Fuel Economy Comparison between a Vehicle Having a Standard Power Train and a Vehicle Having Its Power Train Modified into a Hybrid with Cylinder Deactivation

Tessie A. Cabije, Maria Lorena L. Tuballa, Jaychris Georgette Y. Onia, Roilo O. Ignacio
College of Engineering and Design, Silliman University, Dumaguete City, Philippines

Telesforo M. Belloso and Antonio L. Belloso
Belloso Motor Company, USA

Due in part to rising gas prices and concern over global warming, hybrid vehicles and vehicles with cylinder deactivation have been developed in order to improve automotive fuel efficiency. This study was an attempt at comparing the fuel economy of a vehicle with standard power train and another vehicle modified into a hybrid with cylinder deactivation. These vehicles currently make up less than 1% of vehicles worldwide. Success of this technology shows how some of the remaining 99% of vehicles may be made more fuel efficient.

Keywords: hybrid vehicle, fuel efficiency, global warming, cylinder deactivation, hybrid drive trains

BACKGROUND

Increased global demand for vehicular fuel has resulted in rising gas prices and the development of vehicles with improved fuel economy. One such type of vehicle is the hybrid electric vehicle, which uses an internal combustion engine and an electric motor adapted to provide alternative and additional power to improve fuel economy. Rechargeable storage batteries on the vehicle energize the electric motor. Current hybrid electric vehicles are complicated and are expensive to manufacture, largely because of the high cost of the lithium or nickel metal hydride batteries and the need for especially designed hybrid drive trains. Furthermore, it has not been possible to use this technology to convert standard nonhybrid vehicles into hybrid vehicles.

Another fuel-saving approach is based on the observation that a vehicle usually needs much less power for cruising than it does for acceleration, for passing, or for climbing a grade. This gave rise to the idea of cylinder deactivation. This involves means for deactivating some cylinders in a regular internal combustion engine for economical operation when less power is needed, such when cruising on a level highway, and reactivating them when more power is needed, such as when accelerating or climbing a grade. Fuel savings through this solution, however, have been severely limited, mainly because of power losses associated with the continuing reciprocating motion of the components (pistons, con rods, etc.) within the deactivated cylinders.

Recently, new technology has been developed to combine these two fuel-saving approaches, aimed at maximizing their effectiveness and overcoming their disadvantages. Power losses associated with the continuing reciprocating motion of the pistons, con rods, etc. in the deactivated cylinders are eliminated by simply removing these moving parts altogether. An electric motor is coupled to the engine to supply additional power when needed. Sufficient cylinders are left fully functional, so that it becomes possible to limit use of the electric motor to short periods of acceleration, passing, or climbing a grade. Minimizing electric motor duty cycle permits use of inexpensive lead–acid batteries instead of costly lithium or nickel batteries. Expenses associated with the use of an especially designed hybrid drive train are avoided by simply using the standard drive train already present in the vehicle. These changes make it possible to convert a regular vehicle into a hybrid vehicle and to do so quite inexpensively. The authors tested a prototype to determine the validity of this concept.

METHODS

A 1967 model Volkswagen Sedan (“Beetle”) having a four-cylinder engine with a piston displacement of 1600 cc. was used as the prototype. Prior to conversion, its fuel economy was tested to be 12.5 kilometers per liter of

regular gasoline, equivalent to 30.10 miles per gallon (US).
The piston displacement of the existing engine was reduced from 1600 cc. to 800 cc. by permanently deactivating a balanced pair of cylinders through removal of the pistons, con rods, and other moving parts therein. Air and fuel intake to these cylinders was shut off by removing their corresponding valve rocker arms, thus leaving the intake and exhaust ports shut permanently through the action of the valve springs. Lubricating openings ("spit holes") in the crankshaft serving these cylinders were securely plugged. Ignition wires to the spark plugs in these cylinders were removed. The engine has now undergone permanent deactivation of half of its cylinders.

The engine was converted into an electric hybrid by installing an electric motor of suitable power capacity in parallel position alongside it and coupling its output shaft to the front end of the engine crankshaft via a V-belt, pulleys, and an electromagnetic clutch. Driver-operated means were provided for turning the electric motor on and for engaging it to the crankshaft whenever more power was needed, such as when starting off, passing, or when climbing a grade. This included means for disengaging and turning off the electric motor whenever added power was no longer needed, such as when simply maintaining cruising speed, which was well within the power capacity of the modified engine itself.

For the purpose of conducting the road fuel economy tests, an especially designed calibrated fuel tank was placed in an elevated position in the passenger compartment of the vehicle and connected by special tubing to feed a premeasured amount of gasoline to the engine carburetor by gravity. At the start of each test run, this tank was filled with 1000 cc. of regular gasoline. The car was then started, and the test run was begun. The end point was when the vehicle stopped as the fuel was consumed. The distance traveled was measured via the trip meter of an accompanying pace car, which was switched to "zero" at the start of the test run and then read for the distance traveled at the end point of the test run. The prototype was road tested by a team of six engineers, all of whom are listed as coauthors of this report. A majority of the members of the group attended each test.

