RESEARCH AND EXPERIMENT WITH AUTOMATIC WIPER SYSTEM

Do Van Dung[1], Le Quang Vu[1], Ho Minh Dat[2], Nguyen Van Khoi[2]
[1]Ho Chi Minh City University of Technology and Education, Vietnam
[2]ISUZU VIETNAM CO., LTD, Vietnam

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ABSTRACT

This paper presents the research, manufacture of automatic wiper system and experiment on this system on the vehicle. Based on studying the theory of refraction and reflection of light to make a sensor, helping to identify the rain on the windshield surface by using infrared LED. Controlling the speed of the wiper in the speed range using fuzzy logic, by interrupting the lever after each cycle of operation, the interrupted time is adapted to each rainfall on the windshield surface. And the system will also help the driver's visionless affected by the wiper because the motor runs at high speed. The result is the team has built a sensor and controller which can be used in the vehicle and works well. Through the process of testing, the system has shown its advantages compared with manual controls as usual.

Keywords: *automatic wiper; light refraction; light reflection; rain sensor; fuzzy control.*

1. INTRODUCTION

The wiper system has an important role when the vehicle is going under the rain, the rainwater almost completely reduces the visibility of the driver, so it helps the driver and passengers to observe the situation of outside traffic well.

With a manual-controlled wiper system, drivers can be distracted by controlling the speed of the wipers to match the amount of rain on the windshield, which can be unsafe for the drivers and passengers, especially now the vehicle is on a rainy and slippery road. Therefore, if this system is automated, it will help the driver reduce the hassle of controlling the windshield wiper, making driving in the rain easier.

Domestic and foreign research situations, the study [1] uses a funnel-shaped sensor to collect the amount of water on the windshield and uses the PID algorithm to control the speed of the wiper motor based on the amount of water collected. The research [2] was carried out in the form of a model, using a rain drop sensor module and PID controller to control the speed of the motor depending on the amount of water falling on the resistor plate. Research [3] simulates the operation of automatic wiper systems, presenting the friction conditions of the wipers, driven bar linkage system and the algorithms used to control the speed of the wiper motor.

The above studies only stopped in the form of models or simulations, so the team's goal is to design and manufacture an automatic wiper system using three pairs of infrared LEDs and fuzzy control - Fuzzy logic to control the rain wipers to operate at a suitable speed with rainfall on the windshield.

2. RESEARCH CONTENT

Block diagram of the automatic wiper system, shown in Figure 1.

The control circuit will receive a signal from the sensor to determine whether there is rain or not. The system controls the speed of the wiper by controlling the intermittent operation period of the wiper.

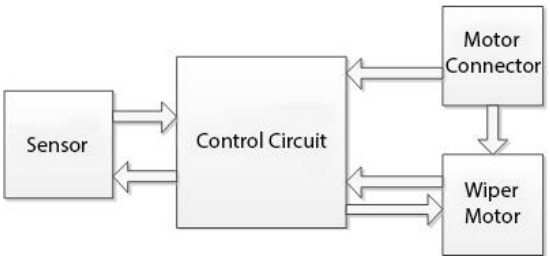

Figure 1. *Block diagram of the system*

Motor connector is connected to the control circuit to supply power to the circuit and wiper motor through relays.

2.1 Design and manufacture of sensors and control circuits

Based on the reflection and refraction of light in different refractive environments, the research designed rain sensors on the windshield using infrared LEDs.

2.1.1 The principle of sensor circuit

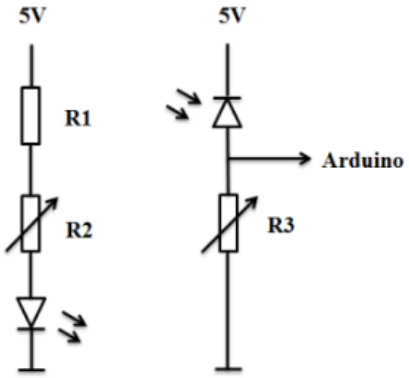

Figure 2. *The principle of rain sensor circuit*

In the circuit diagram of Figure 2, the potentiometer R2 is used to adjust the intensity of infrared generated by the transmitter LED, the potentiometer R3 adjusts the sensitivity of the receiver LED.

