# Enhancement in Integrated Design of Adaptive Cruise Control System and Role of PID

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***Abstract*** **– A system that supports a driver in traffic situations and reduces the total driver workload is a growing research topic. Several of these support systems aim toward full or partial automatic driver assistance, such as those for longitudinal control that are often called Adaptive Cruise Control (ACC) systems. Adaptive cruise control distinguishes itself from cruise control in its use of sensors that measure the headway distance and a controller which adjusts the velocity and distance to the vehicle in front. Adaptive cruise control requires appropriate sensor technology, actuators and control devices and its system design requires data acquisition, control system design and validation procedures. The motivation for these systems is that they aim at increasing the driving comfort, reducing traffic accidents and increasing the traffic flow throughput. The ACC systems autonomously adjust the vehicle's speed according to current driving conditions. In order to accomplish driver comfort the system must resemble driver behaviour in traffic. Simulation results prove the utility of the system.**

***Keywords*** **– Adaptive cruise control; PID controller; Time-gap control; Distance control; ACC modes**

## I. INTRODUCTION

The cruise control is a system that automatically controls the speed of a road vehicle. The principle was first used in the Chrysler 1958 Imperial, based on the 1948 invention of a mechanical engineer *Ralph Teetor*. This system calculated ground speed based on driveshaft rotations, and used a bi-directional screw-drive electric motor to vary throttle position [1]. ACC system has a duty to maintain a constant, predetermined velocity, but also to monitor the velocity of the vehicle located in front of the ACC vehicle. Also, ACC represents the evolution of the conventional cruise control, because it detects the vehicle in front of the ACC vehicle, and based on gained information controls the distance between both vehicles. In this way, the ACC system facilitates the process of driving for drivers and reduces the stress caused by driving in heavy traffic. Based on data of the velocity and the distance of vehicles located in front of the ACC vehicle, the system regulates the braking force of the ACC vehicle and its engine torque, and determines the velocity of the ACC vehicle, which is necessary to maintain safe distance in the traffic[2]. The control logic of the cruise controller can be designed by employing different types of controllers, such as a proportional-integral-derivative (PID) controller or even with feed forward system only [3].

## II. CONCEPT OF ADAPTIVE CRUISE CONTROL

If the vehicle is detected by a sensor in the traffic lane in front of the ACC vehicle, ACC vehicle will slow down to the same velocity and will maintain an appropriate distance from the vehicle in front until it leavs the traffic lane, as shown in Figure 1.

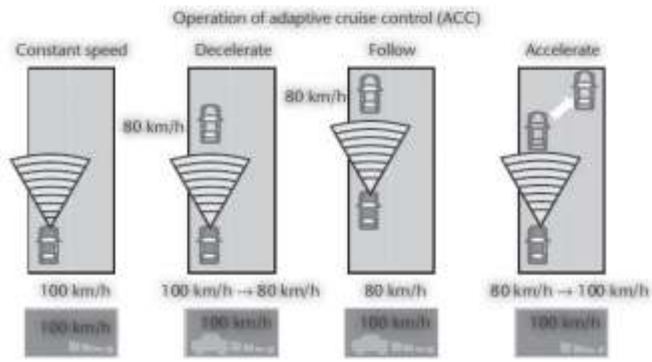


Fig 1: A vehicle equipped with ACC system monitors the vehicle located in front of it

To enable described motion of the ACC vehicle, it is necessary to mathematically describe the movement of the ACC vehicle, and set up a matching algorithm that will allow the operation of the ACC system with the given initial conditions. We can conclude that the basic control parameter for the operation of the ACC system is velocity $v_1$ of the vehicle in front of ACC vehicle, and the distance between the vehicles $d$. In this paper we present the case of movement of two vehicles, provided that the second vehicle is equipped with the ACC system[3].

As seen in Figure 1 the vehicle 2 is equipped with ACC system and is tasked to monitor the vehicle 1 located in front of it at a given distance. If vehicle 1 accelerates, the ACC vehicle 2 will accelerate until it reaches the given initial velocity which it had before encountering an obstacle or the vehicle in front. To achieve the referral, already explained movement, it is necessary to mathematically describe the movement of a vehicle equipped with the ACC system, and set up a matching algorithm that will allow the operation of the ACC system with the given initial conditions.

