4.1 Case:-1: Photoemission Phenomenon with Different Cathode Material and Calculation of Different Parameters for It

4.1.1 System Study:

4.1.1.1 Preliminary System Study:-

In this chapter we aim to present utilization of our development methodology for Photoemission phenomenon experiment.

We have chosen Photoemission phenomenon with different cathode material and calculation of different parameters for it case study for this purpose. We developed simulation architecture. We are chosen this experiment because it has lots of application in research like

- it is useful in photocell for converting light energy into current energy,
- In present day, it is used as sound reproducer in film industry for camera work like shooting, photography or film making.
- It acts as automatic on off switches in case of street light.
- It is used in vehicle counter and traffic control signal.
- Solar panels of Satellite and robots are the most important application of this phenomenon

4.1.1.2 Need of Simulation in Photoemission Concept:-

According to fundamental concept of quantum mechanics, the light has dual nature. In case of photoemission effect, the particle nature of light is vital part of this phenomenon hence understanding of this concept is most important for understanding the complete phenomenon of photoemission effect. The photoemission phenomenon concept and experiment is one of the good and most important ways for the student to
understand the photon concept of light and to explore their ideas related of photon model. The photoemission concept and experiment, the physics faculty consider as very easy concept of modern physics, are explained in short manner in theory lecture as well as in practical of modern physics and quantum physics but on the other hand, the research shows that student has poor understanding of this topic and they have lots of difficulties for the understanding of the basic things of this concept like the experimental set-up, experimental results, and inferences regarding the nature of light. Thus there is need of simulation based model of photoemission effect to deal with this problem of students.

To develop simulation code, we targeted basic parameter which is heart of this experiment that is Photoemission phenomenon and target materials.

Further sections will give theoretical, mathematical as well as computational details about this.

4.1.1.3 Basic and Scientific Application of the Photocurrent:

The significances and characteristics of photoemission process can be explained with application of some basic and scientific uses of the photocurrent. Most basic use of photocurrent in Different types of transistor and diode produces the photocurrent by obeying this effect. There is arrangement of photodiodes which is highly sensitive with sun light and, solar power circuit for photocurrent generation.

In semiconductor, photocurrent is useful for the dexitation of valence electrons from valence band and throws out the electron from valence cell by emission of low energy photon. Due to the removal of electron from valence band, it causes the some current and this current is used for different purpose in semiconductor and it helps to reduce the band gap energy. The most important bring into play of photocurrent in case photomultipliers as detector of low brightness level.

The video camera tube of basic starting models of televisions had worked on photocurrent. It is created by hit outermost cell electron of solids but still the electrons exist within the matter in silicon image sensor and it different electrical devices.
Another application of photocurrent is as sensor of detection of electricity in gold folio electroscope apparatus.

In case spectroscopy of Photoelectron, it is useful for measurement the value of incident photon energy because the value of photon energy is the amount of energy of photocurrent and work energy function of the system. The value of work function can be determined by using simple procedure that first the illuminating complete source with monochromatic radiance of X-ray or ultraviolet light and simultaneously calculating the value of kinetic energy acquired by the photoelectron after illumination ,this value of kinetic energy gives the value of emitted energy of photoelectron.

Spaceship is good example of photoemission phenomenon because it works on the principle photoemission effect. In spaceship, the photocurrent is produced in two form one positive and negative charged form. If the spaceship parts are illuminated by darkness then generates negative current which will be in some kilovolts while if the spaceship parts are came in contact with light then it builds up a positive current of several kilovolts.

Besides, the sunlight and lunar dust collides with each other than dust acquires the charges and it would get charged. Due to repulsion of this charge dust the surface of moon is get underway hence the scientist can able to perform the investigation and observations on the moon surface.

Including all of the above applications, photocurrent is used in night vision devices. Within undersized, there are different applications of photocurrent in our daily life.

