PERSONAL COMMUTING VEHICLE CONCEPT

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Abstract

In the article the author presents the analysis of personal commuting vehicles produced nowadays. The analysis comprises their purposes, functionality, comfort and construction solution of the following elements: drive and steering system, suspension and batteries. The evolution of a vehicle regarding the space necessary for its manoeuvres and parking is the essential parameter of the analysis. The concept of a city vehicle worked out at the Cracow University of Technology is presented in the further part of the article. The vehicle that has been constructed belongs to L6e category. In the article two concepts of such vehicle are presented – a vehicle for a single person and "a tandem" type of vehicle for two persons. The result of introductory tests of a function model worked out on the basis of a concept model is also presented. The function of the frame and its shape is to make possible for the front of vehicle to enter the back of the other one. Construction solution of this type also reduced the space necessary for parking. Two concepts of front suspension system – rotation axle and suspension with swivel axle were evaluated. Manoeuvrability and stability of rectilinear of rectilinear motion were taken into account. The results that were obtained make drawing conclusion referring to further development of such vehicle possible.

Keywords: *transport, city transport, personal commuting vehicle, narrow car*

1. Introduction

The problems that automotive industry has to face are as follows [7]: What vehicle technologies are the future?, How fast could this future happen?, What is needed to make this future happen?, How much would it cost?. Personal Commuting Vehicle is a new type of a vehicle that is smaller and lighter than an average car, yet it is much safer than a motorcycle. Urban and suburban areas are its destination and ensuring personal mobility in these areas is its aim. It is commonly known that human addiction to individual transportation makes its complete replacement by public transport impossible.

That is the reason why it is worthwhile to work out the transport means that could make individual transportation in urban areas more environmentally friendly. This in turn requires defining such characteristics as: number of occupants, kind of a drive system, price of purchase and costs of exploitation.

Average vehicle occupancy in American cities is 1.6 [5, 6] and it is even less in commuting hours and oscillates around 1.4. In European cities the vehicle occupancy is even less and it is about 1.1-1.2 [1]. The best solution for short distances taking into account the present technology of batteries is a light and small vehicle of BEV category (Battery Electric Vehicle). Its low-noise and zero emission performance make it a perfect solution for city environment. When energy efficiency from well to wheel is compared an electric vehicle with lead –acid batteries is on average [7]:
- 1.2 times better that that of the best diesel vehicles (excluding hybrids),
- 1.5 times better that that of the best petrol vehicles (excluding hybrids),

an electric vehicle with lithium batteries is on average:
- 1.5 times better that that of the best diesel vehicles (excluding hybrids)
- 1.8 times better that that of the best diesel vehicles (excluding hybrids)

When CO_2 emission from well to wheel is compared an electric vehicle with lead-acid batteries is on average:

- CO_2 of a diesel powered car = 1.9 x CO_2 of an electric car with lead-acid batteries
- CO_2 of a petrol powered car = 2.0 x CO_2 of an electric car with lead-acid batteries
- CO_2 of a diesel powered car = 2.2 x CO_2 of an electric car with lithium batteries
- CO_2 of a petrol powered car = 2.4 x CO_2 of an electric car with lithium batteries

The problem that is difficult to solve in such a small and light vehicle is safety. One of the solutions to this problem is limiting maximum speed and creating the category of L6e vehicle with 45 km/h maximum velocity, for which a driving license is not required. If higher range is to be considered, the usage of BEV type of L6e category is not suitable as requirements for velocity as well as for active and passive safety is much higher. In this case a vehicle of EREV(Extended Range Electric Vehicle) category is a better solution [8].

The items presented above are not sufficient for designating proper solutions for such type of construction.

Dimensions of such a vehicle create a problem. Taking into account limited parking areas in cities, such a vehicle should neither be too long nor too wide. That is why the vehicles should be designed as: Ultra –Small Electric Car (USUC)-length does not exceed 2.75 m and width does not exceed 1.6 m, or Ultra-Narrow Urban electric Car (UNUC)-width does not exceed 1.2 m.

It should be also remembered that such vehicles should look attractive and be fun to drive so that in spite of the high costs of production people they will be encouraged to buy them.

The precise definition of these vehicle characteristics has not been given yet.

2. Examples of construction solutions

The majority of the UMUC types are vehicles in which occupant's seats are situated one behind the other. That allows for the width of the vehicle to be very narrow. Examples of such a solution namely; Lumeneo Smera [12], Renaul Twizy[14], TTW One[9], Secma Fun [10], Narrow Car[13] are presented in Fig. 1. The list above makes designation of the basic dimensions of vehicles constructed nowadays possible. Two tendencies in the drive systems used nowadays can be observed. The first one is using high power drive system that makes obtaining high values of maximum velocity possible. Such a construction solution is close to meeting the requirements for such types of vehicles according to American definition in which acceleration of vehicles in fewer than 18 sec to the speed of 60 mil/h is required. Combustion engines used in these vehicles ensure low emission of harmful gases and the level of CO_2 emission is lower than 60 g/km. The other tendency concentrates on limiting vehicle traction parameters and simultaneous ensuring its proper range. However, the dimensions such as vehicle width and length are the most important factors. The comparison of the space needed for parking a motorcycle, a scooter, a PCV vehicle and a small vehicle is presented in Fig. 2. The space that is needed for parking a Fiat 500 is the same as for parking 2 Smart type vehicles or 4 PCV type vehicles [9].

