DEVELOPMENT OF INTELLIGENT POWER STEERING SYSTEM FOR PASSENGER CAR

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Abstract

The aim of this study is to present an intelligent hydraulic steering system for the power saving and intelligent operation steering system during maneuver the car. The intelligent hydraulic power steering system (IHPS) is defined in this study as the additional power development for the smoother operation of steering system by means of the operation of hydraulic pump with the activation of Brushless DC motor based on the sensing feedback of the angle of rotation of the steering wheel sensor. The intelligent hydraulic power steering system can easily and economically be converted into a power efficient steering system with the help of sensors feedback. The sensing of the angle of rotation of the steering wheel operates the pump by using FLC controlled electrical. Fuzzy logic controlled (FLC) DC motor assists the power of the steering system even for the changing of small amount of steering angle. The speed of the motor has been varied with the angle rotation as coded. The system develops 5% more steerable force than the Perodua MyVi car needs. The error of the system is recorded 19% which is mainly for the alignment problems of the prototype.
Keywords: Intelligent power steering (IPS); FLC; System effectiveness.

1. Introduction

Intelligent Hydraulic Power Steering (IHPS) is a system that combined the two previous systems which are hydraulic power steering system and electric power steering system into one system which has been developed by referring the theory and concept [1-6]. The IHPS is introduced to overcome the disadvantages and weaknesses that occur on the previous systems. This system is using individual motor to operate the power steering pump. The motor activates by angle sensor which has been installed on the steering wheel. This study is conducted with developing a control algorithm for the optimal operation of the IHPS system. This system overcomes the problems of the (i) Hydraulic Power Steering (HPS) system which is the continuous operation of the pump with the power of engine even in idle condition; (ii) Electrical Power Steering (EPS) system become more popular as an alternative because of its higher efficiency than mechanical steering [7]. However, the sensor used is very sensitive, and a small movement of the steering wheel can cause a significant rotation of the tires which can be dangerous. Furthermore, electric power steering systems run even when the car is at idle position; therefore the engine consumes fuel unnecessarily at certain points. The proposed intelligent system is the auto intelligent operation system and activates the full system with the power needed instantly. This IHPS system is very potential compare with other steering system because of: excellency, lightest and portability; activation the electrical motor with the sensing of the angle of rotation; improvement of the energy consumption; suitability and friendly accessibility for all types of vehicles. With the world trending towards a more energy-saving technology, it is best to explore methods to reduce the consumption of fuel when the car is idle.

The main objective of the development of Intelligent Hydraulic Power Steering (IHPS) system is to save fuel consumption and to resolve the problems that are occurred currently in hydraulic power steering system, steer-by-wire system, and electric power steering system. It is developed with the hydraulic power steering with main cylinder, sensor of the angle of rotation of steering wheel, steering column, electric motor, and power steering pump. This unit is an extremely compact device and provides the ultimate in simplicity as far as installation and maintenance is concerned. This system is introduced with the simple additional electronic device that controls the flow of the hydraulic fluid via power steering pump rotation.

2. KINEMATICS OF THE STEERING SYSTEM

Kinematics of the proposed steering system has been developed by simplifying the kinematics model [8]. Figure 1 shows a front-wheel steering vehicle is turning with turning radius of R which is defined as the distance between the vehicle CG to rotation of turning O. The vehicle follows to the turning trajectory without slip based on the centre of rotation O. The outer wheel turns with turning radius of R_{max} and inner wheel with turning radius of R_{min}. The condition of the vehicle turning is called Ackerman condition and is expressed as,

$$\cot\delta_o - \cot\delta_i = \frac{b}{l} \tag{1}$$

with

$$\delta_o = \cot^{-1}\left(\frac{b}{l} + \delta_i\right) \ \ and \ \ \delta = \cot^{-1}\left(\frac{\cot\delta_o + \cot\delta_i}{l}\right)$$