The sensor circuit uses an infrared transmitter LED and an infrared receiver LED. Transmitter and receiver LED are arranged at an angle of 30 degrees, with this angle we will get reflective rays for the receiver from the transmitter, depending on the amount of rainwater that receiver LED will receive more or less reflective rays, from which the received signal will go into the controller and control the wiper lever speed appropriately.

2.1.2 Analyze the direction and energy of infrared rays inside the windshield

The equation of light refraction law as equation (1)

$$n_1.\sin i = n_2.\sin r \quad (1)$$

In equation (1): *n1*, *n2* is the environmental refractive index, *i* is the angle of incidence, *r* is the angle of refraction. The energy of refracted and reflected infrared rays can be approximated according to formulas (2) and (3) below [4]

Percent of reflection

$$R = \frac{\sin^2(i-r)}{\sin^2(i+r)} \quad (2)$$

Percent of refraction

$$T = \frac{\sin(2i)\times\sin(2r)}{\sin^2(i+r)} \quad (3)$$

In which: R, T respectively percent infrared reflection and refraction. i, r are the incident and refracted angles of the infrared ray.

Based on the above formulas, we determine the direction and energy of the infrared rays inside the windshield before and after rain as shown in Figures 3 and 4.

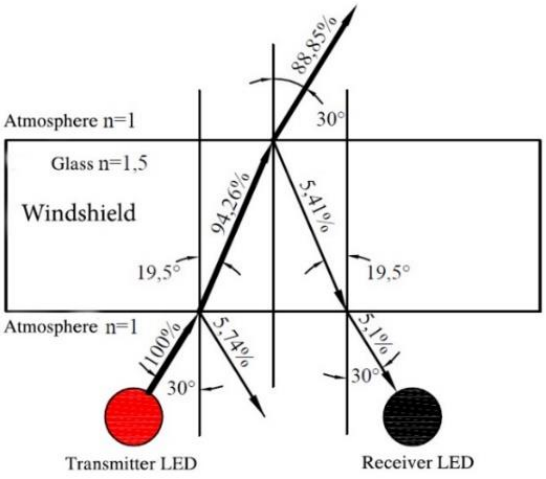

Figure 3. *The direction and energy of infrared rays inside the windshield when it is not raining*

When there is no water at the surface, the receiver LED receives 5.1% of the infrared light generated by the transmitter LED as shown in Figure 2, the rest goes out into the environment in different directions.

When there is water at the surface, due to the different refractive index of water and air, the infrared rays are refracted more outward, at this time Led only receives 0.41% as shown in Figure 4.

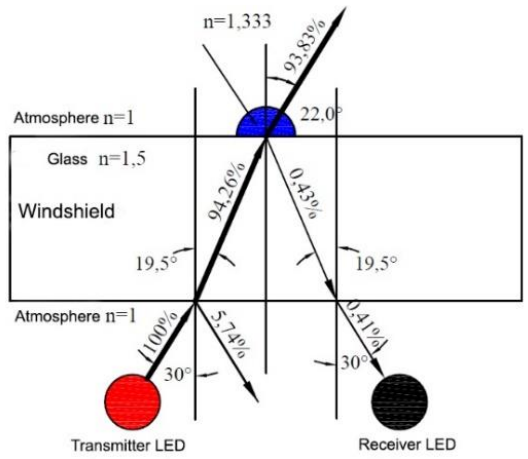

Figure 4. *Direction and energy of infrared rays when there is water on the windshield*

2.1.3 Design and manufacture sensor

After testing many different sensor models, we chose the best option to design the sensor, which is to use three pairs of transceiver LEDs lying around each other as shown in Figure 5. With such a design, each pair of LED transceivers will be adjusted sensitivity to each different environmental radiation conditions, this will help the sensor work best in all conditions such as it rains at night, rains during the day ... Thereby, recognizing the rain easier than a pair of individual transceiver LEDs. At the same time the sensor will have covers to cover radiation from the environment affecting the signal reception of the sensor, these covers are also convenient for mounting the sensor on the windshield, as well as protecting the sensor from external impact.

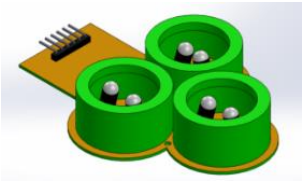

Figure 5. *The design of the sensor*

2.1.4 Design and manufacture control circuit

The control circuit will control 2 relays, relay 1 is used to control the power supply for the High pin of the motor, relay 2 is used to disconnect the Low pin of the motor because at this time Low pin is connected to the GND due to the manual wiper switch is in the OFF position.

