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Regenerative Braking

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***Abstract*: This paper presents an overview on regenerative braking.**

***Keywords*: regenerative braking**

1. Introduction

The electric motors in EVs and HEVs can be managed to operate as turbines to convert the kinetic or plausible power of the automobile mass into electric powered energy that can be stored in the strength storage and reused. An effectively designed braking system for an automobile have to usually meet two wonderful demands:

i. In emergency braking, the braking gadget must carry the car to relaxation in the shortest possible distance.
ii. The braking machine need to maintain control over the vehicle's direction, which requires braking pressure to be allotted equally on all the wheels.

2. Energy consumption in braking

A full-size quantity of strength is consumed by using braking. Braking a 1500 kg car from 100 km/h to zero speed consumes about 0.16 kWh of electricity in a few tens of meters. If this amount of electricity is ate up in coasting by means of solely overcoming the drags (rolling resistance and aerodynamic drag) barring braking, the car will tour about 2 km, as proven in Figure 1. When vehicles are using with a stop-and-go sample in city areas, a huge amount of power is consumed via ordinary braking, which consequences in high gas consumption.

The braking power in standard city areas may also reach up to more than 25% of the whole traction energy. In massive cities, such as New York, it may also reach up to 70%. It is concluded that effective regenerative braking can substantially improve the gasoline economy of EVs and HEVs.

3. Braking power and energy on front and rear wheels

Braking energy and braking strength bump off via the front and rear wheels are closely associated to the braking forces on the front and rear wheels. A full understanding of the braking force, braking power, and braking power ate up by the front and rear wheels in standard force cycles is beneficial in the plan of regenerative braking systems

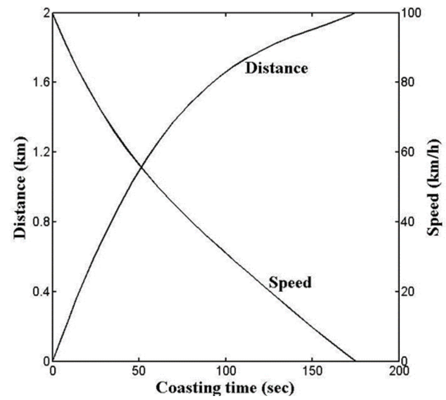

Fig. 1. Coasting time, Speed and Distance

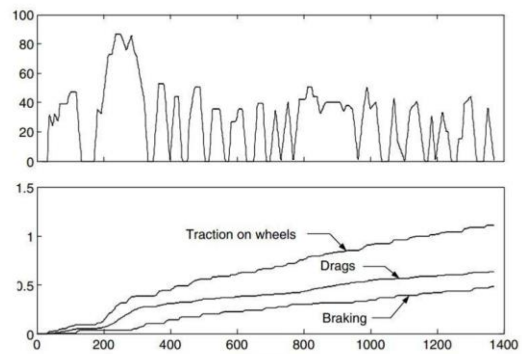

Fig. 2. Total traction energy and energies consumed by drags and braking in an FTP 75 urban drive cycle

Initially, assuming that the braking distribution on the front and rear wheels follow the curve I (refer to Chapter 2), ignoring vehicle drags, the braking forces on the front and rear wheels can be expressed as:

$$F_{bf} = \frac{jM_v}{L}\left(L_b + \frac{h_g}{g}j\right)$$

and

$$F_{br} = \frac{jM_v}{L}\left(L_a + \frac{h_g}{g}j\right)$$

where j is the deceleration of the vehicle in m/s^2, L is the wheel base of the vehicle,

L_a and L_b are the horizontal distances between the vehicle gravity center to the center of the front and rear wheels, respectively, and h_g is the height of the gravity center of the vehicle to the ground. Figure 3 shows vehicle speed and acceleration/deceleration in an FTP 75 urban drive cycle. Figures 4 - 6 show the braking force, braking power, and braking energy of a 1500 kg passenger car in an FTP 75 urban drive cycle. This example has parameters of L =2.7 m, L_a =0.4 L , L_b =0.6 L , and h_g =0.55 m.

