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The Electric Endeavour: Engineering formation through SYNECTRIC electric race car development

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Abstract

The Erasmus University College Brussels (EHB) and its partner the Vrije Universiteit Brussel (VUB) constitute the University Association Brussels (UAB), developing a common integrated policy towards the creation of a university space within the capital of Europe. In this framework, the Master degree curricula at EHB, including the industrial engineering curriculum at the IWT department, are now in a phase of academization, which means the introduction of a research-based academic culture necessary to grant academic Master degrees. One of the main challenges with reforming the contemporary higher education landscape remains the transition from traditional ex-cathedra teaching to a more student-centered education sphere focused on the creation of competences. Although the acquisition of a sound theoretical knowledge will always remain the base foundation of the education of the intellectual, the introduction of project-oriented curriculum elements is a key factor in creating a learning environment allowing acquiring and exercising a wide array of skills and competences, including non-cognitive ones, to benefit the industrial and societal deployment of the engineer. The industrial engineer, as formed by EHB in a four year curriculum (three bachelor years and one master year), shall in fact be a polyvalent, operative intellectual, who is able to implement innovative solutions and to solve problems occurring in industrial practice.

The involvement of master students in a multidisciplinary project is a premier occasion to create a learning environment enabling student personal development in such direction, including teamwork dynamics. The choice of an electrically propelled competition vehicle as pedagogical project presents several key benefits. Not only concerns it a subject which greatly appeals to students and which has a large potential for dissemination and student attraction, but it also presents an occasion to enlighten students towards the philosophy of electric transportation which represents the key solution for future sustainable mobility. In urban traffic, due to their beneficial effect on environment, electric vehicles are an important factor for improvement of traffic and more particularly for a healthier living environment. But also when performance is what it is aimed for, electric traction presents substantial environmental and technical benefits compared with legacy technologies. The introduction of this environmental consciousness enhances the curriculum and contributes to the formation of morally and socially responsible industrial engineers, which is a major

benefit for their own personal development as well as for society as a whole.
The current project is aimed at the realization of a hybrid electric formula-type vehicle, based on a "Predator" class car body. This type of vehicle is used for competitions in Italy, albeit with a legacy drive train, and presents a versatile platform to implement new drive train technologies.

Keywords: education, Series HEV, Student Project, Youth

1 Introduction

The design and commissioning of the drive train is performed by a team of master students in the framework of their master proof, including foreign students under the Erasmus international exchange program, with a number of tasks also done by bachelor students within a research project course.
Support from faculty, including both established lecturers and young researchers, allows for an interaction with the acquired scientific experience within the Association and with ongoing research projects being performed in the electric vehicle field.

Papers will report on the technical evolution of the project and of student experience with collaborative project development in a research-oriented environment.

2 Starting up the project

2.1 Hardware

Starting from scratch was no option, so the decision was made to acquire a race car chassis and body. The one chosen was the “Predator Chassis” [1] (Figure 1). The goal then was to incorporate a hybrid drive train into it. Not an obvious task, because the car was meant to be used in car racing with internal combustion engines (ICE). A hybrid alternative would require more space and weight.
The final aim would be to participate with the vehicle in international student competitions such as the Formula ATA in Italy [2], as well as in national dissemination events.

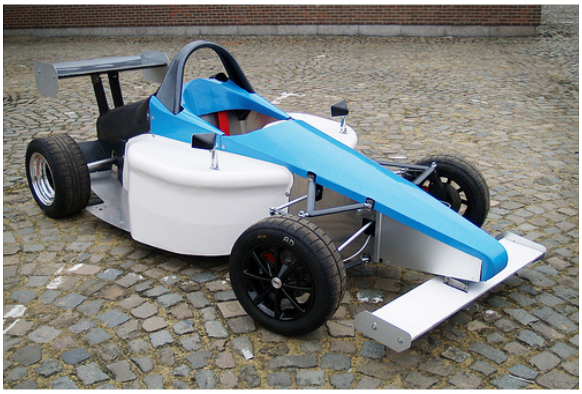


Figure 1: The Predator Chassis [1]

2.2 The birth of a team

To blow life into the Predator chassis we needed human resources. This all is a research project with an educational spin-off.

As stated before we drew up an organigram (figure 2) with faculty members leading and coaching students, each appointed with a specific task.