As shown in Figure 6, when relays 1 and 2 do not work, the Low pin connected to the Low motor pin, High pin connected to the High motor pin as usual, so the circuit will not affect normal operation of motor when automatic mode is not selected.

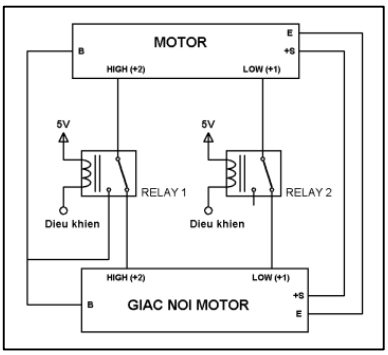

Figure 6. *Automatic control circuit of wiper motor*

When we switch to automatic mode. If it rains, then both relays 1 and 2 will work, this time there will be power from pin B of the connector to the High motor pin, then the motor will operate at High speed. Here, the motor speed will be controlled by interrupting the operating time of the motor after each rotation. Thus, depending on the time of interruption that the motor runs at different speeds. The control circuit is designed as shown in Figure 7.

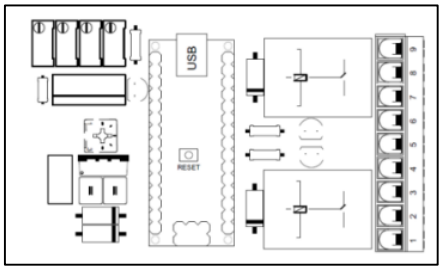

Figure 7. *System control circuit design*

Figure 8. *Control circuit after complete*

The control circuit consists of the Arduino Nano used to receive signals from the sensor and control the two relays operating through a program programmed in Arduino. There are three potentiometers to adjust the sensitivity for three sensors, the other one adjusts the voltage supplied to the transmitter LED in the sensor. Transistors help turn on, turn off the transmitter LEDs, and turn the relay off. The circuit also has a small potentiometer that adjusts the sensitivity of the windshield wipers, meaning that the time the wipers start to work when rainfall is more or less depending on the needs of each person. The switch is used to turn on the automatic mode. When the switch is OFF, the system operates in manual mode as usual. Control circuit and sensor are connected together as in Figure 9.

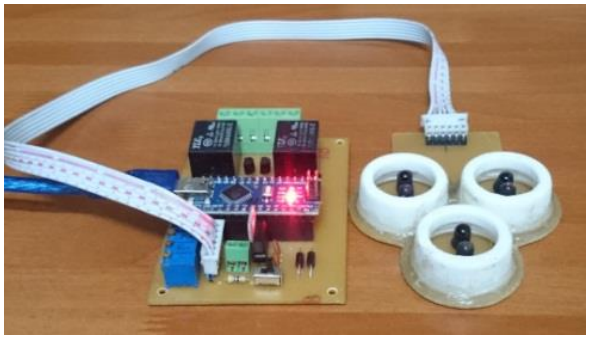

Figure 9. *Sensor connection and control circuit*

2.2 Survey and data collection

Block diagram of connecting parts for survey as shown in Figure 10.

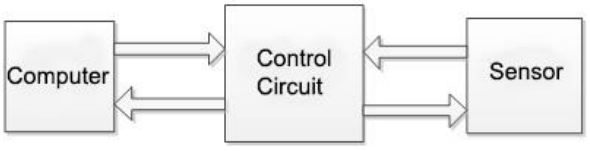

Figure 10. *Block diagram of system connection when collecting data*

The computer connects to the Arduino in the control circuit to load the program and collect data from the control circuit. At the same time, the control circuit will power the sensor and receive signals from the sensor.

To investigate the effect of rainwater on the signal of the sensor, we will track the change of the infrared reflected signal - TB PHAN XA HONG NGOAI in the data collection interface as shown in Figure 11, when it rains and when it doesn't rain. The greater the amount of water on the surface of the windshield, the more infrared will be refracted from the windshield, reducing the intensity of the infrared ray returned to the receiver LED, resulting in a reduced infrared signal.

