Innovation in Scooter Technologies

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Abstract

Executed under the Fifth Framework Programme of the European Commission, the PRAZE project has the objective to develop an advanced electric scooter. Reaching the targets will be done by a co-operation between the 5 different partners: PML FlightLink, Peugeot Motocycles, Sorapec, VUB and CITELEC. In the presented new concept, the energy for driving is supplied by the advanced bipolar Ni-Zn batteries, developed by Sorapec. The drivetrain consists of an innovative new wheel motor drive system, developed by PML. Prototype chassis is the existing one of Scoot'elec, developed by Peugeot. CITELEC is involved in scooter testing and dissemination issues, while the VUB has put to action its proprietary simulation tool for drivetrains, especially electric and hybrid drive systems.

This paper gives an overview of project progress and summarises initial project results. The methodology within the simulations is particularly described.

Keywords: Scooter, modelling, simulation, vehicle performance, wheel hub motor

1 Introduction

The aim of the PRAZE project is to build a scooter that has lower primary energy consumption than both the existing electric and thermal scooters, and to extend the range for electric scooter. Furthermore the product cost is decreased in relation to the current commercially available products, in order to make the electric scooter a viable commercial product, allowing more people to use an electric scooter due to the improved cost and range.

Current electric scooters use mainly DC motors and conventional batteries, either lead/acid or nickel/cadmium. The motor and batteries take more space and weight than a thermal engine and gasoline tank. The kilometre range is reduced and the price is high.

Several new features are incorporated in this development project. The energy for driving won't be supplied by the above-mentioned conventional batteries, but instead by the advanced bipolar Ni-Zn batteries, developed by Sorapec, a company specialising in the research and development of batteries and fuel cells. These batteries provide specific energies of 70 Wh/kg, and this at a foreseen production cost of 40% of the Ni-Cd production cost. Furthermore, the drivetrain consists of an innovative new wheel motor drive system, developed by PML FlightLink and incorporating a high efficiency brushless motor inside the wheel. The system eliminates transmission and gears, improving efficiency, and free space in the vehicle body. Associated electronic control will offer regenerative braking to improve overall energy efficiency. The initial prototypes, use Peugeot Motocycles's existing electric scooter as a base, changing the mounting system to a suitable for wheel motor, adding the wheel motor itself, and energy supplied by conventional Ni-Cd batteries, configured for 36V.

2 Simulation model

VSP, Vehicle Simulation Programme is a modular interactive programme, allowing to compare different drive trains in electric and hybrid vehicles. The programme runs in a LabVIEW environment. LabVIEW is a high-level programming tool, with the advantage of being a user-friendly interface with a high graphical performance. The comparison can be made on the level of performances (acceleration, range, maximum slope, ...), of energy consumption (fuel and electricity) and of exhaust emissions (CO_2, HC, NO_x, CO, particulates, ...). The following paragraphs give a brief description of the models used in the PRAZE scooter model. More information about the programme or one of its components can be found in [1].

2.1 Drive train lay-out

Figure 1 shows the drivetrain of the PRAZE scooter. From left to right one can recognise the vehicle body, the wheels, the electric motor, the converter and battery and on top of it, the auxiliary system (lighting, etc.).

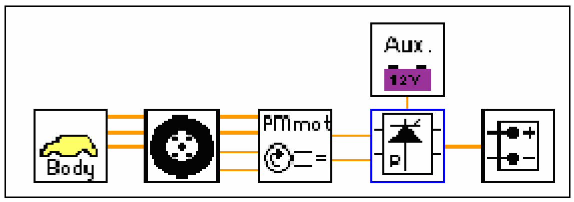

Figure 1 : PRAZE's drive train

2.2 Body

This model contains the data necessary to calculate the main forces acting on the vehicle body. Inputs are the weight of all different components of the drivetrain to calculate the total weight. The vehicle load is also taken into account in the total weight. The aerodynamic drag force is calculated in function of the frontal surface, the aerodynamic drag coefficient C_X, the vehicle speed, the average head wind velocity and the air density. The other forces acting on the vehicle are based on the wheel parameters and hence described in the following paragraph (2.3).