From the point of view of the formation of Industrial Engineers at the academical level, it was our goal to combine in our work both the team-spirit as well as the taste of doing scientific and technological research, and all this, implanted in the curriculum of their bachelors and masters years, not thereafter, like in some other Colleges.

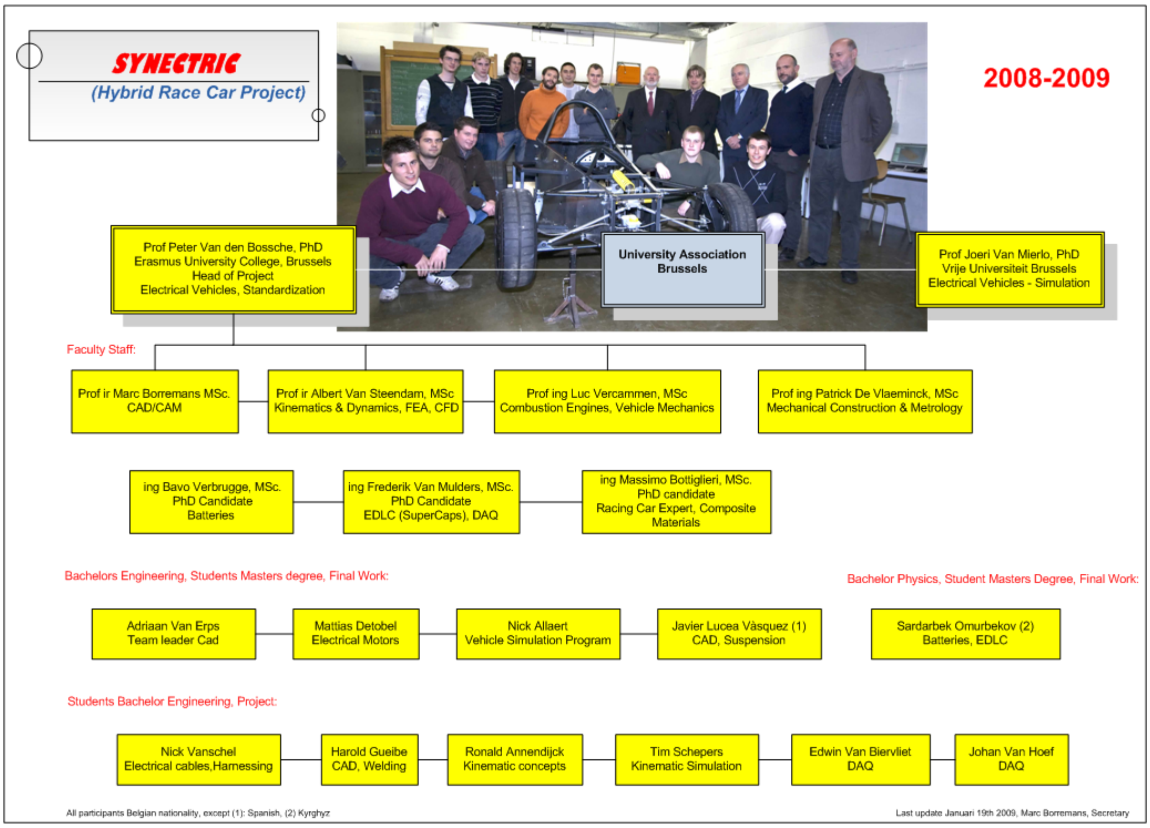


Figure 2: Organigram 2008-2009

2.3 Building up team spirit

A photo shoot was organized to create a real team spirit, where the students could feel their importance in the game; this doesn't seem to mean a lot, but it procures the students the feeling of being related to each other and feeling comfortable with the Faculty Members.

Figure 3: Front: students. Back: Faculty members.

2.4 What's in a name?

It might sound ridiculous but one of the most difficult and controversial problem was to find a name for the project. One can consider this as of no importance, but some people do. Some do because of underlying subconscious reasons, others because of marketing purposes, and finally the ones that won the voting in this case because of scientific reasons. The name that came out by a democratic held voting was "SYNECTRIC", a contraction of the words "SYNERGY" and "ELECTRICITY" (figure 4).

Very important consequence of this 2 month during combat, we could finally set up a website with information about our doings: www.synectric.com. Please pay us a visit, so that we can get a higher hit rate on Google!