In addition to infrared from the transmitter LEDs of the sensor. Receiver LEDs are also affected by infrared radiation from the environment, so it is necessary to collect additional environmental radiation value. Team used LabVIEW software [5] to set up the interface to collect signals from sensors as shown in Figure 11.

Figure 11. *Data collection using LabVIEW software*

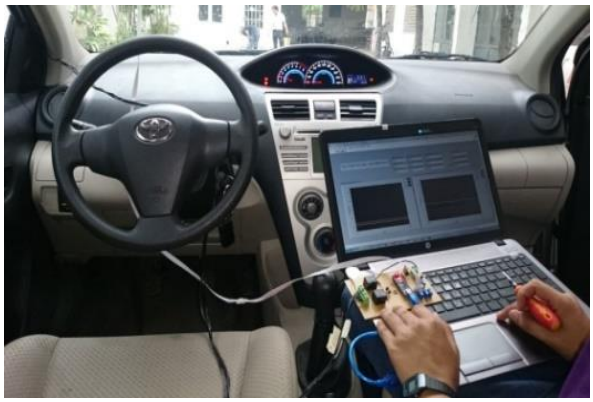

Figure 12. *Adjust sensitivity for receiver LED during data collection*

As a result of the data collection process on LabVIEW, there are actually 112 different environmental radiation values, but because the data table is too large, we minimize some radiation values to 38 values, this still show the value of experimental results, as shown in Table 1.

Table 1. *Infrared reflection value of transmitter LED when no rain and heavy rain according to environmental radiation*

Environmental radiation	Infrared reflection when no rain	Infrared reflection when heavy rain	Environmental radiation	Infrared reflection when no rain	Infrared reflection when heavy rain
0	2.64	1.79	3.84	1.53	0.99
0.5	2.61	1.76	3.97	1.41	0.9
1.12	2.57	1.71	4.04	1.35	0.85
1.4	2.53	1.68	4.1	1.31	0.81
1.68	2.49	1.64	4.15	1.23	0.73
1.98	2.45	1.6	4.22	1.17	0.67
2.17	2.41	1.57	4.3	1.1	0.6
2.29	2.37	1.55	4.35	1.02	0.56
2.44	2.3	1.52	4.41	0.96	0.49
3.05	2.09	1.39	4.45	0.84	0.44
3.25	2	1.31	4.49	0.76	0.36
3.35	1.95	1.26	4.51	0.7	0.33
3.45	1.88	1.22	4.53	0.66	0.29
3.53	1.83	1.19	4.55	0.62	0.25
3.61	1.76	1.15	4.6	0.45	0.15
3.69	1.69	1.1	4.63	0.36	0.1
3.74	1.64	1.08	4.65	0.28	0.06
3.8	1.59	1.04	4.67	0.22	0.03
3.82	1.56	1.01	4.7	0	0

From the collected data table, we have the graph as shown in Figure 13.

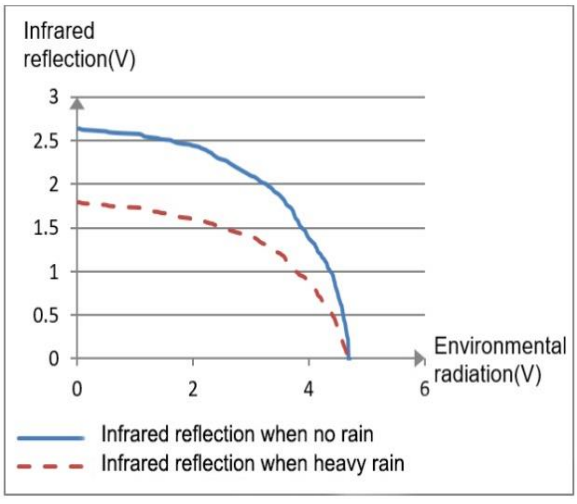

Figure 13. *The graph shows the influence of rain and environmental radiation on the signal of the sensor*

In order for the system to find out when it is necessary to operate the wiper and the speed of the wiper, we need to set an additional line to determine the time to start the wiper, when the infrared reflection value of the transmitter LED below this line, we can determine that it is raining at this time and start wiper motor operation. From this, based on the actual observation of the effect of rainwater on the windshield surface on the visibility of the driver and the collected data, we established the value of infrared reflection when starting wiper as shown in Table 2.

