MAINTAINING VEHICLE SPEED USING A MECHANICAL CRUISE CONTROL

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ABSTRACT

In this article we would like to present cruise control realization. This cruise control is presented as mechanical device for vehicle speed maintenance and has been proposed as a low cost solution. Principle of function in mechanical cruise control is based on a position control of throttle. For the right action of mechanical cruise control it was need to solve some particular tasks related with speed sensing, construct of device for control of throttle position and design of control system of whole mechanical cruise control. Information about car velocity we have gained using Hall sensor attached on a magnetic ring of car tachometer. For control of the throttle was used a small servo drive and as the control unit was used Arduino. The designed solution of mechanical cruise control have been realized for car Škoda Felicia.

Keywords: *cruise control, servo drive, controller, vehicle, throttle*

1. INTRODUCTION

The development of the automotive industry is progressing by leaps and bounds. While a couple of years ago was radio in car one of the modern technology, today we ride in the car without it we can hardly imagine. Every day in the car appears more and more electronic systems, whose main task is not only to make easier the drivers driving, but above all to make it safer. Among the systems that have become basic equipment of every car we can assign cruise control.

Cruise control as a system to maintain a constant vehicle speed is disburden the driver from having to watch the speedometer and constantly keep your foot on the accelerator pedal, which especially when traveling long distances can be quite tedious. Since the beginning of the automotive industry passed evolution of cruise control a long way from purely mechanical principles, that serve to maintain a constant engine speed, over speed control by electromechanical adjusting the speed of the vehicle to after fully electronic speed control.

Cruise control origins date back to around the year 1788. The first inventors dealing with this issue were James Watt and Matthew Boulton, who used the centrifugal governor to control the steam engine. The task of this device were to maintain of machine rotation speed constant, which was actually very close to the regulation at a constant speed.

The modern cruise control had been invented by mechanical engineer, Ralph Teetor, who patented it as the first. The first car with this invention was Chrysler Imperial from the year 1958. This cruise control calculated rotational speed of the drive shaft by speedometer and the actuator for the throttle position adjusting was an electric motor. [1], [3], [7], [8], [9]

2. SOLUTION DESIGN OF THE MECHANICAL CRUISE CONTROL

Cruise control is an electromechanical system consisting of several basic elements. That system include a speed sensor, sensor of brake and clutch pedals, controller and actuators. All these elements work together with a control unit that processes input signals and controls the output variables. [2]

A mechanical cruise control was designed and realized for a car Škoda Felicia with manually operated throttle coupled by cable with the accelerator pedal of the vehicle. The design of cruise control has been based on the control of throttle position by control position of the actuators. In implementing of that control it was necessary to solve several partial tasks associated with each parts of cruise control. When designing the cruise control was compared with a conventional solution, emphasis on low-cost solutions. The basic block diagram of all elements of the cruise control is shown in Fig. 1.

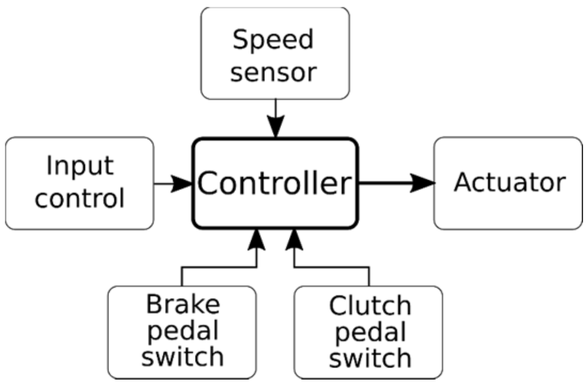

Fig. 1 Block diagram of the basic parts of cruise control

2.1. Sensing of velocity

The data about vehicle velocity are the basic for function of the cruise control. Since that the measurement of speed in the Škoda Felicia is realized by mechanical drive, it was necessary to convert this data into electronic form so that it can be used this vehicle speed information for its control. The construction of Felicia tachometer consist a magnetic ring which can be using a suitable sensor used for sensing the vehicle speed. For this reason was for electronic velocity sensing used circuit with Hall sensor. [5]

In this way we obtained information about vehicle velocity using a rotation of the magnetic ring of tachometer. Important is the precise location of the sensor to the correct position against the magnetic rings so that the sensor can correctly take pulses from magnetic poles of the ring.

The output impulses from Hall-sensor are used for direct evaluation of vehicle speed in control unit. During one turn of the magnetic ring we receive four pulses shown in Fig. 2.

