve timing, replacing the one cam by two cams, improving the exhaust part and replacing the carburettor by an injector.

We used their work and we shared out the different points on which we had to work for the improvement. I chose to work on the creation of the two new cams and the timing of valves opening and closing as I found it more interesting and it was an entire project from the design to the manufacture of the cams.

2. The valves opening and closing mechanism

In most of the combustion engines, the mixture of fresh air and fuel is let in the cylinder by a valve which is opened and closed by a rotation cam.

The cam is composed of two main parts: the base circle and the lobe. The base circle is the part of the cam where the valves are totally closed. The lobe composed of the opening and closing sides enabled the valve to be lifted and pushed down.



The system of distribution is composed of the cam, a pushrod or follower, a rocker arm, a spring and the valve.

The pushrod is lifted by the lobe of the cam and via the rocker arm, it pushes down the valve that is opened. The air and fuel can now fill the cylinder.

Then, as the cam continues its rotation, the follower arrives on the closing side. The follower is taken down and the spring closes the valve. The same process is used for the opening and the closing of the two valves.

In fact, the rotation movement of the cam is transformed into a translation movement for the opening and closing of the valve. Usually, each valve has its own cam that opens and closes it.

The particularity of the GX-31 engine is that there is only one cam which opens and closes the two valves.

You can find a view realised on SolidWorks of the engine on additional 1.

To optimize the filling of the cylinder and thus reduce the consumption, we needed to replace the one cam by two cams. Each valve would be opened and closed with different angles, with its own cam that will be designed specifically. This is one of the two improvements I had to make on the engine.

The other improvement concerned the time when the valve would be opened and closed.

In fact, the original valve timing was determined for the usual running of the engine that is to say for an engine speed between 3000 and 8000 rpm. We chose a speed engine for our car between 1500 and 2000 rpm. It enables to decrease the consumption of fuel and as the speed of the car during the race would be about 30 km/h, we needn't a high speed engine. So it was necessary to change the opening and closing timing of the valves so that it fitted for our specific driven conditions.

3. The opening and closing valve angles

To be able to find the best angles to open and close the valve of the engine, I first made researches on library books and internet websites to find what were the effect of an advance or a delay in opening and closing the valves. I also tried to find some orders of magnitude for the angles to be able to fix my angles.

The values I give below come from *Internal Combustion Engine Fundamentals* by John B. HEYWOOD. I also searched these values on websites, to verify their concordance.

The inlet valve should be opened before the Top Dead Centre (or TDC which means the maximum point where the piston can be during its movement). It permits to optimize the filling of the cylinder volume. In fact, the mix of air and fuel has inertia that prevents to make them moving easily. So, as we open with advance, we have more time to fill the cylinder and make up for the inertia of the gases. Nevertheless, the inlet valve doesn't have to be opened too early; otherwise, fresh air can go directly to the exhaust part. It should be between 10 and 25 degrees before TDC.

Then, the inlet valve has to be closed with a delay, after the Bottom Dead Centre (BDC, where the piston is at its minimum position). Thus, we take advantages of the inertia of the gases as they continue to fill the cylinder while the piston is going to the TDC and we close the valve later. This delay also improves the filling of the volume.
It should be between 40 to 60 degrees after BDC.

For the exhaust valve, we also use an advanced opening to avoid the strong back pressure of the exhaust gases on the piston when this one goes from the BDC to the TDC and to make easier the draining of the exhaust gases. This advanced doesn't have to be too early because it would decrease the power stroke. It should be between 50 and 60 degrees before BDC.

Finally, the exhaust valve is closed with a delay after the TDC, in order to optimize the draining of the burnt gases. Once again, we take advantages of the inertia of the exhaust gases to empty out the cylinder. This delay should be between 8 and 20 degrees after TDC.

Another timing we have to take into account is the overlap, which means when the inlet and exhaust valves are both opened. When it enters the cylinder, the fresh mix has a more important velocity than the exhaust gases. By having opened the two valves at the same time, we use this difference of velocity so that the fresh air chases out the exhaust gases.

Moreover, when the exhaust gases are sucked up by the opened exhaust, a depression is create in the cylinder. Opening the inlet valve while the exhaust gases are chases out, enabled us to use this depression to suck up the fresh air and fuel and optimize the filling of the cylinder. But we have to be careful with the backflows, as the exhaust gases can also go in the inlet part at a low speed engine. The overlap should be between 30 and 40 degrees.

The inlet and exhaust total opening (to say advanced opening + 180 + delayed closing) should be between 220 and 240 degrees.

4. The Degreeing of the cam

After having found these values, I decided to measure the original angles of the engine, with the one cam. This activity is called "Degreeing a cam"

I fixed a degree wheel on the crankshaft and a dial indicator with a magnetic base on the top of the valve to be able to find the exact moment when the valve began to lift. Then I searched when the Top Dead Center of the piston was by using a shaft in the hold of the spark. When I found when the piston was the higher, I marked the TDC and the BDC (which is 180 degree far from the TDC) on the wheel. The, I turned the crankshaft by hand and stopped every time the inlet valve began to open or to close. Then I do the same for the exhaust valve.

On additional 2, you can find the original valve timing diagram of the engine I have drawn.

According that the engine speed will be low (1500-1800 rpm), I chose these angle values:

Inlet valve opening: 15 degrees before TDC
Inlet valve closing: 47 degrees after BDC
Exhaust valve opening: 55 degrees before BDC
Exhaust valve closing: 12 degrees after TDC
Overlap: 27 degrees

Total inlet opening: 15 + 180 + 47 = 242 degrees
Total exhaust opening: 55 + 180 + 12 = 247 degrees

Additional 3 represents the valve timing diagram I chose for the improvement of the engine.

Now that I had established the values I wanted to give for the opening and closing of the two valves, I had to deal with the conception of the cam which will open the valves at the good timing.

5. The design and creation of the cam

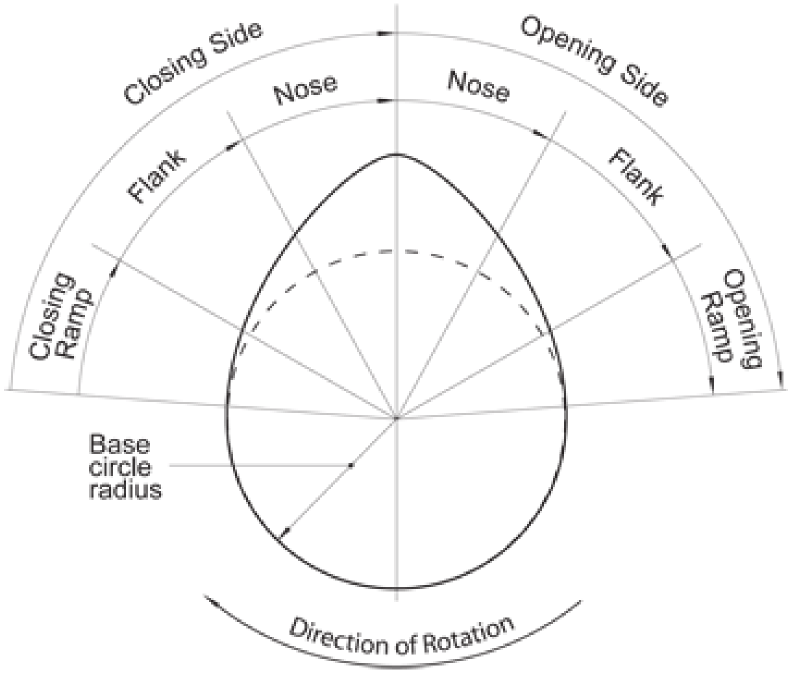
Now we will examine more precisely the several parts composing the cam that enable the valve to be opened and closed. To be able to have the chosen angles, I had to determine the importance of each part of the cam on term of angles.

The base circle represents the time when the valve is closed. This value should be between 140 and 160 degrees of the cam angle.

The ramp (30 to 40 degrees) is the section of the cam from the base circle to where the valve physically begins to open or finishes closing.