2.3 Wheels

This model calculates the wheel power. Therefore it needs first to determine the rolling resistance F_R and the climbing resistance F_C, additional forces to the aerodynamic force on the vehicle. The calculation of the rolling resistance is based on the friction coefficient, which is a dynamic value, depending on e.g. speed and tyre pressure. When driving uphill, the rolling resistance decreases, while the climbing force, due to gravitation, increases. These three forces increased with the acceleration force and the force representing the inertia of the rotating components, are the essential parameters in the wheel power calculation. Within the programme, maximum acceleration and maximum deceleration, the physical limits before spinning are taken into account.

2.4 Motor

The motor module transforms the mechanical quantities into electrical quantities taking into account the limitations and efficiencies of the component at different load levels. In fact, in this module the programme is looking for the current working point in the torque-speed plane of the motor. The component behaviour is simulated by taking into account the whole map of working points. The component characteristics can be defined by physical equations and equivalent circuit (analytical models) or by measured efficiency characteristics (Curve fitting experimental models) fit into look-up tables. It is the latter approach that is used in the PRAZE project

2.5 Converter

The battery voltage and the output parameters of the motor model are used to characterise the efficiency of the converter. This efficiency is function of the input current, power factor, DC voltage, switching frequency and transistor parameters. The switching frequency is selected out of a look-up table in function of the fundamental motor frequency. The model is able to change from electric motor to generator during braking.

2.6 Batteries

Modelling of a battery is extremely difficult. Characteristic parameters used in order to describe the battery are weight, battery type, number of cells, open loop voltage and internal resistance both in function of State Of Charge during charge and discharge, capacity C5, and the Peukert constant. Furthermore, there are certain limitations implemented determining the working area of the battery (max/min voltage, gassing voltage, max current, …). A detailed description can be found in [2].

3 The Speed Cycle

3.1 Definition

With the VUB-On-road measurement equipment some drive cycles are driven with the Peugeot Scoot'elec. This resulted in the following speed cycle.

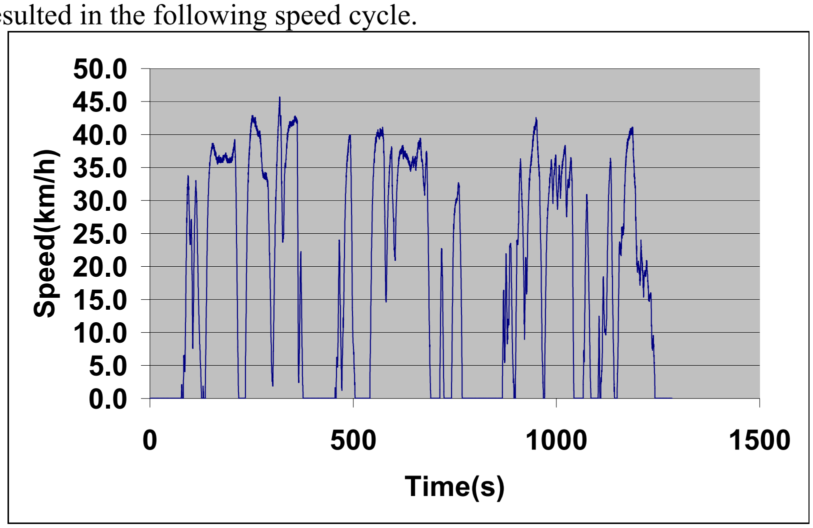

Figure 2: On-road measured speed cycle

As one can see there are several parts were speed remains zero. Due to its acceleration torque at zero speed, the energy consumption of an electric vehicle at standstill is reduced to the consumption of the auxiliaries (headlight, direction indicators, dashboard lights), which has no significant influence on the final consumption.