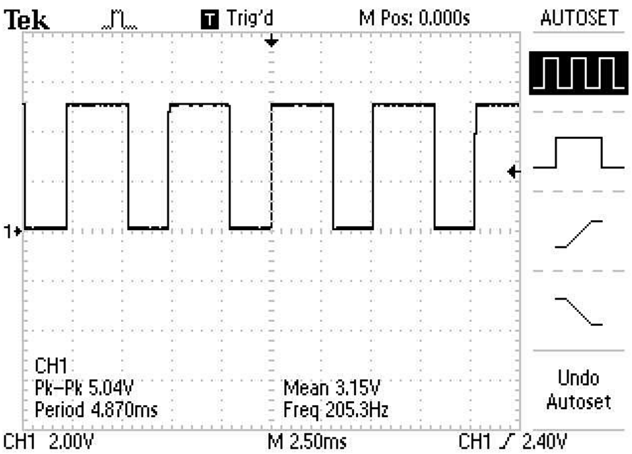

Fig. 2 The output signal from Hall-sensor

2.2. Sensor of brake and clutch pedals

The original brake lights switch was used for sensing of brake pedal press. Since this switch operates to mains voltage in the vehicle, it was necessary to adjust the voltage that the signal from the switch could be used as logic input for control unit of the cruise control. For adapt this voltage to an appropriate level, was used voltage stabilizer LM78L05, its output voltage is 5V with up to 100mA output current.

For detecting pressing of the clutch pedal it is necessary to mount a separate switch. The most efficient solution, in terms to used wiring, it is to use the same sensor as in the brake pedal. Both sensors will have the same function to reset the cruise control.

2.3. Actuator

Since the solution of the mechanical cruise control is based on the throttle position control, it was necessary to select the appropriate actuators and mechanisms, which could be easily controls the position of the throttle and consequently control the speed of the vehicle. As actuator was selected small DC servomotor for its ease of control. Information on the position of the DC servomotor is obtained by means of a potentiometer.

Torque capability was the main parameter for selection of servomotor because it must counteract the force of the engine throttle spring. The scheme of the positioning pulley is shown on a Fig. 3. The force effect of spring F1, was measured by electronic load cell at a distance equal to the internal radius of the pulley, where is stored the original throttle cable. The radius of the pulley is 32 mm from the middle of the shaft. The maximum opening angle of the throttle is $\alpha = 90°$. At this opening angle of the throttle pulley is counteracting force F1. The force of the return spring, which closes the flap has been measured by the electronic load cell and its value is F1 = 50N. Servomotor counteracts the force F1 with force F2 and the maximum rotation angle of the servomotor is $\beta = 120°$. The selected actuator has a torque 2.45 Nm, which means that on the radius of the servomotor pulley 25 cm can develop sufficient force to overcome the spring force of throttle.

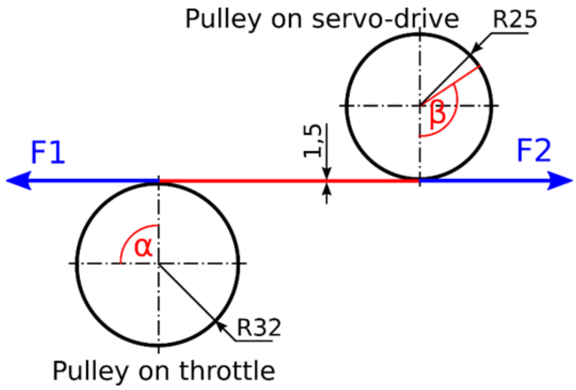

Fig. 3 Scheme of location the pulleys, including action of the forces of the return spring force F1 and servomotor force F2

2.4. Control

Given the ease of programming, connectivity and very good support for management was chosen Arduino Due board with 32-bit microprocessor with 84 MHz frequency - SAM3X8E ARM Cortex-M3. [6]

To operate cruise control are used two buttons. Press for a long or short time, we can define four functions for these buttons. The short presses of buttons represent the SET or RESET function of cruise control. The long presses of buttons are used to adapt the target speed of the vehicle.

Fig. 4 "SET" and "RESET" buttons for control of the cruise control with current and target speed on a display

The algorithm of the main control program, which runs in an endless loop, is shown of Fig. 5. Main control program includes calling of each functions, those task is to load input data, evaluate them and based on them to perform the appropriate action output as needed, for example set the necessary angle of the servomotor.