Figure 4: The “synectric” website

3. The concept

The project necessitates a multidisciplinary approach addressing the various aspects of the drive train, and focusing on the following components:

- the traction battery and its management system (e.g. state-of-the-art Li-ion battery technology), as primary energy system
- a peak power system (super capacitor based, meaning the Electric Double Layer Capacitors (EDLC)), for efficient energy recuperation and acceleration assistance, including its DC/DC convertor
- a high power electric traction motor (e.g. 40kW peak power) and its converter
- the hybrid Auxiliary Power Unit (APU), meaning an internal combustion engine (ICE), and its generator for a prolonged autonomy
- efficient power electronics to (inter)connect the different electric subsystems as mentioned
- intelligent control strategies for optimal performance or efficiency
- weight and drag reducing measures (e.g. new composite bodywork)

After some “pragmatic” discussion the decision was made to choose the concept of a series hybrid system (figure 5).

4. The Electric Motor

The options to be chosen for each of these subsystems need a systematic approach of information gathering, analysis, appraisal and trade-off. For the traction motor for example, the ease of control and the excellent acceleration torque of the archetypal series motor are being compared with the higher efficiency of the induction motor.
Making a goal-oriented choice of an electric motor means that one has to look at the requirements and the functionality.
Our search led us to the company *Netgain* [3] as being the most suited supplier. Criteria that led to this decision were price, quality, customer friendly attitude, availability and delivery date.
In the perspective of our project, the series motors from Netgain were compared to asynchronous motors from other manufacturers.
The series motor is well renowned for his high initial torque, but a frequency controlled asynchronous motor can do the job as well. Using a frequency control it is possible to glide the torque characteristic to the left, making it possible to obtain high torque values at small rotational speeds. As far as the decrease of the torque with higher speeds is concerned, both the AC and DC motors present the same phenomenon.

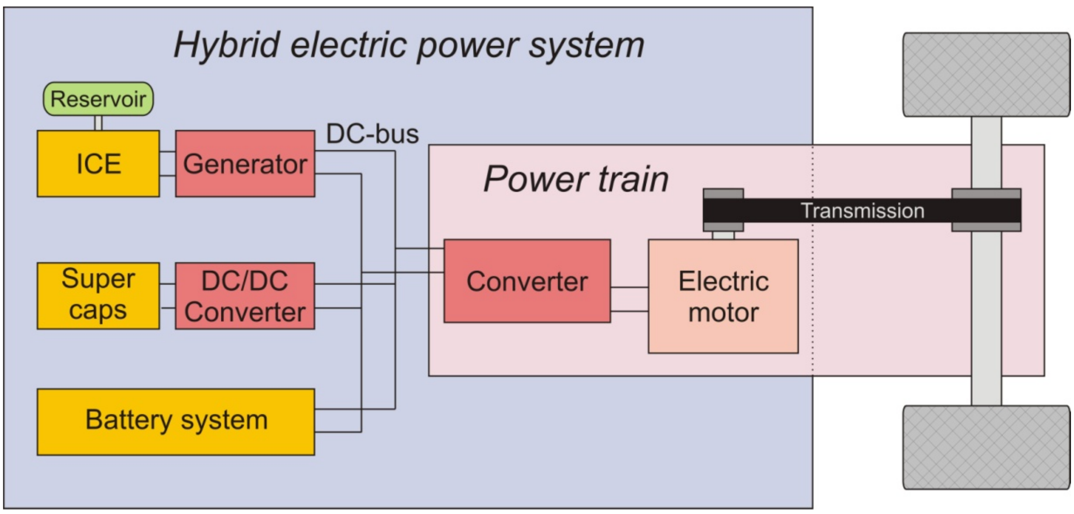


Figure 5: Hybrid drive train

Seen from the constructive aspect both kind of motros seem to be the same, they show a relative easy way of construction. But if we consider the maintenance the AC-motor performs much better (brushless, no commutation…). But these factors do not necessarily are of big importance in a competition.
Looking at the drawings of both kinds of motors another important aspect arises. For the same power the asynchronous motor is bigger than the Netgain series motor. Because of the fact that in our application the compactness of all components plays a determining role (figure 7) the decision was made to go for the *Netgain* Impulse 9 series motor (figure 8).
A side effect of the choice is that the engine control, a DC/DC converter, is of a significant lower price.

