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Design and development of a zero-emission scooter for Taiwan

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Abstract

A prototype zero-emission scooter (ZES) has been developed to solve air-pollution problems in the large cities of Taiwan. The design features of the ZES are described; these include battery, motor/driver, transmission systems, and body-chassis structure. The driving range of the prototype ZES in urban areas is about 40 km per single charge. Its maximum speed is over 50 km h^{-1}, and it can accelerate to 30 m in less than 5 s. A future programme of field trials is also discussed.

Keywords: Electric motorcycle; Lead/acid batteries; Air pollution; Zero emission

1. Introduction

The motorcycle is a very popular vehicle for transportation due to its mobility, convenience, economy, and door-to-door functions. Consequently, more than 10 million motorcycles crowd the urban and rural areas of Taiwan. These machines account for approximately 73% of the total fleet of mobile vehicles. Moreover, motor vehicles are the major cause of the severe air-pollution problems in the large cities. Many advocators, including the Nobel Laureate, Dr Lee (Director of Academia Sinica), have urged the government to adopt electric vehicles, especially electric motorcycles, in order to improve the air quality in cities. The Environment Protection Agency (EPA) has introduced a mandate that requires 2% of the motorcycles sold by every manufacturer in year 2000 to be electrically powered.

The EPA has also started to collect 'air-pollution' fares since July 1995, and part of this money will be used to subsidize the purchasing of electric motorcycles. A programme of field trials has been initiated in universities, and is spreading to larger areas. In 1990, the Energy Commission of the Ministry of Economic Affairs launched a long-term project for the development of electric motorcycles. This project consists of four parts, namely, development of the body, motor/driver, transmission, and battery. Many major manufacturers of mobile vehicles and related industries have joined in the project. These include: motorcycle plants (Sanyang, Kymco, Taiwan Yamaha, Taiwan Suzuki, Yuenfoong, Giant Yeh), motor plants (Shihlin, Taigene), and battery plants (Taiwan Yuasa, Ztong Yee and Kung Long). An outline of this project is given in this paper.

2. Design of zero-emission scooter

2.1. Battery systems

A 48 V battery has been chosen in order to give a low system current and, therefore, a low rating requirement for the electrical components. Four 12 V, valve-regulated lead/acid batteries are used because such batteries are commercially available and spill-proof. The batteries are placed in a 2×2 compact arrangement under the footboard, i.e. in the place where the fuel tank is located in a corresponding internal combustion-engined (ICE) scooter. Thus, the battery has to be short and meet the height limit of the footboard and the required distance above the ground. A battery size of 175 mm×165 mm×125 mm ($l \times w \times h$) is chosen to accommodate these constraints. Such a design allows the centre of gravity of the scooter to drop 100 mm or more. Also, the footboard surface is flat without any bumps and thus allows comfortable driving.

The battery has a capacity of 28 Ah ($C_3/3$ rate) and a weight of 9.5 kg. It provides a normal urban driving range of 30 km/day. The targeted life is 330 cycles under a given electric motorcycle driving pattern. The prototype battery can provide a peak power of 1100 W for 30 s, or a constant power of 425 W for 24 min. The battery charger and capacity indicator are combined together into a single unit. The charger

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applies a constant-current/constant-voltage charging schedule. The capacity indicator is based on the Ah method. A warning LED begins to twinkle when the battery capacity drops to under 40% of the initial value.

2.2. Motor-driver systems

A d.c. brushless motor was chosen due to its higher efficiency, higher power density, and lower maintenance requirements. This motor has a maximum revolution of 6000 rpm. It is designed to operate under the following three conditions: (i) to generate 27 kg cm torque at 5200 rpm for 30 min at a maximum speed of 50 km h^{-1}; (ii) to generate 90 km cm torque at 1800 rpm for 3 min when climbing a 12° hill with a speed higher than 18 km h^{-1}, and (iii) to generate 12 kg cm torque at 3100 rpm for 2 h at a constant-speed driving of 30 km h^{-1}. For producing the torque requirements of the motor, three sets of IGBT switching (controlled by a microprocessor) are used to provide a current of more than 120 A to drive the motor. They are housed in an aluminium box, with a cooling fin outside, that is located on the right-hand side underneath the seat, i.e. at the position of the exhaust pipe on an ICE scooter.