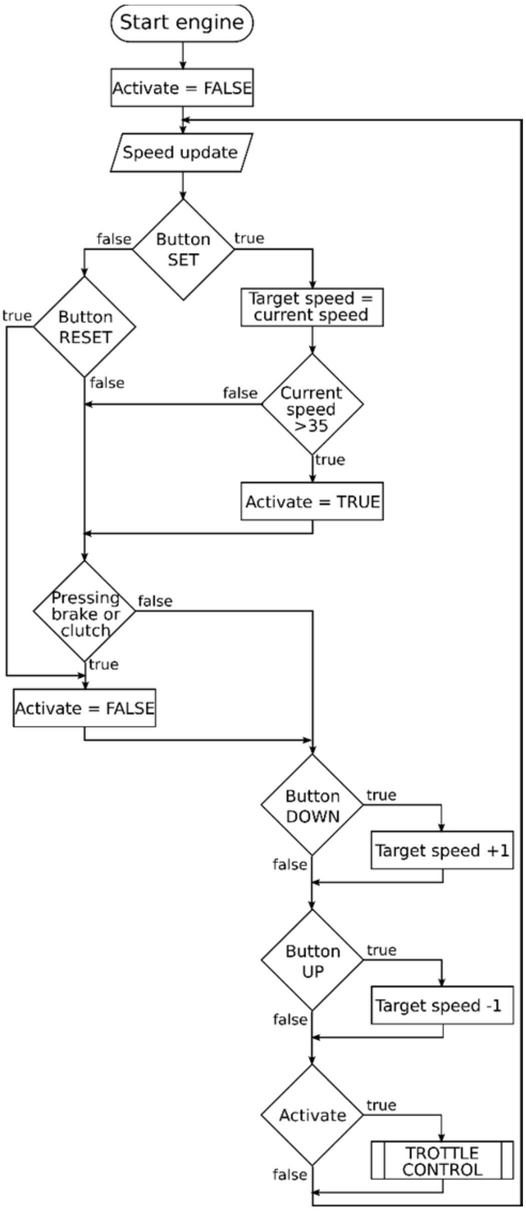

Fig. 5 The algorithm of the main control program of the cruise control

At the start of the engine is constant "*ACTIVATE*" set to false value. Update of the actual speed value runs continuously, independent of the cruise control function. Since the buttons functions are solved as the interruption, their verification occurs after arriving specific interruption. This verification is carried out in an endless loop of the overall program. When pressing buttons SET or RESET is necessary to check the condition of a minimum speed value. If this condition is satisfied, then constant "*ACTIVATE*" is set to true value. Verification of this variable occurs at the end of the loop, when program activates PID controller of servomotor. Otherwise, the program will start from the beginning with an update of the current speed. Verification of pressing buttons UP or DOWN coming before checking the state "*ON*". After pressing the buttons UP or DOWN is the target speed set for the new value. Switching off the cruise control is carried out by pressing RESET button or pressing brake or clutch pedal. After resetting of cruise control is a constant "*ACTIVATE*" set to false value and will be released servomotor and the controller disables the PID controller.

An important part of the control program is the setting of the PID controller, which controls the servomotor and thus the throttle of the vehicle. For setting of PID controller there are a number of methods, but in this case the PID controller was set experimentally. The proportional component of the controller adjusts the degree of throttle opening based on the difference between the desired and actual vehicle speed. Thus, the closer a vehicle to a target speed, the slower it accelerated. This difference can also take negative values, in that case the value of the degree of throttle opening is set to zero. The integration component of the controller causes a rapid balancing of the difference between the target and actual speed and the derivative component applies into small changes of the speed. The proportional component of the controller was set at value *0.3*, integration component to value *0.2* and the derivative component to value *0.01*. The constants of PID controller ensure sufficient dynamics of the cruise control. These settings do not affect the overall dynamics of the vehicle speed. The total weight and engine power affects the dynamics, but in the PID controller design is not considered with these parameters.

3. VERIFICATION OF THE CRUISE CONTROL

The functionality of the proposed solution of cruise control, has been practically verified on the vehicle Škoda Felicia. The results of the individual tests are displayed on a next graphs. During individual tests was monitored maintaining of a constant speed when conditions change and response of the cruise control to changes requested speed. The sampling time for vehicle speed sensing was 1ms. On individual waveforms are displayed desired and the actual value of the vehicle speed and the value of the degree of throttle opening.