The flank (60 to 70 degrees) is from the end of the ramp section to the point where the valve reaches maximum velocity.

Finally, the nose (40 to 20 degrees) is the section of the cam between the maximum velocity on the opening side and on the closed side.



The cam design has to be determined precisely to maximize the way of the fresh and exhaust gases and to avoid problems with too fast valve opening or closing.

First, I had to calculate the maximum lift of each valve. I measure the original valve lift which was 2.67 mm.

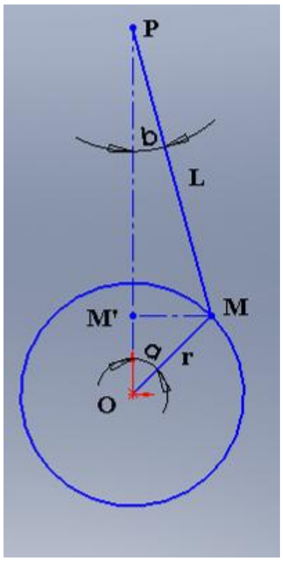
Then, I found three ways of calculating the best valve lift. It could be the 12% of the cylinder bore or the valve diameter divided by 4 or 23% of the valve diameter. For the two valves I calculate the different lifts and I chose the more important value, that is to say 3.12 mm.

That gave me the maximum surface through which the air will flow:

For the inlet valve: $S_{max} = \pi \times D \times L = \pi \times 12.1 \times 3.12 = 118.6\ mm^2$
For the exhaust valve: $S_{max} = \pi \times D \times L = \pi \times 10 \times 3.12 = 98\ mm^2$

The valve lift and the piston motion are linked, as the opening and the closing of the valve depend on the position of the piston and the lift acceleration depends on the one of the piston. So I had to determine the equation of the motion, the velocity and the acceleration of the piston. Here is the reasoning I used to work out the equations.

OP = OM + M'P
OP = r cos(a) + L cos(b)



Now sin (b) = MM'/L And sin (a) = MM'/r
So L sin (b) = r sin (a)
Sin(b) = r sin(a) / L
Now cos(b) = (1-sin²(b))^(1/2) = (1- r²sin²(a)/L²)^(1/2)

0,1 < r/L < 0,2 for most of the engines So $r^2\sin^2(a)/L^2 < 1$
So with the mathematical limited development,
$(1 - r^2\sin^2(a)/L^2)^{1/2} \approx 1 - r^2\sin^2(a)/(2L^2)$

That means $OP = r\cos(a) + L\,(1 - r^2\sin^2(a)/(2L^2))$

We have to use the derivative to determine the speed and acceleration equations.
We establish that w = a/t so a = w t with w = 1800 * 2p/60= 188.5 rad/sec

Velocity: $dOP/dt = -r\,w\,\sin(wt) - r^2/2L \times 2\sin(wt) \times w\cos(wt)$

Now $2\sin(wt) \times \cos(wt) = \sin(2wt)$
So $dOP/dt = -r\,w\,\sin(wt) - r^2 w/2L \times \sin(2wt)$

Acceleration: $d^2OP/dt^2 = -rw^2 \times \cos(wt) - r^2 w \times 2w/2L \times \cos(2wt)$
So $d^2OP/dt^2 = -rw^2 \times (\cos(wt) + r/L \times \cos(2wt))$

The graphs of the piston motion, velocity and acceleration are given on <u>additional 4</u>.

Now that the velocity and the acceleration of the piston had been determined, I could find the characteristic of the opening and the closing of the valve.
First, I could check that the piston wouldn't hit the valve if it was opened when the piston was at the top dead centre. The maximum opening is 3.12 mm for the valve and there will always be 4.52 mm of clearance between the head of the piston and the bottom of the valve.
Then, as I know that the valve has to be opened 15 degrees before the top dead centre, I could draw the graph of the rising.

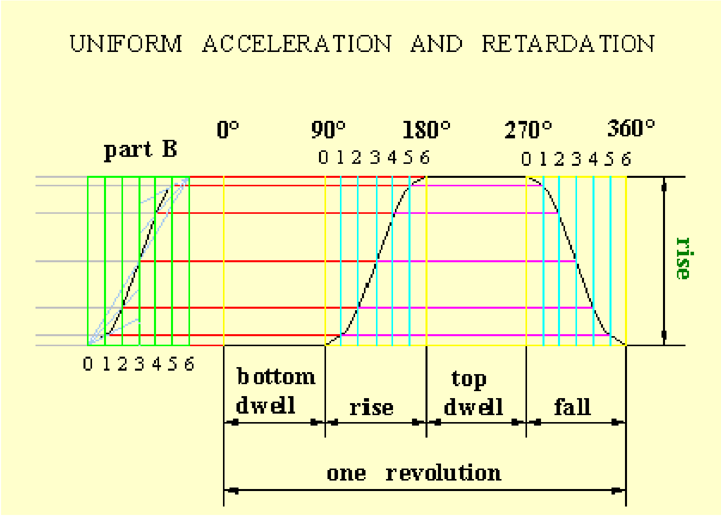
From a website and with the book *Internal Combustion Engine Fundamentals* John B. HEYWOOD, I found an equation that could represent the rising and the fallen of the valves.

$$Lv(\theta) = \frac{1}{2} Lv_{max}\left[1 + \tanh\left(\frac{\theta + AO}{pente}\right)\tanh\left(\frac{180 - \theta + RF}{pente}\right)\right]$$

with Lv_{max} : the maximum valve lift : 3.12 mm
AO : advance opening : 15 degrees
RF : delay closing : 47 degrees
Pente : velocity of the opening and closing that depend on the velocity of the piston.
Need 15 degrees to open to 3.12 mm so v = 3.12 / 15 = 0.208 mm/ ° crankshaft

On additional 5, you can find the graph representing the valve motion that need to be adjusting with our valve timing.

Knowing the valve motion, I could create the graph of the cam like the graph below.
This graph is composed of the rise of the valve. Then the top dwell which represents the time when the valve stays totally opened. Next, the fall, when the valve is closed and finally the bottom dwell, when the valve stays closed.



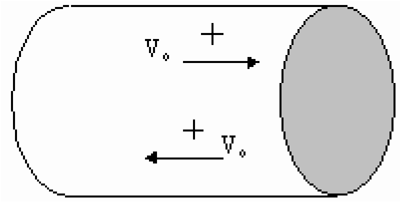
Unfortunately, I didn't have enough time to result in the conception of the cams. But these studies I made could be used as foundations for the next who will work on the complete realisation of the car.

6. The acoustic supercharging

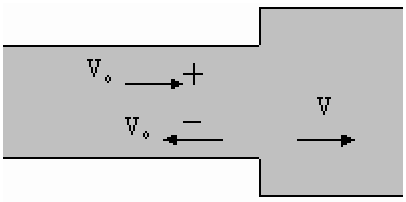
As the Shell eco marathon rules forbid us to use mechanical supercharging to increase the output of the engine, we had to look for another way to improve the compression ratio. One solution could be found with the acoustic supercharging on the inlet pipe.

The principle of the acoustic supercharging is that in the inlet part, the flow is unstable. The result is the creation of a vibration phenomenon of the gases in the pipe and this influences a lot the filling of the cylinder. Thus, at the end of the inlet phase, while the gases are arriving with an important velocity, the inlet valve is violently closed. A phenomenon of compression is created nearby the valve. This generates a wave of pressure that goes up in the inlet pipe, form the valve to the end of the pipe.

