In-wheel motors put a new spin on mobility

Dr Sab Safi of SDT describes a novel, low-noise brushless DC motor designed to fit inside the wheels of low-power electric vehicles to drive them directly.

PRODUCTION OF low-power electric vehicles (EVs), such as wheelchairs, is expected to increase dramatically over the coming decade. Usually, in such vehicles, the driving force of a DC traction motor is transmitted to the wheels via flexible couplings and reduction gears. The torque of the traction motor is multiplied by the gear ratio.

But brushes and gears involve friction and other power losses, create noise, and can increase service requirements. Also, gearbox lubricants can leak, resulting in costly clean-ups.

An alternative drive technology, based on wheel-mounted permanent magnet brushless DC motors, is being developed by several mobility vehicle and electric motor manufacturers. Recent advances in power electronics and rare-earth permanent magnets (PMs) allow the construction of light, efficient brushless DC motors. The continuous improvement in the performance, availability and cost of high-performance PM materials means that, within a decade, the brushless DC motor will become the most common form of drive for low-power electric vehicles.

In-wheel brushless DC drives couple the load of the system directly to the motor without gears or belts. They have few mechanical parts to make contact during operation. They are more durable than two- or four-pole motors with gears and brushes, and can provide high torque levels in a modest package size. They solve many of the performance and limitations which are incurred by gear-motor drives, such as backlash, noise, leakage, and inefficient transfer of torque.

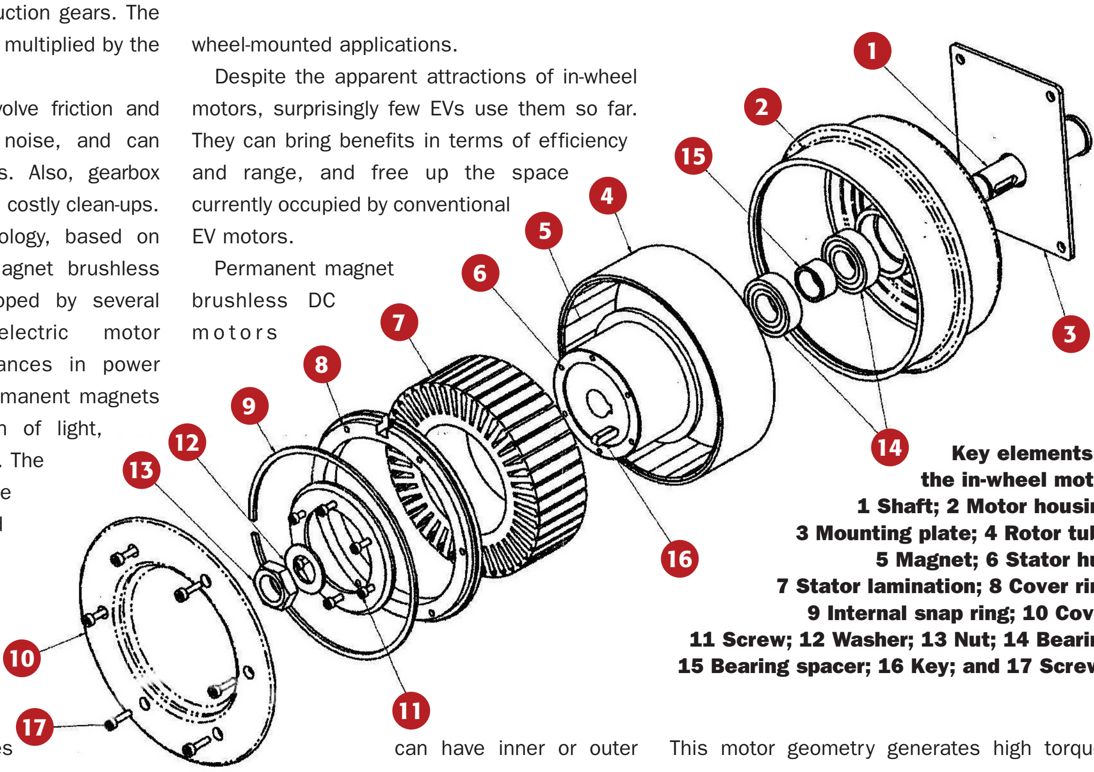
In a wheel-mounted PM brushless DC motor, the motor's torque is transmitted directly to the wheel without using gears and flexible couplings. This cuts transmission losses (and thus energy consumption), noise, maintenance, mass and size. If the transmission gears are eliminated, the motor has to supply a higher torque. Asynchronous motors do not meet this requirement and are therefore not suitable for wheel-mounted applications.

Despite the apparent attractions of in-wheel motors, surprisingly few EVs use them so far. They can bring benefits in terms of efficiency and range, and free up the space currently occupied by conventional EV motors.