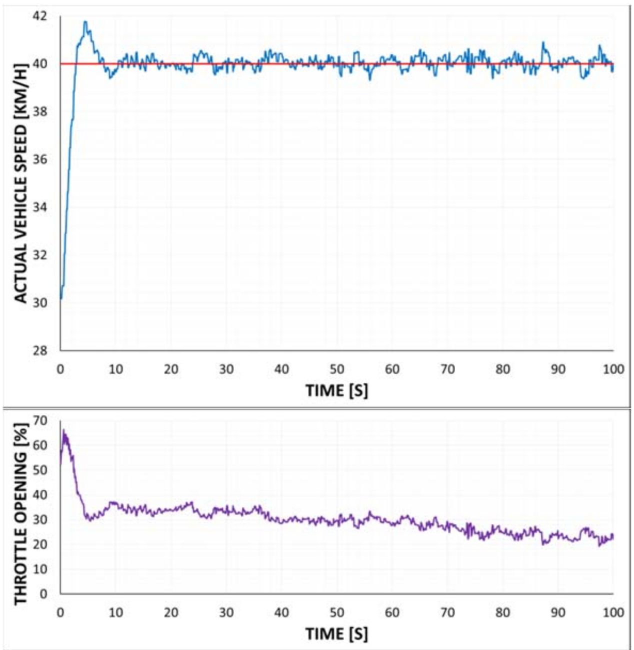

Fig. 6 Maintenance of the constant velocity and corresponding value of the throttle opening

In Fig. 6 can see, as the cruise control adjusts speed relative to changing conditions and corresponding curve of the rate of throttle opening. At the beginning of the test, the vehicle start to accelerate at a slight road incline from the speed of 30 km/h to the speed 40 km/h. Between 10 to 35 seconds vehicle they were at a constant speed in a moderate climb. At the time of 35 to 70 seconds, the car moved around the plane, and we can see that the mean the degree of throttle opening is less than uphill. The last part of the graph was obtained on a vehicle on the road with a slight incline, and at the end of the measurement, the slope of the road increased. The degree of throttle opening value was reduced in order to correct to the vehicle speed. The measurement duration was 100 seconds.

The difference between current and required speed in steady state was approximately ±2%. This difference is shown in Fig. 7 as relative error δ, which was calculated by next equation.

$$\delta = \frac{target\ speed - actual\ speed}{target\ speed} . 100\% \tag{1}$$

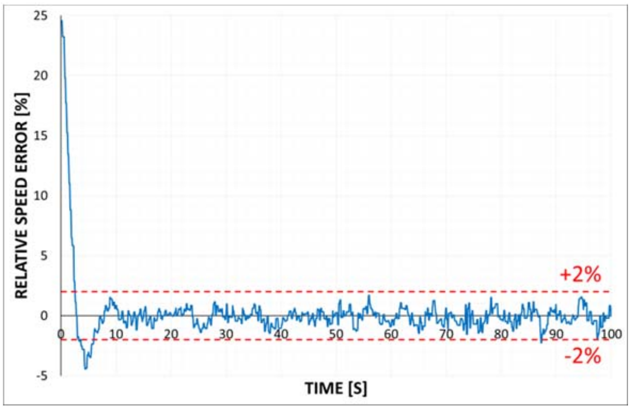

Fig. 7 Increase of the required speed and corresponding value of the throttle opening

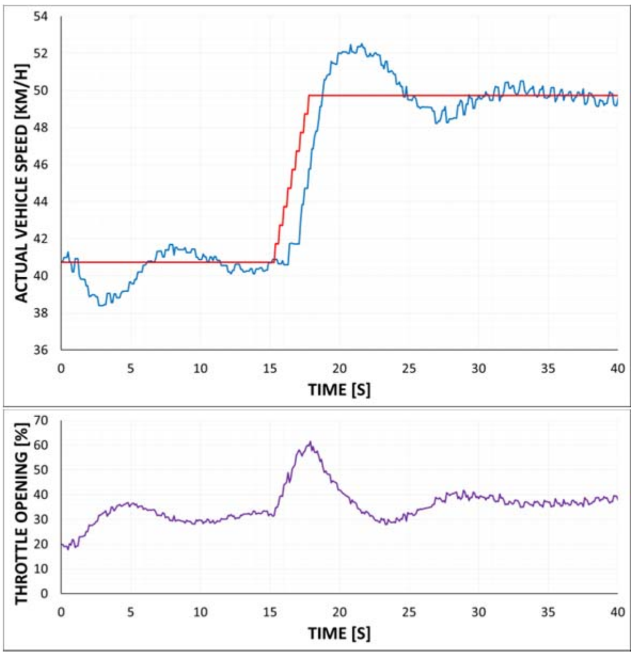

Fig. 8 Increase of the required speed and corresponding value of the throttle opening

Response of designed cruise control to change desired rate were monitored during acceleration respective deceleration of vehicle. The results are shown in Fig. 8, respectively Fig. 9.

