DESIGNING AND MANUFACTURING A MECHATRONIC POWER TRANSMISSION FOR AN AUTOMATIC GUIDING FIELD VEHICLE

M. R. Khadem[1], M. Khadem[2] R. Mohamadi Kaleibar[1]
[1]Mechanical Engineering Dept.,
Shiraz Islamic Azad University,Gha'ani St., Shiraz,
Tel: +98 711 6241963,
E-mail: smr.khadem@yahoo.com
[2]Mechanical Engineering Dept., Shiraz University,
Molla Sadra, Shiraz,
el: +98 711 6289149,
E-mail:mohsen.khadem@gmail.com

Abstract

The aim of this research is to establish and to run a field evaluation test of a diesel 15 HP vehicle with the ability to travel up to 20 Km/hr in a continuous variable speed fashion. The mechanical power transmission system of a 15 HP truck has been replaced with a programmable electrical clutch and brake, and a variable speed electromotor. The field test has been undertaken in the city of Shiraz, Fars Province, Iran. The result of the field test proved that the vehicle can travel a straight path while being controlled via a remote control system. Different features of the vehicle's movement have all been satisfactory. The outcome of this research can be put into much use in the improvement of the precision farming technology.

Keywords

machine control, automatic vehicle, precision farming

Introduction

Hybrid electric vehicles use a conventional gasoline engine for propulsion, and an electric motor for supplemental power, or to drive the vehicle if it has a full electric mode. On other hybrids, such as the Saturn Vue, Honda Insight and Civic Hybrid, the electric motor is used more like a supplemental power source to boost acceleration when extra power is needed. This allows the use of a smaller, more fuel efficient gasoline engine that gets better fuel economy without sacrificing too much performance [www.wikipedia.com].

The main attraction of a diesel engine is that it is more fuel efficient than a gasoline engine: up to 30% better fuel economy as a rule than a comparable gasoline engine of the same displacement. A diesel engine is also much less complicated that a gasoline hybrid, which requires a large heavy battery, electric motor(s), a power inverter to convert the battery's DC (direct current) output to AC (alternating current) for the electric motors, and sophisticated hybrid control system.

A vehicle tracking system is an electronic device installed in a vehicle to enable the owner or a third party to track the vehicle's location. Most modern vehicle tracking systems use Global Positioning System (GPS) modules for accurate location of the vehicle. Many systems also combine a communications component such as cellular or satellite transmitters to communicate the vehicle’s location to a remote user. Vehicle information can be viewed on electronic maps via the Internet or specialized software.

A frequency changer or frequency converter is an electronic device that converts alternating current (AC) of one frequency to alternating current of another frequency. The device may also change the voltage, but if it does, that is incidental to its principal purpose. Traditionally, these devices were built out of electromechanical components such as motor-generator sets or rotary converters But with the advent of solid state electronics, it has become possible to build completely electronic frequency changers. These devices usually consist of a rectifier stage (producing direct current) which is then inverted to produce AC of the desired frequency. A battery may also be added to the dc circuitry to improve the converter's ride-through of brief outages in the input power. Frequency changers vary in power-handling capability from a few watts to megawatts. Aside from the obvious application of converting bulk amounts of power from one distribution standard to another, frequency changers are also used to control the speed and the torque of AC motors. In this application, the most typical frequency converter topology is the three-phase two-level voltage source inverter [www.wikipedia.com.]

In a vision-based automatic agricultural vehicle guidance system for row-crop applications, finding guidance information from crop row structure is the key in achieving accurate control of the vehicle. Auxiliary information, such as the known crop row spacing, is used to aid in the development of the guidance directrix. Two image data sets, one taken from a soybean field and the other taken from a corn field, were used to evaluate the accuracy of the proposed image processing procedure. The proposed image processing procedure was implemented on a vision-based guidance tractor (Han et al., 2004).

A velocity control methodology is presented for an agricultural vehicle with a hydrostatic drive-train. The dead zone inversions compensate for nonlinear valve dynamics. The velocity controller consists of a digital feedback control. A stability analysis of the closed loop system is performed.(Foster, 2004). There is an increasing trend in Japan towards consolidating, and thus enlarging, paddy fields. Because this demands more efficient operations, Nagasaki developed automated six-row rice transplanted. It employs a real-time kinematic global positioning system (RTKGPS) for precise positioning, fibber optic gyroscope (FOG) sensors to measure direction, and actuators to control steering, engine throttle, clutch, brake, etc. The RTKGPS achieves 2 cm precision at 10 Hz data output rate, and the FOG sensors are employed to maintain vehicle inclination. RTKGPS position data, influenced by vehicle inclination, are corrected by the FOG sensor data. FOG sensor drift is corrected by referring to the position data rows. For this to occur, it is necessary to improve the turn control algorithm and steering controller to obtain more precise operations (Nagasaki et al., 2004).

Cone describes the design of a robust automatic guidance system for a combine harvester. The automatic steering system controls the harvester based on the measured position of the swath on the field. The swath is detected using a laser scanner. The desired wheel position is then transmitted over the CAN network of the harvester to the actuator (Cone et al., 2008).