where, δ_o and δ_I are steer angle of the outer and inner wheel in radian, *b* is the thread in m and *l* is the wheelbase of the vehicle in m. The steering system has been developed for the rear wheel drive with front steerable wheels vehicle. The rear and front tracks of the vehicle are equal and the drive wheels are turning without slip. The angular velocities of the inner and outer drive wheels are ω_o and ω_I respectively. The steer angle of the front and rear wheel can be computed when the vehicle turns without slip as,

$$\delta_i = \tan^{-1}\left(\frac{l}{B}\left(\frac{\omega_o}{\omega_i} - 1\right)\right) \tag{2}$$

$$\delta_o = \tan^{-1}\left(\frac{l}{B}\left(1 - \frac{\omega_o}{\omega_i}\right)\right) \tag{3}$$

The steer angle of the vehicle can be defined as,

$$\delta = \frac{l}{R} + \frac{v^2}{gR}\left(\frac{W_f}{c_{af}} - \frac{W_r}{c_{ar}}\right) = \frac{l}{R} + \frac{v^2}{gR}K_{us} \tag{4}$$

$$\text{with } K_{us} = \frac{W_f}{C_{\alpha f}} - \frac{W_r}{C_{\alpha r}}$$

where, W_f and W_r are the load distribution on the front and rear wheel, $C_{\alpha f}$ and $C_{\alpha r}$ are cornering stiffness of the front and rear wheel respectively, and K_{us} is the under steer coefficient which can be used to defined as the steering characteristics of the vehicle. It is noted that if the K_{us} is zero, the vehicle steering behavior is neutral if $K_{us} = 0$; understeer if $K_{us} > 0$; and oversteer if $K_{us} < 0$.

The turning radius of the vehicle can be estimated as,

$$R = \sqrt{\left(l_2^{\,2} + l^2 \cot^2\delta\right)} \tag{5}$$

where, l_2 is the location of CG from the rear wheel in m. In this study, the intelligent system is developed to control the turning radius of the vehicle with maintaining the steering ratio of the vehicle and amplifying the steering force. The steering ratio of the vehicle is defined as the ratio of the turning angle of the steering wheel to the turning of the steerable wheel.

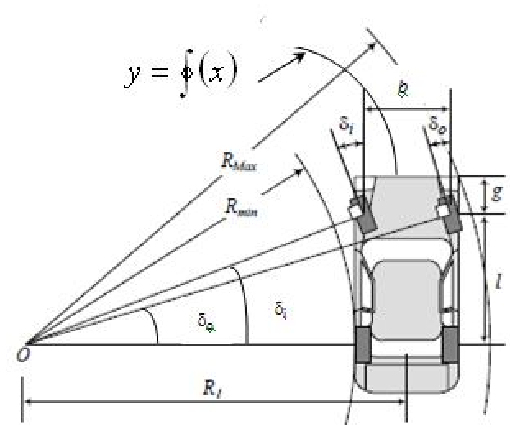

Figure 1: A front-wheel turning vehicle

Consider the vehicle is moving on a trajectory, $y = \oint(x)$ with a velocity v and acceleration *a*. The curvature (ρ) of the path that the vehicle is moving on can be expressed as,

$$\rho = \frac{a_n}{\left(x^2 + y^2\right)} \ \text{ with } \ a_n = \frac{\left(mv^2\right)}{\sqrt{x^2 + y^2}} \tag{6}$$

where, a_n is the normal acceleration in m/s^2 and m is the mass of the vehicle.

2.1 STEERING MECHANISM OPTIMIZATION

Optimization means steering mechanism is the design of a system that works as closely as possible to a desired function. Assume the Ackerman kinematic condition is the desired function for a steering system. Comparing the function of the designed steering mechanism to the Ackerman condition. The error function (root mean square) of the two systems can be defined as

$$e = \sqrt{\int \left(\delta_{D_o} - \delta_{A_o}\right)^2 d\delta_i} \tag{7}$$

where, e is the error function of the tow functions. The error e would be a function of a set of parameters. Minimization of the error function for a parameter, over the working range of the steer angle δ_I generates the optimized value of the parameter.