RESULTS

The group did a series of ten test runs between March 30, 2011 and July 7, 2012. Each test run measured the distance, in kilometers, covered by the test vehicle on one liter (1000 cc) of regular gasoline, as indicated by the trip meter of the accompanying pace car. The first two tests were on the highway north of Dumaguete City towards the city of Tanjay. This is a concrete road, on generally level ground. The rest of the tests were on the highway southwest of Dumaguete towards the town of Zamboanguita where there was less traffic. This is an asphalt road with some gentle dips and rises. All tests were conducted in generally fair weather without rain or strong winds. The results are tabulated below.

Date	Fuel Consumed		Distance Traveled		Fuel Economy	
	Liters	US Gallon	Km	Miles	Km/L	MPG
Mar. 30, 2011	1.000	0.2581	24.1	14.98	24.1	58.04
Mar. 30, 2011	1.000	0.2581	25.0	15.54	25.0	60.21
Apr. 09, 2011	1.000	0.2581	26.7	16.59	26.7	64.28
Apr. 09, 2011	1.000	0.2581	24.5	15.23	24.5	59.00
May 25, 2012	1.000	0.2581	24.4	15.16	24.4	58.74
May 28, 2012	1.000	0.2581	25.0	15.54	25.0	60.21
June 11, 2012	1.000	0.2581	27.5	17.09	27.5	66.21
June 11, 2012	1.000	0.2581	25.9	16.10	25.9	62.38
July 05, 2012	1.000	0.2581	27.0	16.78	27.0	65.02
July 07, 2012	1.000	0.2581	24.1	14.98	24.1	58.04
Average	1.000	0.2581	25.4	15.80	25.4	61.21

DISCUSSION

The test vehicle had fuel economy of 12.5 km per liter, equivalent to 30.10 miles per gallon of regular gasoline before it was modified into a hybrid with deactivation of half of its cylinders. After modification, its fuel economy averaged 25.42 km per liter or 61.21 miles per gallon, showing that the modification made it possible for the vehicle to travel twice as far on a given amount of fuel.

These tests suggest that similar improvement in fuel economy may also be gained by using similar modifications on other vehicles. This remains to be seen until such tests are made.

These tests were made at speeds ranging from about 50 to 75 km per hour, equivalent to about 30 to 45 miles per hour, matching the average speed of traffic in the test highways. It remains to be seen if similar improvement in fuel economy can be gained at higher speeds, such as those in the highways of Europe and the United States.

No acceleration tests were made during these road tests. It had been observed, however, that the test vehicle had no problem in keeping up with traffic, going up grades, or passing some slower vehicles. Acceleration tests to assess performance of the electric motor, combined with the down-sized engine, would yield more useful information.

These tests demonstrate that it is possible to convert an existing vehicle into a fuel-efficient vehicle by combining hybrid technology with cylinder deactivation technology. The fact that this was done without need for expensive lithium or nickel-based batteries and without the need to replace the existing drive train of the vehicle shows that this conversion can be done simply and inexpensively, suggesting that this conversion process may be commercially viable.

These test results also suggest that this type of hybrid technology which uses a standard nonhybrid drive train and uses regular (off-the-shelf) electric motors may be successfully employed in the manufacture of a new, inexpensive type of hybrid vehicle — one simply having a smaller engine.

Seen in the context of rapidly increasing demand for fossil fuel worldwide, escalating cost of automotive fuel, and threats of global warming and climate change, any possible means to improve the fuel economy of the remaining nonhybrid 99% of motor vehicles worldwide would be desirable and worthy of further investigation.

CONCLUSION

A 1967 model Volkswagen Sedan having a four-cylinder gasoline engine with piston displacement of 1600 cc. was modified by deactivating two cylinders through removal of the pistons and associated moving parts therein and sealing said cylinders from ingress of air, fuel, and lubricating fluid. It was further modified into a hybrid vehicle by installing a battery-powered electric motor alongside the engine and coupling its output shaft to the front end of the engine crankshaft via a V-belt, pulleys, and a releasable electromagnetic clutch thereby making it possible for the operator to add power from the electric motor to the engine output whenever more power was needed. Highway tests on the modified vehicle at speeds between 30 MPH to 45 MPH showed that the vehicle traveled twice as far on a given amount of regular gasoline, in comparison with the distance it traveled before modification.

AUTHORS

At the time of this research, Tessie A. Cabije, C.E., was Dean of the College of Engineering and Design, Silliman University, Dumaguete City, Philippines; Maria Lorena L. Tuballa, E.E., Assistant Professor of Electrical Engineering, Silliman University; Jaychris Georgette Y. Onia, M.E., Head of Department of Mechanical Engineering, College of Engineering and Design, Silliman University; Roilo O. Ignacio, M.E., Head of Mechanical Engineering Foundation, Silliman University; and Telesforo M. Belloso, M.E., and Antonio L. Belloso, BSCE of Belloso Motor Co., a Delaware Corporation, USA.

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