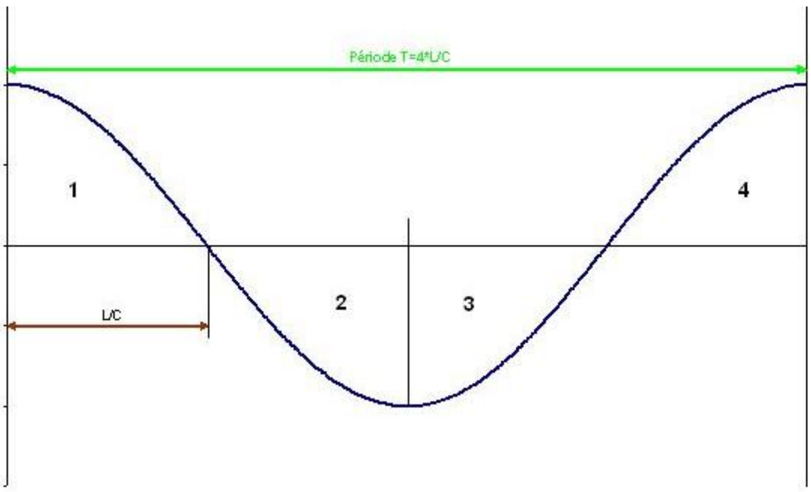
The particularity of a wave of pressure (+) is that if it hits a piece of closed pipe or a narrowing section, it bounces and goes back on the other direction but it is still a pressure wave (+).



On the opposite, if it hits a section enlargement, it goes back on the other direction but becoming a vacuum wave (-) and another part of the gases continues on the same direction.



In our case, it is this last phenomenon that occurs: the pressure wave (1) arriving at the end of the pipe becomes a vacuum wave (2) that goes back to the valve. Then it is the first case: the vacuum wave hits the valve and goes back to the end of the pipe, as still a vacuum wave (3). And then it comes back to the valve but this time it is a pressure wave (4).



At that time, it is interesting to open the valve to take advantages of the pressure wave arriving to improve the filling of the cylinder. The graph on the previous page shows the evolution of the pressure in the inlet pipe function of time.

As we can see, the wave covers four times the inlet pipe before being a pressure wave. So the valve should be opened with a frequency equal to the time the wave makes to cover four times the pipe. But as the valve timing can't be changed because it has been chosen to optimize the cylinder filling, we have to change the length of the pipe. To be able to find the best length, I needed to calculate the wave length (λ) of the wave created in the pipe.

$$\lambda = v / f$$

with c: gases velocity (m/s)

f: frequency (s^{-1}) = RPM/60

<u>Calculation of the velocity of the gases:</u>

V_{piston} x bore ² = V_{gases} x radius ²

so V_{gases} = V_{piston} x bore ²/ radius ²

with : radius = 12,1 / 2 = 6,05 mm

bore = 26 mm

V_{piston} = RPM x 2 x stroke

Stroke = 39 mm

At 1500 RPM : V_{piston} = 1500 x 2 x 39 x 10^{-3} / 60 = 1,95 m/s

At 1800 RPM : V_{piston} = 1800 x 2 x 39 x 10^{-3} / 60 = 2,34 m/s

At 2000 RPM : V_{piston} = 2000 x 2 x 39 x 10^{-3} / 60 = 2,6 m/s

So $V_{gases} = V_{piston} \times (26 \times 10^{-3})^2 / (6,05 \times 10^{-3})^2$

At 1500 RPM : V_{gases} = 36,01 m/s So l = 1,44 m

At 1800 RPM : V_{gases} = 43,22 m/s So l = 1,44 m

At 2000 RPM : V_{gases} = 48,02 m/s So l = 1,44 m

We use the quarter of wave length, so it means that we need an inlet pipe of 0,36 m.

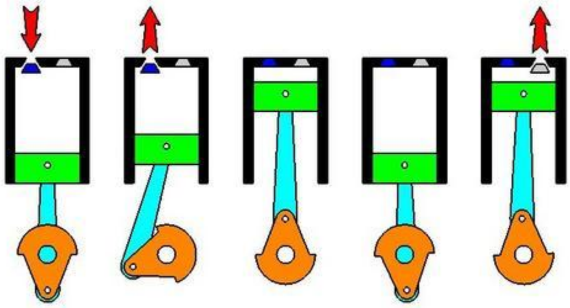
Another way we thought about to improve the pressure in the cylinder was the Atkinson cycle.

7. The Atkinson cycle

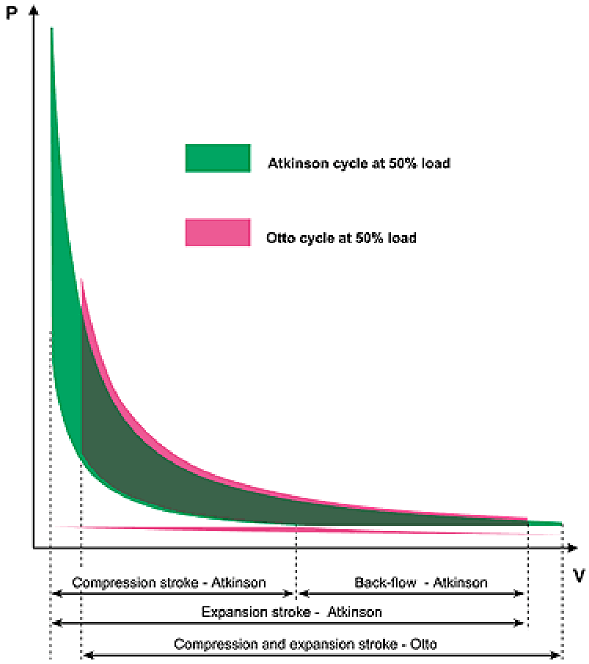
The transformation of the engine from the Otto cycle to the Atkinson cycle can be made easily. The interest of this cycle is to have a compression ration smaller than the expansion ratio.

The admission and exhaust stroke are the same as the Otto cycle.

During the compression stroke, the inlet valve is held opened longer than with the Otto cycle.



So the fresh air escapes the cylinder and goes into the intake manifold rather than being compressed when the piston is going from the BDC to the TDC. As a part of the mixture has been repressed, only a fraction of the air is compressed when the inlet valve is closed. The air volume is expanded beyond the volume when compression began. So we obtained a reduced compression while the expansion stroke stays unchanged. It allows more energy converted from heat to useful mechanical energy. The engine is so more efficient.



Nevertheless, the Atkinson cycle reduces power density compared to the Otto cycle. Indeed, a Atkinson cycle engine doesn't take as much air as it would be with a similar Otto cycle engine. Others four stroke engines, named Miller cycle engines, use this type of intake valve motion but with supercharging in addition. This cycle could be used for our engine if it is easily applicable and does not require too important changes on the engine.

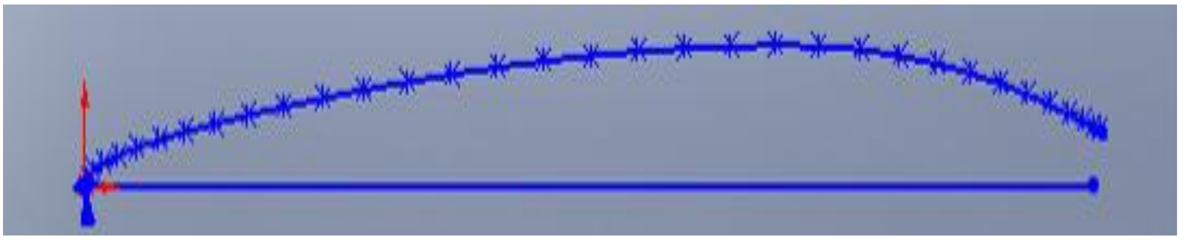
IV. The profile of the Shell eco Marathon car and the vélo couché

During my placement, I have been given a two-week project. We were a team of three persons and we had to manufacture two scaled-down mocks-up of the body of the Shell Eco Marathon prototype and the velo couche.

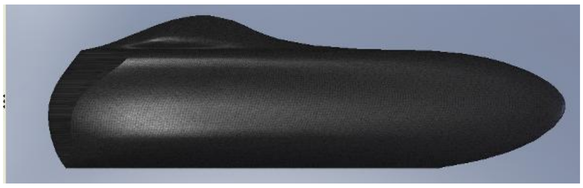
First, we had to find the best streamlined profile, for which the drag coefficient would be the less important, to limit the friction. We used Airfoils, a software that calculates the drag and lift coefficients and the transition-turbulent points of profiles, functions of the vehicle speed, the altitude, the attack angle. We wanted the transition and turbulent point at the same place and the farthest possible on the profile, so that the turbulences don't perturb the vehicle. You can find two screenshots of the profiles on Airfoils on additional 8

Our theoretical results were $C_{lift} = 0$ and $C_{drag} = 0{,}004$ for the body of the Shell Eco Marathon car.

