DC Motors in Automotive Equipment: Applications and Challenges

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ABSTRACT: The technological solution of hydraulic and pneumatic becomes obsolete in comparison to electric drive, mainly due to the efficiency, responsiveness, maintenance, and readiness for integration into a more intelligent system. In pursuing the electrification path, we have seen the integration of motors into more important applications such as steering, and braking among many more before taking the leap to replace the internal combustion engine to a traction electric motor. This paper reviews the main automotive applications that employ DC motor as actuator, and highlight the main issues and challenges in its implementation.

Keywords: *DC Motor, Automotive, Electrification*

1. INTRODUCTION

A direct current (DC) motor is an electric drive that convert electrical energy into rotational mechanical energy using direct current. The current-carrying conductor on the rotor, called armature interact with the magnetic field provided by either permanent magnet or stator winding to produce torque using the principle of Faraday's law. The electrical input as well as the motor design influence the output torque and speed. Regardless the types of motor, the progress are extensive in the range of applications and issues treated [1-2]. Though most motors used in automobile are brushed DC motors, due to advances in control and power electronics have enabled the introduction of a variety of brushless DC motors into automotive applications because of their great performance, compact size, low inertia, and low maintenance requirements.

2. MOTORS IN AUTOMOTIVE APPLICATIONS

DC motors provide significant benefits in systems such as in steering, braking, fuel injection, starter/generator, active suspension, and cruise control. For example, conventional automobiles that use rotary valve hydraulic power steering systems have been adopting electric power steering systems since more around two decades, The main reasons being the responsiveness, efficiency and reliability. The amount of space and weight saved by replacing the hydraulic actuators being the main reason for its adoption. The same shift from hydraulic or pneumatic actuators to electrical are also observed in other applications. Among them are brakes, fuel pumps, electronic throttle controls, engine cooling, blowers for HVAC, and power sliding doors. In this section, we are exploring all the application in automotive that are being electrified. The major issues and challenges in integrating these motors are also highlighted.

A. Electric Power Steering (EPS) System

Electric power steering system has significant advantage: energy conserving, environment protective, easy for installation, convenient in maintenance, comfort, easy to adjust and testing [3-5]. There are two types of vehicle steering systems, hydraulic and electricity- powered. As shown in Figure 1 a), all the components of the steering system are mechanically connected. A fully electronic-based approach replaces the EPS system, a part or the entire mechanical chain, with an electric connection (the steer-by-wire system). Dual actuators are used to control the driver interface as well as the steering system as shown in Fig. 1 b).

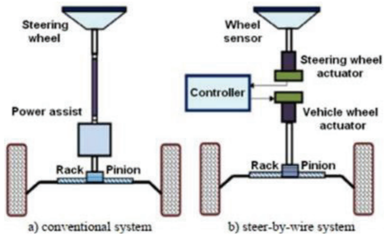

Fig. 1. Steering systems [6].

There are three main types of EPS; column assist for small vehicles, pinion assist for medium-sized vehicles, and rack assist for large vehicles [6-7]. For EPS applications, many motor types have been proposed [7] [8-9].

B. Engine Throttle Control

The traditional mechanical linkage like wire-pulled between the throttle paddle and the air intake valve consumes weight, space and is subject to wear and tear. Replacing them with a motor becomes an obvious solution [10-12]. With its responsiveness, the system improve vehicle drivability, fuel economy, reduced maintenance cost, improved simplicity, engine noise reduction, and safety [11-12]. With the addition of advanced control, fast transient response without overshoot, positioning within the measurement resolution, and control action that does not wear out the components can be achieved [11]. The response rate can also be modified for a control system that offer different driving mode such as economical, and sporty.

The throttle-by-wire systems consist of a direct current motor and a computer controller that converts the position of the gas pedal to the angle of the throttle valve position. The gas pedal sensor transmits the driver command to a Throttle Control Module (TCM), which subsequently determines the proper air–fuel mixture to be delivered into the engine. The TCM locates a suitable control output that sets the throttle valve at the appropriate opening angle, known as the ETC (Electric Throttle Control) system. Figure 8 shows the structure of an electronic throttle.

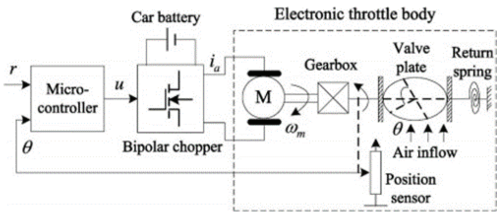

Fig. 8. Electronic throttle structure. [12]

Permanent magnet DC motors (PMDC) has been used in ETC done in [12] and the author has summarized that there are several advantages of using it such as the relatively high torques at low speeds, the linear speed / torque curve of PMDC motors, coupled with their ability to be easily controlled electronically, and the electrical efficiency of the PMDC motor is very often 10% to 15% higher due to the elimination of field copper losses which occur in wound field motors.

C. Electrical Braking System

Both electrical and mechanical braking systems are utilized in different range of application, from large power such as wind turbine to smaller power like in electric vehicles (EVs) [13]. In general, three objectives must be met for electrical braking on EVs which is riding comfort, maximum regenerative energy, and low cost. Many studies show that one-third to one-half of energy is lost while braking [14], and regenerative braking is an energy recovery technique that creates braking torque to brake an EV by converting energy (kinetic to electrical energy) and sending it back to the battery. In [15], the regenerative braking system using a series-wound brushed DC motor shows a braking effectiveness of about 26.34 % compared to 42.83% achieved using a PMDC.

3. CONCLUSIONS

As technology develops in the design of smaller, quieter, and more cost-effective motors and controls, electric motors will be utilized increasingly in automobile. Electric motors power density, thermal characteristics and noise levels are the most important criteria Improvement and optimization of motors to comply with constraints of regulation, usage condition and psycho-acoustics aspect are the directions that are interesting to be observed.

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