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# YOREH MITWA*
# An Electrochemical Rain Sensing Wiper

*(No gains without rains)*

**Pranav Chandekar, Sanket Kelaskar, Amit Dhanawade and Ashish Aiyapillai**
Mechanical Engineering Department
Rizvi College of Engineering (RCOE), Bandra
Mumbai, INDIA

**Amol Madhav Khatkhate**
Associate Professor,
Mechanical Engineering Department
Rizvi College of Engineering (RCOE), Bandra
Mumbai, INDIA

## ABSTRACT
During the Mumbai 26/7 rains, lot of vehicles lost their electronic capability due to water logging in the vehicles (refer figure 1). This resulted in loss of life of individuals as they were incapable of leaving the vehicle as all the power driven windows and doors were sealed. A rain sensing wiper system that works on a principle other than electronics would be a boon in such a situation. The electrical voltage can be made to close/roll down the windows or open the door locks when it rains allowing passengers to escape from the vehicles. In developing countries, there is heavy neck to neck traffic allowing very less reflection time on the part of the driver. Also, situations are common where the vehicles have to follow huge trucks without tail-lights. Such situations can cause the driver to panic resulting in him pressing some wrong button in-order to start the wiper. A low cost automatic rain sensing wiper will be very useful in such a scenario. In this paper, we have investigated an electrochemical switch which is rain sensitive and independent of the electronics of the vehicle. Also, a lot of electrical components are involved in electrically operated rain sensing wiper, hence, there is always a chance of short circuit since the system deals specifically with water as medium. As a result regular inspection and preventive maintenance prove to be crucial for it as compared to our wiper which is eco-friendly and offers high reliability. In this paper, we have compared our electrochemical based wiper system with other existing methods in literature.

**Keywords -** *electrochemical, rain sensitive, wiper, low cost*

## 1. INTRODUCTION
Rain-sensing windscreen wipers appeared on various models in the late 20th century, one of the first being the Citroen SM. As of early 2006, rain-sensing wipers are optional or standard on all Cadillacs and most Volkswagens, and are available on many other mainstream manufacturers. Some vehicles are now available with driver-programmable intelligent (automatic) windscreen wipers that detect the presence and amount of rain using a rain sensor. The sensor automatically adjusts the speed and frequency of the blades according to the amount of rain detected. These controls usually have a manual override.

**Figure 1: Water logging in raining season at Mumbai**

## 2. PRINCIPLE OF OPERATION: ELECTROCHEMISTRY
Electrochemistry is the study of chemical processes that cause electrons to move. This movement of electrons is called electricity, which can be generated by movements of electrons from one element to another in a reaction known as an oxidation-reduction ("redox") reaction (See Figure 2)
Chemical reactions involving the transfer of electrons from one reactant to another are called *oxidation-reduction reactions or redox reactions.* In a redox reaction, two half-reactions occur; one reactant gives up electrons (undergoes oxidation) and another reactant gains electrons (undergoes reduction). A piece of zinc going into a solution as zinc ions, with each Zn atom giving up 2 electrons.*

$$Zn(s) \rightarrow Zn^{2+}(aq) + 2e-$$

In a reduction there is a decrease (or reduction) in oxidation number. Chemical equation representing half-reactions must be both mass and charge balanced. In the half-reactions above, there

* *Yoreh Mitwa means "a dear friend of the early spring rains"*

is one zinc on both sides of the equation. The charge is balanced because the 2+ charge on the zinc ion is balanced by two electrons, 2e-, giving zero net charge on both sides.

$Cu^{2+}(aq) + 2e- \rightarrow Cu(s)$

%% Calculation of voltage generated by Copper cathode and Zinc anode using Nernst equation

Vo = 0.34 -(-0.76) = 1.1;

R_const = 8.314;

