

New Electric Postmen Helper Development and Evaluation

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Light Electric Vehicles (LEV) form a group of promising alternative vehicles for personal mobility and goods delivery. This manuscript reports about the European industrial EUREKA project called 'New Electric Postman Helper.' This project aims to develop the drive train for a range of mobility devices for postal distribution. The severe postal requirements which are not fully fulfilled by the vehicles on the European market today, and the strong interest of the postal organizations in solutions towards this issue, induced the set-up of this project in 2005. The introduction of LEV, in particular two- and three-wheelers, in the postal delivery business allows longer, more efficient and more sustainable delivery rounds. The close collaboration with several European postal organizations has allowed definition of the specifications of the electric power systems with characteristics meeting their specific needs. From an extensive questionnaire, the requirements of the different European postal operators were determined. A set of discriminating parameters was identified and used to calculate the design parameters of the electrical power system range starting from the postal requirements. The required energy capacity of the battery pack and the required motor torque were calculated from the postal parameters by using a dedicated design tool and resulted in the conception of a modular concept for postal electric vehicles.

Keywords: "bicycle", "electric vehicle", "power train", "energy consumption", "simulation".

1. INTRODUCTION

This manuscript reports about the European industrial Eureka project called 'New Electric Postman Helper.' The group of 'Light Electric Vehicles,' sometimes referred to as LEV's, is a promising alternative for vehicles for personal mobility and goods delivery. Personal electric vehicles offer several potential benefits to consumers and to society including lower transportation costs, reduced trip times, and lower environmental impact [13]. A clear interest for LEV's suitable for postal delivery exists among the European postal operators. In particular electrically assisted bicycles for postal delivery seem to have a very high potential. This is also confirmed by the fact that several European postal operators have launched calls for tenders to purchase a large number of electrically assisted bicycles, tricycles and trolleys to implement in their postal vehicle fleets.

Some electric bicycles and electric scooters are being marketed today in Europe and have been evaluated by European or national projects like E-TOUR [1, 2] and NEWRIDE.

The E-TOUR project showed that the performances of electric bicycles for the normal consumer market offered on the European market are often disappointing. This was mainly due to a lack of reliability of the offered

products. The users also experienced a lack of range. In addition, the large difference between the range announced by the manufacturers and the actual range obtained in real use caused a feeling of disappointment among its users. Further, the vehicle was experienced as too heavy and too expensive.

In spite of these drawbacks of conventional commercially available electric bicycles, the feature of electrical assistance offered on the vehicle showed great opportunities and potential for professional uses such as postal delivery. As the postman, delivering mail (and parcels) by bike, needs to carry along a large payload, additional traction force coming from the electrical drive train helps to perform his daily duty. Also, the postal requirements correspond to very high levels of performance, reliability and service. As the power train system is a key component of these electric mobility devices, the main technical objectives of the NEPH industrial project can be summarized as follows: to realise an improvement of the electric and mechanical reliability of the vehicles, to integrate new motor system technology associated with advanced battery technologies (both Ni-MH and Li-Ion based batteries), to include intelligent energy management in order to have an efficient use of the battery capacity (whatever the technology used), to realise a cost decrease due to a modular approach of the system concept, and to have an innovative design in order to facilitate the setting up of associated services required by postal operators.

To realise the above mentioned objectives, the NEPH

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industrial project will focus on the three main parts of the power train system: battery system, electric motor system and the human-machine interface.

2. THE NEPH PROJECT

The NEPH project is related to the study and development of a range of innovative electric power train systems that will constitute the key components of a range of personal mobility devices for helping European postmen. This project has two clear main objectives: the development of a range of mobility devices to deliver mail in urban and suburban areas and to contribute to the 'European Sustainable Development Policy.' The envisaged range of NEPH power trains are integrated into the following devices: electric assisted trolleys, electric assisted bicycles and related types (three-wheelers, four-wheelers). Other mobility devices (moped family for example) could eventually be considered in a later phase.

