ULTRALIGHT ELECTRIC VEHICLES: A NEW CONCEPT THAT PROMISES SUCCESS

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INTRODUCTION

The last few decades have seen the development of a variety of electrical vehicles for urban use. Up to now however, none of them has enjoyed lasting success in the marketplace. The chief reason was that the price was too high, but there were also technical shortcomings that impaired the vehicles' suitability for everyday use.

The conceptual design of a completely novel ultralight electrical vehicle has been developed at the Technical University of Applied Sciences of Rapperswil. The four-wheeled vehicle can carry two adults and either two children or luggage. Several semester studies and degree theses have been dedicated to working out the conceptual design, leading subsequently to a simple, functional design that is ready to be put into production. Care was taken to ensure that the vehicle could be produced cost-efficiently even in short production runs. Decisive in this connection is the integrated design of the chassis with the bodywork, which was developed and designed specifically for this vehicle. The structure is reduced to the bare essentials without in any way impairing its functionality. Furthermore, attention was paid to making sure that individual components and assemblies and indeed the whole vehicle can be manufactured without expensive tooling. A pre-prototype was built and tested in order to check the vehicle's driving behaviour and other characteristics.

DESIGN CONCEPT

"Form follows function" was the guiding principle in determining the shape of the body: the simplicity of the design reflects the consistent use of lightweight construction. Figure 1 illustrates the current design of the whole vehicle. The design should contrast clearly with that of conventional vehicles, without appearing out of place in normal traffic.

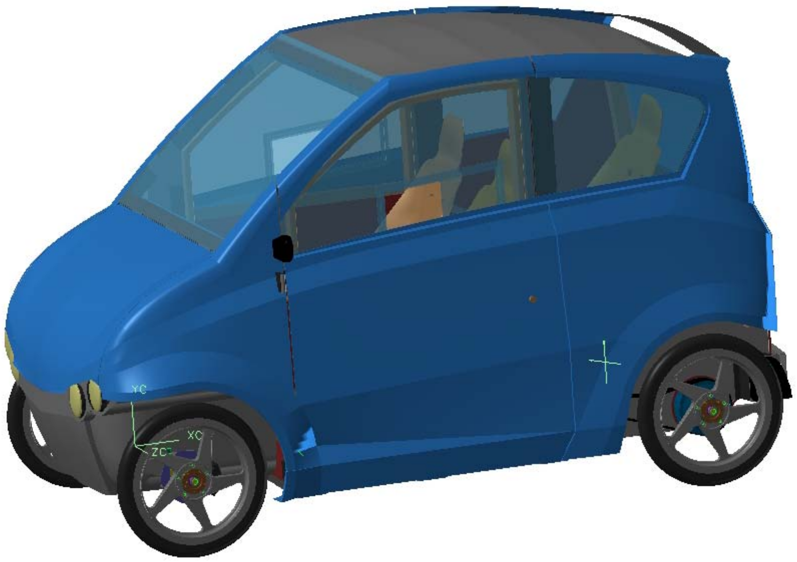

Figure 1: Exterior view of the ultralight electric vehicle

The following Table 1 sets out the technical specification of the vehicle.

Table 1 –Technical specification of the vehicle

Carrying capacity	Adults	2
	Children	2 (or luggage)
Weight	Unloaded without batteries	200 kg
	Batteries	About 50 kg
	Total with maximum load	550 kg
Overall dimensions	Length x width x height	244 x 132 x 149 cm
Drive power	Electric motors	2 x 3.5 kW
Maximum speed		60 km/h
Energy storage	Li-Mn Batteries	72V / 95Ah
Range on full charge		100 km

CHASSIS

A longitudinal torsion beam that is joined to the rigid axles by cast alloy nodes forms the chassis and part of the suspension (Figure 2). All these components are made of aluminium alloy. The longitudinal beam is designed with some flexibility, so that it can adjust to unevenness in the road by elastic torsional deflection. Its required torsional stiffness was calculated by numerical simulation of the dynamic behaviour of the chassis under service conditions.

Figure 2: The longitudinal torsion beam with the rigid axles and the spring-mounted seats

In contrast to conventional design the seats are mounted directly on the chassis torsion beam via a spring mechanism. The seat shells are made of fibre-reinforced plastic (FRP) and are mounted together in an aluminium frame. The batteries are also mounted on this frame, directly beneath the seat bottoms. This solution ensures that the passengers and the batteries, which together make up the greater part of the total mass of the loaded vehicle, are spring-mounted. Thus this design using an unsprung body results in the best possible ratio of sprung to unsprung weight. By making the transmission paths as direct as possible the design ensures that the inertia forces are transmitted very directly to the roadway.

