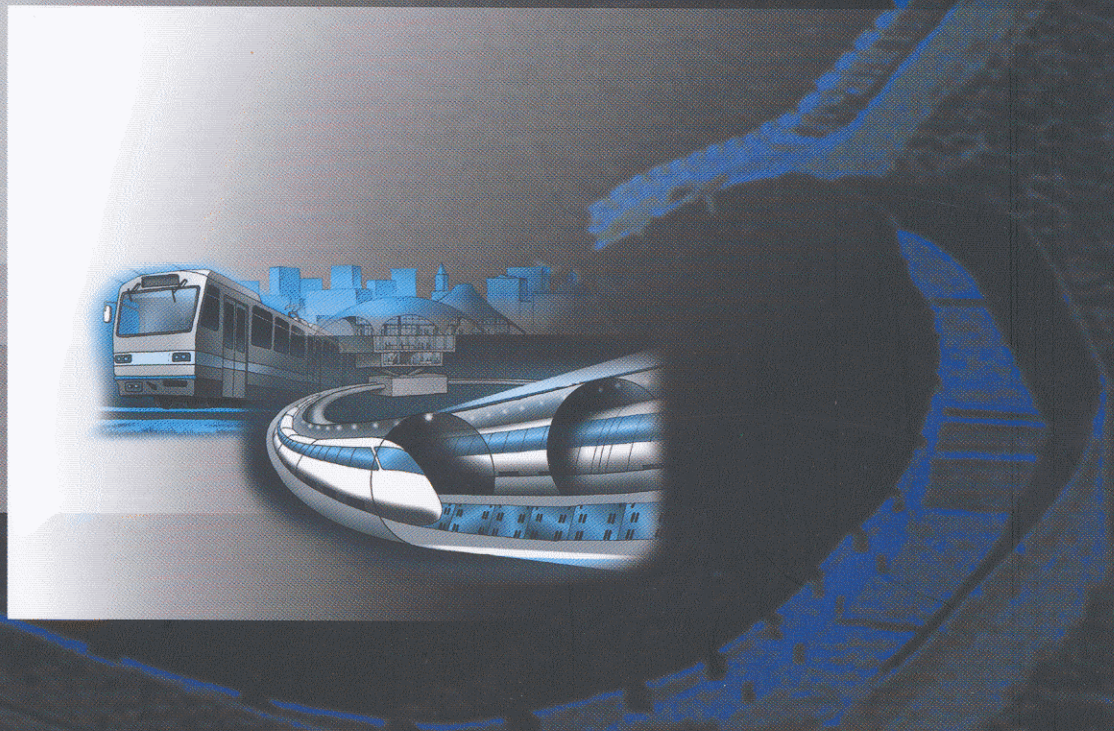




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Wind tunnel testing of low consumption vehicle « Consomini »

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Abstract. This paper presents the study of a very low consumption vehicle. This vehicle took part, among 218 other competitors from all around the world, to the Shell Eco-Marathon race held in June 2004 in Nogaro (France). At this occasion, it travels 1200 km with only one liter of fuel. Our team wins the design and the technology awards. The design of the body, optimized to reduce the aerodynamic drag, has been developed by the CMEFE (group of Competences in Fluid MEchanics and Energetics) of Ecole d'Ingénieurs de Genève. We present also some other activities of this institute.

Keywords: Consomini, vehicle, wind tunnel, aerodynamics, automotive engineering, energy consumption.

Low consumption vehicles : a challenge for the new century

Twenty years ago Shell company launched a great challenge to all engineers : To develop and produce very low consumption vehicles able to run hundreds of kilometers with only one liter of traditional fossil fuel. This challenge appears immediately very motivating. From 680 km per liter in 1985 at 25 kph average speed, the record has been established in 2004 with 3'410 km per liter at 30 kph average speed. During the race, the consumption is calculated by extrapolating the consumption realized over seven rounds of the circuit, this represents a course of approximately 25 kilometers.