Further, The NEPH project is organized around a group of European postal operators which is managed by PostEurop. These postal organizations play an important role in the specification phase as well as for testing the prototypes of the NEPH vehicles. The project is composed of the two following phases: a first industrial phase for the development of an innovative power train system range and a future second demonstration phase for the setup of the associated services (maintenance, after sales services, supply chain,...) and the commercial launching. The NEPH industrial project is composed of different work packages, and its structure and details were presented in a preceding paper about the NEPH project [12].

During the Implementation phase, the constitutive parts of the electric drive train range have been developed. The electric drive train of the NEPH bicycle is very modular. The number of battery packs that are required to perform a specific postal delivery round can vary between 1 and 3 (see also further in this paper). Two different battery packs are available that can be connected to the controller unit and can be fitted on the NEPH electric bicycles: one with a lower energy capacity (9Ah) and one with a larger energy capacity (14.5Ah).

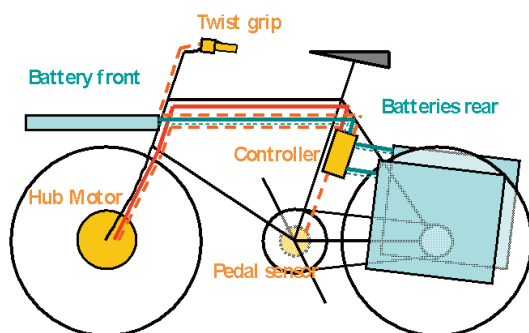


Figure 1: NEPH electrical drive train – schematically.

A schematic representation of the NEPH drive train is shown in Figure 1. The electrical drive train is composed of a hub motor, a controller unit, a pedal sensor, a twist grip and up to three battery packs connected to the unit. The controller unit is communicating with the battery packs to allow an optimal, reliable and safe function of the drive train. Further, the controller receives and sends information from and to the human machine interfaces (twist grip and the pedal sensor) and from the motor.



Figure 2: NEPH bicycle prototype LUDO



Figure 3: NEPH tricycle Prototype MIFA

Several NEPH platforms have already been developed and evaluated that are integrating the NEPH electric drive train components (see Figures 2 and 3).

The outcome of the NEPH industrial project is the internal qualification of an electrical power train system for postal mobility devices. It will therefore be a good opportunity to take part in the CIVITAS initiative by launching a demonstration project (NEPH Demonstration project) in order to look at the societal/human issues, to qualify the maintenance/after sales service and to open new mobility markets. For this demonstration phase, the electric power system range will be sold (on a manufacturing cost basis) to mobility devices manufacturers (bicycle manufacturer, etc.) selected by each European postal operator to

perform the operating tests in a number of European cities.

3. THE NEPH DESIGN TOOL

A dedicated design tool was developed and allows for calculation of the design parameters for the different electrical power system components. Based on the specifications provided by the postal operators, technical characteristics like the required battery pack energy capacity and the required motor torque are obtained. The most important input parameters of this simulation model are parameters used by the postal organisations to describe the characteristics of the delivery rounds: the number of starts and stops (S), the speed attained between two stops (v_b), the total trip length (D) and the total vehicle mass (M). The cumulated height difference (h) during the distribution round is also a parameter that has an influence on the performance but is not always easy to retrieve. The cumulative height difference can be estimated by categorising the distribution rounds into different topographical regions from flat regions (e.g. the Netherlands) to (very) hilly regions (e.g. the Black Forest in Germany).

The required mechanical energy to climb a height difference h, expressed in meters, can be written as: where M is the total mass of the vehicle, including the

$$E_h(Wh) = M \cdot g \cdot h / 3600$$

mass of the driver, expressed in kg.

The required mechanical energy to accelerate a number of times from rest until a certain speed v_b is attained is:

where S is the number of starts; M is the total mass of

$$E_s(Wh) = S \cdot \frac{1}{2} M \cdot (v_b / 3,6)^2 / 3600$$

the vehicle, expressed in kg; v_b is the speed attained between 2 stops, expressed in kph.