3.2 Comparing with ECE-47

The On-road measured speed cycle is used as an input for the simulation programme. Based either on data received from other partners or on the main PRAZE scooter targets, body and component parameters, the corresponding torque and speed values at the level of the wheels are simulated (Figure 3 left). The right part of this figure shows the simulation result by simulating the ECE-47 speed cycle. This demonstrates that the ECE-47 cycle does not correspond really well with daily traffic conditions, since only a few working points are covered. In the positive torque plane the working points are only located on the outer line, which is defined through the limits on the different components. The figures of the simulations beneath are performed with a 5.0 kW motor (delivering a peak torque of 129.1 Nm between 0 and 640 rpm) and a battery with a capacity of 2,7 kWh. The point of 640 rpm or 67 rad/s is greater than the speed limit regulation for a scooter, being 45 km/h.

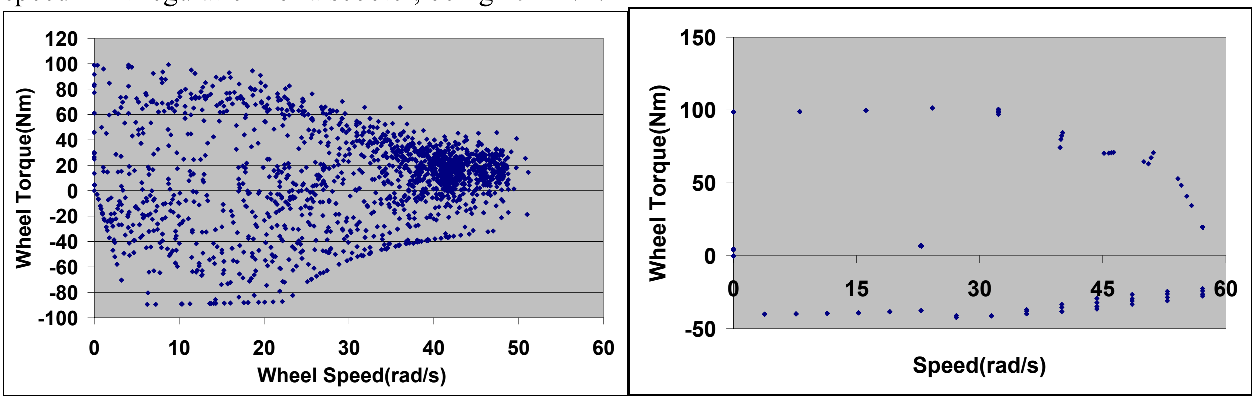

Figure 3: Distribution of operating points for On road measured cycle (left) and ECE 47 (right)

Peugeot Motocycles, as one of world largest scooter developing companies, however found a good correlation between real life consumption and consumption on ECE-47. They do not feel the need for another cycle within this project.

3.3 Frequency Distribution Map

Figure 4 illustrates the relative distribution of the operating points of the on-road measured cycle.

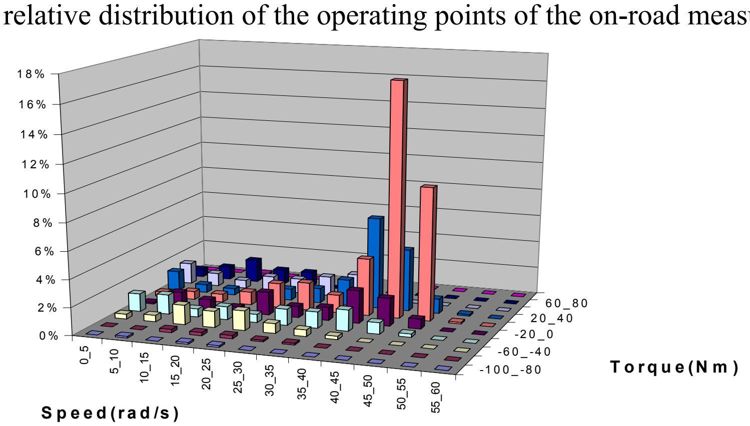

Figure 4 : Relative Frequency Distribution (without stand still)

During the simulated cycle the scooter is standing still for 36% of the time.
One can clearly see the area of frequent use.