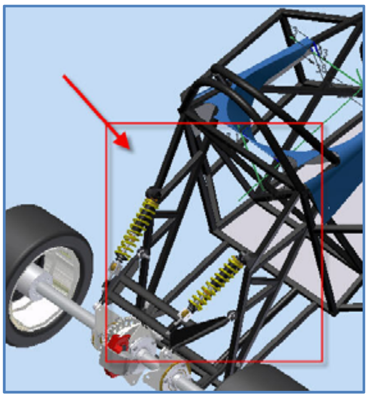


Figure 7: This will become a very crowded space!

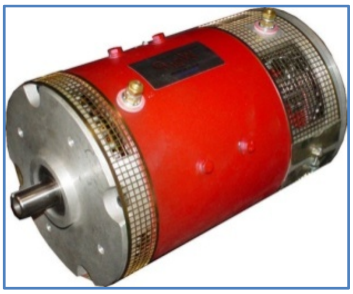


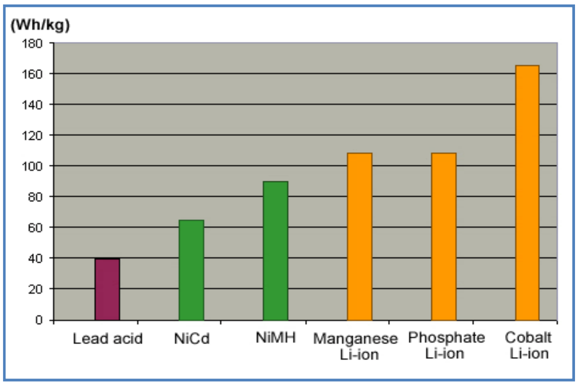
Figure 8: The chosen motor

5. The batteries

The heart of Electrical Vehicles (EV) and Hybrid Electrical vehicles (HEV) are the batteries.
The most suitable batteries for cars are the Lithium based batteries. For our 'synectric' project we choose lithium based battery because of their main advantages over other types [4]:

- *High performance:*
  Provides a High Theoretical Capacity of 170 mAh/g and a High Practical Capacity as high as 165 mAh/g.
- *Extremely safe/Stable Chemistry:*
  High intrinsic safety, non-explosive and will not catch fire under collision, due to overcharging, or from a short circuit. High thermal stability of phases up to 500 Centigrade.
- *High discharge rate capability:*
  Among the best for all high power output demands.
- *Extraordinary long cycle life:*
  2000 cycles (80% DOD) achieves up to 2000 cycles per life-over 7 times the life of Lead Acid and three times of NiMH and 3-4 times of Li-Ion, Li-MN battery.
- *Long service life:*
  Over 6-7 years-up to 2000 cycles (80% DOD).
- *Environmentally friendly:*
  Non-toxic, no-rare metals, wide working temperature range -45°C ÷ +70°C (extremely hot and extremely cold weather will not affect its performance) Flexible Form Factor small in size and light in weight, 1/3 weight of Lead Acid and 65% weight of NiMH. 2/3 size of Lead Acid.

Comparison of rechargeable batteries which are used for HEV [5]:
Figure 9: Comparison of batteries



So we choose the LiFePO4 batteries.

A simulation of the required space of these batteries was performed in our CAD-design of the frame (figure 10), concluding that there would be enough space.

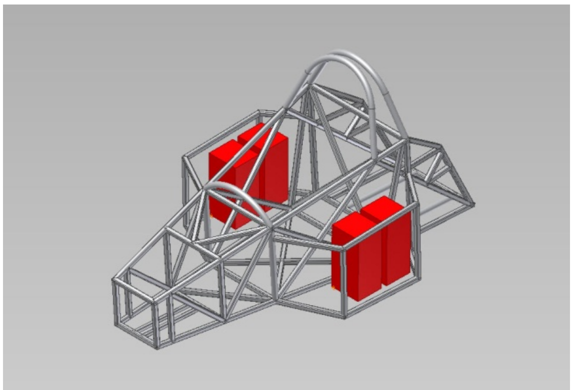


Figure 10: Placement of the batteries

7. Any more electric stuff?

Others students are doing research on the adequate type of generator, supercaps, etc…
Furthermore the use of simulation techniques developed by the Association partner VUB [6] (Figure 11) will be used to great effect in this field, enabling drive train design optimization towards a high performance and efficiency.
The simulation programmes will also constitute a key tool to assess benefits of the hybrid drive train topology to be the relative implemented,

potential performance benefit of the parallel hybrid is to be balanced against the control benefits and the 100% pure electric traction aspect of the series structure.