The required mechanical energy to drive at a constant speed v_{aver} , expressed in kph, over a distance D, expressed in km, can be written as:

where F_r is the rolling resistive force at the wheels of

$$E_r(Wh) = (F_r + F_{Cx}) \cdot r \cdot \omega \cdot D / v_{aver}$$

the vehicle, expressed in N; F_{Cx} is the air resistive force at the wheels of the vehicle; r is the radius of the wheels and ω is the rotational speed of the wheel.

The weight of the battery pack is calculated in an iterative way, as the total weight of the vehicle M (including the weight of the battery packs) determines the required energy capacity of the battery pack E_{bat} , and the required energy capacity determines in turn the weight of the battery pack. A number of discrete battery capacities are implemented in the NEPH design tool.

In Table 1, the different combinations of the battery modules and their related properties that are considered in the NEPH design tool are shown. These weight data are for industrially produced battery packs, including the required robust housing.

The required energy from the battery pack is proportional to the total required mechanical energy, which is a function of the total vehicle mass:

From an energy density point of view (capacity per

$$E_{bat} \propto E_{mech} = E_r + E_s + E_h$$

weight), the combination of three SAFT 'Ni-MH D' modules seems to be uninteresting compared to the combination of two SAFT 'Ni-MH F' modules. However, this solution could have an advantage in terms of weight distribution on the vehicle's platform.

A coefficient of 70% is applied for the calculations, reflecting the ageing effect of the battery during its lifetime. Taking this coefficient into account for the design of the NEPH power train range ensures that the battery is capable of allowing the postman to finish his distribution round with electrical assistance during the complete lifetime of the battery pack.

A user interface was developed in NI LabVIEW™

Battery Module 36 Volt (SAFT)	Capacity [Ah]	Weight (industrial) [kg]
Ni-MH (D) 36V prismatic	9	6.3
Ni-MH (F) 36V prismatic	14.5	9.1
Ni-MH (D) 36V flat	9	6.8
Ni-MH (F) 36V flat	14.5	9.7
Li-ion (MP) 36V prismatic (forecast)	13	4.5
Li-ion (MP) 36V flat (forecast)	13	5.1

Table 1: NEPH battery modules: different combinations

which allows the user to easily adapt the input parameters and to evaluate the resulting design parameters, in particular the required energy capacity of the batteries (see Figure 4).

The examination of different case studies, corresponding to the specific needs of European postal organisations, allowed dimensioning the power system components of the NEPH vehicles. An example of the results of the calculations concerning the required energy capacity (in the case of the NEPH bicycle) is shown in Figure 5. For each combination of a number of starts and stops and a certain trip length, the required energy capacity of the battery pack (expressed in Watt-hours) can be read from the color bar.

These results were also compared with the characteristics of products available on the market.

