Development of electric motor cycle technologies in Taiwan

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Abstract

The development of an electric motor cycle was initiated at the Industrial Technology Research Institute in 1990. Several types of experimental electric scooters have been developed and field-tested, but their individual performances are far from satisfactory. Thus, it has been decided to make improvements on both the key components (such as battery, motor and driver) and the structural designs. The targeted electric motor cycle will adopt well to city-driving conditions and will help to alleviate urban air-pollution problems. The impact of electric motor cycles on the improvement of urban air-pollution problem has been evaluated. It is found that if 20% of the total motor cycle population is replaced by electric versions, a tremendous improvement in air quality will result, but this will still not meet the air-regulation standard. At least a 50% replacement is required to prevent continuous degradation of air quality.

Introduction

With increase in the worldwide environment-protection movement, the electric vehicle is regaining its popularity as a means to return to mankind a clean earth, especially in a small Pacific island such as Taiwan.

Because of Taiwan's unique situation, the number of motor cycles has exceeded 10 million units, i.e., one motor cycle for every two people on the island. The motor cycle has not only become the most popular transportation vehicle, but has also caused an environmental tumor, as it severely degrades the quality of urban air. Moreover, the situation is worsening every day. Therefore, since 1990, the Energy Commission of the Ministry of Economic Affairs in Taiwan has commissioned the Industrial Technology Research Institute (ITRI, a non-profit organization) to develop an electric motor cycle. The objectives of the whole project are to acquire mature and advanced technologies for the fabrication of key components, to design marketable components that are suitable for local situations, to assemble them into a small scooter, and to proceed with making improvements until a balance point is reached between performance, market scale and cost. In addition to the technology developments conducted at ITRI, the local industries (e.g., the motor cycle battery and motor manufacturers) have also joined the project in the hope that cooperative efforts will turn laboratory-scale technologies into commercial products.

In concert with the above project, a simulation study on the improvement of urban air quality with the introduction of various market shares of electric motor

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cycles has been performed. For example, if 20% of internal-combustion-engined (ICE) motor cycles are replaced by electric versions, the reduction in the amount of hydrocarbons in air will exceed levels set by the compulsory pollution control regulations. Such results indicate that the electric motor cycle is quite effective in pollution control, and is appropriate for legislative consideration.

Product objectives

The electric motor cycle, by its very nature, will have the disadvantages of a higher weight and a lower driving range. Furthermore, the cost at the developing stage will be high due to small-scale production. The lack of public battery-charging facilities will also cause an inconvenience. Therefore, an attempt to replace all ICE motor cycles by electric counterparts is too optimistic and unwise at present. But appropriate legislations can allow the electric motor cycle to survive in the competitive market.

According to the report of a contracted market research group, the motor-cyclist's driving speed and average daily driving range in urban areas are both far less than those in suburban areas. In a city such as Taipei, with heavy traffic and frequent stop signs, only about one-tenth of the motor-cyclists' driving speed will exceed 40 km h^{-1}, and the average driving speed is less than 15 km h^{-1}. In addition, 68% of the average daily driving range is less than 25 km, and 70% of the daily driving time is less than 1.5 h. Therefore, the proposed electric motor cycle is designed to be a transportation vehicle for those whose drive in urban areas with short-distance travel, e.g., daily commuters, housewives' shopping and collection of children, students' in-campus driving, etc. The target performance for the electric motor-cycle is as follows:

- maximum speed: 45–50 km h^{-1}
- driving range: 60–65 km (at constant speed 30 km h^{-1})
- acceleration: 0–30 m in 6 s
- climbability: 21%

On very conservative estimation, the above specifications will satisfy the requirements of more than 50% of local motor-cyclists.

Technology development

Battery

The low energy density of the lead/acid battery makes it unable to compete with gasoline. The battery, therefore, is the bottleneck for the development of electric vehicles. In fact, even if the battery's performance is increased two to three times, it is still trailing behind gasoline. This does not mean, however, that the electric motor cycle, that relies on battery for driving power, is impractical. In fact, if customers are willing to pay for heavier vehicle weight, a battery-driven motor cycle is feasible.

In order to comply with the performance targets, the weight ratio between the total batteries and the total vehicle weight should be in the range of 0.33 to 0.40. Therefore, the weight of the electric motor cycle is heavier than that of a conventional machine by 20 to 30 kg. As this increase in weight is mostly due to the batteries, with elaborate design and other arrangements, the centre of gravity of an electric motor cycle can be far lower than that of the conventional one. This latter feature increases both driving stability and safety. Thus, a flat and short battery is preferred. Also, such size dimensions will help to reduce the unwanted phenomenon of electrolyte stratification.

