System Modelling and Controller Design of an Electric Power Steering System

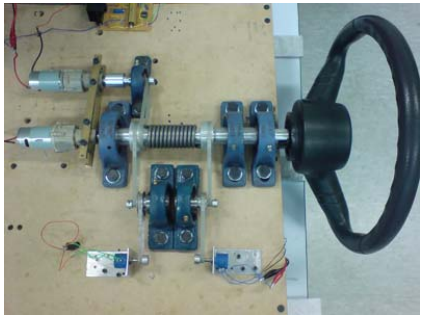
Aims and Objectives

The aim of this research is to develop a controller which fulfils the two primary functions of an EPS system:

- oReduce the amount of steering torque exerted by the driver
- oControl the return-to-centre motion of the steering wheel

The dynamics of an EPS system are investigated and a mathematical model is proposed. The model is used to design a controller via simulation (MATLAB and Simulink) before model identification is carried out (SigLab). An EPS controller is developed and tested (dSPACE and ControlDesk) for the experimental EPS rig built.

Modelling of an EPS System



The equations of motion for the EPS system are:

$$J_{sw}\ddot{\theta}_{sw} = T_d - K_{tb}(\theta_{sw} - \theta_{tb}) - B_{tb}(\dot{\theta}_{sw} - \dot{\theta}_{tb})$$

$$J_{tb}\ddot{\theta}_{tb} = K_{tb}(\theta_{sw} - \theta_{tb}) + B_{tb}(\dot{\theta}_{sw} - \dot{\theta}_{tb}) - Kc(\theta_{tb} - \theta_c) - B_c(\dot{\theta}_{tb} - \dot{\theta}_c) + T_a$$

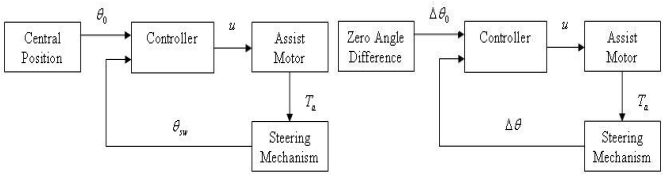
$$J_c\ddot{\theta}_c = -T_l + K_c(\theta_{tb} - \theta_c) + B_c(\dot{\theta}_{tb} - \dot{\theta}_c)$$

State-space analysis yields transfer functions, used in controller design via simulation:

$$\frac{\theta_{sw}(s)}{T_a(s)} = \frac{5833(s+17.5)(s+1.8)}{s(s+1375)(s+1.819)(s^2+215.7s+1.259\times10^4)}$$

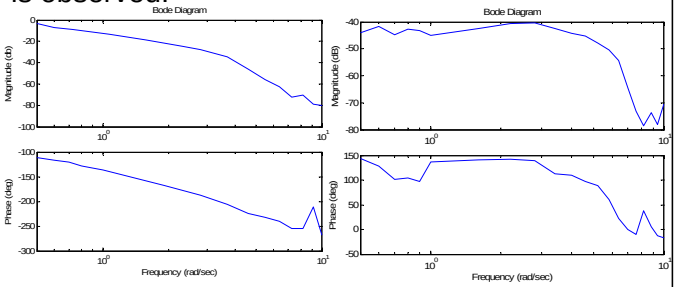
$$\frac{\Delta\theta(s)}{T_a(s)} = \frac{-33.33(s+17.5)(s+1.136\times10^{-6})(s-1.136\times10^{-6})}{s(s+1375)(s+1.819)(s^2+215.7s+1.259\times10^4)}$$

Controller Design

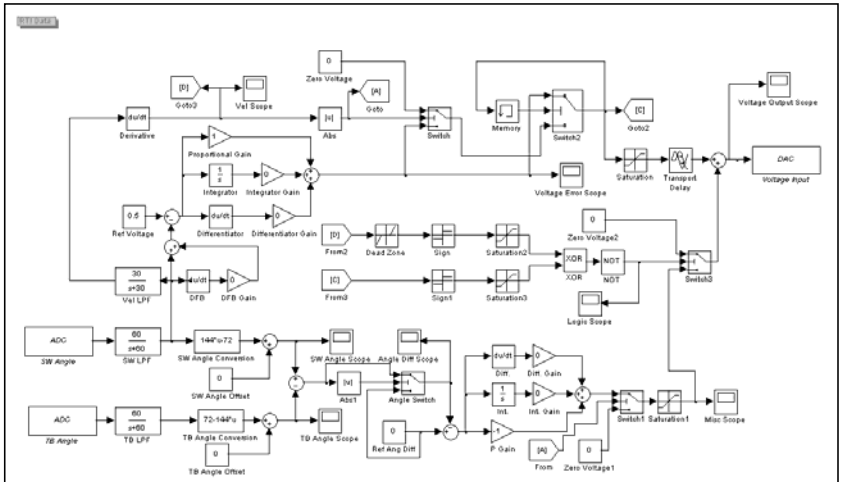


Control logic of return-to-centre (RTC) controller and reduction of steering torque (RST) controller

Two separate controllers (RTC and RST) are first designed in a virtual environment before model identification is conducted. A strong correlation between the simulation and experimental models is observed.



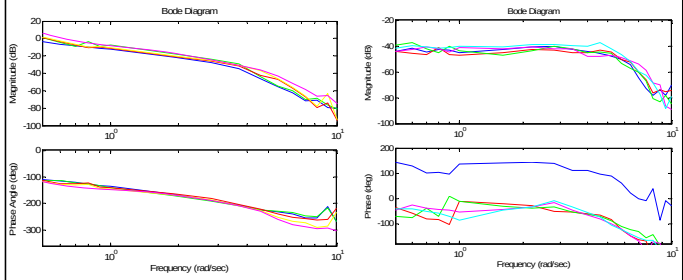
The two controllers are combined before testing.



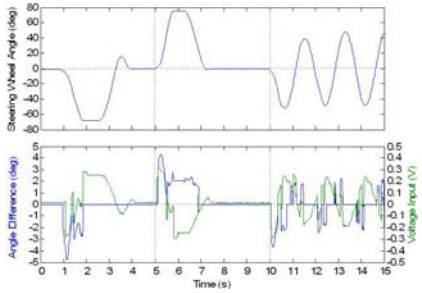
Block Diagram of EPS Controller

Experimental Results

The controllers are tested for stability and performance.



Optimised gain tuning yields a stable controller which exhibits a smooth return-to-centre motion with no overshoot, and reduces the steering torque required to turn the steering wheel.



Conclusions

A fully functioning EPS controller is developed for the experimental rig. It successfully controls the return-to-centre motion, reduces the amount steering torque exerted by the driver, and realises various steering feels by the simple tuning of PID controller gains.

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