The RMS is defined for the continuous variables δ_{Do} and δ_{Ao}. This study focuses to make the error of the system as minimum as possible by optimizing program of the controller. As the road profile is undulated, the truning behavior of the road of course will different for each of the point . Therefore, the error (e) of the functions could be define as the discrete values which can be defined as,

$$e = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\delta_{D(o)} - \delta_{A(o)}\right)^2} \tag{8}$$

where, $\delta_{D(o)}$ is the proposed steering system equipped vehicle outer wheel steer angle and $\delta_{A(o)}$ is the Ackerman steering system equipped vehicle outer wheel steer angle in degree.

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$$e = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\delta_{D(o)} - \delta_{A(o)}\right)^2} \tag{9}$$

where n is number of data taken.

3. BASIC PRINCIPLE OF OPERATION

The intelligent power steering system shows in Figure 2 which has been develop 1:8.5 scale of the MyVi Perodua car. It works with the help of an Electric Motor and a control unit with sensors. The motor is powered by battery which assists the movement of steering when the driver turns the wheel. An electronic control system for a steering system having an electric motor coupled to the steering system for providing power assist. The steering system is of the rack and pinion type having an input gear coupled to the steering wheel and a pinion gear in meshing engagement with the rack. Two torsion sensors are coupled across the input and pinion gears and generate analog output signals. When no input torque is applied to the steering wheel, the output signals from the two torsion sensors are equal. When input torque is applied to the steering wheel, the signals from the torsion sensors vary linearly in opposite directions. An electronic control unit controls operation of the electric power assist motor in accordance with the output signal from one of the torsion sensors. Failsafe circuitry is provided for monitoring the outputs of the redundant torsion sensors to insure proper control of the electric power assist motor. The failsafe circuitry provides

(i) A sensor-to-sensor check to insure the output voltage of one sensor is consistent with the output voltage of the other sensor.

(ii) A sensor limit checks to insure that the output voltage from each sensor does not exceed a predetermined limit.

(iii) A sensor direction check to insure that the signal being used to drive the electric power assist motor, as derived from one sensor, will drive the motor in the same direction sensed by the other sensor.

(iv) An excess assist check to insure that the signal used to drive the electric assist motor, as derived from one sensor, will not cause the motor to provide a greater amount of assist than an amount requested, as detected by the other sensor.

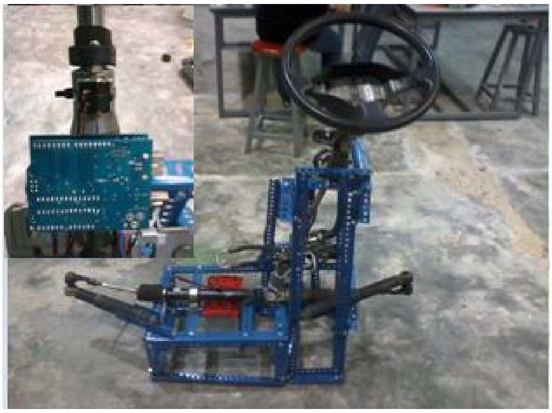

Figure 2: Intelligent power steering system

4. RESULT AND DISCUSSION

The prototype of the intelligent steering system has been tested into the lab with different loading to investigate the performance of the system. The IHPS system is completely developed and this system is working properly as expected. The power losses recorded from motor to power pump is approximately less than 20% and can be accepted for first prototype design experiment. The motor is working properly and the speed is enough to create a pressure inside the hydraulic cylinder. The load proposed on this steering arm is equal to 294 N (approximately 30 kg) that giving by a couple of absorber. The test driver feels the differences while turning the steering wheel when the pump is running compare to the turning without running the pump.