The undercarriage concept is likewise very simple. The aluminium wheels are mounted on the rigid axle at the rear and on the steering arm in front. Two disc brakes are mounted in front, and two drum brakes with the hand-brake mechanism at the rear. To reduce weight the brake drums are of aluminium alloy with a hard surface coating.

BODYWORK

A light tubular space frame carries the superstructure surrounding the passenger compartment (Figure 3). It is securely fastened in the back at the rear to the fixed axle via the axle stubs and in the front in the middle of the transverse beam between the A-pillars. Cold joining methods are used exclusively for the joint of the space-frame, so as to avoid welding with its accompanying risk of thermal distortion an heat affected zones. The aluminium sections of the tubular frame are generally straight, or bent in two dimensions in the case of the roof frame. They are fastened together with corner plates, by riveting combined with adhesive joining. The sandwich floor and the polycarbonate windows form large shear-resistant elements that further stiffen the structure. The polycarbonate windshield is additionally coated with a scratch-resistant material.

Figure 3: The tubular lattice frame with shear-resistant floor and windows

The integrity of the tube-frame was checked by a crash analysis in order to ensure the safety of the occupants under collision conditions. Other important safety elements are the side-impact bars in both doors, which are made of aluminium profiles, and the front-end, which absorbs energy in case of a frontal collision (Figure 4). A fibre reinforced monocoque sandwich construction was chosen for the latter because not only does it offer great freedom in deciding the shape, but it also allows building in a number of different functions in the same component and additionally shows excellent crash behaviour. The hang-on body parts are likewise made of thermoformed panels, and are directly joined to the tube frame with thick-film polyurethane adhesive.

The roof and back are clad with flexible plastic sheet cross-ribbed with glass-fibre reinforced plastic sections. In good weather conditions both can be rolled up.

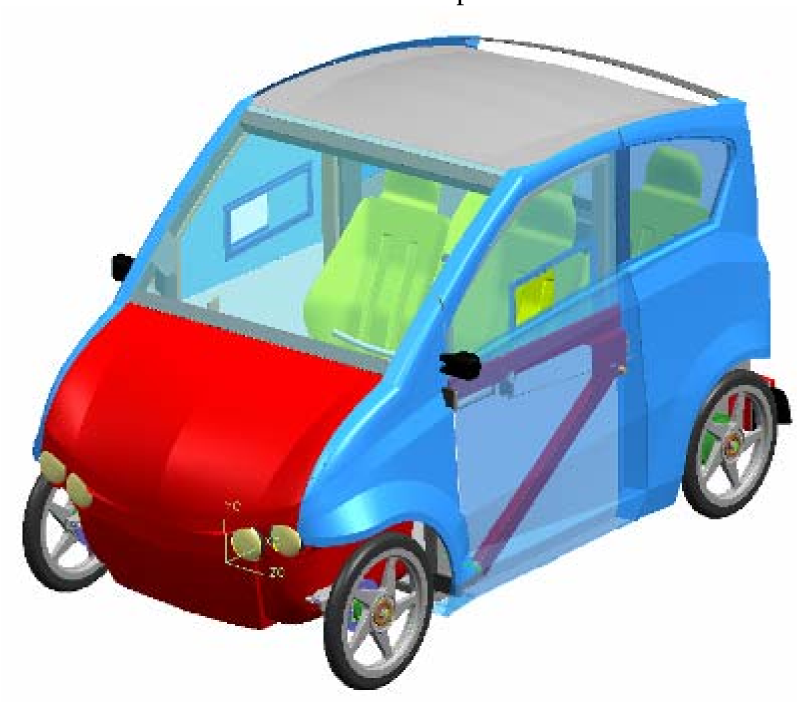

Figure 4: Passive safety elements: fibre reinforced monocoque front end and aluminium side impact beams

POWER TRAIN

The two electric motors are mounted on a generously dimensioned carrier plate and drive the rear wheels (Figure 3).

The motors are permanent-field disc-armature 36V DC motors connected in series, each of 3.5 kW. They are located inside the passenger space and are thus protected against salt spray. The power supply consists of lithium-manganese accumulators provided by the Chinese Citic Guoan MGL Group with a total capacity of 95 Ah at 72V, giving the car a range of 100 km.

Torque is transmitted to the wheels by toothed belts with the appropriate drive ratio, giving the car a maximum speed of 60 km/h. Regenerative braking is used to conserve energy.

PRESENT STATE OF THE PROJECT

A drivable pre-prototype was built in the second half of 2006 to test the feasibility of the concept as well as the performance and comfort of the car. Figure 5 shows the finished pre-prototype; the front end, doors and inside finish were not included in order to limit the cost.