4.1.1.4 Photoemission Phenomenon:

In1987, photoemission phenomenon was reported and described by the scientist Hertz H. Some material emits electron if we would illuminated or passed the light into the material. This effect generally referred as photoemission effect. In this effect not only electron emits but also some other rays like x-rays, ultraviolet rays and γ-rays are produced.
According to Einstein’s theory, the energy value for each quantum is equal $h\theta$. We know that all the electrons are sited inside the metal surfaces and they are bounded with the surface of metals by some energy. Hence they required the particular amount of energy for escaping from the surface this extra energy is consider as work function. If the incident light energy on the metal surface is greater than the binding energy of the electron inside the surface then the electron gets activated and Such a way that each photon releases one electron from the metal surface. This is nothing but the photoemission phenomenon.

Fig.4.1. the photoemission phenomenon Electromagnetic radiation strikes a surface, “knocking” electrons in the material out of surface.
Red light is very bright but the amount photoelectron generations become zero.

Green light is very dim but still the amount photoelectron generations possible

Blue light is very dim as compare green light but still the amount photoelectron generations with more energy than green light

Fig. 4.2. the photoemission phenomenon with different wavelength
The few parameters perform the important role in photoemission phenomenon like

a. Photoelectric Current,

b. Stopping Potential,

c. Threshold Energy,

d. Work Function.

When the photon incident on a metal surface, it causes the emission of electron this electrons are called photoelectron (Fig-4.2) and the current produced by electron is called photocurrent (Fig-4.2). The intensities of photo electrons change according to target material.

The stopping potential is potential difference applied to the metal system for stopping the emission of electron from the metal surface which is ejected due to the falls of photon on it. The Threshold Frequency is defined as the minimum frequency of incident light required for the emission of electron from the surface. Work Function is the minimum amount of energy required for the starting of electron from the surface of the target material and if the value of energy of incident radiation is less than the work function of metal, no photo electrons are emitted.

The hertz is first person who was discovered the phenomenon of photoemission and later the two scientists namely Thomson and Millikan who were proved this concept with experimentally. After the experimental verification the great scientist Einstein proposed equation for supporting this phenomenon. This phenomenon is nothing but the conversion of photon energy into electric energy. The experimental apparatus for system is as shown in fig 4.3 (Actual Experimental Apparatus of photoemission phenomenon Apparatus Model No. AP-8209, PASCO Products). It consist a vacuum glass tube with target material which photosensitive material and collector. The target to negative terminal and collector connected to positive terminal of battery through the variable resistor. Voltage difference between the plat and collector can be changed with rheostat. When the suitable value of photon energy incident on the target material then electron are emitted and move towards the collector and finally some measurable amount of current flows through the circuits.
Figure 4.3: Actual Experimental Apparatus of photoemission phenomenon
Apparatus Model No. AP-8209 PASCO Products.

Some of factor performs the important role in photoemission phenomenon because
the value of kinetic energy of electron and photocurrent depends on this parameter
which is described as follows:-

- The voltage difference between anode and cathode:-
  for an any given target material, if the value of intensity and frequency of
  incident photon remains fixed and at this situation if we increased the applied
  voltage value between the target material and cathode then photocurrent value
  increase up to its saturation sate. If we changed the polarity of power supply
  and apply the same procedure for reverse situation then photocurrent decrease
  by increasing the value of applied voltage between the cathode anodes and
  finally it becomes a zero.

- Intensity of incident photons:-
For any given target material, if the value of applied potential and frequency of incident photon remains fixed and at this situation if we increased the intensity of incident photons then photocurrent value increases at constant value of stopping potential.

Frequency of incident photons: - for an any given target material, if the value of intensity of incident photon and applied voltage between the target material remains fixed and at this situation if we increased the frequency value of photons between the target material and source then photocurrent value increase .the value of frequency of photon decides the minimum working range of any material that is called threshold frequency.

- Photo metal or target materials:-
  If we repeat this experiment for different material then we would get different values of threshold frequency for different materials

### 4.1.1.5 Earlier Study on the Photoemission:-

According to the lots of physics education research and its result shows the different fact. Professors of physics are bearing in mind and get the wrong impression about the easiness of photoemission concept and students' mastery in them.