- The area at high speed (around 40km/h), close to maximum, and low to moderate torque (0-40Nm) is mainly frequented.
- The remaining working points are evenly spread in the operation area.
- At standstill the torques are varying from low braking till high acceleration.

Remark that the simulated speed cycle is based on an on-road measured cycle, which means that this cycle is depending on :

- Traffic conditions
- Driver behaviour
- Test vehicle characteristics[1]

4 Performances and limits

4.1 Limits

Each component has its own boundaries. For instance, there is a limit on the depletion current of a battery. The values must be in between those limits, called 'the working domain of a component'. Due to the simulations with different component sizes, those limits will change. In the following table a list is given of the component that limits the acceleration of the scooter.

Motor Power \ Battery Content	2kWh	2,7kWh
3kW	Maximum torque + maximum battery current	Maximum torque
5kW	Maximum battery current	Maximum battery current

When battery current is the limiter, it means that the scooter has a too powerful motor according to its battery. In the case the motor torque is the limiter, the battery can deliver more power than the motor can produce. The best cases are those where one reaches its limit while the others are close to their corresponding limit. The following paragraph shows this duality with the four different configurations.

[1] This could be the reason why the operating points on the ECE 47 were on the outer line, while those on the measured cycle were rather on the limit of the vehicle, since the speed profile of the ECE 47 obliges a full throttle acceleration.