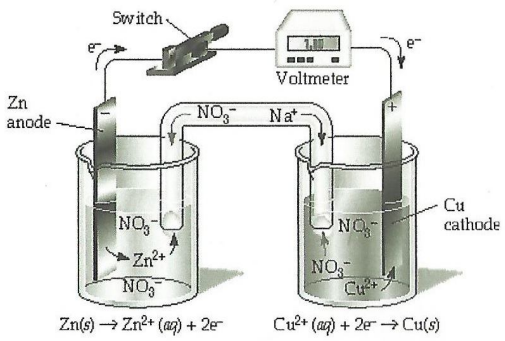


**Figure 2 – Electro-chemical Cell**

Proper choice of electrodes and electrolytes will enable us to create the electrochemical rain sensitive cell

F = 96485;

Temp_Cu = 25 + 273;

Temp_Zn = 25 + 273;

Zn = 0.001;

Cu = 5;

V_cell = Vo - (R_const*Temp_Zn/(2*F))*log(Zn) + (R_const*Temp_Cu/(2*F))*log(Cu)

The electrochemical rain sensitive cell produces a voltage of around 1.1 V

## 3. ADVANTAGES AND LIMITATIONS

## 3.1 Advantages

a) In developing countries, there is heavy neck to neck traffic allowing very less reflection time on the part of the driver. Also, situations are common where the vehicles have to follow huge trucks without tail-lights. Such situations can cause the driver to panic resulting in him pressing some wrong button in-order to start the wiper. A low cost rain sensing wiper will be very useful in such a scenario.

b) Also, during the Mumbai 26/7 rains, lot of vehicles lost their electronic capability due to water logging in the vehicles. This resulted in loss of life of individuals as they were incapable of leaving the vehicle as all the power driven windows and doors were sealed. A rain sensing wiper system that works on other principle than electronics would be a boon in such a situation. The voltage can be made to open the power locking windows allowing passengers to escape from the vehicles.

c) In developed nations, when the vehicle is left in the open and a snowfall occurs such a system would turn on the wipers and scrub the snow. When the ignition is turned off the wiper still keeps on running allowing for better visibility for the driver. The shut off ignition should close the opening for the water thereby stopping the wiper.

d) During normal driving in cities with heavy traffic, the car heats up very fast and the bonnet also tends to have a very high temperature. The collected water can be used to cool the bonnet in such a situation when there is no rainfall.

e) Lot of electrical components are involved in electrically operated rain sensing wiper there is always a chance of short circuit since the system deals specifically with water as medium. As a result regular inspection and preventive maintenance prove to be crucial for it.

f) The initial cost of traditional rain sensing wiper is considerably high as compared to the proposed one ; so in regions where rainfall is as scarce as one to two months annually it is not economical to invest such a high amount in it.

## 3.2 Limitations

Even though the redox (reduction-oxidation) reaction is spontaneous, response time for this electrochemical rain sensing wiper may be more as compared to traditional method since some amount of rainwater needs to get collected for the wiper to operate. This needs to be tested and checked in laboratory. Also in case of smog or fog may not be wiped from windshield which is done by certain rain sensing wiper

For this rain sensing wiper to work continuously for years it depends of life of electrolyte and electrodes. Often after a very long drive when galvanic cell(battery) reaches polarization the it is recharged by generator and after prolonged usage the electrolytes are changed or distilled water is added as substitute. It takes about 6 to 7 years of driving to make certain galvanic cell inoperable.

Temperature makes some issue with galvanic cell (battery). When the temperature is very low the density of electrolyte increases and in certain cases freezing of electrolyte occurs which obstructs the flow**.**

## 4. WORKING OF ELECTROCHEMICAL RAIN SENSITIVE CELL

The galvanic cell used consists of two electrodes ie Zinc and Copper. These are attached to the water collecting container which is supported by a spring. The other end of spring is fixed to a base plate , further the two beakers containing respective electrolytes are placed on the plate exactly below those corresponding electrodes.

When it is raining the water droplets tend to fall on the car's windshield and the water starts getting collected in the container through the water collecting tube which acts as a passage for the rain water. As a result the weight of the container increases due to the rainwater accumulation.

