

# MAGLEV Driveline for Wheeled Fuel Cell Powered Vehicles

Henry Kamau

VBD Automotive Technologies, Ltd.

## ABSTRACT

VBD Automotive Technologies have developed a MAGLEV driveline for wheeled fuel cell powered vehicles. The driveline known as the "Magnetic Hubless Wheel Drive" (MHWD), essentially allows for the elimination of the high torque output requirement for wheeled vehicles which currently derive their traction/driving force from the torque applied at the wheel hub to overcome the wheel radius.

The frictionless Magnetic Hubless Wheel Drive converts the electric current, from the fuel cell power plant, at the wheel circumference and applies the MAGLEV traction force directly on the inside face of the rotating magnetized road wheel eliminating the need for a wheel hub and substantially reducing mechanical losses inherent in a convectional driveline.

The elimination of a mechanical link from the power plant of the vehicle to the traction wheel allows for new performance and safety enhancing features to be built into the vehicle e.g. variable wheelbase and wheel track for city traffic maneuverability and comfortable highway cruising in a small economical vehicle.

The description of the MHWD deals with the driveline operating system and mechanical retention and control of the hubless MAGLEV wheels when the vehicle is levitated marginally to reduce friction from the inside face of the traction wheel.

This technology is ideally suited to fuel cell powered vehicles which despite major advances in fuel cell stack power densities, require ultra efficient and innovative drivelines that enhance the vehicle's range and power output.

"The Safari" concept car designed by VBD Automotive Technologies is featured with the MHWD installed.

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## INTRODUCTION

The Magnetic Hubless Wheel Drive (MHWD) [1] is designed to propel and levitate a wheeled fuel cell powered vehicle by the use of force generated by magnetic flux between permanent magnets fixed laterally to the inside of a road wheel with alternating poles adjacent and dual electromagnets or superconducting electromagnets, supplied with a variable frequency alternating electrical current, mounted to a support brace that slides along the inside of the road wheel.

The inside of the road wheel fitted with permanent magnets effectively forms a portable track of infinite length for the sliding action and magnetic levitation of the support brace to which the vehicle body is attached.

When magnetized by a varying frequency alternating current, the electromagnets mounted on the support brace repel and attract the alternating poles fixed to the magnetized wheel successively with each current cycle causing the road wheel to rotate.

## Background

The innovative MAGLEV drive system relates to the propulsion and magnetic levitation of a wheeled vehicle body by the use of magnetic force generation and in particular pertains to the use of an infinite length portable track in the form of a magnetized hubless road wheel attached to the vehicle body by a support brace through which magnetic force generated is converted into tractive force for the propulsion and magnetic levitation of the vehicle body without the need for a separate independent fixed track.

Applying the drive output at the circumference of the hubless road wheel substantially reduces the additional power required to overcome radial torque of convectional hub driven wheels making this method of propulsion the most efficient for fuel cell powered vehicles, thus enabling the technology to progress beyond the levels of emissions and energy savings achieved by hybrid and battery operated electric vehicles.

## Technology Classification

Under World Intellectual Property Office (WIPO) classification, the technology would be categorized as **B60L 13/10** "Combination of electric propulsion and magnetic suspension or levitation".

## Conventional Related Technologies

### Magnetic levitation

Magnetic levitation transport, or MAGLEV, is a form of transportation that suspends, guides and propels vehicles via electromagnetic force. This method can be faster and more comfortable than wheeled mass transit systems. MAGLEVs could potentially reach velocities comparable to turboprop and jet aircraft (500 to 580 km/h). Since much of a MAGLEV's propulsion system is in the track rather than the vehicle, MAGLEV trains are lighter and can ascend steeper slopes than conventional trains. They can be supported on lightweight elevated tracks. MAGLEVs have operated commercially since 1984. However, scientific and economic limitations have hindered the proliferation of the technology. MAGLEV technology has minimal overlap with wheeled train technology and is not compatible with conventional railroad tracks. Because they cannot share existing infrastructure, MAGLEVs must be designed as complete transportation systems. The term "MAGLEV" refers not only to the vehicles, but to the vehicle/guideway interaction; each being a unique design element specifically tailored to the other to create and precisely control magnetic levitation and propulsion.

