# ELECTROHYDRAULIC PROPULSION IMPLEMENTED ON A JOHN DEERE WINDROWER

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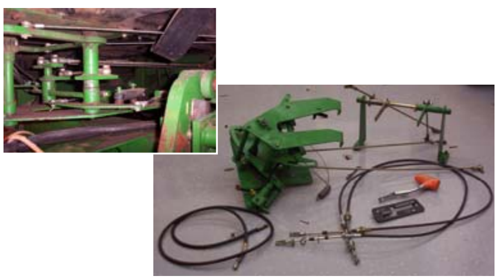
## Mission Statement

*The mission of this project is to design a propulsion control system that is easier to manufacture and control than the current mechanical four-bar linkage system on a John Deere windrower.*

***A Windrower is a self-propelled forage cutting and conditioning machine. These machines are known for their ability to cut hay and forage with remarkable speed on varying terrain. John Deere Windrowers are driven by a Heavy-Duty hydraulic propulsion system.***

Above Pictures from www.deere.com

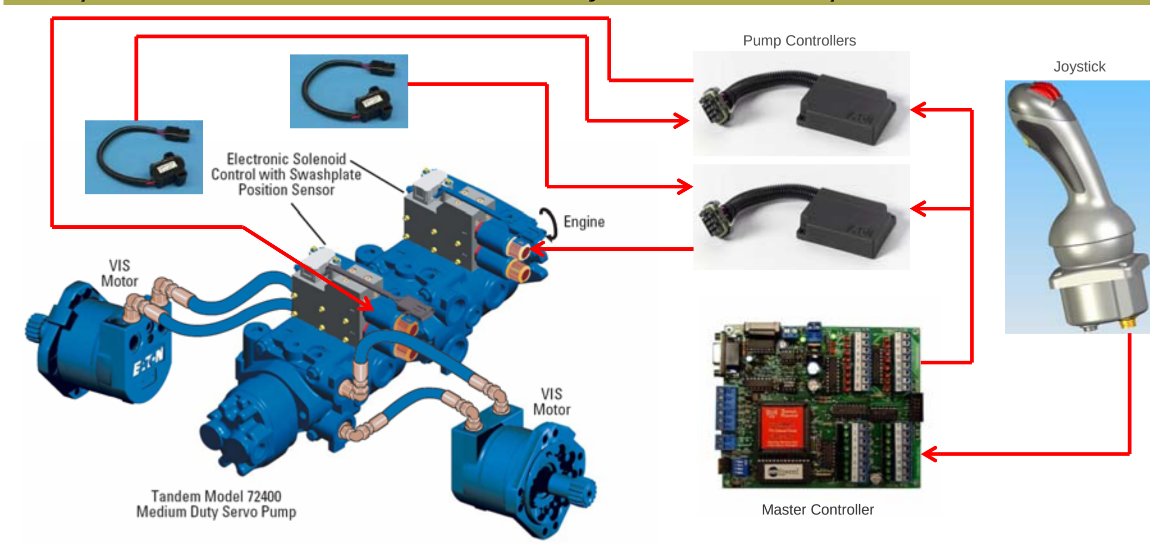


## Current Propulsion System

*Current John Deere windrowers employ a four-bar mechanical linkage that controls two hydraulic pumps. This system (pictured to the left) consists of:*

- ***Sector gear***
- ***Steering column***
- ***Steering linkages***
- ***Hydro-handle linkages***
- ***Centering device (with spring)***
- ***Hydraulic Solenoid (safety lock)***

## Proposed Solution: Electro-Hydraulic Propulsion




*In order to improve manufacturability and operator control, an Electro-hydraulic system as depicted above was designed and implemented on a prototype machine. The following components make up this new system:*

•***Joystick:*** *A Joystick, provided by Eaton Corporation, is used to input speed and steering from the operator.*

•***Master Controller:*** *A master controller is the brain of the system. It analyses the joystick input and outputs the necessary pump displacement.*

•***Pump Controllers:*** *Two Eaton TCA controllers prepare the signal for the hydraulic pumps.*

•***Electronic Swash-plate Control:*** *Manual pump controls have been changed to electronic solenoids with position sensors*

Pictures from www.deere.com

## Design Constraints

***The following are major concerns and limiting factors in the design:***

- ***Operator Safety***
- ***Pump Response Time***
- ***Cab structure***
- ***Turning Speed***
- ***Cost of components***
- ***Controller I/O signals***
- ***Space for components***
- ***Component complexity***