Steinberg et al. (1996) performed the extensive study on the learning behavior of student about the photoemission effect by consisting student interview ant questionnaire related to this topic. They found that after result analysis of activity, many of the students unable to explain the basic concept and experimental arrangement of photoemission effect. Steinberg et al. (2000) mentioned following some difficulties:

- The student simply apply the concept V=IR to photoemission phenomenon
- The student cannot make difference between intensity of light and frequency of light
- The student apply thinking that a photon is a charged object
- The student unable to make any statement about the graphs of photoemission effect like I-V graph
- Unable to explain photon relation with photoemission effect
In summary, physics education research has shown that students do not know the basic information about the experimental circuit arrangement and the classical and quantum concept require for photoemission. By using traditional method, student could not achieve the learning goals of photoemission. While simulation based model of photoemission helps the students understand the concept in dipper way and prediction of result of experiment.

4.1.2 Detailed System Study:-

Recording the dynamic values of work function was required as a general java model development goal. The approach to develop the pseudo code for photoemission phenomenon was to use an apparatus as shown in fig to obtain the desired readings. Next the photocurrent current was measured and recorded for different material and simultaneously, the reverse voltage which was used for reduce the photocurrent value up to zero was noted. Finally, this data were analyzed to derive the value of work function for each target material. The system shown graphically in fig-4.4

Fig-4.4 Schematic in 3 parts of photoemission apparatus
All measurements were made in the applied physics Laboratory in SCOE Research Campus.

With this experimental set up (fig. 4.4), we can be able to perform the experiment number of times that can serve the quantum theory of radiation. The target material that is photocathode is not emitted the photoelectron if the incident photon of approximately one wavelength and applied potential in between the cathode and anode which opposes the energy of photoelectron. The potential energy gained (or kinetic energy lost) is $eV$ where “e” is the charge of the electron and $V$ is the potential difference or voltage between the anode and cathode. The voltage is required for the stopping of photoelectron current is directly proportional to the value of maximum kinetic energy of those photoelectrons.

$$KE_{\text{max}} = eVi$$

From the Einstein photon energy equation and plank’s description of black body radiation, the energy for photon, $E$, is given by-

$$E = h\nu = \frac{hc}{\lambda}$$

Where $h$ is Planck’s constant, $\nu$ is the frequency of the light, $\lambda$ is the wavelength of the light, and $c$ is the velocity of light in vacuum.

In this phenomenon, each of the incident photon energy transfers to the electrons in the metal surface. This total energy divides into two parts, some of energy is used to detach the electron from the metal surface (known as the work function, $\Phi$), while remaining part is used to the motion of the same electron that is kinetic energy of the electron.

According to equation of maximum kinetic energy (1) and energy (2) then
The value of work function varies from material to material and it is smallest for alkali materials. If we want the photoemission effect then the system should be satisfied the condition $h\vartheta > \Phi$. For accurate results, the value of small current must be noted.

4.1.3 Procedure of actual experiments:-

4.1.3.1 Front Panel of Photoemission phenomenon Apparatus:-
On the front panel of Photoemission phenomenon Apparatus, there exist four knobs, three buttons and two digital displays. The back panel of the apparatus consists of four ports (labeled A, K, ‘down arrow’, and POWER SUPPLY).
With the help of the apparatus, the value of the photocurrent can be ascertained through the photoemission tube and that of the voltage can be ascertained across the Photoemission tube.

• **Switch of Current Range:**
  This switch is useful for the defining and fixing the value of current. It can be available between the range of $10^{-8}$ A to $10^{-13}$ A.

• **Ammeter:**
  It is display on Photoemission phenomenon Apparatus for the measurement of the value of photocurrent from the process of photoemission.

• **Voltmeter:**
  It is display on Photoemission phenomenon Apparatus for the measurement of the value of potential or voltage which will be developed across the photoemission tube.

• **Switch of Voltage Range:**
  This knob is useful for changing the value of voltage from -2V to +30V. This range is applicable for designing the graph between current and voltage. Voltage knob also applicable to set the stopping potential of the different cathode material by changing -2V to 0 V.

• **ON or OFF knob:**
  On the front panel of apparatus the power switch act as ON and OFF function knob.