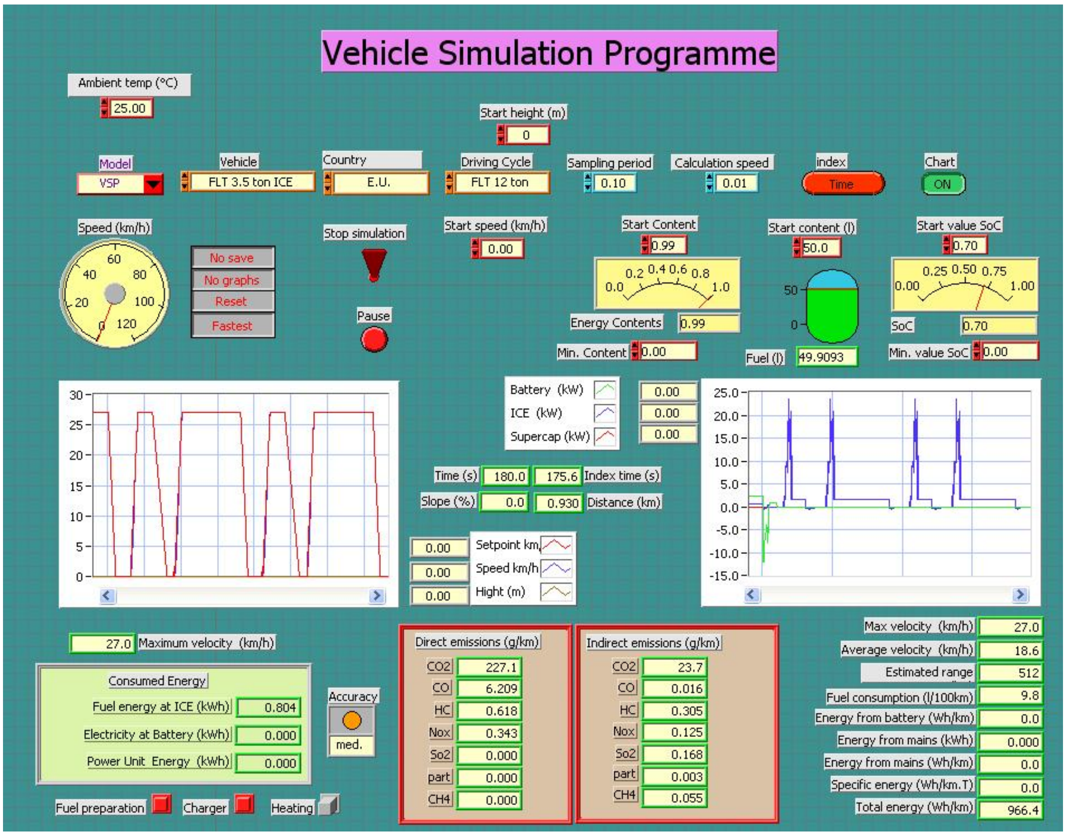
Other ongoing research projects by both Association partners with a direct feedback into the project include battery modelling,
EDLC application development and power electronics, all elements which contribute to obtaining the vehicle's desired performance and endurance use of advanced composite materials developed at EHB to optimize the vehicle and to anticipate on future designs.

8. Versatility of the project

Besides the pure electrical traction aspects, the project also appeals to mechanically oriented students, who perform 3D modeling of the vehicle, determine the forces balance and study the use of advanced composite materials developed at EHB to optimize the vehicle and to anticipate on future designs.

As stated earlier in this paper the whole imple-

Figure 11: Electric Vehicle Simulation in Labview



where the

mentation of a hybrid race car not only is a matter of electricity in a broad sense, but also of mechanics; in other words it is a multidisciplinary problem. Students, even professional engineers, are often not aware of the fact that most encountered problems in their real life are of a polyvalent nature. That's why we, Faculty Members *of the third kind*, promote projects that may not only focus on one specific spot of science or technology, but constitute an assembly of a multitude of competences. It is our aim to bring together in our projects students and Faculty Members that all individually represent a little bit of the whole puzzle of the big problem. This necessitates cooperation, and thus, learning to work together in a team, being able to perform concurrent engineering and find a way to communicate between people of totally different educational backgrounds. Anticipating the acquisition of the Predator Chassis, some simulation techniques were performed at the VUB, looking forward to practice them on the material "model", the fully equipped Predator. These findings are replicated in their Master Proofs [5].