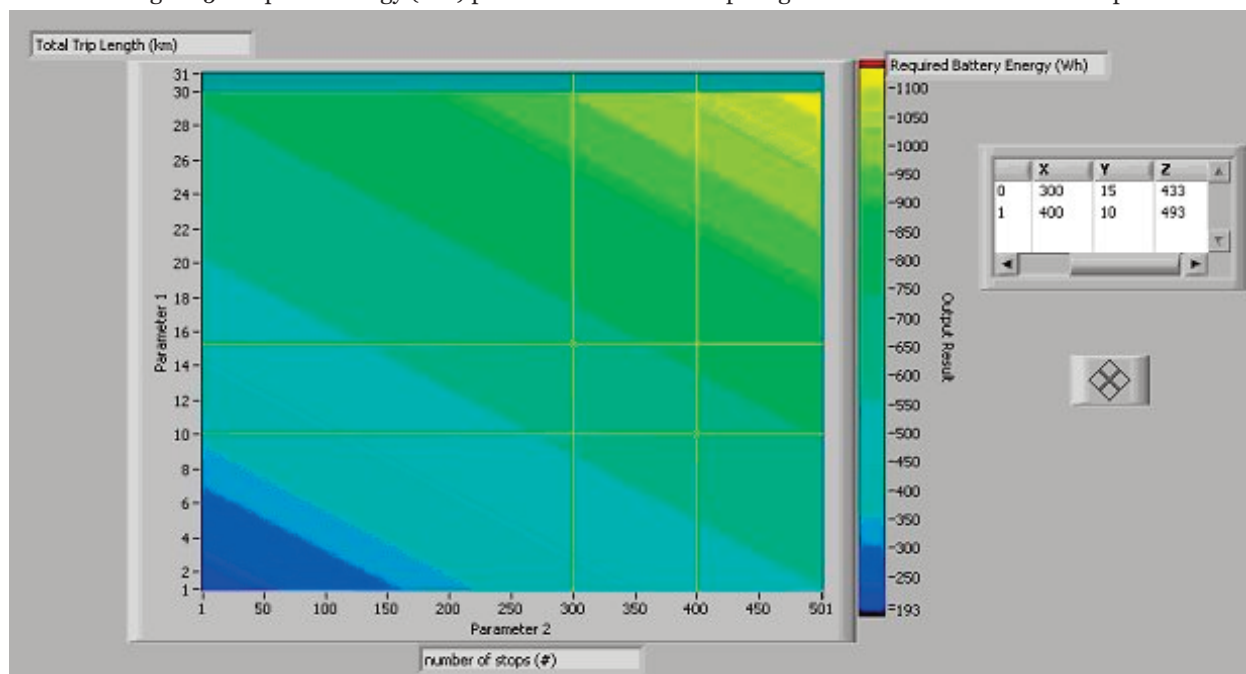
Figure 4: User interface NEPH design tool

This analysis showed that a gap exists between the postal requirements and the characteristics of commercially available products (which are often not designed for heavy duty applications such as postal delivery). This observation was also supported by the experience of the different postal operators who had tested some of these vehicles for postal service.

4. ON-ROAD TEST RIDES

Several test rides have been made with the NEPH prototypes, in order to validate the NEPH design tool as well as to have some practical experience with the prototype electric bicycles under real life conditions corresponding to postal usage. An area with significant steep slopes and a high number of mail boxes has been

Figure 5: Required energy (Wh) plotted in function of trip length and number of start and stops



chosen (see Figures 6 and 7).

A short round (distance: 2.1km, cumulative height difference: 22m per round) in this area was defined and the electric bicycle was charged with an important amount of payload (45kg continuously). One battery pack of 13 Ah was fully charged and the postal round was repeated until the battery pack was fully discharged. The following results were obtained:

- Distance covered: 10.7 km (± 5 rounds)
- Cumulative height difference: 110 m
- Number of start and stops: 735

Comparing these performances obtained during the test rides with the calculations of the NEPH design tool by using the results of the test rides as input data gave

Result obtained during test rides	Calculated with the NEPH design tool
13 Ah (one battery pack)	13.1 Ah



Figure 6: Test rides in Brussels



Figure 7: Topographic map of the region

a satisfying result:

The prototypes have been equipped to measure and log several parameters (motor temperature, battery current, vehicle speed, etc.) The prototypes have been used for several test tracks, and the measurements have been used to characterize the performances of the NEPH vehicles. These results could also be used to validate the design tool that was developed.

A specific test was performed to measure the energy consumption of the start-and-go operation typical for postal usage of the bicycle. The battery current and voltage was measured during the time the bicycle was used to accelerate and stop 4 times. This test was repeated several times and different payloads were applied. The results of the energy consumption, calculated from the measured current and voltage at the battery side, was compared to the output of the NEPH design tool. These results are shown in Figure 8.

Three different lines can be seen on the graph in Figure 8 corresponding to the calculated energy consumption for the 4 start and stops with different values for the speed attained between 2 stops: 10km/h, 12km/h and 14km/h, respectively.

