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Reduction of Vehicle Speed using an Alternator

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***Abstract*— An experimental work was carried out to investigate the feasibility of using an alternator to reduce the speed of a rotating shaft, with the prospect of using this technique in automobiles to reduce the drive shaft speed prior to applying the friction brake.**

A test rig was constructed to simulate the basic foreseen requirements for this project to succeed. The experimental test results indicated a reasonable reduction in vehicle speed and stopping distance of up to 4%, paving the way for the adaption of this technique in automobiles.

Keywords— ***Automotive Alternator; Automotive Braking; Battery Charging; Brake Stopping Distance, Vehicle Speed Reduction***

List of symbols

Symbol	Definition	Unit
i	longitudinal tire slip	%
I	output current	amp
N	rotational speed	rpm
P	power	W
r_e	effective tire radius	m
v	vehicle speed	m/s, km/h
V	output voltage	volt
s	drop in brake stopping distance	m
t	brake stopping time	s

I. INTRODUCTION

The quest towards more efficient, more economic and less pollutant automobiles has driven the automotive industry to explore and adapt various innovations in recent years. New systems and components have been investigated with the aim of reducing fuel combustion and emissions.

An investigation to evaluate friction in diesel and gasoline engines revealed that mechanical friction consumes approximately 4-15% of total fuel. Accordingly, improving fuel economy by even by 1% is considered significant [1]. Technologies employed for minimizing engine friction include enhancing material coatings, lubricants additives and roller cam followers. Engine friction reduction has the potential to reduce fuel consumption by 10% [2] and CO_2 emission by 1-5% [3].

Gasoline direct injection involves injecting fuel directly inside the combustion chamber at high pressure which improves fuel efficiency. These engines have the potential of improving fuel economy by up to 25% due to reduction in pumping losses and heat loss, as well as reducing exhaust emissions by 12-15% [4].

A significant technology employed for improving fuel economy and reducing CO_2 emissions is engine downsizing. This involves using a smaller engine boosted by a turbocharger to replace a traditional engine with larger swept volume. The turbocharger provides the smaller engine with adequate torque and power output. The amount of engine downsizing depends on the boost that the turbocharger and/or supercharger provide. Engine downsizing can provide a 9% reduction in fuel consumption and 2-12% reduction of CO_2 [5].

Variable Valve Actuating (VVA) systems include Variable Valve Timing (VVT) and Variable Valve Lift (VVL) systems. Recently, most major car manufacturers have deployed different types of VVT mechanisms for controlling the engine valve timing. In comparison with fixed valve engines, VVT provides a reduction of 1-4% in CO_2 emissions. In VVL systems two different approaches are employed to control the lift height of the valves namely the continuous and discrete VVL [3]. Reduction in fuel consumption of up to 10% is obtained by the VVL system [2].

Cylinder deactivation technology is intended for engines with large capacities (6, 8 and 12 cylinders). It enables running these engines at full capacity (all cylinders) during high power demand and part capacity (usually half the number of cylinders) during low power demand. When the engine is running at part capacity a significant reduction in pumping losses is achieved. Cylinder deactivation provides a reduction in fuel consumption of up to 18% in part load operation and a reduction in CO_2 emission of 6-8% [6].

This work is aimed at investigating the feasibility of using an alternator driven by the driveshaft to reduce the speed of a vehicle in conjunction with the friction brake. It is anticipated that this would reduce the brake effort required to reduce the vehicle speed and consequently reduce stopping distance, friction pad wear, fuel consumption and emission. Bearing in mind that the alternators used in passenger cars have a very low efficiency of 50-60% [6] and they approximately consume 1- 1.5 kW of engine power [7]. Thus, when the driveshaft is used for driving the alternator this will reduce engine power demand as well as helping to reduce the vehicle speed during braking.

II. METHODOLOGY

A test rig to simulate the basic components of a friction disc brake in addition to an alternator driven by drive shaft is shown in Fig.1. A single-phase 1.5 kW, 1410 rpm, AC electric motor (1) was used to drive both the 60 amp alternator (3) and the disc brake (4) (mounted on the driveshaft) via a multi-pulley belt-drive (2). The belt-drive provides a speed ratio of 1:3 between the drive shaft and alternator.