Basic technical data of the vehicle in Fig. 1 are given in the Tab. 1.

Tab. 1. Technical data of the vehicles

Type	Lenght [m]	Widght [m]	High [m]	Mass [kg]	Maximum Velocity [km/h]	Range [km]	Type of drive line
Lumeneo Smera	2.5	0.86		450	130	150	Electric 2x15 kW
Renault Twizy	2.3	1.13	1.47	420	75	100	Electric 15 kW
TTW One	2.5	1.1	1.7	488	180	25 (Battery)	ICE 55 kW Electric 15 kW
Narrow Car	2.5	1.1	1.7	300	85	150	ICE 20 KM
Secma Fun elec	2.1	1.06	1.47	240	45	40-50	Electric 1.9 kW
Commuter Cars Tango	2.57	0.99	1.5	1360	240	128	Electric 2x21.5 kW

Lumeneo Smera

Renault Twizy

TTW one

Narrow Car

Secma Fun

Commuter Cars Tango

Fig. 1. Examples of constructionsolutions

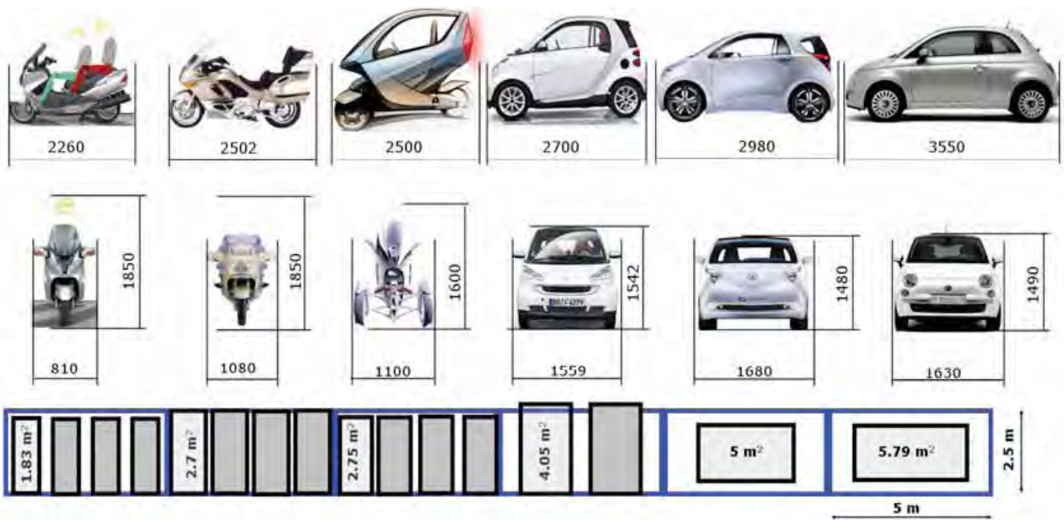

Fig. 2. Comparison of the space needed for parking PCV vehicles, small city vehicles, motorcycles and scooters [9]

The review presented above covers only some examples of the construction solutions of vehicles that may solve the problems of personal mobility. It does not deal with micro vehicles which dimensions due to the comfort requirements are not very different from the dimensions of A type of vehicles.

3.Concept of a PCV type of vehicle

It was assumed that the category of a vehicle will be of L6e. It determined the value of the maximum power of a drive system, a vehicle total mass, its maximum velocity while at the same time it allows for the use of simple construction solution. That was why the cost of production was expected not to be very high. Moreover, the vehicle was expected to be easily adopted for the disabled and that was why the steering devices were to be entirely manually operated.

The introductory concept was defined as the project of Agnieszka Fujak the student of Academy of Fine Arts Cracow. It was to be used for parking areas. This concept is presented in Fig. 3.

Fig. 3. A vehicle for parking areas [2]

Fig. 4. Parking of vehicles or tandem drive [2]

In order to reduce the area used by vehicles while parked, the front track of wheels was planned to be smaller so as to make possible for the front one vehicle to drive into the rear of the other one. This situation is presented in Fig. 4.