Fig. 1 : Consomini : A very high efficiency vehicle able to cover 1230 km with only one liter of traditional fossile fuel.

Energy efficiency is our main focus

After months of efforts, the vehicle with low fuel consumption - Consomini – made a run of 1'234 km with one liter of fuel at an average speed of 30 kph at the 20th Shell Eco-Marathon, which took place May 15th and 16th, 2004 on the French circuit of Nogaro. The prototype held the attention of the jury. The team wins the design and the technical awards. Three institutes of the University of Applied Sciences of West Switzerland (HES-SO) shared their knowledge and their competences in order to build a car, baptized "Consomini". This took the departure of 19th and 20th edition of the Eco-marathon.

The LMTH of Ecole d'Ingénieurs de l'Arc jurassien built the propulsion (four stroke engine), the laboratory for carried systems developed the electronics. The department for mechanical engineering of Ecole d'Ingénieurs de Fribourg designed the frame. Finally, the CMEFE (group of Competences in Fluid MEchanics and Energetics) of Ecole d'Ingénieurs de Genève design the body, and carried out aerodynamic investigations in wind tunnel.

This project constitutes the first step of a main project related to the development of an urban vehicle with low fuel consumption using bio-fuel.

The team includes twenty professors, assistants and students. They work on several engineering fields such aerodynamics, thermal systems, materials, mechanical systems, etc. They built a very efficient vehicle using high technologies. Carbon and Kevlar fibers, high resistance steels, etc. The total weight of the vehicle is 30 Kg.



Fig. 2 : The Consomini team

Engineering

This year Consomini wins two awards : Design and Technology. The solutions developed by the team are very innovating.



Fig. 3 : Body and frame are only one

The body in carbon-Kevlar developed using scaled tests in wind tunnel, the directional wheel at the rear (solution never chosen before), the ergonomics and the electronic interface lead to a second rank at the design competition.

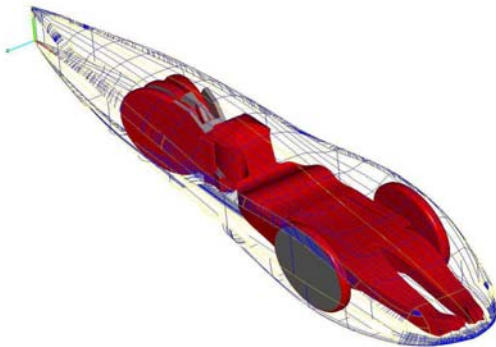


Fig. 7 : Interior's volumes and general shape

The propulsion system developed by our team includes a sophisticated electronics and a real time communication system to manage all parameters by the team during the race. This lead to a third rank at the technology competition.

Aerodynamics

The aerodynamics was developed by the CMEFE of Ecole d'Ingénieurs de Genève. Design and aerodynamics were studied using an experimental approach. Models were built to perform wind tunnel tests. The regions where a separation of the flow can occur were investigated using visualization methods and pressure measurements. The forces and moments, essentially the drag and the lift, were measured using six components balances developed at the CMEFE.

During a first step a 1/8 scale model is built based upon expertise and specifications. Then, preliminary tests are done in a small wind tunnel. This approach reduces significantly the costs.

The geometry is then scanned using a 3D scanner. The data file is processed using state of the art surface software to produce a CAD file. The geometry is smoothed using surface splines. The numerical data are translated into a NC command file for machining. A four axis machine is used to produced a full scale model.



Fig. 4 : 3D scanning of the 1/8 scale model

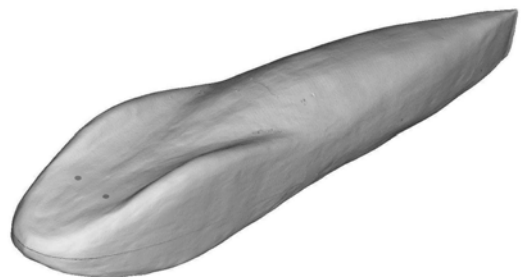


Fig. 5 : Data file after scanning

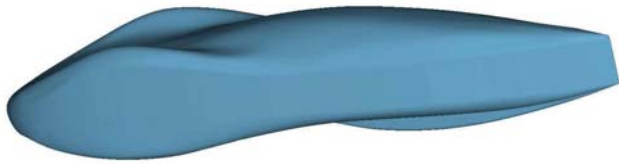


Fig. 6 : Final data file ready for the production of the full scale prototype

The full scale model is produced in two parts. They are assembled, polished and instrumented. The structure to install the model on the balance is also added to the model.