Table 1
Specifications of zero-emission scooter

	Parameter	ZES 2000
Dimensions	length × width × height (mm)	1680 × 640 × 1080
	wheel base (mm)	1170
	carry capacity (person)	2
	weight (kg)	105
	maximum speed (km h^{-1})	over 50
Performance	acceleration, 0 to 30 m (s)	within 5
	hill climbing at 12°	10 km h^{-1} or above
	range (km)	65 at 30 km h^{-1}
	type	d.c. brushless motor
Power	rated power (kW)	0.75
	maximum revolution (rpm)	6000
	control method	PWM
	type	sealed lead/acid
Battery	voltage (V)	48
	capacity (Ah)	28 (C_3/3 rate)
	weight (kg)	38 (9.5 × 4)
	dimensions (mm) (length × width × height)	175 × 166 × 125 mm
	type	180 W on-board
Charger	input power	a.c. 110 V, 3 A
	standard charging time (h)	6–8
	capacity indicator	Ah accumulation
Transmission	type	2 stages, automatic
	reduction ratio	16.3–7.2
	tyre (front/rear)	3.00–10-4PR tubeless
	tyre pressure (kg cm^{-2})	2.0 (both front and rear)
	brake	disk (front), drum (rear)
Others	d.c.–d.c.	48 V–12 V, 100 W
	electrical component	12 V
	turning radius	1.6
	cushion (front)	telescope
	cushion (rear)	single side

2.3. Transmission systems

A two-stage automatic transmission is used to meet both maximum speed and acceleration requirements. A reduction-gear train is used instead of a conventional belt-type CVT to reduce transmission friction losses. The gear change is controlled automatically by a planet gear set and a clutch. The reduction ratio between the first and second stages is 1.624.

The efficiencies at all ranges are more than 90% compared with 80% for the belt-type CVT at the best point. The merit of this arrangement becomes evident as battery capacity is limited in the electric vehicle.

2.4. Body-chassis structures

Driveability and safety are the major concerns with the body structure. The zero-emission scooter (ZES) is heavier than an ICE motorcycle of the same size; it has a weight of about 105 kg. This heavier weight may exert a negative influence on the driveability. The increased weight is necessary, however, for reinforcing the chassis structure so that it has sufficient strength to secure the four batteries in place for safe driving. The motor, driver and transmission are independent modules, but they can be assembled easily into one power unit. Since the batteries are located beneath the footboard, the helmet space is left unchanged. The on-board charger is placed at the back in a metal box that can be unlocked by the main switch key. It is easy to pull out the charging cable and connect it to a 110 V wall outlet.

2.5. Performances

All the specifications regarding the battery, motor, driver, transmission, body-chassis structure, charger and capacity indicator are listed in Table 1. The prototype ZES is shown in Fig. 1.

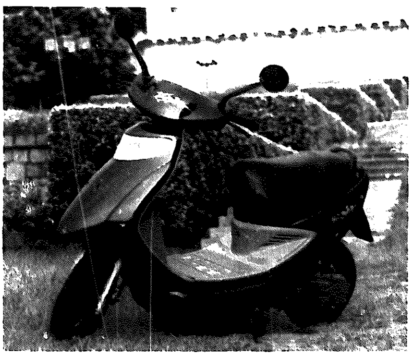

Fig. 1. Prototype zero-emission scooter.

3. Future outlook

Eight prototype ZESs were assembled and put on test in June, 1995. A two-year, test-ride programme commenced at that time. In the first year, these eight ZESs will be used, but in the second year, 30 more ZESs will be provided for evaluation. During the first year, the test-riders will be chosen from staff of the Industrial Technology Research Institute. In the following year, the programme will be extended to workers and students within government organizations and colleges.

The objectives of the test-ride programme in the first year are as follows: (i) to obtain riders' impressions and comments; (ii) to evaluate and improve components' durability; (iii) to assess charging convenience; (iv) to collect information for the next stage of testing; (v) to revise operation and maintenance manuals; (vi) to evaluate the necessary charging facilities; (vii) to analyse customer satisfaction; (viii) to assess maintenance convenience; (ix) to assess battery performance, and (x) to educate the public.

A Steering Committee (which includes people from industry, government, universities and research institutes) will be formed to monitor the project. With these localized test-ride programmes, all related problems, such as technologies, component endurance, charging facilities and regulations, will be gradually solved. In addition, the public will be educated and the obstacles for promoting the ZES will be removed.

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