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A dynamic model for the performance and environmental analysis of an innovative e-bike

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Abstract

The paper describes a performance and environmental analysis of an innovative e-bike by means of a dynamic model equipped with a suitable control for the management of the assisted drive of the e-bike.
The main advantage of this approach consists of the opportunity to simulate different tracks, e-bikes characterized by different parameters (total mass, wheels moment of inertia) and different control strategies.
The authors have also conducted an environmental analysis of the studied vehicle, particularly comparing the e-bike with a thermal moped, in terms of environmental impact.

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keywords: pedelec; e-bike; environmental analysis; dynamic model

1. Introduction

Strong problems related both to the air quality and to the use of petroleum [1] have been caused, in the recent years, by the increasingly vehicular traffic. Particularly, the most of consumption and pollution are attributable to the great mass of the vehicle and not to the mass of the handled passengers. Under this point of view, a vehicle as the electrical assisted bicycle (e-bike) [2]-[4] can be considered a promising alternative vehicle for both personal mobility and goods delivery, especially for small and medium distances.

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The e-bikes are normally powered by rechargeable battery [5]–[8], and their driving performance is influenced by battery capacity, motor power, road types, operation weight, control, and particularly the management of assisted power.

A classification of these BEVs (battery electric vehicles) is necessary. A first kind is represented by a pure electric bike [9]–[11], which integrates electric motor into bicycle frame or wheels, and it is driven by motor force only using a handlebar throttle. A second kind is a power-assisted bicycle, frequently called e-bike or pedelec [12], which is a human–electric hybrid bicycle [13] that supports the rider with electric power only when the rider is pedalling.

A number of aspects favour the use of electric bicycles in different situations. These include lower energy cost per distance travelled for a single rider; savings in other costs such as insurance, licenses, registration, parking; improvement of the traffic flow; environmental friendliness; and the health benefit for the rider.

This paper investigates the performance and the environmental impact of an innovative electrically assisted bicycle by means of a dynamic model equipped with a suitable control for the management of the assisted power. The proposed approach allows to simulate different tracks, e-bikes characterized by different parameters (total mass, wheels moment of inertia) and different control strategies. An environmental analysis (well-to-wheel) has been performed taking into account a comparison with the tailpipe exhaust emissions of the regulated pollutants of a thermal moped by using the simulated speed-time profiles. This study, then, gives informations related to some advantages on air quality that could be obtained, in urban contexts, by using electrical assisted bicycles instead of thermal two-wheeler.

2. The e-bike prototype

The dynamic model adopted for the numerical analysis refers, in terms of the adopted parameters, to an innovative e-bike [14, 15] that will be briefly recalled in this section. The innovative prototype is based on the following solutions:

- the electrical motor location;
- the battery pack located into the frame;
- the mechanical transmission;
- the low cost measurement system of the driving torque.

Differently from a common approach, in which the electric motor is located on one of the three hubs of the bicycle, a basic idea of the e-bike prototype consists of a central motor located in a bottle, as shown in Fig. 1, while a gearbox is located in a central position, between the pedals, as pointed out in Fig. 2.