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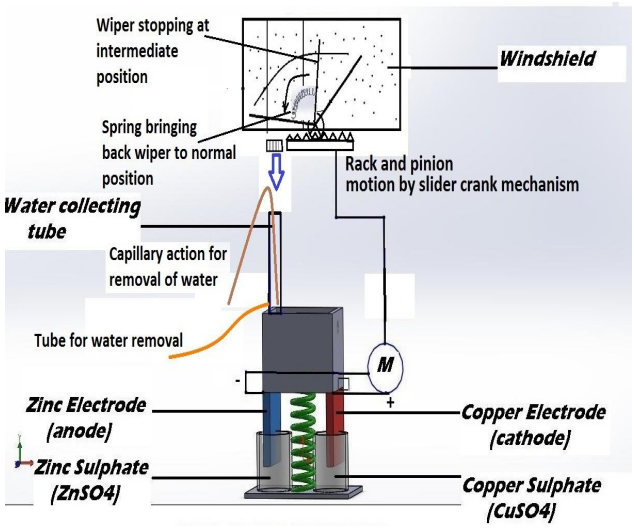


**Figure 3: Schematic diagram of the electrochemical wiper mechanism**

Hence the container is displaced from its original position downwards due to which the spring is compressed. The electrodes which are attached to the container simultaneously get dipped in their respective electrolytes which results in electrochemical reaction and therefore electricity is produced. This electricity is harnessed to run the motor. The rotary motion of the motor is converted to reciprocating motion by rack and pinion mechanism. This motion is fed to the wiper via connecting road which is attached to the pinion. Thus the wiper moves thereby cleaning the rainwater off the windshield which serves the purpose

## 5. COMPARISON OF DIFFERENT TYPES OF RAIN SENSORS

The main advantage of Yoreh Mitwa is that it is independent of the micro-controller unlike all the other wipers. Yoreh Mitwa needs least voltage in the range of 1-3 V meanwhile all the rest need 6V and above. Cost of replacement excluding labor is low of our proposed wiper ie **INR 1500** while the others are quite high except for the probe based sensors.

| | **Different types of rain sensors** | | | | |
|---|---|---|---|---|---|
| | ***Plate based sensor (ref 2)*** | ***Piezo-electric sensor (ref 1)*** | ***Probe based sensor (ref 4)*** | ***Optical based rain sensor (ref 3)*** | ***Electro-chemical rain sensor*** |
| **Operating principle** | Micro controller based | Micro controller based | External circuits connected to micro controller | Micro-controller based | **Independent of micro controller** |
| **Working** | Small drops of water change the resistance | Water between plates decrease resistance | Contact of water with probe completes rain circuit | Change in reflection due to rain water | **Rainwater energy is converted into displacement of electrochemical switch** |
| **False rain detection rate** | Very high | Less than 5 % | Less than 2 % | Less than 2 % | **Less than 2 %** |
| **Voltage required** | 12 – 5 V DC | 12 – 5 V DC | 2 – 6 V DC | 12 – 5 V DC | **1 – 3 V per single cell** |
| **System response time** | Not mentioned | 500 ms after rain contact | On collection of 10 cu.cm | Very low | **110 – 260 ms after rain contact** |
| **Sensor surface size** | Very large | <= 4 cm x 4 cm | >=2.58 cm x 2.58 cm | Not applicable | **1 cm x 1 cm** |
| **Placement of sensor** | On the windshield | On the windshield | Inside the font hood | Inside the car cabin | **Inside the front hood** |
| **Cost of replace-ment** | Quite high | Quite high | Around Rs 1000 | Around Rs 7000 | **Around Rs 1500** |
| **Adaptation** | Changes the aesthetics of the vehicle | Embedded on windshield | Volume of rain collected is high | Seamless integration with vehicles | **Adaptable to all vehicles** |

**Table 1: Comparison of Rain Sensors**

## 6. RESULTS AND DISCUSSION

A standard wiper motor model has been developed by Lucas [5] as seen in Figure below. The parameters used in the model are tabulated below. Also, we have validated the model by verifying it by conducting suitable experiment in our lab.