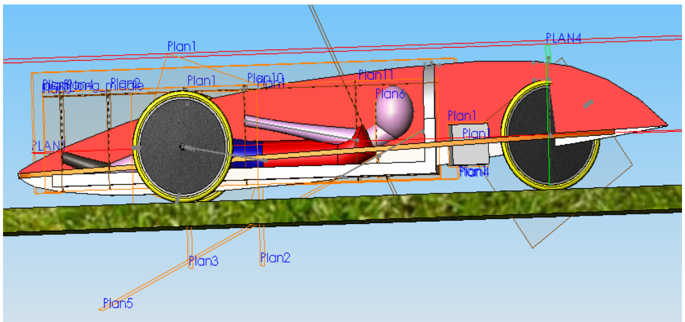
After having found the best shape, we used SolidWorks, a software on which we imported the profile found and then we could draw the body in three dimensions.



Streamlined profile of the Shell Eco marathon body

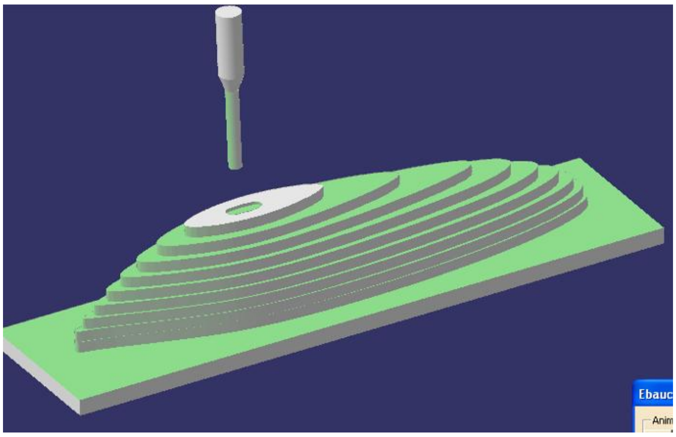


Drawing on Solidwork of the recumbent bike body



Drawing on Solidwork of the Shell Eco marathon body

Then, when the body was completely drawn, a manufacturing program was written to be able to machine it on the CNC (computer numerical control) machine. The coordinates of the origin point, the manufacturing speed were entered on the computer. On the drawings below, you can see a simulation of the manufacture done by the CNC machine which machines only on 180 degrees. So we made the first half and then the other.



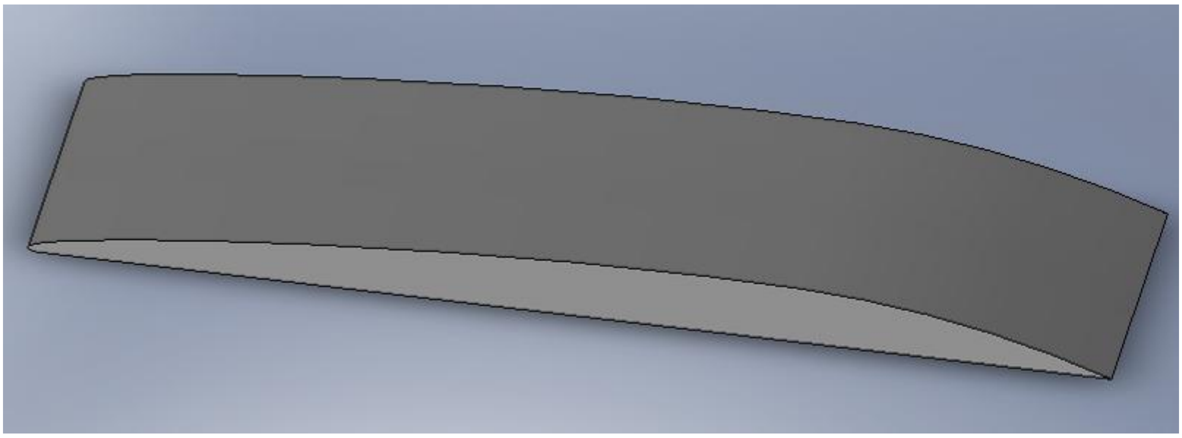
The Computer Numerical Control Machine

At the end, we had to smooth it with sand paper. We chose to manufacture one of the two mocks-up on balsa, a sort of light wood, and another in form, to compare the two materials. The balsa is easier to manufacture ant to sand at the end while the form cannot be very smooth.

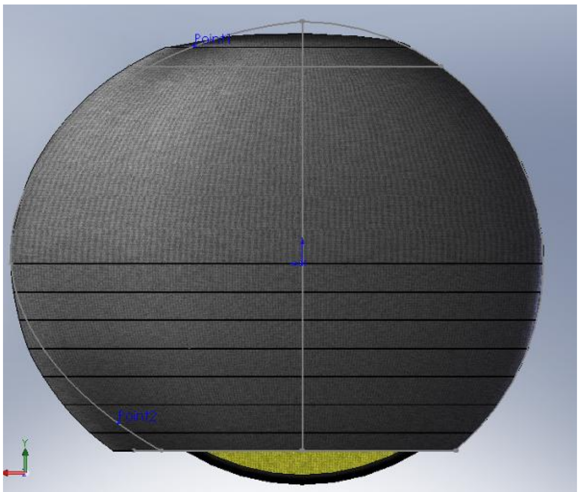
The balsa mock-up of the recumbent bike body

The solar panels,
the mock-up of the Shell Eco marathon body
and below the one of the recumbent bike body.

We also manufactured the solar panels and the wheel as we thought they are part of the prototype and they would have effect on the streamlined shape. We used aluminium foils to simulate the solar cells.



The shape of the solar panels



I specially worked on the profile of the wheel streamlined body. First, we found a good profile on Airfoils. Then, I used the wheel drawn on SolidWorks and I created the streamlined body around the wheel, with the profile imported.

This 2-week-project was very interesting. First, it enabled me to learn how to use SolidWorks, the design software. It was very difficult to use it on my own as I haven’t worked on it before. But as I had to search alone, I learned more things than if I had done with somebody who would have told me what to do.

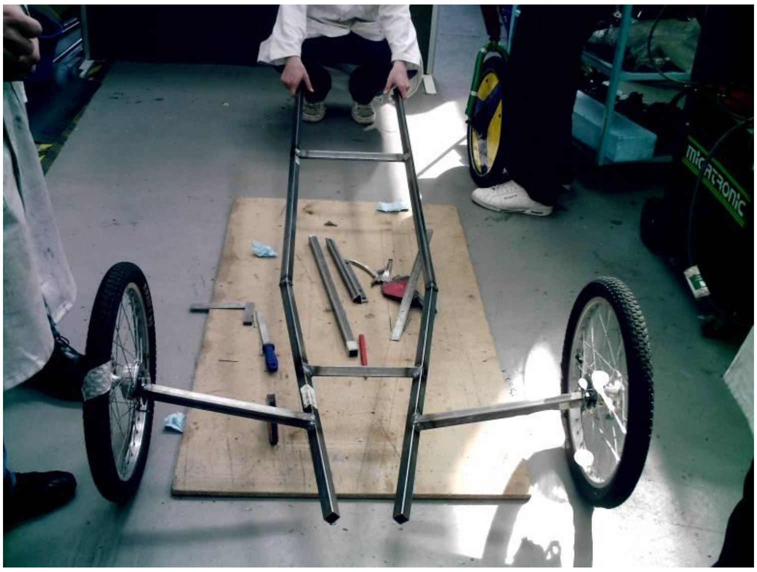
This project also enabled me to work on a new way. As we had only few days to create the two mocks-up, we couldn’t spend lots of time in thinking on how we would do this or searching the best way to do something. We had to make decisions quickly and while some were making the conception of a part of the mock-up on the computer, the others were manufacturing those that were already done.