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When the brake-pedal (5) is depressed it switches on the alternator which charges the battery and by doing so it decelerates the driveshaft. This does not intervene with the operation of the disc brake. However, during experimental tests the disc brake was intentionally deactivate in order to verify the sole effect of charging the battery on reducing the speed of the rotating shaft. The control box (6) incorporates a voltage regulator to keep the alternator output charging voltage at the recommended maximum value of 14.5 volt, since a higher charging voltage overheats the battery electrolyte and shortens its life [8]. The control box also incorporates an AC motor speed controller to adjust the AC motor speed and thus obtain the required driveshaft and alternator speeds.

1. Electric motor
2. Pulley drive
3. Alternator
4. Disc brake
5. Brake pedal
6. Control box

Fig.1: Test rig

In this work, an electric motor with 1.5 kW output power was used since the power required to operate an alternator is calculated by multiplying the output current by the output voltage of the alternator as expressed by the following equation [9]:

$$P = I \times V = 60 \times 14.5 = 870\ W \qquad (1)$$

When the mechanical and electrical losses which is about 20% [9] (174 W) is taken into consideration, the power requirement to operate the alternator becomes 1.044 kW. The remainder of 456 W power of the motor is allocated for turning the driveshaft.

In order to verify the validity of this technique, the system was subjected to experimental tests. The test procedure involved running the driveshaft at different rotational speeds (500 to1000 rpm) which correspond to alternator speeds of approximately (1500 to 3000 rpm). Then, the reduction in driveshaft speed due to charging is measured. These rotational speeds were chosen because the peak efficiency of an alternator is produced at 2000-2500 rpm [10]; in addition to the fact that this range of driveshaft speed correspond to a realistic vehicle speed of approximately 60-120 km/has shown below.

The driveshaft and alternator speeds were set to the required values by adjusting the motor speed controller in the control box. A digital photo tachometer was used to measure the alternator and driveshaft speeds prior to charging and during charging of the battery. A digital multi-meter was used to measure the regulated output voltage and output current of the alternator.

The relationship between vehicle speed and driveshaft rotational speed can be determined using the following formula [7]:

$$v = \frac{2\pi N r_g}{60} \qquad (2)$$

When the longitudinal tires slip (i) is taken into consideration and the above vehicle speed given in m/s is converted to km/h (multiplying by 3.6), the above formula becomes:

$$v = 0.377 N r_g (1 - i) \qquad (3)$$

The most common passenger car tire size in 2015 is reported to be p215/55R17 [11], which has an effective wheel radius of 0.325.The longitudinal tire slip is usually assumed 2-5% [7]. If these arbitrary values are substituted in the above equation (assuming a longitudinal tire slip of 3%), a relationship between the vehicle speed (km/h) and the driveshaft rotational speed (rpm) can be expressed as:

$$v = 0.12N \qquad (4)$$

The above formula can be used to determine the vehicle speed at different driveshaft speeds, as well as, determining the drop in vehicle speed as a result of charging the battery.

The reduction in brake stopping distance due to charging the battery can be obtained by multiplying the drop in vehicle speed (m/s) due to charging by the brake stopping time as follows:

$$s = v\,t \qquad (5)$$

Data from several sources [12-14] was used to estimate the average brake stopping time at the vehicle speed range adopted in this work.

III. RESULTS AND DISCUSSION

Test results of the alternator's regulated output voltage and output current at rotational speeds of 1500 to 3000 rpm are shown in Figs.2 and 3 respectively. For the aforementioned speed range, the alternator produced 13.93-14.36 volts and 35-60 amps. These results are in good agreement with previous results [15] and they indicate that the alternator is functioning properly.

The effect of charging the battery on the driveshaft speed is shown in Fig.4. The results indicate a reduction of 23 to 37 rpm at driveshaft speeds of 500 to 1000 rpm, with an average drop of 4% in driveshaft speed at this speed range.

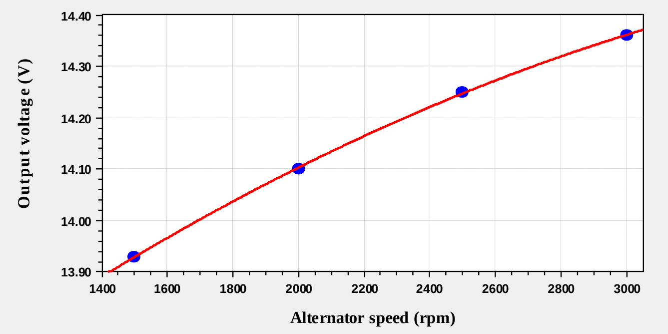

Fig.2: Alternator regulated output voltage at operating speeds.