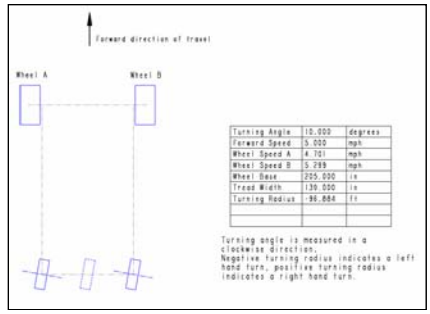
## Design Procedure

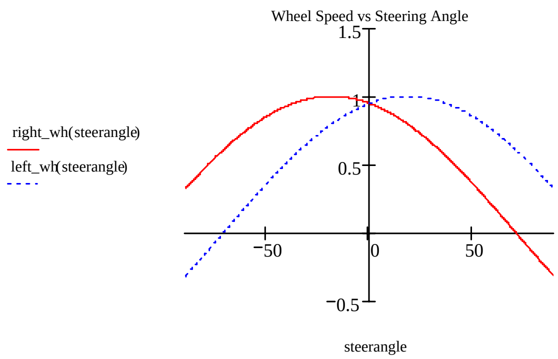
### *Calculations*

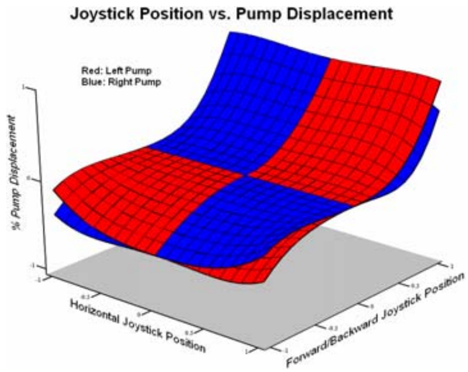
*In order to determine the appropriate Steering control algorithm, a model (pictured to the right) was made with Pro/Engineer© to display the differential wheel speeds at a certain steering angle. After analyzing data collected from this program, a mathematical equation was derived to model the behavior of the steering. The plot below, which compares wheel speed to the steering angle, uses this equation to shows how fast each wheel is turning relative to the other at a certain steering angle.*

*The next step was to determine the output function of the joystick. The 3-dimensional plot below shows the correlation between joystick position and wheel speed.*

*Further calculations were completed to make sure that the responsiveness of the pump was not too fast for the operators safety. This was done with information given by the supplier.*




### *Benchmark Testing*

*A series of benchmark tests on the steering systems in no load situations have been executed to compare the mechanical steering system to the electrohydraulic system. The following performance characteristics are determined from the tests:*

- *Time it takes for the steering to center*
- *Reaction time for a sudden change in direction*
- *Reaction time for a sudden change in propulsion*
- *Amount of hysteresis when steering one way and then the other*

### *Program Computer Simulation*

*The programming software package, TRiLOGI©, used to program the controller was also used to simulate the program. The Screenshot to the right depicts what a simulation looks like. This helped to determine what each output would do, when the specific inputs were entered.*

### *Mock Controller Set-up*

*In addition to testing the program, it was necessary to perform trials with the hardware before actually installing it on the windrower. By creating a mock system, each of the hardware devices were tested to ensure their functionality.*

## Advantages of Electrohydraulic Propulsion

- ***Lower manufacturing cost for the steering assembly:*** *An electrohydraulic system has much fewer parts than the current system, and is expected to cut assembly time significantly.*
- ***Less wear and service points:*** *Taking out mechanical linkages eliminates many contact surfaces and thus the need for lubrication.*
- ***Better handling and control:*** *The electrohydraulic system reduces the amount of "play" in the steering caused by loose components. In addition, programmed response times can prevent unwanted over-steer. Centering of the steering will also be more accurate with electronic controls.*
- ***Additional safety features:*** *Implementing electronic controls allows for several safety features to be added, such as slower reverse speeds, automatic centering in park, different steering modes at different speeds and pump displacement feedback.*
- ***Future increased technology capabilities:*** *Equipping a machine with a controller provides great potential for future projects. Some areas that may be explored include: wheel speed feedback, Can-Bus connections, operator feedback and GPS capabilities such as yield mapping and auto-steering.*

## Safety Features

- ***Zero Pump Flow during loss of power***
- ***Less responsive steering at high speeds***
- ***Steering is easier to center***
- ***Slower speeds in reverse***
- ***Pump displacement feedback (ensures proper displacement setting)***

## Future Developments

- ***Multiple Steering Modes***
- ***Wheel Speed Feedback***
- ***Active Steering Intervention (Stability control)***
- ***Steering Wheel/Propulsion lever Inputs***
- ***CAN-Bus Connections***
- ***Operator Feedback***
- ***GPS capabilities***

## Project Impact

*Electro-hydraulic technology in the construction, forestry and agriculture industry has been rapidly gaining acceptance in the past ten years. Forage machinery has yet to join this trend, but recent concern for the controllability of windrower machines has been sparking advancements industry wide in steering and propulsion. Electrohydraulic propulsion would be a significant step toward improving the manufacturability, handling, control and safety of these machines.*


## Acknowledgements

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