V. The manufacture of some parts of the chassis

1. The shaft of the axis of the wheels

With a team of two people, I was in charge of the conception and realisation of the axis of the front wheels of the car. We had to deal with the problem that the centre of the wheels was not at the same level as the chassis.

We thought of several solutions to be able to have a solid fixation of the wheels. We manufactured two steel bar and then we had to fix it so that the chassis could be at the good height, that is to say 15 cm by the wheels. We used square pieces of steel to screw and weld the axis on the wheels.
Before welding the axis on the chassis and the wheels, we had to check that the axis had the good angles.



The chassis of the Shell Eco Marathon car with the wheels

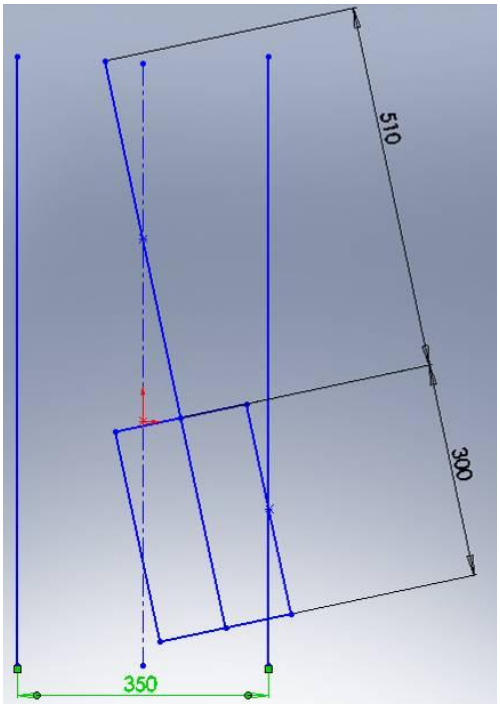
First we had to deal with the good inclination angle of the axis, that is to say 9 degrees.
Then, we had to check the wheels would be parallel together and with the chassis.
It was difficult to check all these angles because every time we changed one, the other changed also. We finally managed to put everything correctly and weld it.

2. <u>The engines support</u>

After the wheels axis, we had to think about how the two engines (the electrical and the thermal ones) and the batteries would be put on the chassis, knowing that the two engines had to be fixed on the fork of the rear wheel to make the transmission easier.

a. The Thermal engine support

The problem we encountered was that the wheel revolves of 12 degrees on its axis so we had to be careful that this support wouldn't hurt the chassis. From the rear of the wheel to the piece that will separate the engine from the pilot, we had 300 mm and the chassis measured 350 mm. As you can see on the drawing opposite, if we had made a support of these dimensions, it would have been too big and hurt the chassis when the wheel would have turned.



First, we thought about making the support smaller on the length but with the same width. Another solution was making it as long as possible but reducing the wide. You can see the two solutions <u>on additional 6.</u>
Finally we chose to make a mix of the two solutions so that the support could be as big as possible (<u>additional 7</u>).

Another solution was to use the support for the test of the engine already made. We could sawed it at the good length and then screw and weld it on the horizontal fork.

b. The electrical engine and batteries support

Then, we decided to deal with the support for the electrical engine and the batteries.
I was in charged of the fixation of the three batteries on the chassis.

At the beginning, we wanted to distribute the batteries on a bar fixed on the chassis, two on top of the bar and the other underneath it.
But finally, it was decided to create a support, still fixed on a bar, but with small pieces of steel to avoid the batteries to move during the race. We sawed the bars at the good length and then we welded them.

This work on the chassis enabled me to do something different from the theoretical researches on computer or calculate. We had concrete problems to solve (the arrangement for the batteries, the incline of the wheels . . .) and we had to find several solutions that we tested and improved every time it didn't work. I could use tools and realise something that was material that we could touch.

VI. Placement assessment and prospects

Here is a comparative table of my projected planning and the real planning I did.

Week	Projected	real
07-April 13-April	Understand the running of the cam-valve system	Researches on valve timing
14-April 20-April		Researches on acoustic supercharging and Atkinson cycle Choice of the angles
21-April 27-April	Find the best angles for the opening and shutting of the valves	Researches on the cams
28-April 04-May		Mocks-up project
05-May 11-May	Find the best profile for the cam, fitting with the valve timing chosen	
12-May 18-May	Manufacture of the cam	Measurement of the original valve timing Piston motion
19-May 25-May	Implement the cam on the engine and check the valve timing is correct	Valve motion
26-May 1-June		Work on the chassis
2-June 8-June		
9-June 13-June	Adjust the implement	Placement Report Placement Presentation

As you can see on the table, I didn’t manage to respect my projected planning.

First, I had few-week projects during my placement that I didn’t expected.
I was asked to create two mocks-up of the body of the Shell Eco Marathon car and of the recumbent bike that took me two weeks.
Then, I participated in the manufacture of the chassis of the Shell Eco Marathon car.
During these projects, I couldn’t continue my main project.

Moreover, I didn’t respect the periods I expected because they were not suitable for my project. I spent more time for having information about the running of the valves and cams system and to determine the cam profile than I thought.

Nevertheless, these studies on the cam and the valve timing could be on the future used to improve in concrete terms the engine so that it consumes the minimum of fuel.

The graph of the cam needs to be determined, using the valve motion and the valve timing established. Then, the cam should be drawn on SolidWorks and finally manufactured on the CNC machine.

The followers should also be re manufactured to fit best to the new cams realised.

Conclusion

During this ten-week placement abroad, at NEWI, I completed a project which I found very interesting. During the first few weeks, it was difficult to begin because I needed lots of information about the system valve-cam and I needed the help of my supervisors, then, little by little, I began to work on an autonomous way. The autonomy and freedom we were given enabled me to gain more self-confidence and to make decisions alone.

Concerning my work, the valve timing is determined and although the cams have not been manufactured yet, their characteristics are almost specified. I hope my work will allow other students to continue and finish the cams.

The small projects, that is to say the mocks up of the bodies and the realisation of parts of the chassis of the car, enabled me to do something different from the research on books and websites that I had been doing. I could discover the different steps to make streamlined bodies and I could manufacture pieces.

During this placement, I could use knowledge I gained on Thermal machines about the running of the engine. Even if my knowledge on the specific subject of the distribution system was not enough, I nevertheless have the basis on the global engine running that helped me to understand what the other members of the team were doing. My mathematical knowledge was also useful, when I had to determine the motion of the piston and used cosinus and sinus formula.

It was an enriching human experience as I associated with people from several different regions and I worked in a team of 13 people. There was a good atmosphere; we had several meetings to know what the others members were doing as our subjects were linked. For example, the exhaust valve timing was necessary to determine the length of the exhaust pipe.

Another great experience was to live and did this placement abroad. I could discover the Welsh culture. I visited several cities (Liverpool, Chester, London) and improved my English speaking and listening on everyday life. I could also gain more technical vocabulary speaking with my supervisors Olivier and Graham.

This project also enabled me to have a first general survey of the research on car industry. As I wanted to work in this field and more especially on the research and development of engines, the work on the improvement of the Shell Eco Marathon engine was a great experience. Moreover, as I am interested in environmentally friendly engines, I could see the different improvements that can help reduce the fuel consumption.

To conclude, this placement abroad was a great experience that I don't regret at all. For me it was a test to see how a placement abroad could be and as it is very conclusive, I hope on my future studies I will be able to repeat this experience for a longer period.