### Fuel cell vehicles

A fuel cell is an electrochemical energy conversion device. Fuel cells differ from batteries in that they are designed for continuous replenishment of the reactants consumed; they produce electricity from an external supply of fuel and oxidant (typically oxygen or air, although chlorine and chlorine dioxide have also been used among others) as opposed to the limited internal energy storage capacity of a battery. Additionally, while the electrodes within a battery react and change as a battery is charged or discharged, a fuel cell's electrodes are catalytic and relatively stable. Typical reactants used in a fuel cell are hydrogen on the anode side and oxygen on the cathode side (a hydrogen cell). Usually, reactants flow in and reaction products flow out. The electrolyte remains in the cell. Virtually continuous long-term operation is feasible as long as these flows are maintained.

A Fuel Cell powered vehicle, such as an automobile, uses hydrogen in fuel-cell conversion as its primary source of power for locomotion. In fuel-cell conversion, the hydrogen is turned into electricity through fuel cells which then power electric motors.

Hydrogen can be obtained through various thermochemical methods utilizing methane (natural gas), coal (by a process known as coal gasification), liquified petroleum gas, biomass (biomass gasification), or from water by

electrolysis or by a process called thermolysis. A primary benefit of using pure hydrogen as a power source would be that it uses oxygen from the air to produce water vapor as exhaust. Another benefit is that, theoretically, the source of pollution created today by burning fossil fuels could be moved to centralized power plants, where the byproducts of burning fossil fuels can be better controlled. Hydrogen could also be produced from renewable energy sources with no net increase in carbon dioxide emissions. However, the technical challenges required to realize these benefits may not be solved for many decades, and may never be economically feasible.

### Hubless wheel

A hubless wheel (also known as a rim-rider or centerless wheel) is a type of wheel with no center hub. A variety of working hubless wheel vehicles including at least two motorcycles have been built.

Although hubless wheels are striking in appearance, their numerous practical disadvantages have precluded their widespread use as an alternative to conventional wheels. They are difficult and expensive to manufacture, requiring a great deal of precision machining, and the design leaves the bearings and other mechanical parts largely exposed to the elements. The drive system is especially problematic since a conventional axle and Continuous Velocity (CV) joint cannot be used; options include using chain or belt drive.

### Variable frequency drive

A Variable Frequency Drive (sometimes abbreviated VFD) is a system for controlling the rotational speed of an alternating current (AC) electric motor by controlling the frequency of the electrical power supplied to the motor. A variable frequency drive is a specific type of adjustable speed drive. Variable frequency drives are also known as adjustable frequency drives (AFD), variable speed drives (VSD), AC drives or inverter drives.

When a VFD starts a motor, it initially applies a low frequency and voltage to the motor. Starting at such low frequency avoids the high in-rush current that occurs when a motor is started by turning on a switch. When a VFD starts, the applied frequency and voltage are increased at a controlled rate or ramped up to accelerate the load without drawing excessive current.

## MAGLEV DRIVELINE

### Magnetic Levitation

The innovative "Magnetic Hubless Wheel Drive" system seeks to apply part of this magnetic levitation technology for the propulsion and magnetic levitation of fuel cell powered wheeled vehicles where the vehicle/guideway interaction occurs within a magnetized hubless road wheel.

This arrangement will allow for the use of an infinite length portable track applicable for use by fuel cell powered wheeled road vehicles utilizing existing infrastructure

(normal roads for cars, trucks and buses) as opposed to the convectional fixed MAGLEV monorail tracks with finite length limiting the use of the technology to MAGLEV trains with specialized tracks requiring new infrastructure (MAGLEV monorails) as is the case today.

Where superconducting electromagnets are used in the support brace of the Magnetic Hubless Wheel Drive, a protective insulation sheath is used to protect sensitive electronic devices such as pace makers that may be used in close proximity of the superconducting electromagnets, a feature that currently prevents heart patients on pace makers from using electrodynamic MAGLEV trains that utilize superconducting electromagnets in their monorail system infrastructure.

## Fuel Cell Vehicles

The innovative “Magnetic Hubless Wheel Drive” system seeks to become the most efficient mode of propulsion for vehicles powered by fuel cells where economical use of the electricity generated by the fuel cell power plant for the propulsion of the vehicle and minimization of drivetrain frictional losses is critical to the sustainable success of fuel cell powered vehicles and resultant reduction GHG emissions to reduce the effects of global warming.

Alternative drive systems proposed such as hub mounted electric motors still require to overcome radial torque while with the Magnetic Hubless Wheel Drive the drive output is generated at the circumference of the wheel reducing the input power requirements for the propulsion of the vehicle making more efficient use of the electricity generated from the fuel cell power plant.