• **Adjustment of voltage:**
  This knob fixes the voltage value between from -2V to +30V which is applied across the photoemission tube and also fixes the value of stopping voltage.

• **Calibration of Current:**
  The value of instrumental current has to be zero for proper measurement of photocurrent and it can make at zero with current calibration knob.

• **Photoemission tube Signal switch:**
The Photoemission tube Signal switch has to set at CALIBRATION for calibration of photoemission tube current or has to set at MEASURE for measurement of photocurrent.

4.1.3.2 Measurement Accuracy
The precision of the values captured depends on two aspects. The first aspect is the small magnitude of the photocurrent. The second is the situation wherein the voltage is not capable of stopping due to the cathode dark current and the anode reverse current. In order to capture and measure even the smallest of photocurrents precisely, the instrument comes with a current amplifier that is highly sensitive and steady. The level of dark current as well as that of the anode reverse voltage is kept low in the photoemission tube.

4.1.3.3 Measurement of photocurrent-potential Characteristics of different cathode materials at Constant wavelength, and Different Intensity:

In order to evaluate and relate the photocurrent versus potential schematic of different cathode material at different incident photon intensities, the following steps need to be followed.

4.1.3.4 Arrangement of apparatus before Measurement:

1. Fix the mercury lamp source in mercury wooden box and close all the opening of mercury wooden box in such way that no light will pass through it. And also enclose the window of photon emission tube.
2. Make and set the power switch of mercury lamp and Photoemission phenomenon Apparatus at ON position.
3. The situation of mercury lamp and apparatus do not change up to 20 minutes because they needs warm up before the measurement.
4. Now after the heat up process make voltage range knob position and photocurrent range knob position at -2V to +30V and $10^{-11}$A respectively.
5. Remove the ‘A’, ‘K’, and ‘down arrow’ (GROUND) cables from the back panel of the apparatus. This will make zero status of the current amplifier.
6. Now set the photoemission tube signal switch at on calibration name side as shown in above fig.

7. Make the current value in current display at zero amperes by changing current calibration button.

8. After calibration process photoemission tube signal button set at measure side.

9. Cables of ‘A’ ‘K’ and ‘down arrow’ (GROUND) reconnect to its initial position on back side of the apparatus.

4.1.3.5 Procedure for measurement of potential and photocurrent of photoemission tube at Constant wavelength and Different Intensities (Sodium metal as cathode):

For Slit dimension 3 mm:-

1. Open the window of box of photoemission tube and place the slit 3 mm dimension on the front of tube and also set the filter whose filtering range is 425nm after the slit for constant value of wavelength i.e. frequency also.

2. Open window of mercury source wooden box, the light will emits from source and it will falls on filter and hence finally the spectral line whose wavelength is 425nm will falls on cathode material of photoemission tube.

3. Do the change and rotate voltage adjust switch on front panel of apparatus from -2 V to +30V in such way that the value of current display will set on zero not this value of current and voltage.

4. Now increase the value of voltage in small equal interval manner and also not the value of current with respect the voltage in observation table.

5. The process will continue for the end of the VOLTAGE range switch.

For Slit dimension 6 mm:-

1. Open the window of box of photoemission tube and place the slit 6 mm in the place of 3mm slit dimension on the front of tube and also set the filter whose filtering range is 425nm after the slit for constant value of wavelength i.e. frequency also.
2. Open window of mercury source wooden box, the light will emits from source and it will falls on filter and hence finally the spectral line whose wavelength is 425nm will falls on cathode material of photoemission tube.

3. Do the change and rotate voltage adjust switch on front panel of apparatus from -2 V to +30V in such way that the value of current display will set on zero not this value of current and voltage.

4. Now increase the value of voltage in small equal interval manner and also not the value of current with respect the voltage in observation table.

5. The process will continue for the end of the VOLTAGE range switch.

For Slit dimension 9 mm:-

1. Open the window of box of photoemission tube and place the the slit 9 mm in the place of 6 mm slit dimension on the front of tube and also set the filter whose filtering range is 425 nm after the slit for constant value of wavelength i.e. frequency also.

