

“FUEL ECONOMY IMPROVEMENT WITH USE OF BRUSHLESS DC MOTOR IN AUTOMOTIVE RADIATOR FAN ASSEMBLY”

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Abstract - The electrical power demand in automobiles is rising steadily. Especially in luxury vehicles, due to application of new electrical systems that enhance passenger comfort and safety.

Brushless DC motor (BLDC) remains an important and fast growing motor type with many performance advantages over brushed DC motor (BDC). BLDC motors are more efficient, high-powered, silent, deliver high torque, have longer lifetime and higher speed compared to BDC motors.

The project involves replacement of BDC fan motor of cooling module with a BLDC fan motor and evaluating improvement in performance, fuel efficiency and noise, vibration and harshness of vehicle. Component level durability of BLDC motor is also checked.

Key words: Brushed DC motor (BDC), Brushless DC motor (BLDC) Introduction.

1. INTRODUCTION

The radiator fan has an important job in the engine compartment. It can push air through the radiator core or pull it through. It must cool the antifreeze that circulates through the block and head passages and reduces the engine temperature. Fan designs have specific purposes for different sized vehicles and profiles. In old vehicle engine, mounted fans are used for radiator cooling. Engine mounted fans are less effective in traffic because they pull little air when the engine rpm is low. The use of electric motors and drives that run independent of the vehicle main engine increases the efficiency and effectiveness of engine cooling. Electric radiator cooling fan usually switch on when the engine coolant reaches a set temperature. Currently permanent magnet direct current motors (PMDC) power radiator fan. PMDC motor having brushes suffers from poor efficiency and friction problems and periodic maintenance of the brushes in order to avoid the appearance of sparks. The reason for their success was the fact that it was a mature technology, widely available, cheaper and did not require complex controller. Permanent magnet brushless direct current (PMBLDC) motors are one of the motor types rapidly gaining popularity because of higher efficiency, long operating life, high dynamic response, noiseless operation, higher torque per weight ratio. Thus, automobile is undergoing a revolution in the design of its electrical system.

2. BODY OF PAPER

Aim of Project: To Improvement Fuel Economy with Use of Brushless Dc Motor in Automotive Radiator Fan Assembly.

3. PROBLEM STATEMENT

Fuel efficiency is a historical goal of automotive engineering. The government of India has proposed to introduce Corporate Average Fuel Efficiency (CAFE). CAFE norms means from April 1, 2017, India will adopt CAFE norms which requires cars to be 30 percent or more fuel efficient from 2022 and 10 percent more between 2017 and 2021. The fuel efficiency or the improvement of the mileage will be decided based on the consumption of fuel by a vehicle to run 100kms. the introduction of CAFE norms is aimed at reducing the carbon emission of the automobile industry. Twenty-five years after Congress enacted the Corporate Average Fuel Economy (CAFE) standards, petroleum use in light-duty vehicles is at an all-time high. It is appropriate to ask now what CAFE has accomplished, and at what cost. This chapter begins by addressing energy and CAFE: What is the current rationale for fuel economy standards? How have vehicles changed, in particular in regard to fuel economy? What is the impact on oil consumption? The first section addresses a series of questions the committee was asked about the impact of CAFE. The second section explores the impact of CAFE on the automotive industry, the final section reviews the impact on safety. To understand how the fuel economy of passenger vehicles can be increased, one must consider the vehicle as a system. High fuel economy is only one of many vehicle attributes that may be desirable to consumers. Vehicle performance, handling, safety, comfort, reliability, passenger and load-carrying capacity, size, styling, quietness, and costs are also important features. Governmental regulations require vehicles to meet increasingly stringent requirements, such as reduced exhaust emissions and enhanced safety features. Ultimately, these requirements influence final vehicle design. Technology content and the subject of this report-fuel economy. Manufacturers must assess trade-offs among these sometimes-conflicting characteristics to produce vehicles that consumers find appealing and affordable.

Engines that burn gasoline or diesel fuel propel almost all passenger cars and light-duty trucks. About two-thirds of the available energy in the fuel is rejected as heat in the exhaust and coolant or frictional losses. The remainder is transformed into mechanical energy, or work. Some of the work is used to overcome frictional losses in the transmission and other parts of the drive train and to operate the vehicle accessories (air conditioning, alternator/generator, and so on).