This is our challenge. Not in a professional environment, but already at the educational level.

9. Mechanical aspects

So far, the whole project was more or less presented as an electric and/or electronic problem. In the previous paragraph 8 we mentioned the presence of a mechanical aspect. As we will explain now, this aspect is not of second order; it is concurrent with the electrical aspect. The both go together, and our students were working in parallel. The outcome findings of all we experienced are that one doesn't work without with the other. It is an iterative process, whereby the mechanical findings are the input of the electric research and vice-versa. Is it a never ending story? Sure.

9.1 CAD3D

Modern scientific and technological research necessitates the use of 3D software to draw, design and simulate the complex problems of all kind. The natural thing to do was to draw the Predator chassis and body in 3D, anticipating future use. No drawings were delivered with the acquaintance of the Predator, so a team of students took the challenge to reverse-engineer the Predator chassis.
Because of the tradition in our College to use Autodesk^R software since decades, 3D-models of the Predator were drawn in Inventor^R, at first in the 2008 version, later in the 2009 version.
Many students were involved in this huge task. It was a matter of learning or extending the knowledge of the Inventor^R software, measuring pieces, weighting, drawing these ones, putting pieces together in subassemblies…..then in assemblies…
One student was appointed to be the leader of the team. But that was not sufficient. We had to put 6 P.C.'s in a network, with one server keeping track of all the drawing files and history of them (the Vault Data Management of Inventor Software). As we never experienced this kind of task before, a lot of ICT knowledge was acquainted.

The drawing of this 3D-model procured us a though insight of the construction and working of a vehicle. The idea is to use the drawings as a basis for simulation techniques in software programs. In the future is can be used as a "template" to change frame or body.

Another nice challenge is to make animations to show students the working of steering, suspension etc…

Rendering pictures, animations etc...can help us to make up a dossier to find sponsors (figure 12).

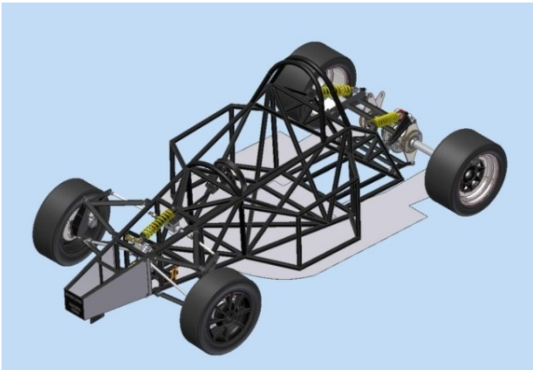


Figure 12: 3D-model of Predator

Today 3D-CAD drawing is presented as a way to construct models on the basic of solids modelling. All manuals and tutorials of current software programs discuss the building up of work pieces via solid modelling. However, in ancient times, the seventies, solid modelling mathematics were not yet developed and all 3D software relied on surfaces. Then came a time that solid modelling techniques were in vogue. The big

issue was to develop the mathematics to bind surfaces techniques and solid (volume) designs. Nowadays this is the case. But the generation of engineers that was familiar with surface modelling mostly retired. It's hard to find people, manuals, and tutorials on surface modelling. But we do need them. This year our team finally took the challenge to get familiar with surface modelling to draw complex shapes, like the body.
Figure 13 is a 3D representation of the left and right body pieces. They were drawn in solid modelling and took us a lot of time.