Figure 5: The pre-prototype, without front-end, doors or inside finish

The driving tests gave the following results:

- The functionality of the car is fully proven. In particular the sprung seating behaved ideally, even though the air-cushion spring had no shock absorber. The drive train also performed well: the motors proved reliable, and the tooth-belt transmission gave no problems. The very direct handlebar steering took some getting used to, but gave the car a rather sporty feel. The coordination of the battery management system and the drive motor electronics needs attention. Under sudden peak loading – a steep hill, or very rapid acceleration – the battery management system would sometimes shut down to protect the battery.
- On-the-road performance was convincing. The 7 kW drive system handled stop-go traffic conditions perfectly. Even when the car was fully laden (300 kg) there were no problems, as the motors can provide a short-term peak power of 10 kW.

- Passenger comfort left something to be desired. The ride was bumpy, despite the special tyres to compensate the lack of conventional springing. Apart from that, the steering geometry needs optimising to improve the tracking.

Based on these results the design was modified. Within a few days a sprung chassis was developed, produced and assembled. Figure 6 shows the CAD image of the new sprung chassis. Two transverse leaf springs made of glass-reinforced plastic better absorb the shocks from road bumps and so improve passenger comfort.

Figure 6: Reworked chassis with leaf springs and special tyres

Road tests confirmed that the reworked suspension in combination with the special tyres significantly improved the comfort of the ride.

CONCLUSION AND FUTURE OUTLOOK

The project presented here shows that by means of multimaterial construction and logical and consistent integration of functions it is possible to produce a cost-efficient ultra-light passenger vehicle. Thanks to the very low weight of 250 kg including batteries a nominal drive power of only 7 kW ensures adequate performance. In addition, after modifying the suspension the drive comfort was acceptable.

The exterior design is currently being reworked. The new design is meant to give the vehicle its own special character. Since the ultra-light electric car represents a new class of vehicle, its external appearance should set it completely apart from conventional vehicles. The firm ID-Connect has been given an order for the redesign; Figure 7 shows a first draft of the car's new appearance.

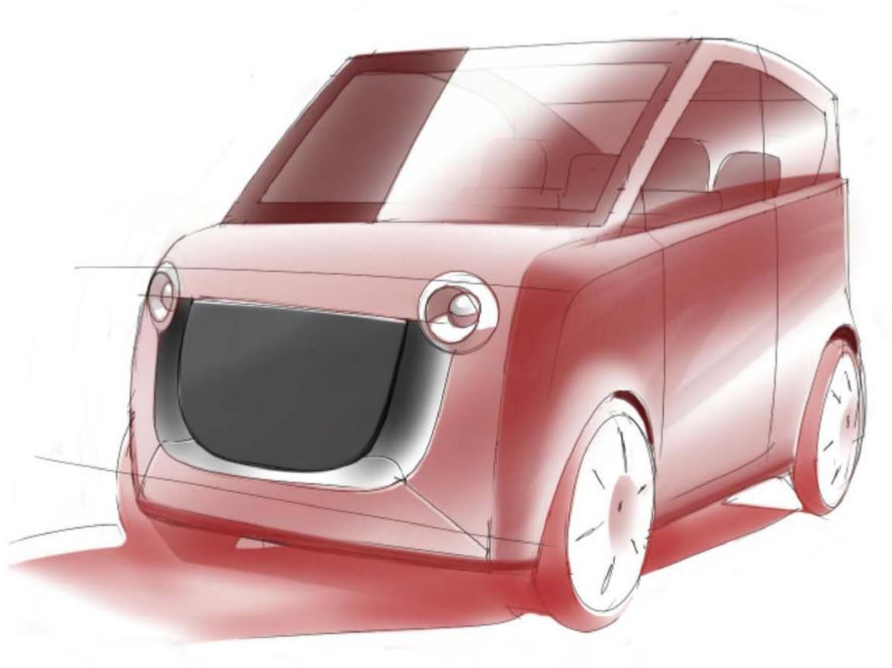

Figure 7: The new exterior design

In 2007 two complete prototypes will be built to the reworked design, with the goal of securing the official Swiss type approval for the vehicle.

ACKNOWLEDGEMENTS

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REFERENCES

Henne M., Wielatt L. (2006), *Ultraleicht-Elektrofahrzeug: Ein neues, erfolgversprechendes Konzept*, Proceedings Automotive Day 2006, Biel

Henne M. (2006), European Patent EP06015896, *Elektrisch betriebenes Kraftfahrzeug, insbesondere Personen- oder Kleintransportfahrzeuge.*