In addition, standby losses occur to overcome engine friction and cooling when the engine is idling or the vehicle is decelerating. As a result, only about 12 to 20 percent of the original energy contained in the fuel is actually used to propel the vehicle. This propulsion energy overcomes inertia when accelerating or climbing hills, the resistance of the air to the

vehicle motion (aerodynamic drag), and the rolling resistance of the tires on the road. Consequently, there are two general ways to reduce vehicle fuel consumption: increase the overall efficiency of the powertrain (engine, transmission, final drive) in order to deliver more work from the fuel consumed or reduce the required work (weight, aerodynamics, rolling resistance concepts are illustrated in figures

4. CURRENT CONDITION

BRUSHED MOTORS

Direct current electrical motors function through the creation of magnetic fields whose attraction and opposition keeps a central rotor turning. In a brushed motor, fixed magnets are placed on either side of a rotating electromagnet, one oriented to a positive pole, the other to a negative one. The electromagnet is formed by a series of coils (usually three placed at equidistant points around the rotor) called the commutator. When electricity is passed through these coils, they generate their own magnetic field that is repelled and attracted to the magnetic fields generated by the fixed magnets. Current is transferred to the coils of the commutator by metallic brushes, which rotate along with the rotor. When the motor is switched on, current is passed to the electromagnets whose magnetic fields are repelled by one fixed magnet and attracted to another, causing the rotor to turn. As the rotor turns, the metallic brushes come into and out of contact with each coil in series so the opposition and attraction between the resulting magnetic fields and the fields of the static magnets keeps the electromagnet turning.

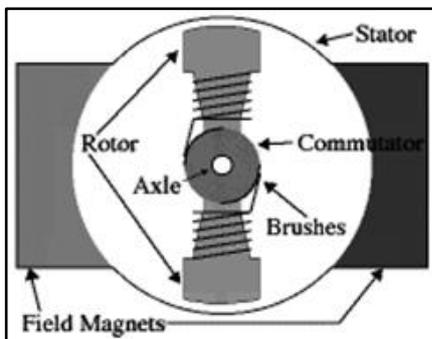


Fig. 4.1: Brushed DC motor.

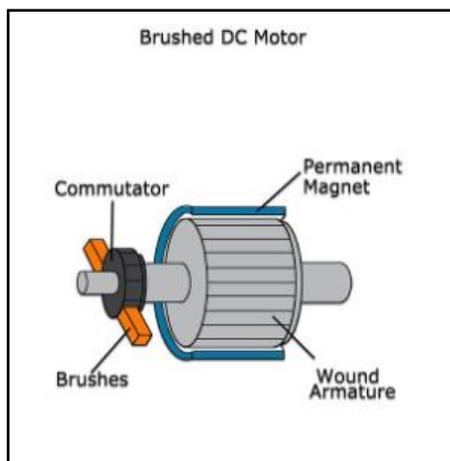


Fig. 4.2: Brushed DC motor.

5. PROPOSED CONDITION

BRUSHLESS DC MOTOR

In a brushless DC motor, the positions of the fixed magnets and the electro-magnetized coils are reversed. The fixed magnets are now placed on the rotor and the coils are placed in the surrounding casing. The motor functions via current being passed through each surrounding coil in series, so repulsing and attracting the fields of the fixed magnets and keeping the rotor they are attached to turning. For a motor of this kind to work, the coils of the commutator need to be kept synchronized with the magnets so that the fields are continually in opposition and the rotor is kept turning. This requires an electronic controller or microprocessor to coordinate the application of current to each electromagnet coil

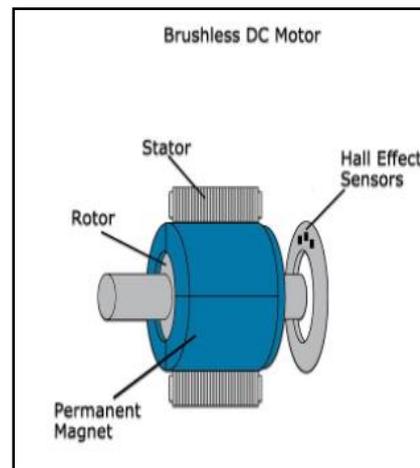


Fig. 5.1: Brushless DC motor

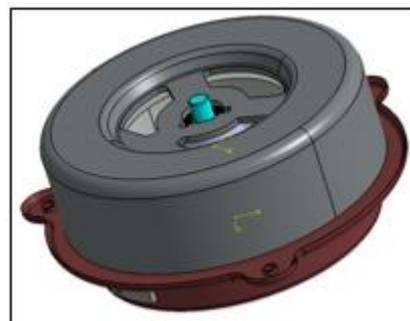


Fig. 5.2: Assembled brushless DC motor.

