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IFAC-PapersOnLine 49-16 (2016) 045–049

Electromechanical steering of an articulated vehicle

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Abstract: In this research, an electromechanical steering system for an articulated frame-steered vehicle is developed. Using electromechanical steering instead of hydraulic steering could enable energy savings and more accurate control. The system is tested and demonstrated in a case machine. It is discovered that electromechanical steering is able to steer the vehicle similarly to the original system.

Keywords: coupled electric drives, hybrid electric vehicles, slew drive, electromechanical steering, articulated steering

1. INTRODUCTION

Fossil fuels are getting scarcer and thus more expensive, which also affects the agricultural industry. Burning of fossil fuels also produces harmful environmental effects. Hybridization of work machines is one possible way to reduce fuel consumption, therefore spending less money and causing less pollution. In this research, a control system for an articulated frame steered non-road mobile machine (NRMM) with electromechanical steering is presented.

Articulated frame steering (AFS), such as used on the CASE IH Steiger tractor (Fig. 1), has some advantages over the traditional Ackerman-steered vehicles. These include track holding and a small turning radius. Traditionally the AFS has utilized hydraulic cylinders as a means of steering. The electromechanical steering used in this research could enable decreased fuel consumption, as no energy is lost in circulating the hydraulic fluid even when steering is not necessary, as well as more precise steering control.

Fig. 1 Case IH Steiger with articulated frame-steering (Case IH)

2. METHODS

In this section the mechatronic design of the system is presented in detail. Also the test methodology is described. A description of the case machine is also included.

2.1 Specification of mechanics

Different alternatives for electromechanical steering are studied in a master's thesis (Lehtinen, 2013). An intuitive solution would have been simply to replace the original hydraulic cylinders of the case machine with an electric linear actuator, but a slew drive solution provides more grounds for research. Slew drives are commonly used for example in rotating cranes, rock drills, and wind mills.

Even though a steering system is always an integral part of a whole vehicle's control system, it can be treated as a separate subsystem. It is assumed that it sends some status information to the higher level control system and receives at least simple run/stop –information from the higher level system.

A dSpace MicroAutoBox II (MABX, (dSPACE)) is used as the controller platform in this research. It is a development system commonly used in automotive domain and features an IBM PowerPC 900MHz CPU and comprehensive I/O. The application program is developed in Simulink (MathWorks, 2013), which is a simulation tool with code generation features, allowing rapid prototyping with model based software development. Graphical user interface (GUI) is implemented in dSPACE ControlDesk (dSPACE), which is a program for building user interfaces for control and measurement on the MABX. In Simulink a platform developed for hybrid powertrains by Hybria ((Hyb16)) was utilized. The GUI portrays relevant information from the slew drive and provides three different means for controlling the drive: an external joystick, a slider in the graphical user

Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2016.10.009

interface and a predefined velocity signal, which was used in the initial testing phase.

The MABX reads a velocity command from a joystick which is a P-Q Controls Model 220 with SAE J1939 connectivity (P-Q Controls, Inc.). It then controls two Bosch Rexroth HMS-series inverters via the CANopen protocol (CAN in Automation) accordingly. One inverter unit acts as a master, the other as a slave.

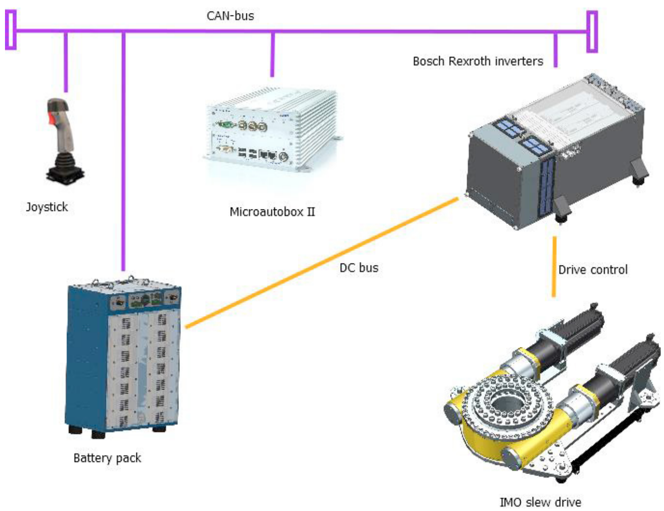

Fig. 2 Control system hierarchy

From the numerous control methods provided by the IndraDrive (Bosch Rexroth) inverters three were chosen as potential candidates for this implementation: position control, velocity control and torque control. Traditionally in the hydraulically operated systems, the joystick operates a pilot valve so a constant control results in a constant velocity of the hydraulic actuator. Therefore, velocity control was an intuitive choice. A further advantage of the electric slew drive implementation is that the response from control to angular motion remains constant and is not dependent on the turning angle.

As the servo motors are mechanically coupled via the slew drive, synchronous motion of the motors is crucial to keep energy losses minimal and avoid excessive wear of the drive components. The IndraDrive inverters provide various synchronization options so they served as a natural starting point for testing.

In the lack of realistic testing conditions the steering was simply driven back and forth and the responses were recorded. Also a subjective estimation of the steering response was performed. The testing environment, along with the load haul dumper (LHD) used as a testing platform for the control system, is presented in Fig. 3.

Fig. 3 The testing platform and test environment

3. MECHANICAL CONSTRUCTION

The layout (Fig. 4) shows the electromechanical steering system and how it's connected to the electric system in the demo equipment. Photo of electromechanical steering system is illustrated in Fig. 5.

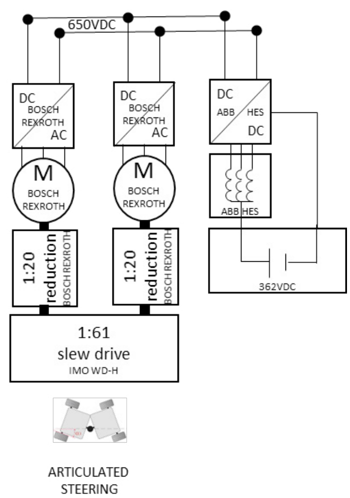

Fig. 4 Steering system lay-out

The key component in the electromechanical steering system is the dual input slew drive, IMO WD-H with 1:61 ratio. The slew drive is installed in to the pivot point of the loader. The mechanical connection between slew drive and loader is a kind of floating mechanical connection. The floating connection means that the slew drive is connected rigidly only to the loaders front frame. The loaders rear frame connection is made symmetrically with two reaction rods which has ball joints on the both ends. The floating connection prevents tilting forces going through the slew drive so the slew drive needs to take care only for the rotational turning torque. The slew drive could take quite big tilting forces too, but since the tilting forces in the loaders pivot point are unknown, it was safer to do floating installation in this case. Variating tilting forces can also cause variation to the rotating torque, which would make it difficult to measure the real steering forces and energy consumption in steering, so from research point of view the floating connection is better.