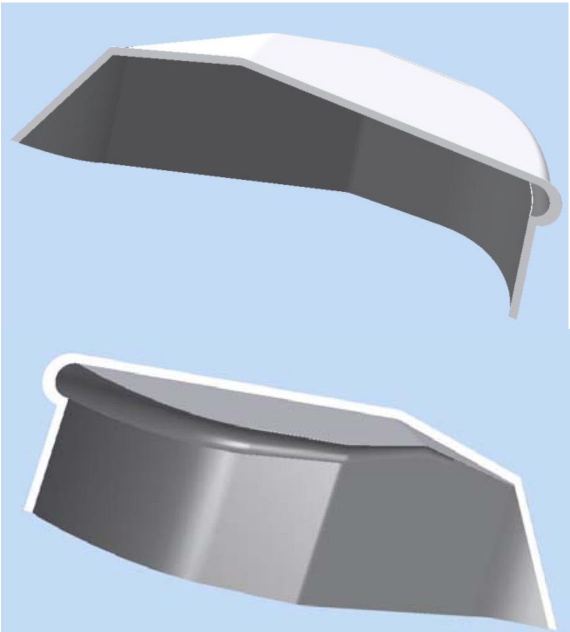


Figure 13: Body pieces, left and right

Then we got familiar, after some training, with surface modelling and this led us within a shorter period to the figures 14 and 15.

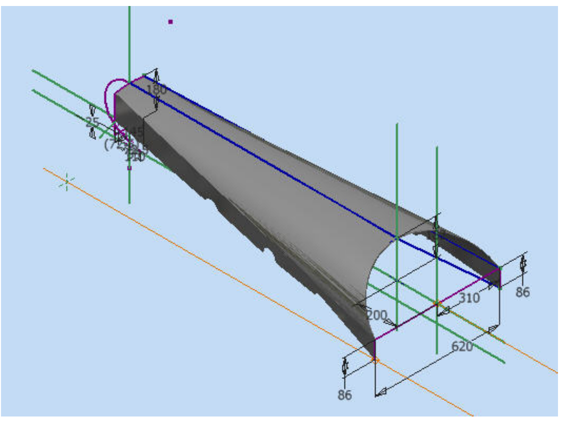


Figure 14: Middle piece drawn in surface modelling

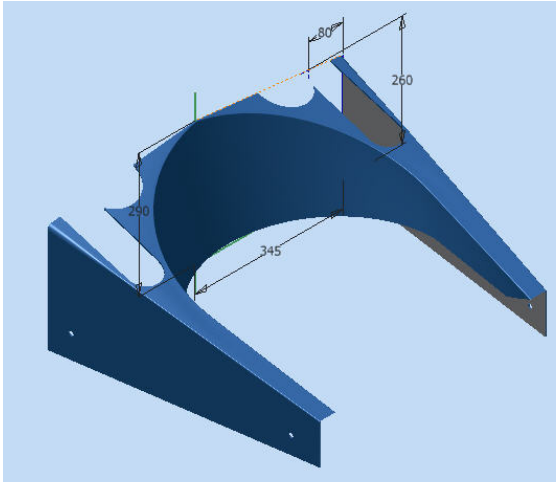


Figure 15: Back middle piece drawn in surface modelling

9.1 Aerodynamics Cx

Once the 3D-drawings of the car will be finished the challenge will be to determine the drag C_x of the car. We see two options:

- Make a model of the car with a 3D-printer; adopt similitude theory to it, and put the model in a wind tunnel
- Drop the 3D-model in a CFD program

The only drawback of these methods is that the serious induced drag by the turning wheels will not be taken into account. But there is no alternative, except making use of advanced techniques used in formula 1 racing.

9.2 Rolling resistance

Another important factor to take into consideration is determination of the rolling resistance. This can only be done in real time and conditions. It is a challenge for the next academical year.

9.3 Strength analyses (FEA)

What about the strength (elasticity) of the frame? Will the frame stay straight with al these bending forces executed by the weight of the batteries at both sides? We have to find out in a strength analyses program.

9.4 Construction engineering aspects (CAD/CAM)

All components to be added to the chassis, ICE, engine, DC convertor etc…should be constrained to the chassis. Some construction ideas and drawings about suspension parts have to be designed and fabricated.

9.5 Heat management

A totally different discipline, rather the domain of thermodynamics and heat transfer, is the heat management within the back of the car, and within the side bodies carrying the batteries. A fan will be necessary. Dimensioning the fan, and maybe find a regulation, is another challenge.

10. Conclusion

All this proves that the whole project is a multi-disciplinary one, tackling all aspect of engineering sciences. Working out this project in a team during the engineering formation of our students will benefit to all of us, give us some added value in knowledge and learning to work in a team.

Acknowledgments

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