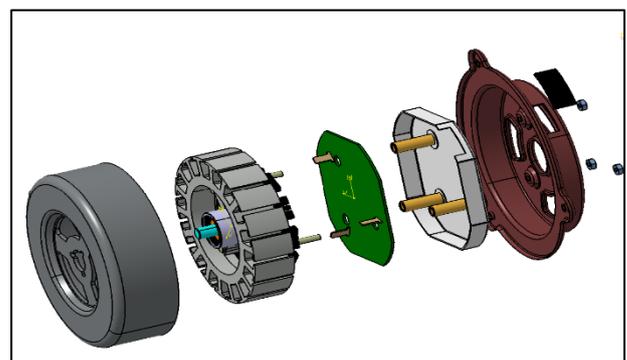


Fig. 5.2: Exploded view of Brushless DC motor

6. DIFFERENCE BETWEEN BRUSHLESS & BRUSHED MOTOR

Feature	BLDC Motor	Brushed DC Motor
Commutation	Electronic commutation	Mechanical brushes and Commutator
Efficiency	High (Voltage drop on electronic device is smaller than that on brushes)	Moderate
Maintenance	Little/None	Periodic/limited brush life
Thermal performance	Better	Poor
Communication	With ECU using LIN/CAN	No ECU communication
Speed Range	Variable	Two speed with Resistor Or fix
Electric Noise	Low	High
Lifetime	Long	Short

7. METHODOLOGY

The experiment for validation of this idea will be conducted as follows:

1. Instrument a vehicle with fuel economy measuring equipment – flow meter, data logger and heat exchanger (to normalize temperatures of fuel in the tank and fuel returning from engine)
2. Conduct a baseline fuel economy test basis a known drive cycle (in this case, MDC or Mumbai Drive Cycle and CDC or Combined Drive Cycle) on the vehicle using a chassis dynamo
3. Replace the brush-type DC motor in the radiator fan assembly with a brushless DC motor of equivalent specification
4. Install the modified radiator fan assembly on the vehicle
5. Repeat the fuel economy test with the update configuration
6. Compare the results and check for improvement in fuel economy over baseline.

8. EQUIPMENT

- 1) Donor vehicle
- 2) Brushless DC motor – T.B.D.
- 3) DFL fuel flow measurement device
- 4) DAS2A data logger
- 5) Panasonic Toughbook laptop
- 6) Chassis dynamometer
- 7) Climate chamber – Hot Chamber.

9. TEST CONDITION

The test conditions will be as follows:

- 1) Test cycle – MDC and CDC cycles as described above. These cycles are based on actual data logged driving in metro city traffic.
- 2) Environment controlled at 45 degrees Celsius and at a relative humidity of 40%
- 3) Air conditioner ON at all times
- 4) Donor vehicle’s engines run-in for 1000 km to ensure representative engine friction losses
- 5) New tires to ensure safety using the dynamometer
- 6) Vehicle kerb weight and coefficients for rolling and aerodynamic friction entered in the dynamometer control system to represent correct resistance loads (*values obtained from manufacturer*).
- 7) Test cycle – MDC and CDC cycles as described above. These cycles are based on actual data logged driving in metro city traffic.
- 8) Environment controlled at 45 degrees Celsius and at a relative humidity of 40%
- 9) Air conditioner ON at all times
- 10) Donor vehicle’s engines run-in for 1000 km to ensure representative engine friction losses
- 11) New tires to ensure safety using the dynamometer
- 12) Vehicle kerb weight and coefficients for rolling and aerodynamic friction entered in the dynamometer control system to represent correct resistance loads (*values obtained from manufacturer*)

By taking a baseline and updated measurement on the same vehicle, with the same test cycle and using the same test equipment, any variation experiment to experiment is minimized. The instruments used will return accurate readings within an error range of 0.1 kpl. Thus, using this method, any substantial improvement in fuel economy can be robustly verified.