4.2 Acceleration results

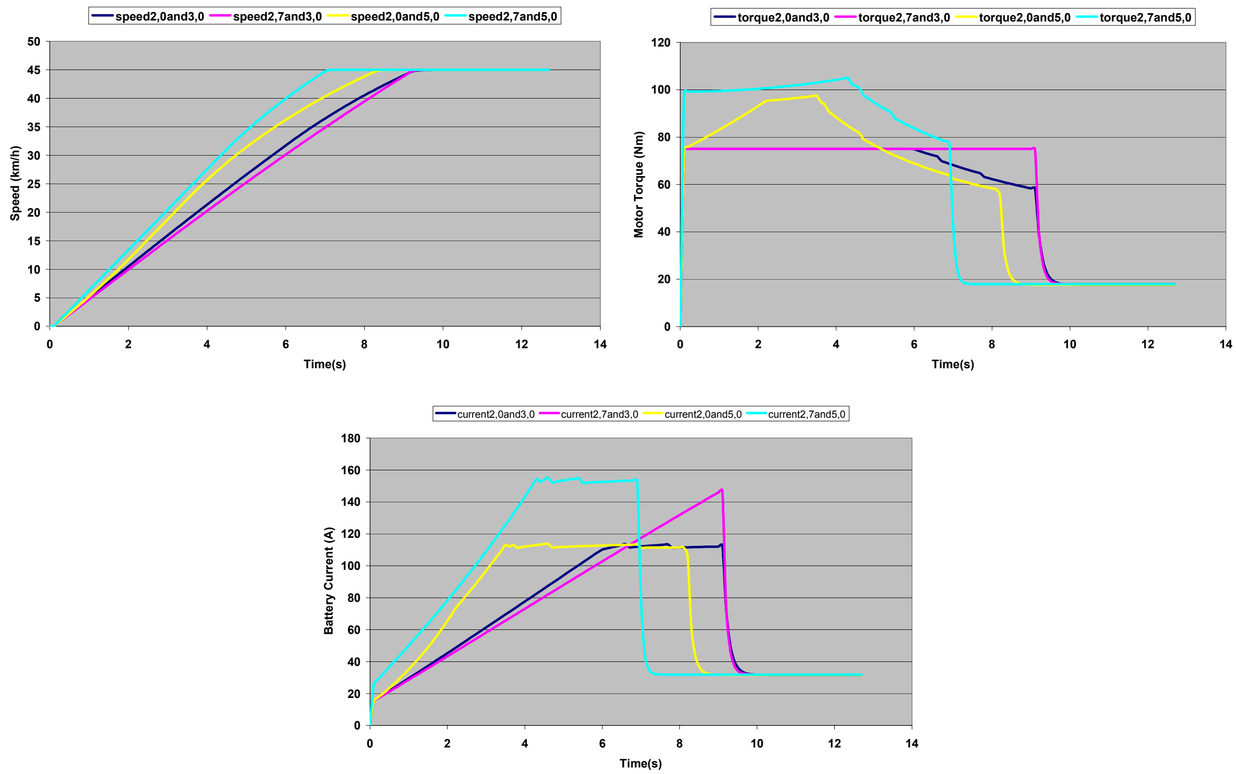

Figure 5 : Simulation results of the acceleration test

In the speed graph one can clearly see that the 2,7 kWh battery within the 5,0 kW-powered engine gives the best acceleration. The 3,0 kW scooter with 2.0 kWh battery can accelerate a little bit faster at low speed than the one with the larger battery and same motor due to the fact it’s weight is lower, although the larger one reaches its maximum speed just as fast. After all, at high speed the current is not the limiting factor within the larger one, so the acceleration torque can remain its maximum value during a larger acceleration time. Furthermore, the limiter on the 3,0 kW scooter with the small battery jumps from maximum torque to maximum depletion current. Other limiting parameters that are not visualised in the figures above are e.g. motor current, wheel slip, battery voltage, …

4.2.1 100m distance

One of the parameters that characterises the performances of a scooter is the time it needs to cover 100 m starting from standstill. The target in the project is to remain Scoot’elecs time. Although Scoot’elecs time wasn’t determined yet so tests were carried out in order to define an appropriate goal for the PRAZE-scooter.

Table 1 : Acceleration 0 to 100 m

PRAZE			Scoot'elec
Motor type	Battery content	Time(s)	Time(s)
3.0kW	2.0kWh	12.3	11.6
	2.7kWh	12.5	
5.0kW	2.0kWh	11.8	
	2.7kWh	11.3	

The time mentioned for Scoot'elec is a measured value while the others are simulation results. They indicate that all of the different configurations used give a similar acceleration to the scooter as for the Scoot'elec meaning none of them is preferred on this criterion. So, a smaller motor does not affect the acceleration performance that much. In a further stage of the project one will also compare acceleration starting from different initial speeds.

5 Technical issues of the project

Prototypes are currently in a test phase. A few intermediate results/considerations are already available.

5.1 Vehicle dynamics

The electric motor integrated in the rear wheel increases considerably the unsuspended weight. The immediate issue is the alteration of the behaviour. In order to qualify this effect, additional weight has been added to the rear wheel of a thermal scooter. The final outcome of this testing was that the current suspension system was not able to give unconditioned satisfactory handling.

5.2 Motor and control unit

Two types of motor are put within the scooter prototypes (60 mm or 5 kW and 45 mm stack or 3,5 kW). Both motor give to the scooter sufficient acceleration power, meeting the targets of the Praze project. In order to reduce the unsuspended weight, the smaller motor is preferred.

The controller set up values can be altered by means of a RS232 serial link via a personal computer. Data for logging is provided via this communication port. The preliminary tests made clear a few changes should be made within the control strategy, however the global result was 'working properly'.

5.3 Battery

The main drawback of the Ni-Zn-battery is the formation of Zn dendrites. The new proposed separator membrane, micro-porous polypropylene membrane (CELGARD®) combined with a gelled electrolyte gives a good cycle life, a slight decrease of capacity and rather low internal resistance, less expensive than the first considered one. Optimisations could still be achieved.

The zinc electrode is doped with additives such as graphite or zinc alloys in order to increase the percentage of used material. The obtained results were 15-20% higher then in the non-doped version. The collector is a thin plate between the nickel and the zinc electrode, which make good electrical contact by means of a special paste and inserting metallic needless.

6 Website

More information on this project can be accessed at the url: http://www.praze.org.

7 Acknowledgements

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8 Conclusions

Simulations contribute enormous in the development of new innovative products, e.g. electric scooters. Within the PRAZE project VUB takes care of the simulations. This paper presents the model used for simulation, inclusive all the components, the results obtained with the simulation programme as well as an extension on other matters (technical and dissemination) arising during this project.

9 References:

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