Acceleration of vehicle was monitored from a speed of 40 km/h to a target speed of 50 km/h and deceleration of vehicle back from speed of 50 km/h to a target speed of 40 km/h.

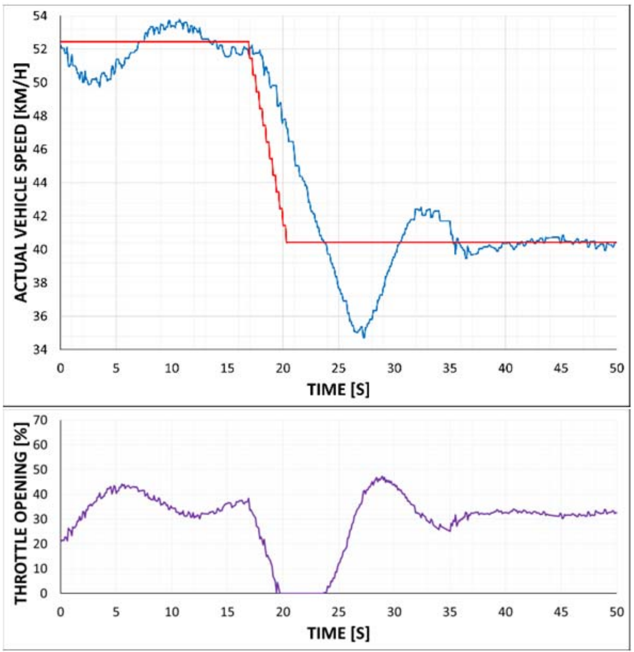

Fig. 9 Decrease of the required speed and corresponding value of the throttle opening

At Fig. 10 shown a test where cruise control has to respond to a step change of desired velocity.

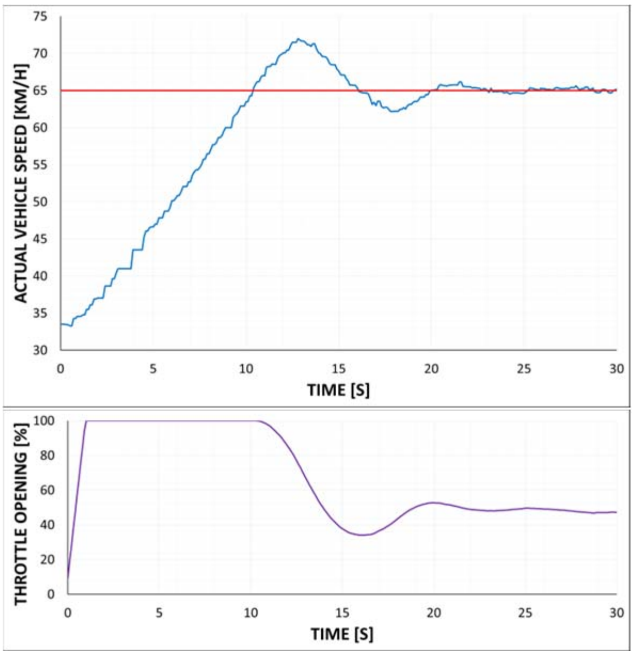

Fig. 10 Decrease of the required speed and corresponding value of the throttle opening

The vehicle is moved from the start of the test at 33.5 km/h and the target speed of the cruise control was set at

65 km/h. As can be seen from the figure, the vehicle has reached the required speed for approximately 10 seconds.

4. CONCLUSIONS

This article presented the design and implementation of cruise controller for passenger car. Hardware and software of this mechatronic system is designed to control the vehicle cruising speed by control of its throttle position. This low-cost solution has been designed and at the final stage realized and tested for a vehicle Škoda Felicia. As can be seen from the test results shown in end of the article, the proposed system was able to maintain the required vehicle speed not only on straight road, but also when rise or fall of the road. The relative speed error in steady state was less than ±2%.

ACKNOWLEDGMENTS

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