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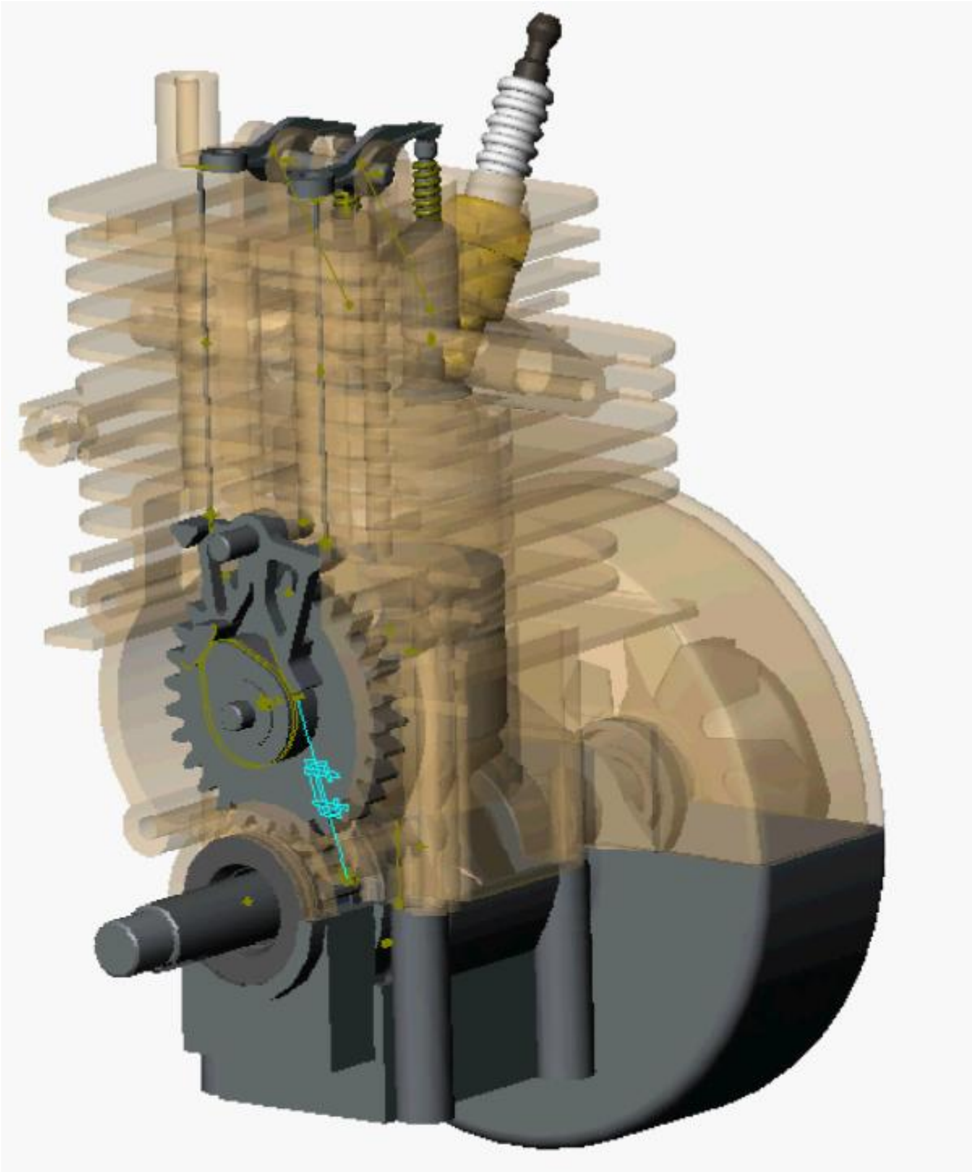
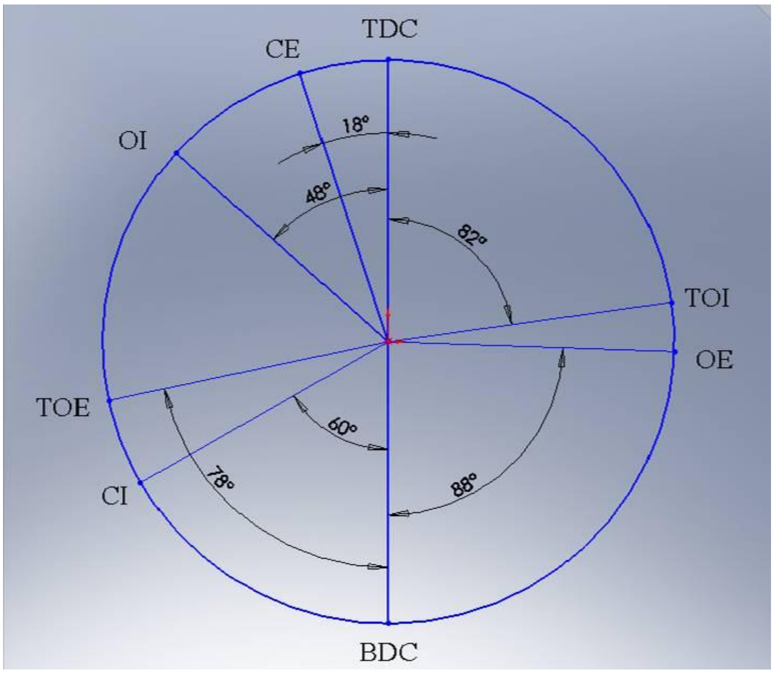
Additional