A teleportation system for a hydro-static transmission (HST) drive crawler-type robotic vehicle is described by Murakami. The system was developed to satisfy the needs of various farm operations and teleportation in unknown agricultural fields. The vehicle can travel autonomously by using an RTK-GPS and a fiber-optic gyroscope during supervisory control, and the operator interface also provides a field navigator based on Google Map technology. The vehicle's position and heading direction was capable of 1 Hz update using precise satellite image maps. The results of field tests using direct control showed that it is difficult for the operator to control the movement of the vehicle along the target lines. On the other hand, the vehicle could travel in a straight line with a maximum lateral error of 0.3 m by using supervisory control. Development of machine vision and laser radar based autonomous vehicle guidance systems for citrus grove navigation (Murakami et al., 2008).

Current production navigation systems for agricultural vehicles rely on GPS as the primary sensor for steering control. In citrus groves, where the tree canopy frequently blocks the satellite signals to the GPS receiver, an alternative method is required. Subramanian discusses the development of an autonomous guidance system for use in a citrus grove. The vehicle used for this study was a common tractor. Machine vision and laser radar (ladar) were individually used for guidance and a rotary encoder was used to provide feedback on the steering angle. A PID Controller was developed to minimize the path error. The vehicle's guidance accuracy was tested in flexible test paths constructed of common hay bales.

Materials and method

For developing a vehicle in the category of hybrid machines, the process is based on selection of required mechanical, electrical and electronic devices and integrating them with each other. The energy transfer block diagram from the input power source to the driving wheels is shown in Fig.1

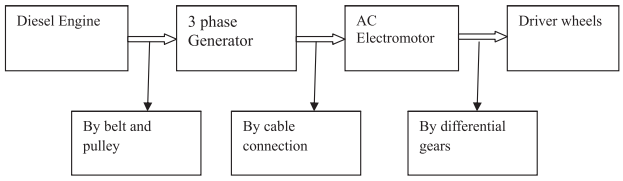

Figure 1. block diagram of energy transfer in the designed vehicle

Designing requirements of vehicle are based on the following assumptions. These specifications of the vehicle are logically selected to be corresponding for a real field working circumstances similar to a small farm tractor.

Table1. Designing Requirements for the vehicle

Speed	from 0 to 30 kilometer per hours, forward and reverse directions
speed change	continuously variable in forward and reverse direction
Carrying capacity	800 kg including load and vehicle weight
Field condition	compacted soil with 10 percent slopes in the worst condition

Figure 2. A prime assembly of the hybrid field vehicle

To attain a vehicle with this capability, after some dynamic calculations and considering the accessible technologies, the purchased accessories prepared are:

1. Diesel engine: 14 KW with single cylinder
2. Electrical generator: 10KW, 3 phase, 380 output voltage
3. Ferequency convertor: Vacon NXL
4. Electic motor: 3 phase, 8 KW
5. Assembly of a vanet including: chasses, steering system, the front and rear wheels, differential drive on rear axle and suspension system
6. A package of wireless remote control system

The machine is made for traveling by the operator like a usual car in transport outside the field and also for straight traveling in the field. A double rail guiding system was planed as the means of straight motion, as shown in Fig.2, 3.

Figure 3. Double rail guiding mechanism for the car traveling in the field

The misplaced parts of the conventional vehicle are gasoline engine, clutch, gearbox, and brake system. The new option for replacement was diesel engine which is more suitable for field working. The electrical clutch, speed changer and a brake were all being covered by the Frequency Convertor Unit. Laboratory performance tests and field tests are undertaken and a hard fault and remedy period used up for capable running of the machine.

Results and discussions

In this fundamental technology research, based on the seizing and try and error design style, a new appliance of update technology is introduced into agricultural activity. The results of this experiment are categorized as:

a) Power transmission through the variable speed AC electromotor to the differential drive to the wheels had the capability of proper running. The test reveals that the AC electromotor equipped with Frequency Convertor unit could not efficiently transmit torque and power in low speed working range. Due to this difficulty the 1450 rpm AC electromotor was replaced with a 900 rpm one.
b) The electronic switching of electromotor as the power transmission unit of the vehicle is moderately analogous with the clutch and brake of a diesel or a gasoline car. The most important outcome of the designed mechatronic clutch and break in the electromotor is its programmability, and feasibility of its soft start and stop setting.
c) The RF (radio frequency) or wireless remote control works well up to 3 kilometers distance from the vehicle. The remote control has an on/off switch, can adjust rpm and the rotational direction of electromotor. The forward and backward velocity in both the remote mode or the control panel mode by operator was up to 20 km/hr during the field tests.

The main obstruction in a qualified working and the errors that lower the accuracy of the machine operation are:

1. The noise induced by vibration of the diesel engine. The electronic hardware is susceptible to mechanical disturbances in their vicinity use.
2. The road condition and its unevenness greatly affected the control devices. A proper suspension spring and damper must be designed to prevent shocking the control units.

Conclusions

This simple hybrid field car can be an opportunity in farm machinery progress. Precision farming needs a technology with high compatibility to electronic command. A precise point identification of plot and controllable allocation in the field is essential for Site Specific Crop Management (SSCM), as a goal of sustainable farming. Outcome of this project can be a technology gift to upgrading cultivation and a service to natural source conservation.

A team of mechanical engineers and electronic engineers is needed to guarantee the success of such plan. Most of today's attention is focused on the vehicle locating system, car tracking and guiding of the usual field machine. Meanwhile this study tries to pay more attention to the basic redesigning of machine construction for more compatibility with farm setting.

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