2. Open window of mercury source wooden box, the light will emits from source and it will falls on filter and hence finally the spectral line whose wavelength is 425nm will falls on cathode material of photoemission tube.

3. Do the change and rotate voltage adjust switch on front panel of apparatus from -2 V to +30V in such way that the value of current display will set on zero not this value of current and voltage.

4. Now increase the value of voltage in small equal interval manner and also not the value of current with respect the voltage in observation table.

5. The process will continue for the end of the VOLTAGE range switch.
4.1.4.1 Primary Data:

4.1.4.2 Sample readings of actual experiment For Following Materials:-

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Different Photosensitive (Target) Metals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aluminium</td>
</tr>
<tr>
<td>2</td>
<td>Calcium</td>
</tr>
<tr>
<td>3</td>
<td>Copper</td>
</tr>
<tr>
<td>5</td>
<td>Iron</td>
</tr>
<tr>
<td>6</td>
<td>Magnesium</td>
</tr>
<tr>
<td>8</td>
<td>Sodium</td>
</tr>
<tr>
<td>9</td>
<td>Zinc</td>
</tr>
<tr>
<td>10</td>
<td>Barium</td>
</tr>
<tr>
<td>11</td>
<td>CsNaK3Sb</td>
</tr>
<tr>
<td>12</td>
<td>Potassium</td>
</tr>
</tbody>
</table>

Table:-4.1 actual materials for actual experiment

A. Measurement of potential and photocurrent of photoemission tube at Constant wavelength and Different Intensities (Sodium metal as cathode):

By applying the above procedure, the following readings were noted at constant wavelength (frequency) 425 nm for different intensities. The following observation table shows the measured values of photocurrent and potential.
Same type of measurement is applicable for different cathode material by using same apparatus and same procedure of measurement.

**B. Measurement of photocurrent-potential Characteristics of different cathode materials at Constant Intensity, and Different wavelength:**

In order to assess the current versus voltage characteristics of different wavelength, 125, 150, 175, 200, 225, 250, 275, 300, 325, 350, 375, 400, 425, 450, 475, 500, 525, 550, 575, 600, 625, 650, 675, 700, 725, and 750 nm respectively, the following steps should be followed:

**C. Arrangement of apparatus before Measurement:**

1. Fix the mercury lamp source in mercury wooden box and close all the opening of mercury wooden box in such way that no light will pass through it. And also enclose the window of photon emission tube.
2. Make and set the power switch of mercury lamp and Photoemission phenomenon Apparatus at ON position.

3. The situation of mercury lamp and apparatus do not change up to 20 minutes because they needs warm up before the measurement.

4. Now after the heat up process make voltage range knob position and photocurrent range knob position at -2V to +30V and $10^{-11}$A respectively.

5. Remove the ‘A’, ‘K’, and ‘down arrow’ (GROUND) cables from the back panel of the apparatus. This will make zero status of the current amplifier.

6. Now set the photoemission tube signal switch at on calibration name side as shown in above fig.

7. Make the current value in current display at zero amperes by changing current calibration button.

8. After calibration process photoemission tube signal button set at measure side.

9. Cables of ‘A’, ‘K’, and ‘down arrow’ (GROUND) reconnect to its initial position on back side of the apparatus.

D. Procedure for measurement of potential and photocurrent of photoemission tube at Constant wavelength and Different Intensities (Sodium metal as cathode):

1. Open front cavity of photoemission tube and also, set the specific value of the dimension of slit as per user requirement for constant value of intensity of photon.

2. Use the different color filters for making different wavelength and keep the position of filters in between source and tube but the value of dimension of slit remains constant throughout the experiments.

3. Open the window of wooden box of source then photon will falls on filter which will be fixed as per requirement of wavelength.

4. The particular wavelength of photon will passes through the filter and will shine on cathode in photoemission tube.

5. It will shows photocurrent value in display.

6. Make note of photocurrent and wavelength in following table

7. Apply the same procedure for different wavelengths and measure the value of photocurrent.
E. Measurement photocurrent of photoemission tube at Constant intensity and Different wavelength (Sodium metal as cathode):

As per above discussion and by applying above process, the measurement of photocurrent is done for different wavelength and these are as follows.