Permanent magnet brushless DC motors can have inner or outer rotors. Usually they are of inner-rotor type, with their outer part being fixed while the inner part rotates. The rotor is connected directly to the axle and an outer stator.

In outer-rotor direct-drive traction motors, the rotor is connected directly to the wheels, and the inner stator is fixed to the axle. Inner-rotor motors require their own bearings, while outer-rotor designs do not, leading to a simpler construction.

The drive wheel motor is an electronically commutated, brushless PM traction motor integrated into the wheel. It is, in effect, a DC motor turned inside-out, with the coils (windings) staying put in a stationary housing surrounding the rotor, and the magnets mounted in the rotor doing the turning. Each winding is switched in succession electronically by power transistors, causing the rotor to spin.



Key elements of the in-wheel motor: 1 Shaft; 2 Motor housing; 3 Mounting plate; 4 Rotor tube; 5 Magnet; 6 Stator hub; 7 Stator lamination; 8 Cover ring; 9 Internal snap ring; 10 Cover; 11 Screw; 12 Washer; 13 Nut; 14 Bearing; 15 Bearing spacer; 16 Key; and 17 Screws.

This motor geometry generates high torques due to a combination of factors. First, the motor diameter is large. The tangential forces between rotor and stator act at a large radius, resulting in higher torque. Secondly, a large number of small rotor and stator teeth create many magnetic cycles per motor revolution. More working cycles means increased torque. In other words, the copper losses and electrical time constants remain low. These motors need more magnetic poles than a conventional brushless, inner-rotor DC motor.

Today, most low-priced electric wheelchairs use light-duty, two-pole motors, powered by electricity which enters them at two points. This works well for wheelchairs that are mainly used indoors and carry people weighing less than 115kg. However, they can burn out easily under heavy-duty operation.

For tougher duties, there are electric

wheelchairs driven by four-pole motors with electricity entering the motor at four points. Heat is distributed more evenly, and these motors have a lower rate of burn-out.

Motors for existing mobility products, such as wheelchairs, are typically brush-type machines up to 280W, 1.8 Nm. A new generation of wheelchairs is emerging which must be able to go faster, carry greater weights and go uphill. More powerful and efficient motors will be needed for these vehicles, but high-power brush-type motors (above 500W) would need to be unacceptably large, and would thus be unsuitable.

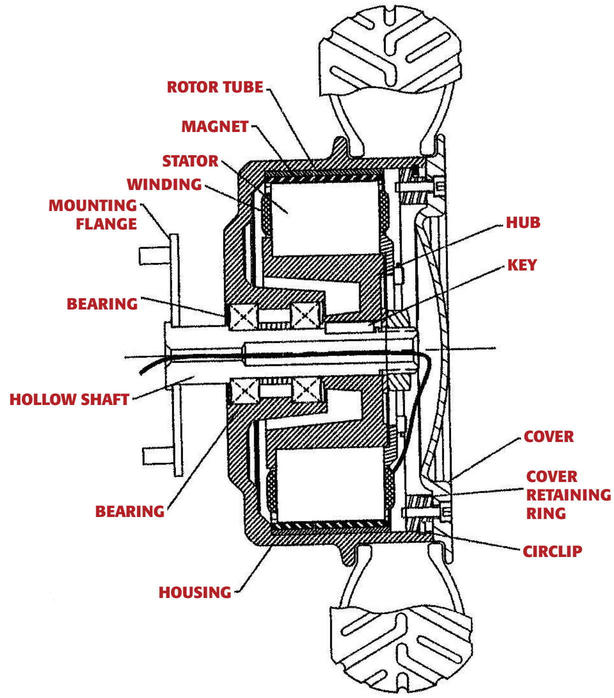
For this reason, SAFI Drive Technology (SDT) has developed a low-cost, high-performance brushless motor, that combines low torque ripple, low cogging torque, and low noise. The compact motor also delivers low moments of inertia and low frictional loss torque.

The motors, designed for in-wheel use, have aluminium hubs lined with permanent magnets. Inside the hub is a multi-phase, DC brushless motor, arranged so that the rotor surrounds, and rotates around, the centre-mounted stator. The rotor is made up of a series of independently-controlled electromagnetic coils driven by a proprietary power electronics module. To achieve strong magnetic fields from small, light magnets, rare-earth magnets are used.

Brushless motors can be driven by square waves, or sine waves which provide more precise control. The motor is optimised for low torque ripple and low cogging torque by using sine waves and a skewed air-gap. Because there are no sliding brushes, frictional and commutation noises are eliminated, reducing dramatically the sources of motor noise.

In-wheel brushless DC drives typically operate at 12, 24 or 36V DC, but can be custom-wound to meet customer requirements. Current machines run at speed from 50-500 rpm, but this can also be optimised to meet specific needs.

In future, larger in-wheel drives could be used to drive vehicles such as golf carts, forklifts, motorcycles, and even cars. D&C



A cross-sectional view of the in-wheel motor