Additional 1



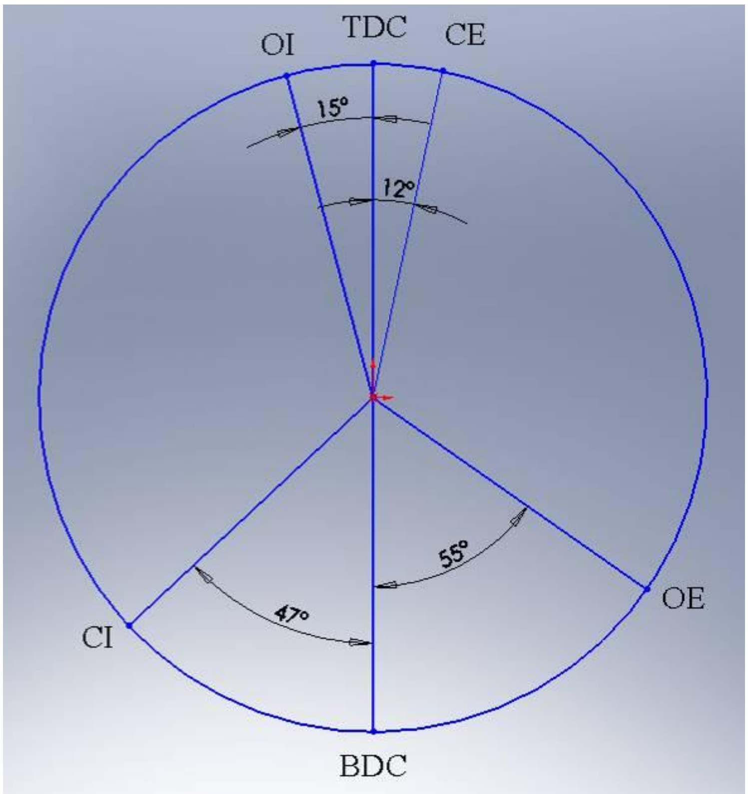
The GX-31 engine

Additional 2



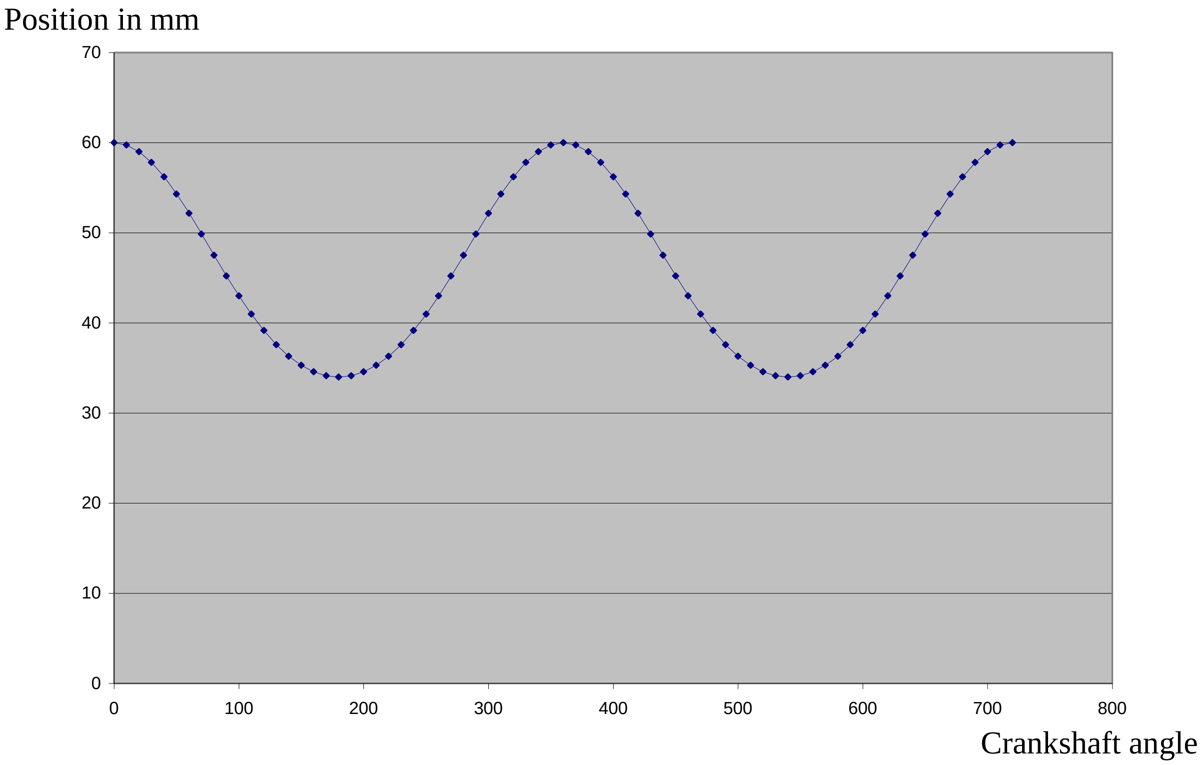
Original valve timing diagram

Additional 3

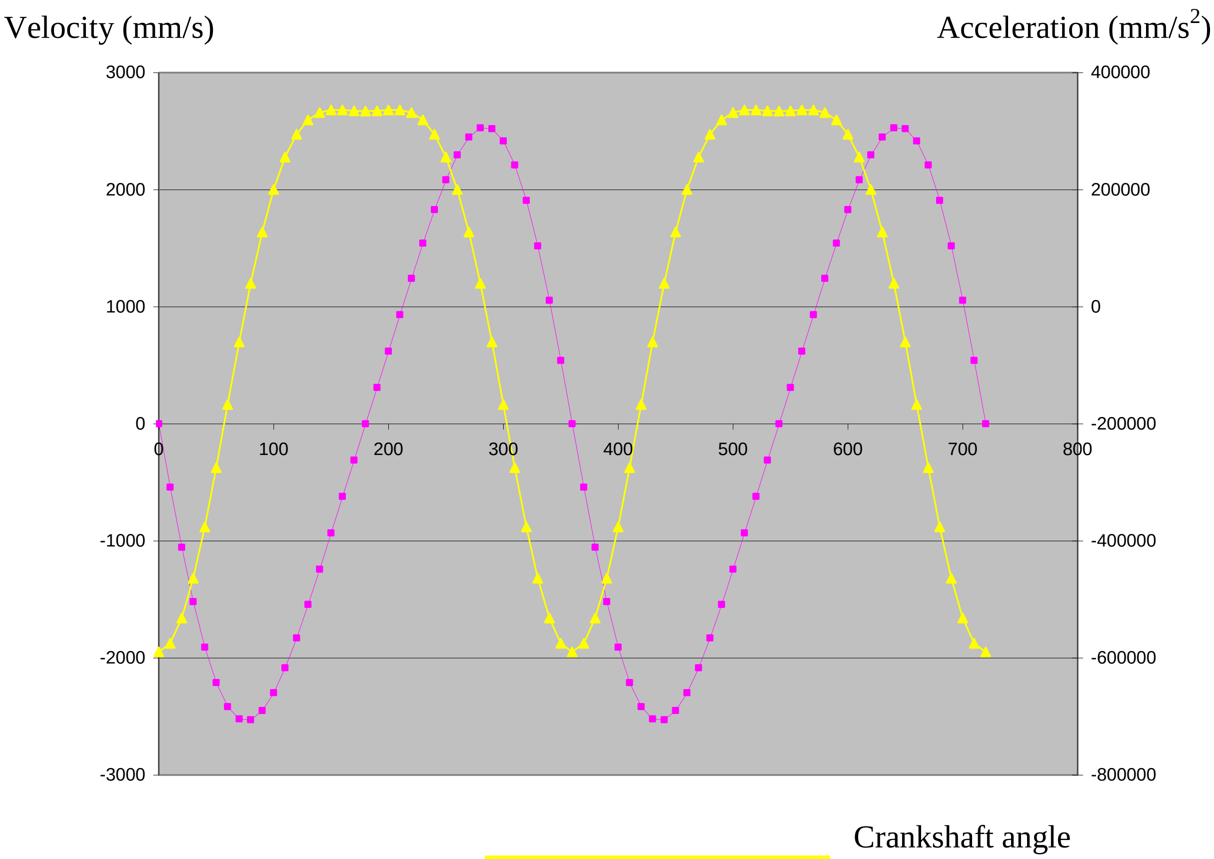


Valve timing diagram chosen

Additional 4



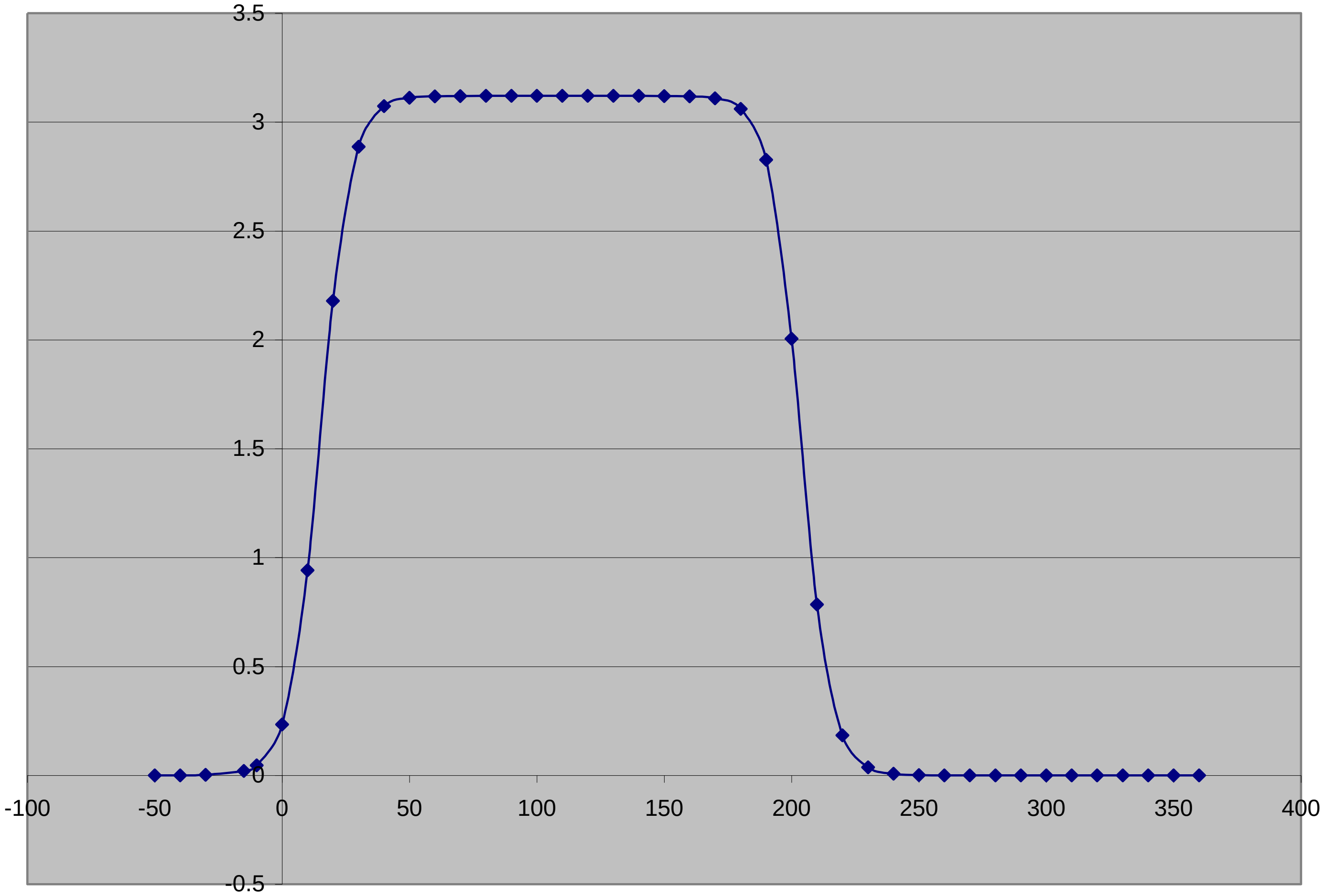
Piston motion



Piston velocity **Piston acceleration**

Additional 5

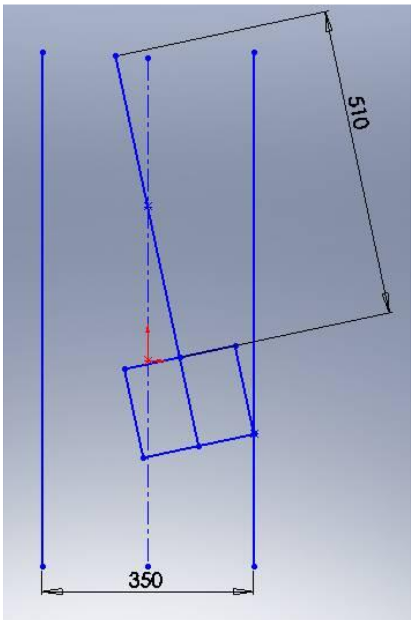
Valve Motion (mm)