The influence of this parameter is clearly significant and will determine to a large extent the required battery capacity. The influence of the payload is also important and increases the required energy from the battery pack. Especially during the numerous accelerations performed during a postal delivery round, the postman will request most traction force from the

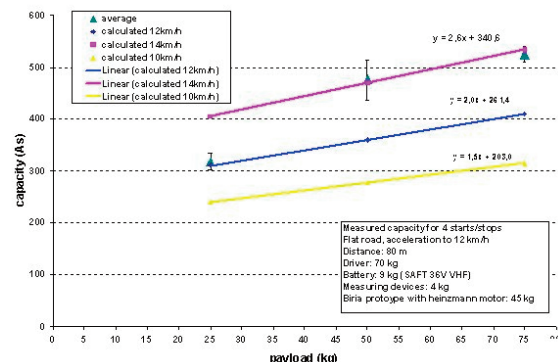


Figure 8: measurements versus calculation for start and go operation

electric drive train.

A different mode of operation was also analysed: driving on a flat road at a continuous speed. To exclude wind and to assure a completely flat surface, energy measurements were done in a gym court. A few rounds were driven with the prototypes around an indoor football court.

Again the obtained results were compared with the NEPH design tool. The results, in case of a payload of 75 kg and expressed in As/km, can be seen in Figure 9:

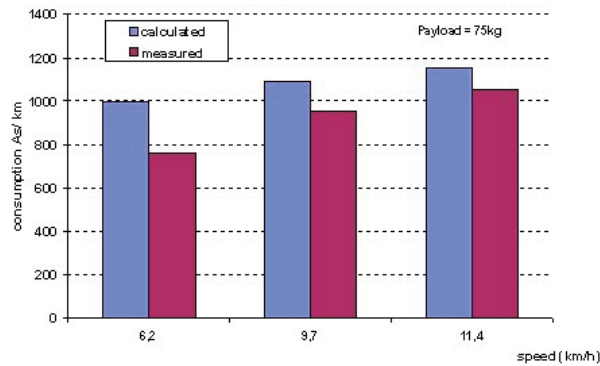


Figure 9: Measurements versus calculations for flat road driving

Again, good correlation between the measured energy consumption and the calculations can be observed. The influence of the average speed can be seen on the graph of Figure 9.

5. CONCLUSIONS

In this paper, the results of the development of an electric postal bicycle are presented. The development of a range of power system components constituting the NEPH electrical drive train was based on a bottom-up approach. Starting from the description of the postal needs, the required components have been developed and evaluated. Furthermore, different bench tests of the power system components, as well as road tests of the complete electric mobility devices, have been carried out and have validated the performances of the vehicles.

A dedicated design tool has been developed and validated and now also allows one to forecast the performance of a specific configuration of the modular NEPH drive train. The NEPH electric bicycles that have been developed were first internally tested within the industrial consortium and are now being evaluated at several postal organizations. The modular approach of the NEPH project in combination with the design tool will allow each postal organization to design postal electric bicycles corresponding to their specific needs and will allow for matching and optimising the distribution rounds to the capacity of the NEPH vehicles. An interesting outcome of this work is the importance of the required battery capacity. This capacity can be calculated for each postal delivery round and will vary from region to region. The most demanding delivery rounds lead to a configuration with two or three VHF modules of 14.5Ah (36V). The high total vehicle mass (about 180kg including the driver) requires a high traction force at the wheels of the bicycle. If the effort of the postman is to be limited, a high output torque of the electric motor is requested, especially in hilly environments.

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7. AUTHORS



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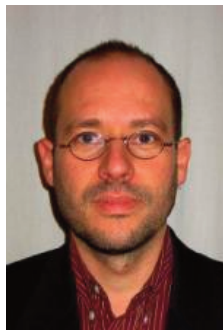
vehicles and in the development of electric postal bikes. Further research goes to the evaluation of hybrid electric drive trains for road vehicles.

Jens Nietvelt graduated in 2006 as an Electromechanical Engineer at the Vrije Universiteit Brussel. His master thesis dealt with the development of electrically assisted postal bicycles. After his graduation he was assigned as a part time researcher at the department ETEC. His research involves the development of electrically assisted bicycles.



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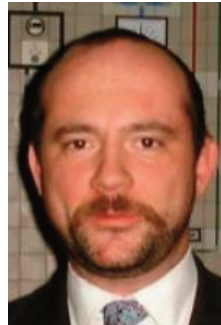
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