In the case of linear movement of the ACC vehicle on a flat surface, it is necessary to achieve a balance of forces acting in the direction of the vehicle, which by convention corresponds the x coordinate. Such movement can be described as

$$\sum F_x = 0 \quad (1)$$

where $F_x$ represents forces acting in the direction of x coordinate. Previous equation in a developed form can be written as follows

$$F_o = R_f + R_j + R_v \quad (2)$$

where $F_o$ is circumferential force to a point, $R_f$ is rolling resistance, $R_j$ is resistance of inertial forces when decelerating and $R_v$ is air resistance. In order to achieve greater quality regarding the work of the ACC vehicle, it is necessary to control the velocity of ACC vehicle $(v_2)$ .This velocity control is based on the velocity of the vehicle in front $(v_1)$, as well as the parameter of the distance between vehicles $(d)$. The distance parameter is further controlled and kept constant when the vehicles are located at a given distance. In case that during the constant velocity of ACC vehicle occurs decrease of the distance from the vehicle in front, which is moving, it is necessary to perform braking of the ACC vehicle. Thus the velocity of the ACC vehicle is reduced to the velocity of vehicle 1 which is moving in front of it. By doing so the contact (collision) between the vehicles is avoided[6,7].

## III. ENHANCEMENT IN ACC

For the ACC to work correctly, the ACC equipped car has to determine how the lane in front of it curves, and which car is the 'lead car', that is, in front of the ACC car in the lane. A typical scenario from the viewpoint of the ego car is shown in the figure 2. The ACC car (blue) travels along a curved road. At the beginning, the lead car is the pink car. Then the purple car cuts into the lane of the ego car and becomes the lead car. After a while, the purple car changes to another lane and the pink car becomes the lead car again. The pink car remains the lead car afterwards. The ACC design must react to the change in the lead car on the road.

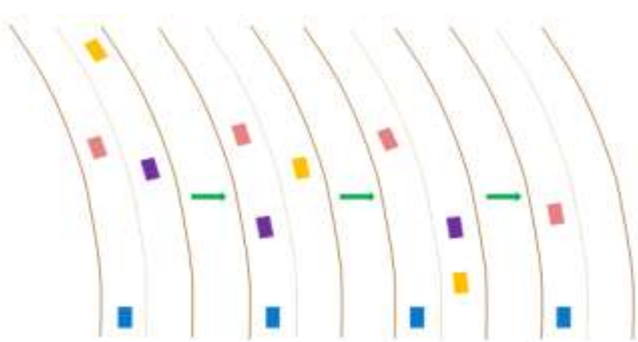

Fig 2: ACC vehicle scenario on curve road

Now to distinguish between the target vehicle and vehicle in side lane is the key of achieving adaptive cruise control. So in order to improve tracking ability, the process of vehicle running in curve is divided into three phase: Enter the curve (EC), In the curve(IC) and Come off the Curve (CC). While the front vehicle (the target vehicle) has entered the curve, ACC vehicle is still in the straight road. We define this situation as EC. When the front vehicle and ACC vehicle are in the curve, we define it as IC. When the front vehicle has already come off the curve, ACC vehicle still in the curve, We define it as CC[8].

Another enhancement in existing ACC which segregates the critical and non critical tasks unlike the present systems in which both are handled by single processor. When the ACC equipped vehicle detects a vehicle (in front) in the same lane it is travelling, initially the speed reduces and the sensor on adjacent sides of vehicle are engaged to check the adjacent lanes for any traffic movement. If the adjacent lane is unoccupied, the system automatically decides to steer the vehicle to adjacent lane at an optimum speed without losing the stability of the vehicle and accelerates the car to the set cruise speed. After overtaking , which is decided by the input from the sensors on adjacent side of the vehicle, it once again steers the car back to the previously occupied lane[9].

## IV ROLE OF PID CONTROLLER AND SIMULATION

In [10] a first step in determining acceptable PID tuning parameters is to approximate the system response with a first-order plus dead time(FOPDT) model. So step response obtained from simulation will give the values for parameters $K_p$ , $\tau_p$ , and $\theta_p$. So momentum balance is

$$\frac{d(mv)}{dt} = \sum F$$

with $m$ as mass of vehicle and passengers, $v$ as the velocity of the vehicle. Assuming constant mass of the vehicle, a constant drag coefficient $c_x$ and a linear gain between gas pedal position and force, the momentum balance becomes

$$m\frac{dv(t)}{dt} = F_p u(t) - \frac{1}{2}\rho A\ c_x v(t)^2$$

with *u(t)* as gas pedal position(%pedal), v(t) as velocity(m/s), m mass of the vehicle, $F_p$ as thrust parameter(30N/%pedal), $\rho$ air density(1.225kg/m$^3$).