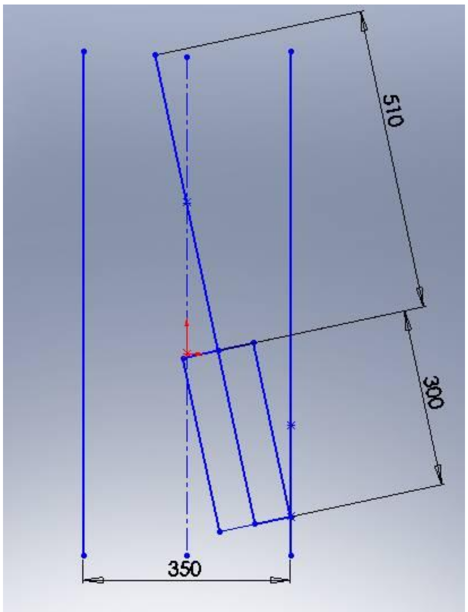


Crankshaft angle (degree)

Valve motion

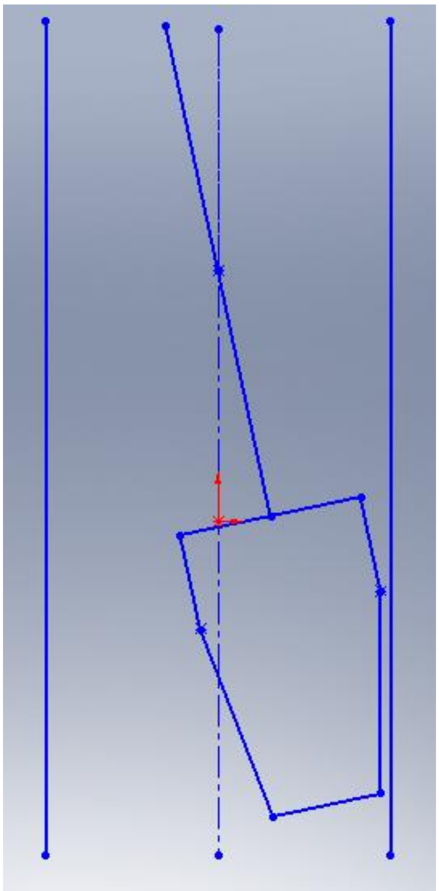
Additional 6





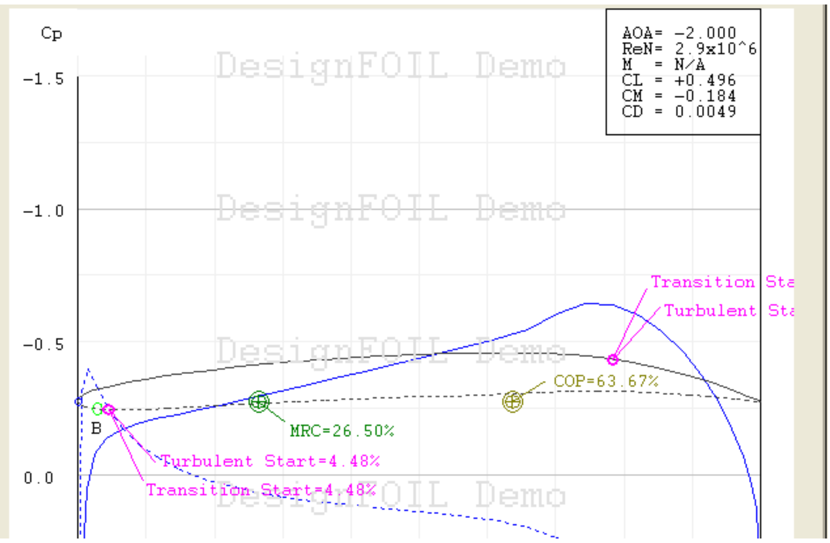
The shape of the thermal engine support

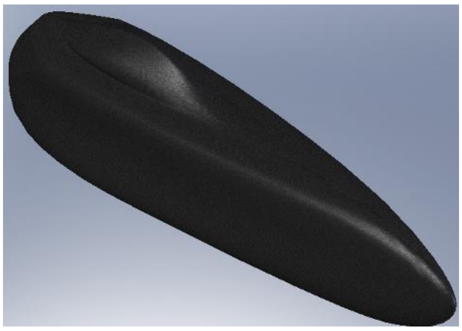
Additional 7



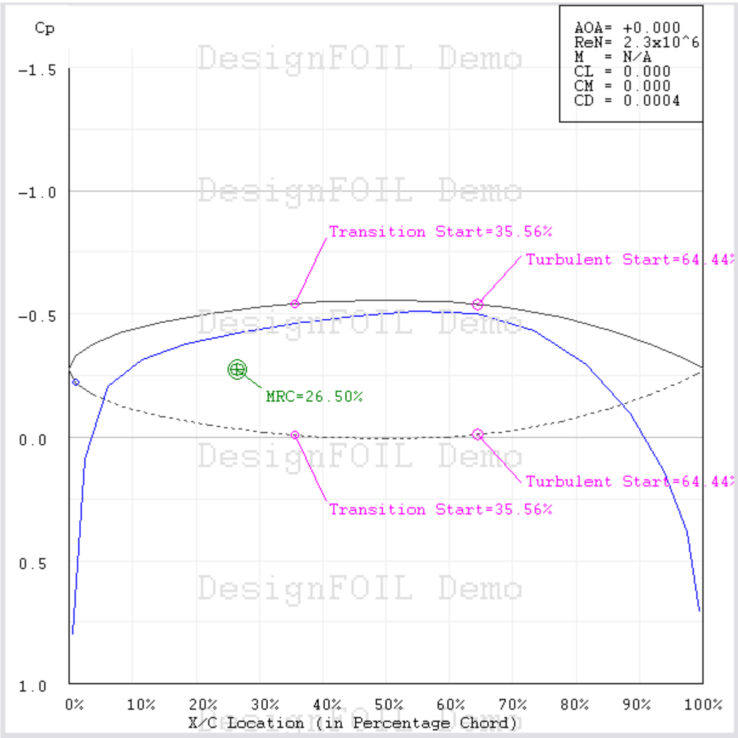
The chosen shape of the thermal engine support

Additional 8





Vélo couché body



Shell Eco Marathon body