An improvement of motor control unit for SBW steering system

M.Z.M. Nasir[1,3,*], M.H. Harun[2,3], F. Ahmad[2,3],A.R. Dwijotomo[2], H.M.S. Firdaus[1] and M.A. Abdullah[2,3]

[1)] Fakulti Teknologi Kejuruteraan Mekanikal dan Pembuatan,Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[2)] Fakulti Kejuruteraan Mekanikal,Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[3)] Centre for Advanced Research on Energy, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

[*]Corresponding e-mail: mzakaria@utem.edu.my

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ABSTRACT – A steer by wire concept is used for preparing an automatic steering system in this research. The motor control unit is developed attach with rack and pinion steering system to follow the desired direction. This paper present ECU consist microcontroller with motor driver using H bridge system. Based on experiment for DLC and slalom input steering, the electric steering system that are developed using actual rack pinion type with the integration of the Electronic Control Unit (ECU) and sensors produce more accurate and smoothly with a little noise and 0.03 second delayed.

1. INTRODUCTION

Vehicle electrification or Drive by Wire has a trend in automotive industry and has been undergoing worldwide development. The SBW system is significant especially in the direction of autonomous vehicle development [1,2].The rack and pinion type has been chosen in this research which offers advantage by using one motor to control the angle of both front tires. Therefore, DC motor must be precisely control to ensure steering capability and stability.

The steering system introduced in this research work consist of rack and pinion steering attached with DC motor, two position sensors, and ECU modules as shown in Figure 1.1.

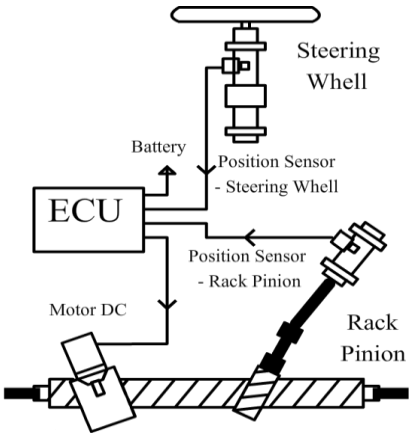

Figure 1.1 Schematic diagram of the SBW experiment

2. RESEARCH METHODOLOGY

Rack and pinion system convert the rotational motion of the steering wheel or driver input into linear motion which turn the tire into desired direction, and provide gear reduction or steering ratio, making easier to turn the tire. The DC motor generate torque required to push the tie rod in rack pinion linkage system. Two precision potentiometer sensors are installed to measure pinion angle rotation and steering wheel angle rotation. The ECU controller compare shaft rotation angle between steering and rack pinion to generate feedback action through motor actuator.

Standard DC brush motor which provide 150W power rating and rotational speed 80 rpm used in this research. The torque calculated by dividing the motor power output (watt) against angular velocity (rad /sec) as follow:

$$T = (Pw * \eta) / \left(\frac{2 * pi * n}{60}\right) \quad (1)$$

The ECU modules is designed consists of microcontroller unit minimum system and motor driver circuit. The MCU is installed within the microcontroller minimum system (minsys) circuit. The minsys refers to minimum configuration circuit for MCU to run properly.

Motor Driver Circuit

The electric steering system (SBW) design required another circuit that can support the motor for turning the rack and pinion gear moving to left and right. The H-Bridge circuit designed provide and facilitate the motor to turn reverse and forward direction. This circuit can be composed with 4 MOSFET which function like a switch [3]. Thus, the motor driver circuit will act as the current buffer for the MCU designed to drive the DC motor accordingly.

Circuit Configuration

For circuit design configuration with I/O port, PORTA MCU is functioned as ADC input to read the position from potentiometer sensor data. PORTB work as output to signaling the H Bridge. There is protection circuit between H bridge and MCU using opto-coupler to isolate MCU and H Bridge via light signaling to ensure no real electric connection occurs. To ensure the opto-coupler isolate the system, the supply voltage between MCU and motor driver are separated. This setup designed configuration resulting noise protection for MCU such as voltage spike generated from motor load.

3. RESULTS AND DISCUSSION

Two types of signal data measured in the experiment simultaneously, namely the signal of the rotational and linear signal captured by the two potentiometer sensors for each of the circular motion and displacement which will be analyzed using self tuning PID control method.