The length of a vehicle was to be 2 m that made parking perpendicularly to the edge of the road possible. The width of a vehicle was to be 0.9 m that made entering the gate of average width possible. Front wheel track was limited to 0.5 m that made driving between the rear wheels of the other car possible. The introductory analysis showed that it is possible to drive vehicle joined in this way. When the length of a vehicle was not larger than previously mentioned and the wheelbase was 1.56 m the total length of the joined vehicles should not exceed 3 m. That is why the turning radius value is acceptable on the average road curves although only the front axle of the first vehicle was turned. It has also to be noted that the vehicle can perform more than one function. It is possible to separate this vehicle into two self sufficient vehicles and to re-join them when needed. The person in the second vehicle when they are separated can drive their own vehicle and carry on their own transport tasks. Joining of the vehicles into “tandem” system results in diminishing motion resistance when compared with two vehicles that are driven independently. Since both vehicles are equipped with batteries it can be assumed that that the range of such a joined vehicle is much larger than that of a single one. Chassis is made up of a steel frame to which two different front suspension systems with two different steering systems can be mounted. The first one is rotation axle with the values of the front axle turning angle over 45° (Fig. 5). In the second one it is planned to use standard steering system that limits the values of the turning angle to 30°. When rotation axle is used it is possible to obtain as little value of turning angle as 1.6 m. The vehicle equipped with this rotation axle is very manoeuvrable. However, during rectilinear movement it should be predicted that around the rotation. axle of the front wheel system there is a possibility of vibration excitation with high amplitude values that are difficult to be damped. What is more, the caster angle during turning results in creating the roll angle. This has to be taken into account when the possibility of coupling of vibration around, rotation axle and roll vibration and the increase of forces on steering bar are considered. That is why the maximum speed of such a vehicle is limited to 25 km/h.

Fig. 5. Rotation axle [3]

Construction solution of a vehicle frame made mounting alternative front suspension that consists of two wishbones that are not parallel and are of different lengths with coil spring with hydraulic dampers possible (Fig. 6).

Fig. 6. Suspension with swivel axle [4]

The front track of wheels that was reduced and that made the "tandem" type possible was left unchanged. The value of the turning radius that was measured was 2.85 m that is the proof of vehicle manoeuvrability. The force values on the steering bar during standstill turning was 32 N for rotation axle and 55 N for standard steering system.

Dual speeds electric Crystalyte motors [11] of 850 W each were used for driving the vehicle. The characteristics is presented in Fig. 7.

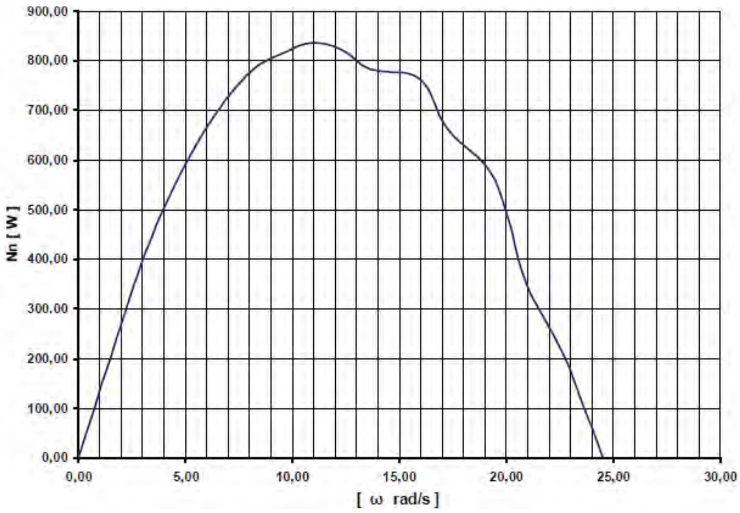

Fig. 7. Characteristics of an engine [11]

Maximum velocity of the vehicle equipped with such engines was about 40km/h. The vehicle was equipped with standard lead-acid batteries with 48 V total voltages. Total weight of the batteries was 24 kg and these batteries guarantee the vehicle range of about 35 km. With this voltage the assumed vehicle speed that was 45 km/h was not reached. Moreover, acceleration values of a vehicle were rather small and did not exceed 1.6 m/s when the weight of a vehicle was 220 kg. The increase of current supply voltage would make the traction characteristics better. It is possible to increase the voltage to 72 V in the case of these engines.

The test of a drive in tandem system was done. Functional model of a second vehicle was built and the measurements of turning radius and traction characteristics of such a assembly were done. As in the case of two vehicles joined together only front wheels of the first vehicle were turned the turning radius was increased to a large extend. In order to avoid such high values of slip angles of vehicle drive axle's wheels when driving a tandem type the turning angle of wheels was reduced to 15°. The value of turning radius that was obtained was about 6 m. This value is slightly higher than average values of turning radius of vehicles and may be acceptable when the fact that these vehicles may be separated for manoeuvring is taken into account. The values of acceleration and maximum velocity when 48 V voltages were applied were much lower so that if these vehicles were to be used as tandem type the voltage used should be higher.

4. Conclusion

The proposition of the PCV type of a vehicle presented here is a functional model. Construction of this model made evaluation of the presumed construction and costs concepts possible. The vehicle is very simple in realization, the costs of its construction were less than 10,000 PLN. In the case when the driving system can be entirely manually operated the vehicle may be considered as suitable for the disabled and its big wheels and ground clearance) make it suitable for the use in rural areas. The results that were obtained during the introductory test confirm the possibility of using such type of vehicles in tandem system. However, it should be noted that when the described batteries were used the range of the vehicle was too small. If other batteries for example lithium were used the range would be larger but in that case the cost of batteries would be much higher. The increase of engine voltage would make the performance higher so that it can make the vehicle reach maximum acceptable speed of 45km/h. The option of two types of front suspension that was proposed make selection of the vehicle function possible.

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