Figures 4 - 6 indicate that:

i. The front wheels consume about 65% of the total braking power and energy. Thus, regenerative braking on front wheels, if available only on one axle, is more effective than on rear wheels.

ii. The braking force is almost constant in the speed range of less than 50 km / h and decreases when the speed is greater than 40 km / h. This characteristic naturally matches that of an electric motor that has a constant torque at the low-speed region and a constant power at the high-speed region. Further**,** Figure 6 indicates that most braking energy is consumed in the speed range of 10 to 50 km / h.

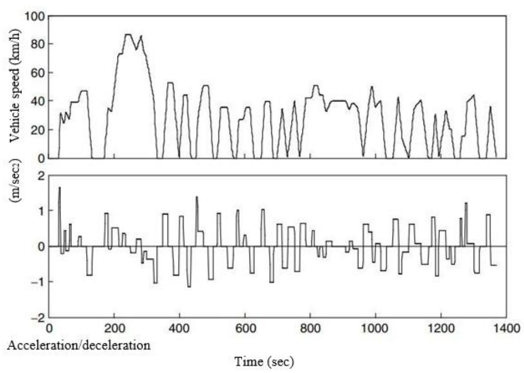

Fig. 3. Vehicle speed and acceleration/deceleration in an FTP urban drive cycle [1]

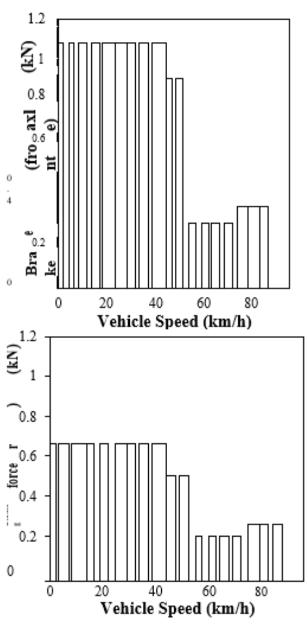

Fig. 4. Braking force vs. vehicle speed in an FTP 75 urban drive cycle: (a) on front wheels and (b) on rear wheels [1]

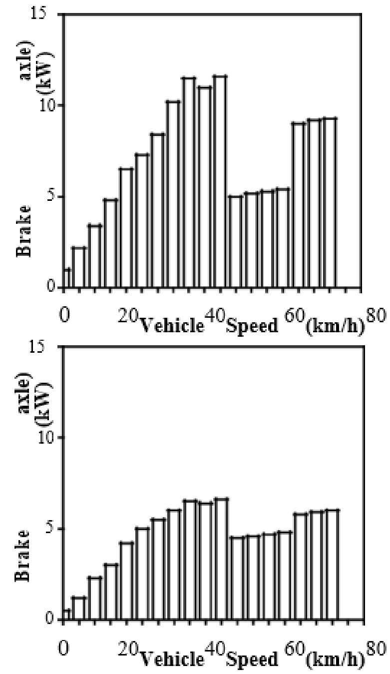

Fig. 5. Braking power vs. vehicle speed in an FTP 75 urban drive cycle: (a) on front wheels and (b) on rear wheels [1]

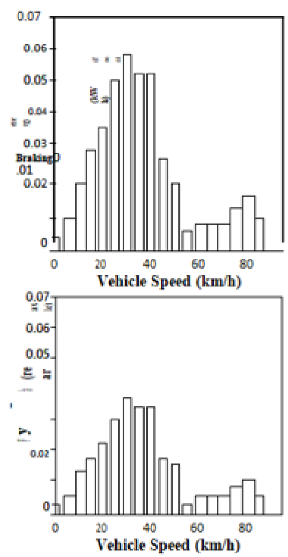

Fig. 6. Braking power vs. vehicle speed

4. Conclusion

This paper presented a study on regenerative braking.

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