Table 2. *Figures show the infrared reflection when start operate the wiper*

Environmental radiation	Infrared reflection when start operate the wiper	Environmental radiation	Infrared reflection when start operate the wiper
0	2.45	3.84	1.43
0.5	2.42	3.97	1.31
1.12	2.38	4.04	1.25
1.4	2.34	4.1	1.21
1.68	2.3	4.15	1.15
1.98	2.26	4.22	1.085
2.17	2.24	4.3	1.015
2.29	2.2	4.35	0.95
2.44	2.155	4.41	0.875
3.05	1.965	4.45	0.755
3.25	1.875	4.49	0.675
3.35	1.825	4.51	0.61
3.45	1.75	4.53	0.57
3.53	1.7	4.55	0.53
3.61	1.63	4.6	0.36
3.69	1.56	4.63	0.27
3.74	1.53	4.65	0.19
3.8	1.49	4.67	0.13
3.82	1.46	4.7	0

From the actual table of data determining the time to start wiping, we get the graph as shown in Figure 14.

In Figure 14, ΔV is the voltage drop when rain starts. This value helps us know whether the rain is more or less to determine the interrupt time after each operation cycle.

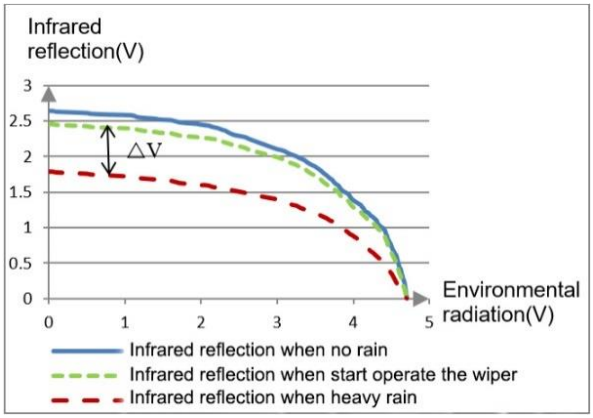

Figure 14. *The graph shows the infrared reflectance value when it does not rain, starting to operate wiper rain and heavy rain according to environmental radiation*

Because the effect of rainwater on the view of people inside the vehicle is different, some people want to operate the wiper when the water droplets just appear on the windshield, others want to start wiping when it rains harder. Based on that need, we built four more characteristic lines similar to those showing infrared reflection when operating the wiper as in Figure 15, this helped the user to adjust the sensitivity of the sensor.

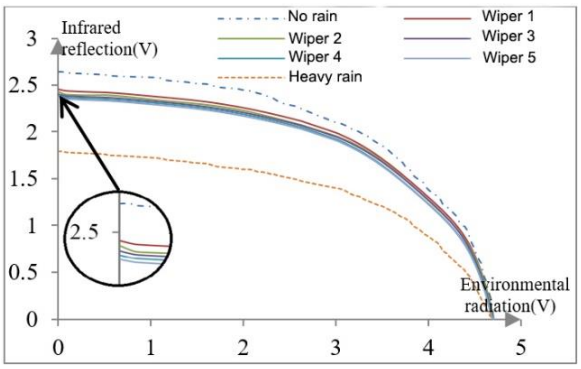

Figure 15. *Make 5 characteristic lines to adjust the sensitivity of the sensor*

2.3 Control the speed of windshield wipers using the fuzzy control [6]

The purpose of using fuzzy control is to help the windshield wipers be controlled and operated better. The wiper speed will be appropriate to eliminate rainwater on the windshield, and does not affect the driver's view. The input of the controller consists of two components, environmental radiation and ΔV. Environmental radiation is the infrared value in the environment, this radiation has a negative effect on the receiving process of the transmitter and receiver LED. If the radiation is larger, the receiver LED less receives the infrared from the transmitter LED but mainly receives infrared from environmental radiation. So, we need to determine the value of environmental radiation so that when the receiver LED receives the signal, we subtract the value of environmental radiation, we will get the infrared reflection value from the transmitter LED.

As mentioned above, the environmental radiation value greatly affects the reception of the transceiver LED, so it also affects the ΔV value, so to know whether the rain is heavy or not, the controller needs to collect both environmental radiation values and ΔV as shown in Figure 16.