In order to make electric motor cycles affordable, the best quality, least expensive, value-regulated lead/acid battery (VRB) has been chosen for development. The experimental scooter will have a 48-V system and, therefore will require four batteries of 26 to 30 Ah (*C*/3 rate) capacity. Each battery will weigh less than 10 kg. Such specifications are not too severe as some commercial batteries have qualities very close to these specifications. The cycle life should retain 75% of its initial capacity after 330 charge/discharge cycles under testing at 80% depth-of-discharge and ECE 40 driving pattern conditions.

Fast charging is also a requirement. From a practical view, however, recharging 30% of the battery capacity in 15 min is sufficient for most emergency situations. Therefore, a small output power charger will satisfy the requirements, and will reduce both the size and the cost.

Motor/driver

In order to meet the targeted performance requirements of the electric motor cycle, a d.c. brushless motor that has high power density has been chosen for development. The parameters that influence its performance are as follows:

- power consumption, efficiency characteristics
- torque, speed characteristics
- shape dimension, weight limits
- operation voltage, current limits
- operation temperatures and heat dissipation on procedure
- operation characteristics
- driving types
- overload capability

The maximum power output of the motor currently used in the experimental scooter is 1.5 kW, and the top speed is 6000 rpm, for a 6-step, square-wave drive and a two-stage, current-limit protection. On a 21% slope, the vehicle can climb continuously for 3 min. The best efficiency under rated operation exceeds 85%.

Transmission system

The requirement of a transmission system equipped with a gear-change function in an electric motor cycle is still a controversial question. Since the motor chosen for the electric motor cycle is small and has to meet both acceleration and climbing specifications, an automatic transmission system will be adopted. This system will give a large gear-ratio at low speed (to provide the benefit of a torque increase) and will automatically change to a small gear-ratio at high speed.

The other advantage with using an automatic transmission system is that the motor can always be operated in a high-efficiency range. Field tests showed that with an urban driving pattern (ECE40), the range per charge can be 70% of that for constant-speed driving conditions.

Test ride response

A local company has been assigned to investigate consumer response from test rides. Two experimental electric scooters with performances close to the targeted specifications have been used. The results show that more than 50% of the test riders wanted to buy an electric scooter, but only 40% of these showed such interest before undertaking a test ride. This indicates that most drivers have a negative impression about electric scooters before they ride one.

Environment improvement with increase in electric motor-cycle market share

Taiwan's unique circumstances – if it has small land area, high population density and short commuting distances – make motor cycles the most popular form of transport. This erodes air quality, especially in urban areas. In recent years, for example, the detected CO levels in Taipei City have been well in excess of the maximum allowable concentration; unaccepted rate for 8-h average CO concentration has increased from 50% in 1987 to 80% in 1991, and is getting worse.

Over the past few years, the government has made many efforts to improve the urban air quality through regulations that control the emissions from motor vehicles. These regulations can be grouped into five big categories: (i) motor vehicle regulations; (ii) improvement of the fuel qualities; (iii) emission control devices; (iv) traffic control systems; (v) alternative transportation means. It is concluded that electric vehicles are the most effective way for improving the CO and THC emissions. Some estimations show that the CO-emission improvement could be as high as 70%. Therefore, introducing electric vehicles appears to be the only way to prevent the further degradation of urban air quality.

To evaluate the effect of electric motor cycles on the improvement of air pollution problem in Taipei from 1991 to 1996, three similation studies have been conducted with different motor cycle penetrations of the market. The Caline-4 line source simulation model and current CO- and THC-emission data have been used as a reference and a natural growth rate in motor vehicles has been assumed. The first simulation study did not have any electric motor cycle substitution, but with all new motor cycles after 1991 meeting the second-stage emission standards. The second simulation case assumed a 20% electric motor-cycle replacement, while the third simulation case took a 50% electric motor-cycle replacement. According to the simulation results, 24.8 and 35.1% of CO will be reduced with 20 and 50% electric motor cycle replacement by 1996. These levels are both higher than the 17.4% value obtained from the first case study. As far as hydrocarbon emissions are concerned, the reduction resulting from 20 and 50% electric motor-cycle replacement will be 12.2 and 17.2%, respectively. Again, this is far better than the 5.8% from the first case study.

Despite these encouraging findings, data from the 8-h average concentration simulation indicated that 20% electric motor-cycle replacement is not sufficient to meet air-regulation standards for most parts of the city. Up to 50% electric motor-cycle replacement will just prevent the continuation in the degradation of air quality. Since a large increase in the market share of electric motor cycle will be difficult, the development of electric cars is also necessary to solve the problem of urban air pollution.

Future outlook

The introduction of electric motor cycles can solve part of the air pollution problem in Taiwanese urban areas. Nevertheless, improvements in the scooter's performance (such as cycle life of the battery, reliability of the motor, driver, charger, etc.), as well as reduction in the cost of production are areas that demand further investigation. Also, in order for the electric motor cycle to gain popularity, other facilities such as battery charging stations need to be established.