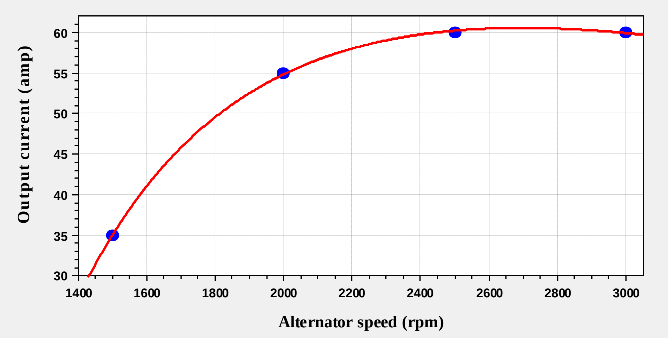

Fig.3: Alternator output current at operating speeds.

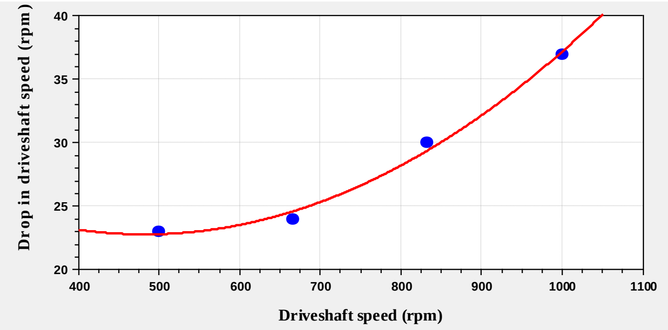

Fig.4: The effect of charging on reducing the driveshaft speed.

To interpret these results in practical terms if this technique is to be employed in automobiles, the results seem to be promising. For instance, the reduction in driveshaft speed could be used to calculate the reduction in vehicle speed as shown in Figs.5.The reduction in vehicle speed due to charging when the brakes are applied is found to be approximately 2.8 to 4.4 km/h for vehicle speed of 60 to 120 km/h.

As for effect of charging the battery on the stopping distance, Fig.6 shows that the brake stopping distance is reduced by 1.8 m to 4.7 m for vehicle speed of 60 to 120 km/h. This represents an average reduction of approximately 4% in brake stopping distance. The significance of these results is highlighted by the fact that a reduction of braking time by 0.5 s could decrease death from front end collision by 30-50% [16].

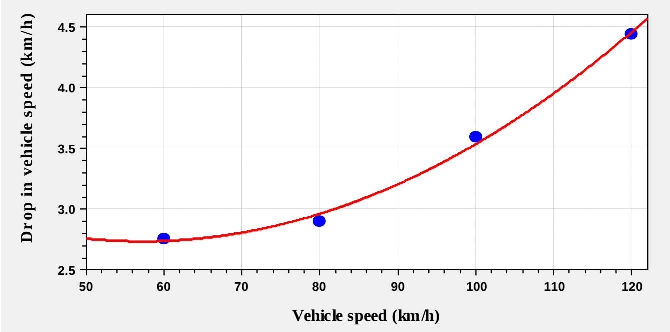

Fig.5: The effect of charging on reducing the vehicle speed.

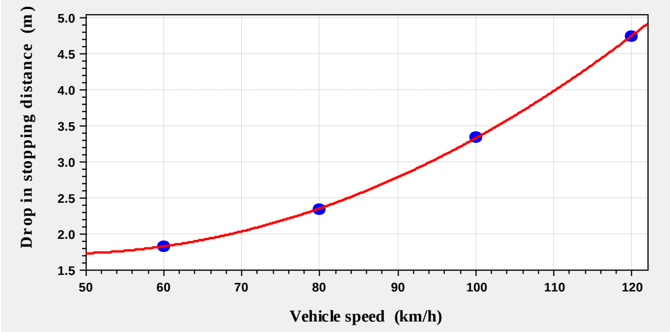

Fig.6: The effect of charging on reducing the brake stopping distance.

IV. CONCLUSIONS

In view of the above results, the prospect of using an alternator to reduce the speed of a vehicle during braking seems to be promising. The anticipated advantages are reduction in vehicle speed and stopping distance by approximately 4%. This will consequently result in reducing the probability or the fatality of front end collision as well as reducing friction pad wear and prolonging its service life. In addition to that, if further investigations prove that charging the battery by the driveshaft during braking is efficient enough to discard the use of engine power for this purpose, then there are the additional advantages of reducing the fuel consumption and engine emission.

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