

#### IV. EXPERIMENT

Experimental studies are conducted to balance the Gyrocycle. PD gains are selected as  $k_{LP}, k_{RP} = 700$  and  $k_{LD}, k_{RD} = 70$  in the implementation. For the gain scheduling method, we have found our gains empirically as listed in the Table II. The offset angle value,  $\beta_e$  is determined by the value of  $(\theta_L + \theta_R)/2$ . These gains prevent the flywheel from leaning in one direction.

TABLE II  
GAIN SCHEDULING VALUES

$\theta = (\theta_L + \theta_R)/2$	Gain $\beta_e$
$23.29 < \theta$	-0.5
$11.65 < \theta$	-0.3
$5.4 < \theta$	-0.2
$-5.4 < \theta < 5.4$	0
$-5.4 > \theta$	0.2
$-11.65 > \theta$	0.3
$-23.29 > \theta$	0.5

Fig. 4 shows the lean angle of the system. We see from the plot that Gyrocycle maintains balance well for a certain time of period. However, after 60 seconds, Gyrocycle falls down. This is because there is no gyro effect induced by the flywheels since the left flywheel is rotated more than 30 degrees. Beyond this angle, two flywheels are unsynchronized and the system becomes unstable. Fig. 5 shows that both flywheels diverge from zero degree in the opposite direction and Gyrocycle falls down at last.

The compensation value,  $\beta_e$  is plotted in Fig. 6(upper plot). The angle between two flywheels is also plotted in Fig. 6 (lower plot). For the stable balancing performance, the difference between two angles of the flywheels should be zero. This is a left problem for the future research topic.

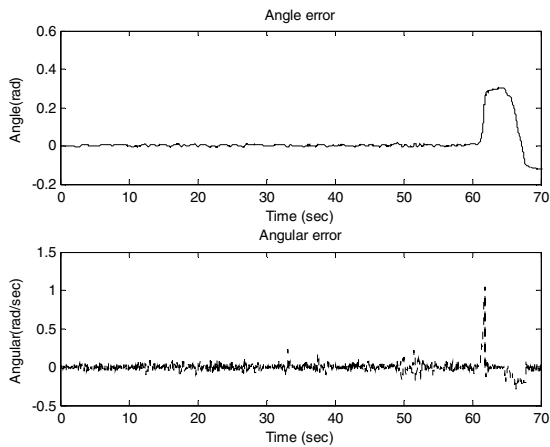


Fig. 4. Lean angle and angular velocity of Gyrocycle

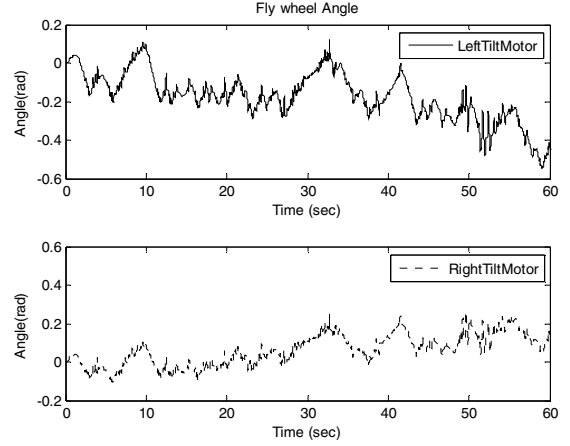


Fig. 5 Angle and angular velocity of flywheels

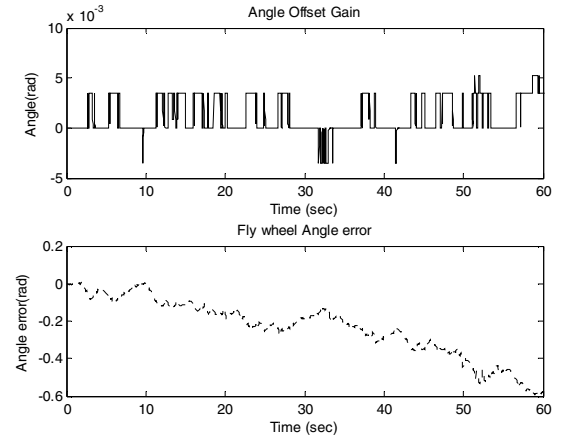


Fig. 6 Angle and angular velocity of Gimbal

#### V. CONCLUSION

In this paper, a single-wheel personal vehicle has been developed and its balancing angle is controlled. Although the current situation is not carrying a human driver, the balancing control performance of Gyrocycle is tested. Gyrocycle maintains balance within 60 seconds well and then it falls down. This is because no gyro effects are induced by flywheels since two flywheels are tilted more than 30 degrees. Two flywheel systems are needed to be synchronized by minimizing the angle difference to maximize the gyro effect. Synchronization of two flywheels is a future research problem.

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