At the end of the tests, the full scale model is scanned another time to get an archive data file of the final version of the model. The model used for the tests is also the master of the molds used to produce the vehicle.

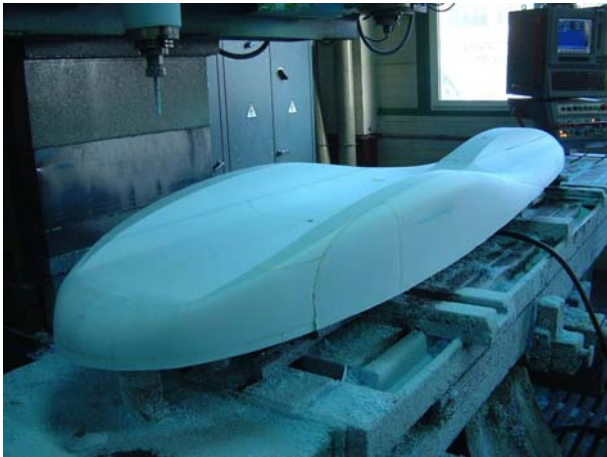


Fig. 8 : Machining of the full scale prototype

Wind tunnel investigations

The wind tunnel tests have shown very high performances trough the full speed range. The coefficients of drag, lift and lateral force are calculated. They are presented in Fig. 10.

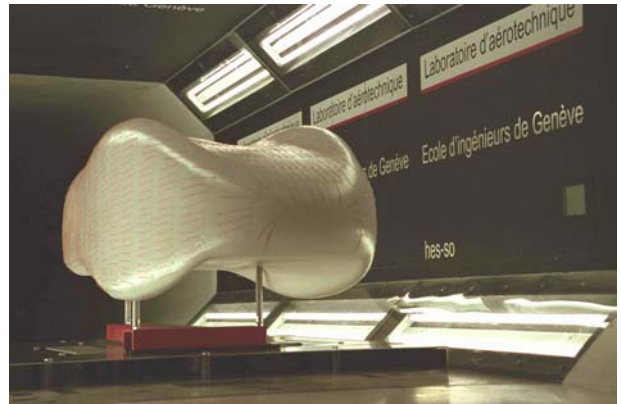


Fig. 9 : Investigations in the wind tunnel test section of CMEFE

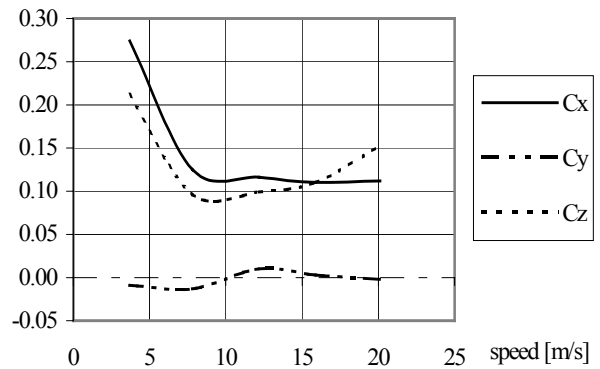


Fig. 10 : Drag coefficient C_x , lift coefficient C_z and lateral force coefficient C_y

The engine

The four stroke engine has been developed by the team at the LMTH. The fuel used a traditional 95 Ron fossil fuel available at every station. The mechanical power developed by the engine is 1 hp at 3'000 rpm.