The use of partial or full magnetic levitation and force from magnetic flux to propel the vehicle will minimize frictional losses associated with today's drivetrains in vehicles and eliminate the need to oil or grease bearing components or surfaces in the drivetrain further improving environmental efficiency. In addition, significantly reduced maintenance costs over convectional driveline systems makes propulsion by magnetic hubless wheel drive the most viable option for fuel cell powered vehicles.

## Hubless Wheel

The innovative “Magnetic Hubless Wheel Drive” system seeks to house the force generating component of the propulsion system inside the hubless wheel while overcoming the traditional shortcomings of a hubless wheel by eliminating the need for costly, high precision, high reduction gear ratio, mechanical propulsion components which has restricted commercialization of attractive and aesthetic hubless wheels.

Energy consumption is also minimized by applying the drive power at the circumference of the wheel rather than at the centre via a hub, reducing the need for additional power to overcome the radial torque for the wheel to rotate. This allows for more efficient use of the energy generated by the vehicle's fuel cell powerplant and for the reduction of global

warming by reducing GHG emissions through reduced energy requirements.

## Variable Frequency Drive

The innovative “Magnetic Hubless Wheel Drive” system seeks to use a variable frequency drive to regulate the rotational speed and torque output of the hubless road wheel which will minimize the need for power increases by reducing the need to increase the electrical current to the electromagnets for the acceleration or deceleration of the vehicle as is the case with all convectional electrical vehicles where the energy absorbing current is increased to accelerate or decelerate the vehicle body. Use of varying frequency to accelerate or decelerate the vehicle body will allow for more efficient use of the electricity generated by the vehicle's fuel cell powerplant.

Additional braking force can be obtained by adding a braking circuit to dissipate the braking energy or return it to the power source thereby increasing energy utilization. A reverse magnetic sensor can also be used to reverse the current phase for the purposes of deceleration or reversing the vehicle.

## Renewable Energy Resource Utilization

Commercialization of on-board vehicle renewable energy resources such as solar power from photovoltaic cells to complement the fuel cell power plant, has been severely restricted by low energy generation levels of solar power restricting sustainable use through convectional drivetrains.

The innovative “Magnetic Hubless Wheel Drive” system provides the most efficient use of renewable energy resource generated for the generation of tractive force by eliminating the need for additional power to overcome radial torque for the generation of tractive force from a hub centered drive shaft as the Magnetic Hubless Wheel Drive generates tractive force directly at the tractive circumference substantially reducing the power required to generate the same tractive force thereby allowing for the sustainable use of renewable energy resources to power the vehicle alongside the fuel cell power plant, the ultimate hybrid vehicle.

## Carbon Emissions

When used in conjunction with renewable energy resources such as solar power, the innovative “Magnetic Hubless Wheel Drive” system, which is the only sustainable method of propulsion for low energy density on-board vehicle renewable energy resources such as fuel cell power plants, has the potential to eliminate ozone depleting carbon dioxide emissions in the transport sector.

## FUEL CELL VEHICLE APPLICATION

### Vehicle Propulsion and Levitation

The principal application for the innovative “Magnetic Hubless Wheel Drive” system is for the propulsion and partial or full magnetic levitation of wheeled fuel cell powered vehicles.

Implementation cost is significantly reduced when compared with magnetic levitation trains (MAGLEVS) as the proposed fuel cell powered vehicle application will be able to utilize existing infrastructure i.e. roads without the need for any modification of existing infrastructure.

### MAGNETIC HUBLESS WHEEL DRIVE

The magnetic hubless wheel drive is designed to propel a wheeled fuel cell powered vehicle by the use of force generated by the magnetic flux between permanent magnets fixed laterally to the inside of a road wheel with alternating poles adjacent, and dual electromagnets or dual superconducting electromagnets supplied with a variable frequency alternating electrical current mounted to a support brace that slides along the inside of the road wheel.

The inside of the road wheel fitted with permanent magnets effectively forms a portable track of infinite length for the sliding action and partial or full magnetic levitation of the support brace fitted with electromagnets as the road wheel rotates sliding through the support brace.