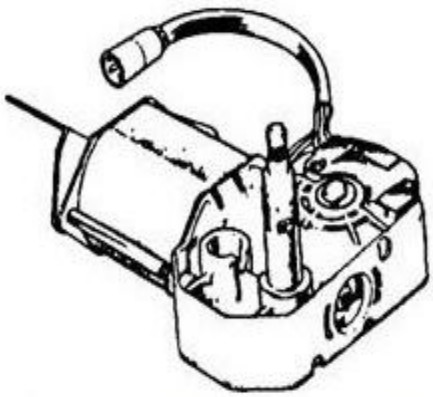

**Figure 4: Wiper motor developed by Lucas**

$$T = F\ \mu\ f_s\ f_l\ l\ (\omega_a/\omega_m)(R_h/R_c)(1/e)$$

where
T = torque to move one wiper arm (N-m)
F = force onto blade on screen (N) = (W + 0.8)cos(β + λ)
W = 90 gms weight
Frictional force,0.8 N = maximum frictional force on blade [6]
β = angle of travel by wiper (rad) = max 180 - 2λ
λ = relief angle on windscreen = 15 degree
μ = maximum dry coefficient of friction, which is 2.5
$f_s$ = multiplier for joint friction, which is 1.15
$f_l$ = tolerance factor, which is 1.12
$l$ = wiper arm length, m = 0.24 m
$\omega_a$ = maximum angular velocity of arm, rad/s
$\omega_m$ = mean angular velocity of motor crank, rad/s
e = efficiency of motor gear unit which is 0.8
$R_h$ = motor winding resistance, hot-Ω = 1.05
$R_c$ = motor winding resistance, cold-Ω = 1

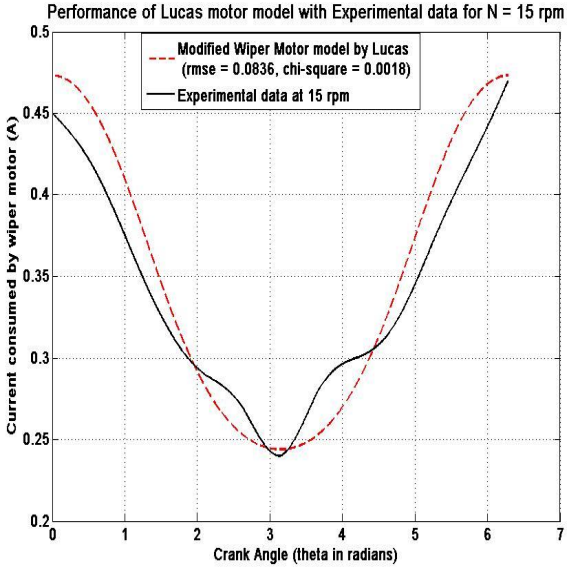


**Figure 5: Performance of Modified Lucas Wiper Motor model with experimental data at 15 rpm.**

The above graph has been obtained after suitable modifications have been done so as to minimise the errors with the experimental data. We conducted the electrochemistry experiment in the lab manually. As specified earlier the electrodes of zinc and copper were used in the solutions of zinc sulphate and copper sulphate respectively. The reaction was **spontaneous**. The voltage obtained from the reaction was 1.027 Volts. Salt bridge which was used ( U tube glass apparatus) was manually drafted with both the ends of it installed by porous cotton plugs.

## 7. CONCLUSIONS AND FUTURE WORK

As this proposed mechanism does not involve a micro-controller thus it proves to be highly reliable in places where there is heavy rainfall and vehicles lose their electronic capability. Based on the initial experimental results, a suitable ARAI standard compatible product will be designed. The sensitivity of the product will be compared with the existing products in the market.
Pilot project on a local transport BEST bus will be carried out to prove the effectiveness of the technology. Furthermore, following enhancements will be done in due course of time which will lead to value addition of the above rain sensing wiper :

a) Design of model by first principles and correlation of model at other rpm with actual data.
b) Automatic speed control of wiper based on rate of rainfall.
c) Enhanced cooling effect during hot summer and during long drives.
d) Automatic rolling down of windows during electronic circuit breakdown or malfunctioning allowing for easy escape of passengers from the vehicle.
e) Testing of response time after rain contact.
f) Design of voltage buffer to provide for required current for operating wiper at different speeds.

The introduction of this new type of system in current vehicles needs to also be checked in terms of its effect on the fuel economy and the gains/losses that it has as compared to existing rain wiper system.

## 8. ACKNOWLEDGMENTS

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