Fig. 11 : The four stroke engine

The electronics

A computer manages all data coming from several sensors and from the telemetry. It controls the engine, the propulsion system and gives to the team information regarding consumption, average speed, etc.

The propulsion

The energy is given to the rear wheel by the use of a chain. The clutch is designed to engage without any slipping who would results in loss of energy.



Fig. 12 : Propulsion system with clutch

The CMEFE of Ecole d'Ingénieurs de Genève

The CMEFE is an institute acting in the field of fluid dynamics and energetics. It exists since 1920.

The partners of CMEFE are vehicle manufacturers, sport equipment producers, sport teams, energy industries, etc. High quality human and material resources are available at CMEFE in the field of fluid dynamics, thermal systems engineering and energy conversion.

Equipments

CMEFE equipments includes several wind tunnels from low speed to supersonic flows. It includes the instrumentations, visualization systems, laser Doppler velocimetry, etc.

The **main wind tunnel** of the CMEFE is equipped with four blowers of 100 hp each for a total of 400 kW. The maximal air velocity is 300 kph in a test section of 6.6 ft x 4.9 ft. A second test section is also available for experiments with dimensions of 11.2 ft x 11.2 ft.



Fig. 13 : CMEFE main wind tunnel,
300 kph, 6.6 ft x 4.9 ft

The **calibration wind tunnel** has a small and very low turbulence test section and is used to calibrate instrumentations as hot wire anemometers.

The **Eiffel wind tunnel** has a test section of 1.3 ft x 1.0 ft where flows until 300 kph can be achieved. It uses a 30 hp electrical motor.

The **supersonic wind tunnel** is used to study airflows until Mach numbers of 2.4 (about 2'900 kph). The dimensions of the test section are 0.4 ft x 0.3 ft.

CFD software

The CMEFE develops numerical algorithms to compute flows around bodies or to investigate many questions. It uses also commercially available codes for thermal and fluid dynamic studies.



Fig. 14 : Supersonic wind tunnel (Mach 2.4)

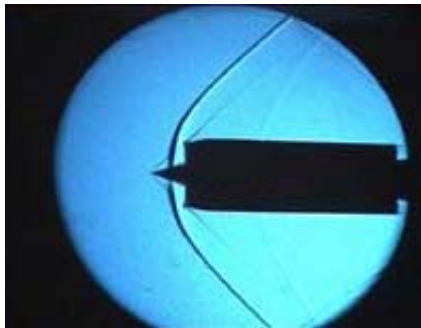


Fig. 15 : Visualization of shock waves using a Schlieren system



Fig. 17 : World champions of high speed skiing are working with CMEFE

Conclusions

The University of Applied Sciences of West Switzerland (HES-SO) developed and produced a very high efficiency vehicle. The CMEFE was in charge of the aerodynamics.

Olympic games held in Salt Lake City went at the



Fig. 16 : Examples of balances used to measure forces and moments until 6 components (3 forces and 3 moments simultaneously)

3D scanner

As described in this paper, the CMEFE used a 3D scanner to record experimental changes done on models and to supply to the customer high quality data files (Laboratory of metrology).

CMEFE expects from its participation to the World Engineer's Convention the possibilities to meet students, professors and industrial companies from other countries. This is a unique opportunity to start partnerships and discover all faces of engineering around the world.

Other activities

For many years the CMEFE worked on the aerodynamics of buildings and constructions (evaluation of loads due to the wind), other activities are also undertaken in the field of aerodynamics and energy. Professor Michel PERRAUDIN, in charge of this laboratory, develops also many systems related to measurements, calibration and testing.

Today, our institute is acting in several projects of inlets for high speed trains, thermal analyses for energy production, energy concepts for cities, methods for measuring friction coefficients, sensors, etc.

The CMEFE has also a world reputation for its contribution to the sports. Luge team from France for the

References :

CMEFE to improve its performances. Sky surfers, flying men, high speed skiing use the CMEFE resources to develop their revolutionary systems.

References :

<http://www.eig.unige.ch/cmefe>

<http://www.consomini.ch>

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