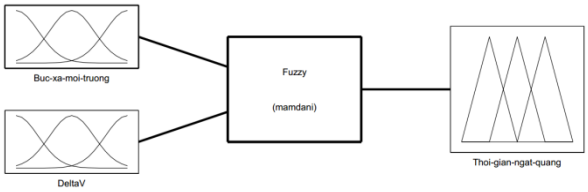

Figure 16. *Construction of a fuzzy controller*

2.3.1. Fuzzy controller results

Once fully established, we can show the results of the controller. Corresponding to each environmental radiation input value and ΔV, we obtain an output value that is the interruption time, represented by the 3D spatial diagram as shown in Figure 17.

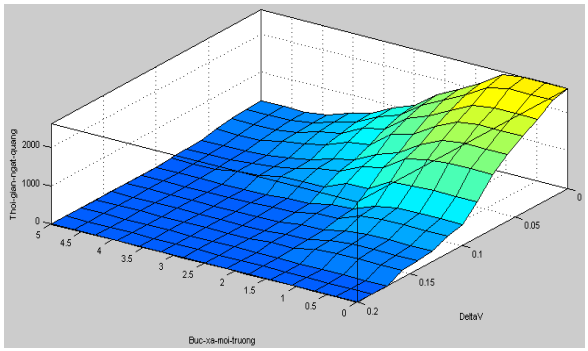

Figure 17. *The controller results, displayed in 3D space*

From this output, we will use it to control the speed of windshield wipers.

2.3.2. Simulate the system with the controller

Simulation of wiper system and controller save research time, while avoiding dangerous cases during vehicle experiments as shown in Figure 18.

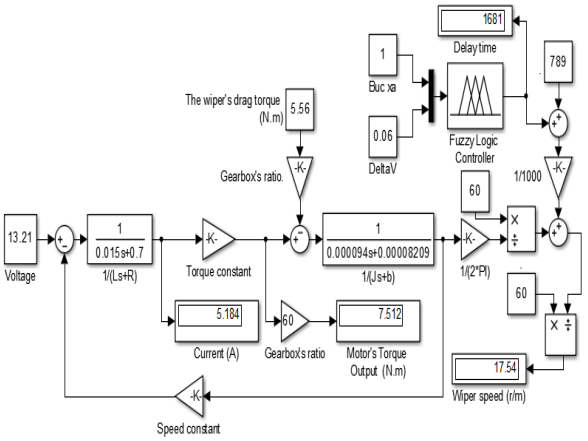

Figure 18. *System simulation by MATLAB*

The simulation results show a general overview of the effect of environmental radiation and rainfall (ΔV) on the speed of the wipers through the data collected from the system simulation process as table 3.

Table 3. *Data simulating the effect of rainfall and environmental radiation on the speed of the windshield wiper (rpm)*

Environmental Radiation / ΔV	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
0.02	15	15	15	16	18	22	24	27	31	31	31
0.04	16	16	16	18	20	24	24	28	32	32	32
0.06	18	18	18	20	23	26	28	31	33	33	33
0.08	21	21	21	21	25	28	28	32	34	34	34
0.1	26	26	26	28	31	33	34	63	63	63	63
0.12	28	28	28	28	32	34	34	63	63	63	63
0.14	30	30	30	32	33	63	63	63	63	63	63
0.16	31	31	31	32	34	63	63	63	63	63	63
0.18	63	63	63	63	63	63	63	63	63	63	63
0.2	63	63	63	63	63	63	63	63	63	63	63

From the data in Table 3, using MATLAB software(,) we draw the graph as shown in Figure 19.

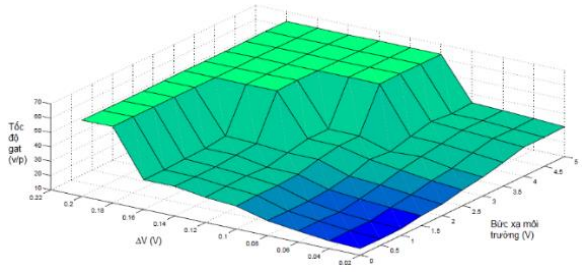

Figure 19. *Simulation results are displayed in 3D space*

After installing the system on the vehicle, we collected the actual data shown in Table 4.

This actual figure has a deviation from the simulation process due to the frictional resistance between the wiper and the unstable glass surface when we take measurements to get the data.