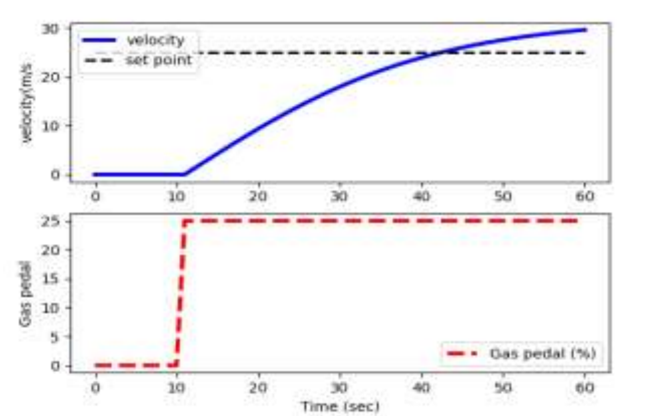


Fig 3: FOPDT model result

So from fig.3 we get $K_p$=*1.2* , $\tau_p$=20sec , and $\theta_p$=0sec.

Now using the FOPDT model parameters to design PID controller $K_c$ , $\tau_I$ , $\tau_D$. and simulation results obtained are shown in fig.4.

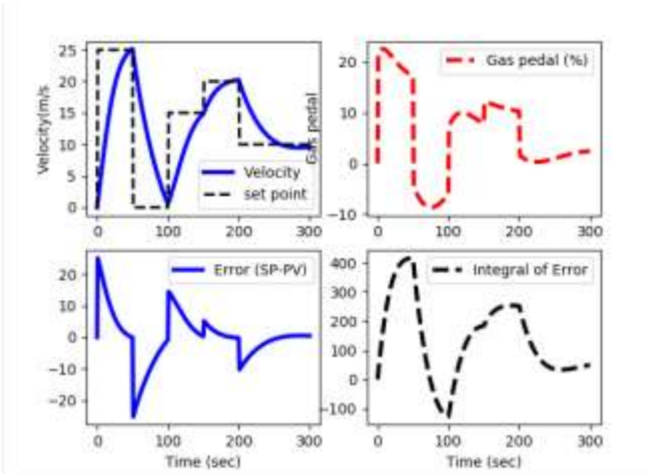


Fig 4: PID controller for velocity

To test our ACC model we have considered the influence of the changes in the relative velocity between vehicles when the second vehicle is equipped with the ACC system. The influence of changes in the relative velocity between the vehicles shows how the second vehicle (ACC vehicle) behaves when the initial velocity of the first and the second vehicle is different. Distance between vehicles remains unchanged, as all other parameters relevant to the work of the ACC system.

Table 1 :Initial conditions for the ACC simulation and their notation

| Notation and value | Explanation |
|---|---|
| $v_{02} = 100kmph$ | The initial velocity of the vehicle with the ACC system |
| $t = 10sec$ | Simulation time |
| $m_2 = 1600\ kg$ | Mass of the ACC vehicle with the driver |
| $c_x = 0.29$ | Drag coefficient |
| $A = 2.02m^2$ | The front surface of the ACC vehicle |

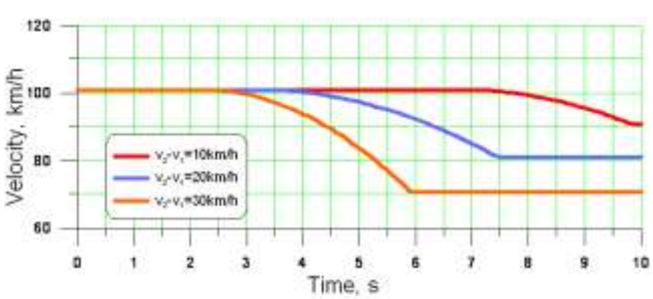


Fig 5: Velocity vs time plot

From Figure 5 can be seen that the greatest change in velocity occurs when the velocity difference is 30 km/h, and the smallest change when the velocity difference is 10 km/h, which was expected. The beginning of the velocity change is different, because the vehicle needs less time to reach the velocity of the first vehicle if the velocity difference between the first and the second vehicle is smaller.

## V. CONCLUSION

After examining the results it can be concluded that this model, which simulates the operation of the ACC system, is very good in terms of velocity equalization between the first and second vehicle (ACC vehicle). Also, when it comes to velocity equalization distance between the vehicles remains constant, which again points to the model of good quality. When the velocity of the vehicles is equal distance between the vehicles remains constant, but it cannot be pre-specified. Distance between the vehicles depends on the velocity difference and initial distance between the vehicles at which ACC system starts to act. The next step in further development of this model would be Curve radius prediction and use of RTOS.

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