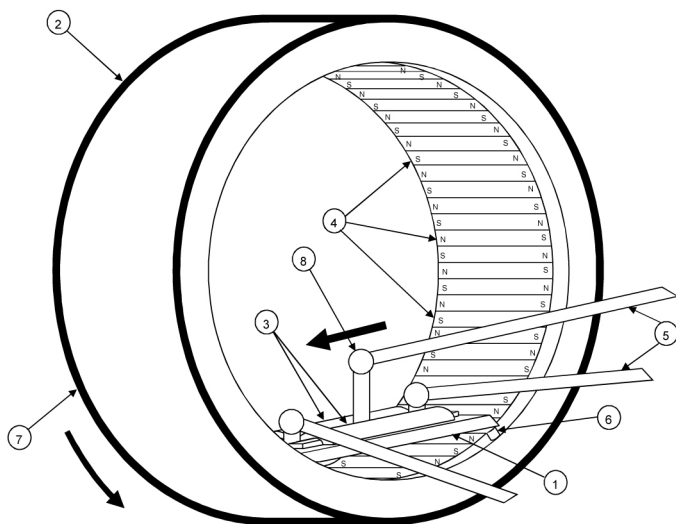


**Figure 1. Isometric view of the Magnetic Hubless Wheel Drive system**

When magnetized by a varying frequency alternating electrical current, the electromagnets mounted on the support brace alternately repel and attract the alternating poles of the permanent magnets fixed to the road wheel successively,

causing the road wheel to rotate as it slides continuously through the support brace.

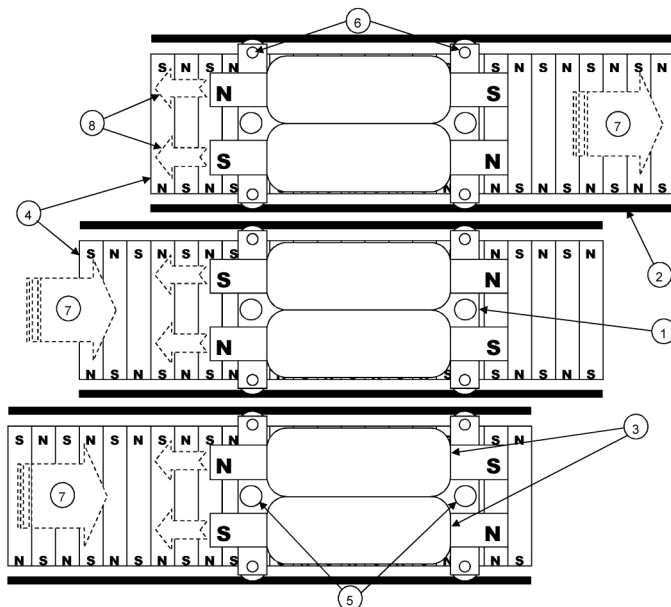


**Figure 2. The drive sequence schematic represents the workings of the propulsion system as the electromagnet changes current direction and polarity forcing the magnetized wheel to rotate**

Reversing the varying frequency alternating electrical current causes the road wheel to rotate in the opposite direction providing either reverse motion for the vehicle or frictionless braking while maintaining partial or full magnetic levitation for the vehicle when in motion in either direction.

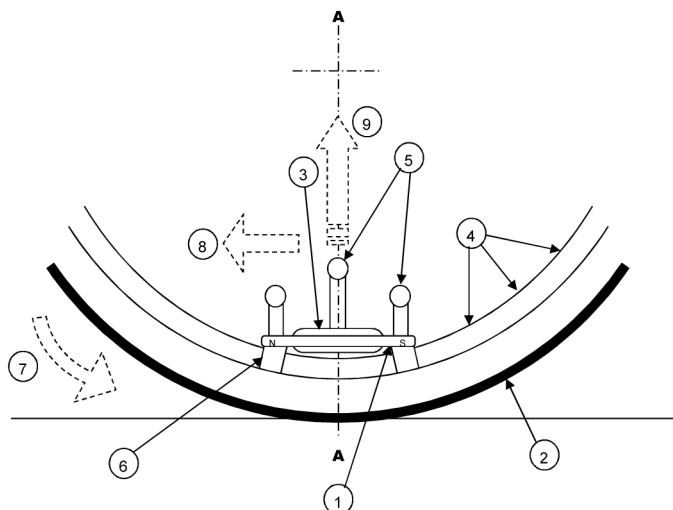


**Figure 3. The side view shows the relative motion of the various components when in operation.**

To reduce the friction load on the support brace slider and roller bearings in contact with the road wheel, partial or full magnetic levitation is achieved by the variable frequency