Table 4. *Actual data on the effect of rainfall and environmental radiation on the speed of the windshield wiper*

Environmental Radiation / ΔV	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
0.02	15	14	15	17	18	22	24	26	30	30	31
0.04	16	16	16	17	20	24	24	28	32	32	32
0.06	18	18	17	20	23	26	28	31	33	33	33
0.08	20	20	20	22	24	28	28	31	34	34	34
0.1	26	26	27	28	31	34	33	63	63	63	63
0.12	28	28	28	29	32	34	33	63	63	63	63
0.14	30	30	30	32	33	63	63	63	63	63	63
0.16	31	31	31	31	33	63	63	63	63	63	63
0.18	63	63	63	63	63	63	63	63	63	63	63
0.2	63	63	63	63	63	63	63	63	63	63	63

The process of spraying water to simulate rain on the windshield surface when spraying much the drag decreases, when spraying less the resistance increases. Therefore, the

operating results of the actual system have errors compared to the simulations. From Table 4, using MATLAB software, we draw a graph showing the effect of ΔV and environmental radiation on the wiper speed as shown in Figure 20.

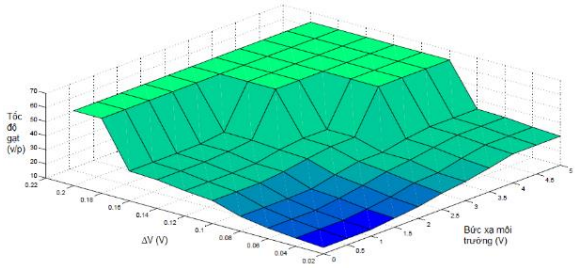

Figure 20. *The actual graph shows the wiper speed according to rainfall and environmental radiation*

Reliability of the simulation process compared to reality: variance is 0.106, standard deviation is 0.3.

Conclusion: with a deviation of 0.3 rpm, we find the error of the simulation process is small, so the simulation process is completely reliable.

2.4. System testing on Toyota Vios

2.4.1. Test arrangement

The sensor will be glued to the windshield, in the middle and top of the windshield. The sensor is located in this position to ensure a clear view of the driver inside the vehicle, and it also recognizes rainwater more easily. The source of the sensor will be taken from the control circuit, and the control circuit will receive the signal from the sensor as shown in Figure 21. The High and Low pins of the motor and motor connector are connected via two relays of the control circuit to control the wiper motor.

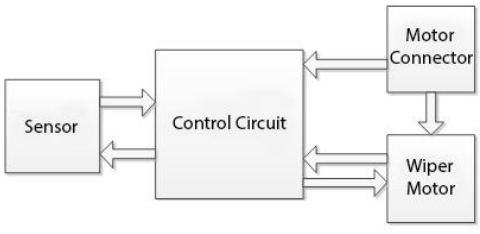

Figure 21. *Block diagram of system*

At the same time, the remaining wires are connected between the connector and motor as usual. In addition, the control circuit also receives signals from the motor's S pin to determine the timing of the interrupt time, and take power to operate from pin B of the motor connector.

Figure 22. *Sensor placement on the windshield*

Control circuit is placed under the bonnet to save wires, and helps the system to be tidier.

Figure 23. *Control circuit is located under the bonnet*

2.4.2. System test

The system was tested in many different conditions such as rainy day, night, spraying water when it is sunny ... Test results show that the system works well under different conditions.

Figure 24. *System testing on Toyota Vios*

Figure 25. *System test at night*

3. RESULTS AND CONCLUSIONS

Through testing, the system operates stably with different environmental conditions both day and night.

The advantage of the system is that it is possible to control the windshield wipers at different speeds depending on the amount of rain on the windshield. This helps the driver to avoid distractions while driving when controlling the wipers in accordance with the outside rain. Drivers can control the low, high wiper speed as usual when not using automatic mode because the control circuit is connected in parallel with the manual system on the vehicle.

Although the system can be installed in the car and works well, there are still some disadvantages. Sensors and control circuits are handmade, so aesthetics is not high.

Development direction:

- Standardizing the system according to industrial design.
- Control the wiper speed according to vehicle speed.

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Corresponding author:
Le Quang Vu
Ho Chi Minh City University of Technology and Education
Email: vulq@hcmute.edu.vn