The experiment conducted on actual rack and pinion steering system in laboratory. Position tracking test is performed to ensure the motor could follow the desired steering input. Steering wheel is turned as input for Double lane change (DLC) and slalom test. USART communication is used to track and measure the position, which available inside the micro for logging the sensor data to PC.

Based on experiment, the DC motor attached with rack and pinion tend to closely follow the input signal for DLC test as shown on the Figure 3.1. Its demonstrate an actual rack pinion shaft position measured from potentiometer sensor follow the steering wheel input accordingly. There is a bit delay around 0.03 second between the input and actuator. This error occurred due to mechanical delay in rack pinion system.

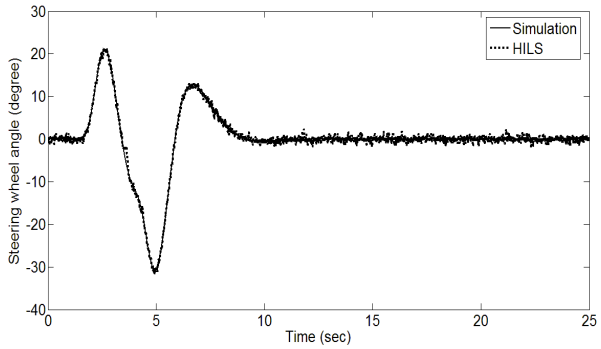

Figure 3.1 Double Lane Change result

Figure 3.2 shows the DC motor actuator run smoothly (HILS) for slalom input steering with fast responses. This demonstrates that the motor has enough power and speed to drive rack and pinion steering system designed. The steering torque need 0 to 2 Nm during normal driving ranges and emergency manoeuvre can demand up to 15Nm [3,4,5].

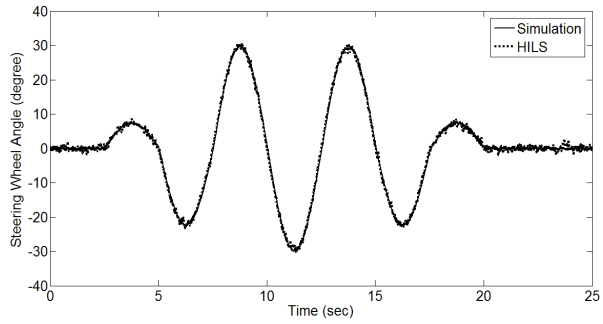

Figure 3.2 Slalom test result

4. SUMMARY

In this study, a modification motor control unit for Steer by wire test rig has been developed. The hardware design using actual rack and pinion steering type and only one DC motor to control both of front wheel tire with slight modification on MCU and H bridge. The MCU consist of ATMEGA32 provide many feature and computational power for this purpose. In advance, power MOSFET 1404 is used for switching element in H bridge to drive high current motor designed working perfectly. Result from experimental proved that simple PID controller can effectively drive this SBW system.DLC and slalom test for input steering provide very good responses via DC motor and controller to follow the desired direction accurately.

REFERENCES

[1] R. S. Sharp and R. Granger. (2003). On car steering torques at parking speeds. *IMechE Journal of Automobile Engineering, 217,87–96.*

[2] M.Z.M.Nasir, AR. Dwijotomo, M.A.Abdullah, K.Hudha(2012). Hardware-in-the-Loop Simulation for Automatic Rack and Pinion Steering System, *Journal of Applied Mechanics and Materials* , *Vol 229-231,2135-2139.*

[3] Tong-Jin Park, Chang-Soo Han, Sang-Ho Lee. (2005). Development of the electronic control unit for the rack-actuating steer-by-wire using the hardware-in-the-loop simulation system, *Mechatronics, Vol 15, (8), 899-918*.

[4] Mohd Zakaria Mohammad Nasir**,** Khisbullah Hudha, Mohd Zubir Amir. (2012). Modeling, Simulation and Validation of 9 DOF Vehicle Model for Automatic Steering System, *Journal of Applied Mechanics and Materials* , *Vol 16, 192-196. ISSN: 1660-9336.*

[5] Fu Xiuwei,Fu Li, Kong Feng (2005), Research of Automotive Steer-by-Wire Control Based on Integral Partition PID Control,*Genetic and Evolutionary Computing, 2009. WGEC '09*. 561-564.