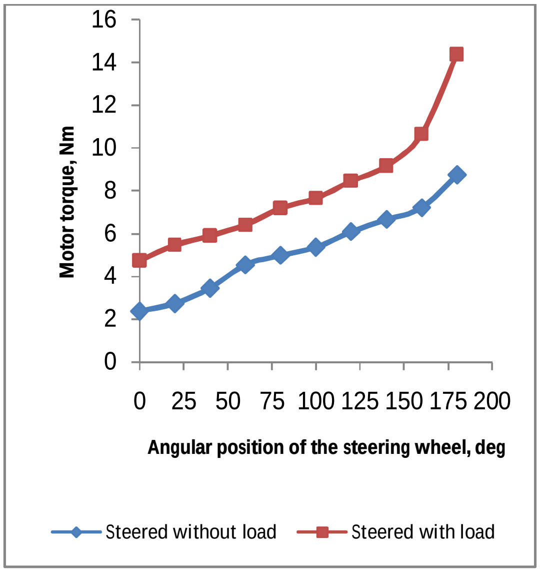

Figure 3: Performance of the motor with the response of the sensor and controller.

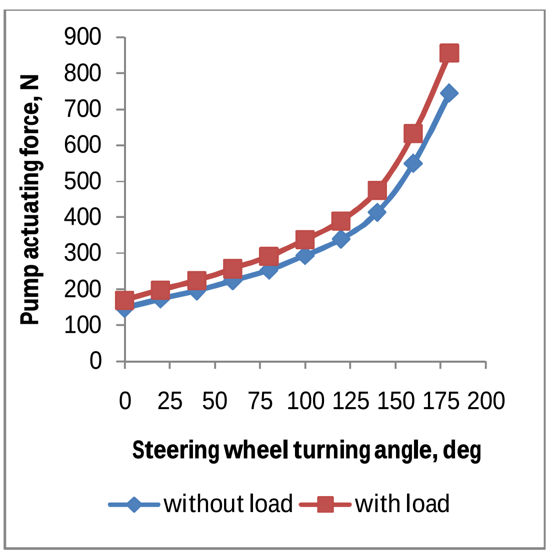

Figure 4: Performance of the pump

The percentage difference or also known as percentage error occurs on this system is equal to 18.63 %. The percentage is higher due to some problem occurs on the prototype structure design. One of the problem that affecting this error is due to the belting tightening. The belting used has efficiency up to 95% for transmitting power but this efficiency will be decreases if the belt is no enough tightened. Figures 3-4 shows the performance of the system and Figure 5 shows the performance of the motor which is powered by the battery.

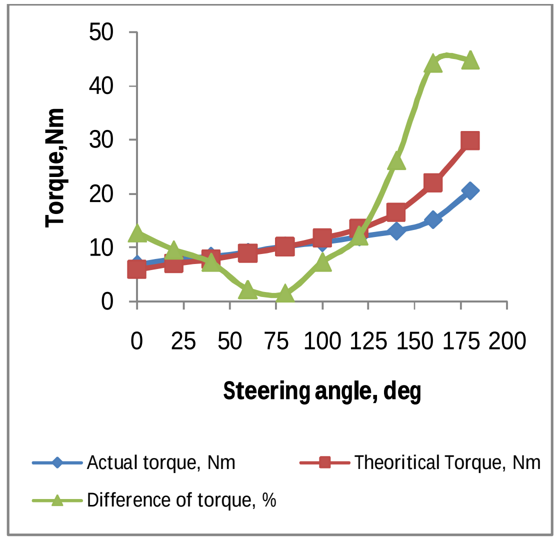

Figure 5: Variation of the motor performance

5. CONCLUSION

The following conclusion has been made based on the system operation and performances:

1. The Intelligent Hydraulic Power Steering System (IHPS) was successfully designed as a prototype. Compared to the conventional power steering, the IHPS has a lower average minimum speed and it reduces power loss and makes fuel consumption more efficient with no direct contact with engine crankshaft.
2. This system was implemented successfully but the changes were hard to detect because the load carried in this prototype was a too low which only 300 N. The actual load is approximately 2600 N for a Produa Myvi.

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