10. RESULTS AND DISCUSSION

10.1 Results of Descriptive Statics of Study Variables

Table 10.1: CITY MODE

Tip IN %	Neutral		1st gear		2nd gear		3rd gear		4th gear		5th gear	
	AC Cut off Threshold (Acc Pedal Base)	AC Cut off duration	AC Cut off Threshold (Acc Pedal Base)	AC Cut off duration	AC Cut off Threshold (Acc Pedal Base)	AC Cut off duration	AC Cut off Threshold (Acc Pedal Base)	AC Cut off duration	AC Cut off Threshold (Acc Pedal Base)	AC Cut off duration	AC Cut off Threshold (Acc Pedal Base)	AC Cut off duration
5	No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-40%)		No A/C Cut-off (0-70%)		No A/C Cut-off (0-70%)	
10	No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-40%)		No A/C Cut-off (0-70%)		No A/C Cut-off (0-70%)	
15	No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-40%)		No A/C Cut-off (0-70%)		No A/C Cut-off (0-70%)	
20	No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-40%)		No A/C Cut-off (0-70%)		No A/C Cut-off (0-70%)	
25	No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-40%)		No A/C Cut-off (0-70%)		No A/C Cut-off (0-70%)	
30	No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-40%)		No A/C Cut-off (0-70%)		No A/C Cut-off (0-70%)	
35	No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-40%)		No A/C Cut-off (0-70%)		No A/C Cut-off (0-70%)	
40	No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-40%)		No A/C Cut-off (0-70%)		No A/C Cut-off (0-70%)	
45	No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-40%)		No A/C Cut-off (0-70%)		No A/C Cut-off (0-70%)	
50	No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-40%)		No A/C Cut-off (0-70%)		No A/C Cut-off (0-70%)	
55	No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-40%)		No A/C Cut-off (0-70%)		No A/C Cut-off (0-70%)	
60	No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-30%)		No A/C Cut-off (0-40%)		No A/C Cut-off (0-70%)		No A/C Cut-off (0-70%)	
65	MINIMUM: Accelerator pedal 30% and above	3 sec	MINIMUM: Accelerator pedal 30% and above	3 sec	MINIMUM: Accelerator pedal 30% and above	3 sec	MINIMUM: Accelerator pedal 50% and above	3 sec	MINIMUM: Accelerator pedal 80% and above	3 sec	MINIMUM: Accelerator pedal 80% and above	3 sec
70	MAXIMUM: 6 sec or tip out to 5% whichever is earlier.		MAXIMUM: 6 sec or tip out to 5% whichever is earlier.		MAXIMUM: 6 sec or tip out to 5% whichever is earlier.		MAXIMUM: 8 sec or tip out to 5% whichever is earlier.		MAXIMUM: 8 sec or tip out to 5% whichever is earlier.		MAXIMUM: 8 sec or tip out to 5% whichever is earlier.	
75												
80												
85												
90												
95												
100												

Table 10.2: ECO MODE

Tip IN %	Neutral		1st gear		2nd gear		3rd gear		4th gear		5th gear	
	AC Cut off Threshold (Acc Pedal Base)	AC Cut off duration	AC Cut off Threshold (Acc Pedal Base)	AC Cut off duration	AC Cut off Threshold (Acc Pedal Base)	AC Cut off duration	AC Cut off Threshold (Acc Pedal Base)	AC Cut off duration	AC Cut off Threshold (Acc Pedal Base)	AC Cut off duration	AC Cut off Threshold (Acc Pedal Base)	AC Cut off duration
5	No A/C Cut-off (0-30%)		No A/C Cut-off (0-50%)		No A/C Cut-off (0-50%)							
10	No A/C Cut-off (0-30%)		No A/C Cut-off (0-50%)		No A/C Cut-off (0-50%)							
15	No A/C Cut-off (0-30%)		No A/C Cut-off (0-50%)		No A/C Cut-off (0-50%)							
20	No A/C Cut-off (0-30%)		No A/C Cut-off (0-50%)		No A/C Cut-off (0-50%)							
25	No A/C Cut-off (0-30%)		No A/C Cut-off (0-50%)		No A/C Cut-off (0-50%)							
30	No A/C Cut-off (0-30%)		No A/C Cut-off (0-50%)		No A/C Cut-off (0-50%)							
35	No A/C Cut-off (0-30%)		No A/C Cut-off (0-50%)		No A/C Cut-off (0-50%)							
40	No A/C Cut-off (0-30%)		No A/C Cut-off (0-50%)		No A/C Cut-off (0-50%)							
45	No A/C Cut-off (0-30%)		No A/C Cut-off (0-50%)		No A/C Cut-off (0-50%)							
50	No A/C Cut-off (0-30%)		No A/C Cut-off (0-50%)		No A/C Cut-off (0-50%)							
55	No A/C Cut-off (0-30%)		No A/C Cut-off (0-50%)		No A/C Cut-off (0-50%)							
60	No A/C Cut-off (0-30%)		No A/C Cut-off (0-50%)		No A/C Cut-off (0-50%)							
65	Accelerator pedal 30 % and above	MINIMUM: 3 sec	Accelerator pedal 30 % and above	MINIMUM: 3 sec	Accelerator pedal 30 % and above	MINIMUM: 3 sec	Accelerator pedal 30 % and above	MINIMUM: 3 sec	Accelerator pedal 50 % and above	MINIMUM: 3 sec	Accelerator pedal 50 % and above	MINIMUM: 3 sec
70		MAXIMUM: 6 sec or tip out to 5% whichever is earlier.		MAXIMUM: 6 sec or tip out to 5% whichever is earlier.		MAXIMUM: 6 sec or tip out to 5% whichever is earlier.		MAXIMUM: 6 sec or tip out to 5% whichever is earlier.		MAXIMUM: 8 sec or tip out to 5% whichever is earlier.		MAXIMUM: 8 sec or tip out to 5% whichever is earlier.
75												
80												
85												
90												
95												
100												

10.3 EXPECTED OUTCOME

- Fuel efficiency improvement by more the 0.5% KMPL
- Lower rate of field failures and decreased the maintenance requirements as well as cost.
- Due to compact design easy to engine bay design & packaging.
- Improvement in vehicle NVH.

11. REFERENCES

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