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Current (Amps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
<td>1.094</td>
</tr>
<tr>
<td>150</td>
<td>1.315</td>
</tr>
<tr>
<td>175</td>
<td>1.535</td>
</tr>
<tr>
<td>200</td>
<td>1.695</td>
</tr>
<tr>
<td>225</td>
<td>1.293</td>
</tr>
<tr>
<td>250</td>
<td>0.964</td>
</tr>
<tr>
<td>275</td>
<td>0.731</td>
</tr>
<tr>
<td>300</td>
<td>0.549</td>
</tr>
<tr>
<td>325</td>
<td>0.406</td>
</tr>
<tr>
<td>350</td>
<td>0.298</td>
</tr>
<tr>
<td>375</td>
<td>0.209</td>
</tr>
<tr>
<td>400</td>
<td>0.141</td>
</tr>
<tr>
<td>425</td>
<td>0.089</td>
</tr>
<tr>
<td>450</td>
<td>0.051</td>
</tr>
<tr>
<td>475</td>
<td>0.025</td>
</tr>
<tr>
<td>500</td>
<td>0.009</td>
</tr>
<tr>
<td>525</td>
<td>0.001</td>
</tr>
<tr>
<td>550</td>
<td>0</td>
</tr>
</tbody>
</table>

Table: Actual readings of potential and photocurrent at constant intensity for Na

Similarly the following table shows the measurement of photocurrent for different cathode material at various wavelengths at constant value of intensity.
4.1.4.2.1 Sample readings from actual experimental setup on Model No. AP-8209:

Table: 4.4 actual readings of potential and photocurrent at constant intensity for different materials

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>125</th>
<th>150</th>
<th>175</th>
<th>200</th>
<th>225</th>
<th>250</th>
<th>275</th>
<th>300</th>
<th>325</th>
<th>350</th>
<th>375</th>
<th>400</th>
<th>425</th>
<th>450</th>
<th>475</th>
<th>500</th>
<th>525</th>
<th>550</th>
<th>600</th>
<th>650</th>
<th>700</th>
<th>750</th>
<th>800</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery 0 V</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Intensity to 100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Different Target Material Current (Amps)</td>
<td>1.094</td>
<td>1.315</td>
<td>0.89</td>
<td>0.507</td>
<td>0.261</td>
<td>0.102</td>
<td>0.026</td>
<td>0.0</td>
<td>0.147</td>
<td>0.08</td>
<td>0.034</td>
<td>0.009</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Aluminium</td>
<td>1.094</td>
<td>1.315</td>
<td>1.077</td>
<td>1.2</td>
<td>0.564</td>
<td>0.086</td>
<td>0.027</td>
<td>0.247</td>
<td>0</td>
<td>1.217</td>
<td>0.068</td>
<td>0.003</td>
<td>0.009</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Calcium</td>
<td>1.094</td>
<td>1.315</td>
<td>0.661</td>
<td>0.329</td>
<td>0.132</td>
<td>0.027</td>
<td>0.095</td>
<td>0</td>
<td>0.147</td>
<td>0</td>
<td>0.002</td>
<td>0.001</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Copper</td>
<td>1.094</td>
<td>1.315</td>
<td>1.126</td>
<td>0.703</td>
<td>0.416</td>
<td>0.213</td>
<td>0.731</td>
<td>0</td>
<td>0.089</td>
<td>0</td>
<td>0.051</td>
<td>0.141</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Iron</td>
<td>1.094</td>
<td>1.315</td>
<td>1.535</td>
<td>1.695</td>
<td>1.293</td>
<td>0.964</td>
<td>0.604</td>
<td>0</td>
<td>0.041</td>
<td>0</td>
<td>0.016</td>
<td>0.109</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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4.2 Case -2: M Verses H Characteristics for Different Material

4.2.1 Need of simulation model of M Verses H Characteristics:

In this chapter, the modelling of hysteresis loop has been carried out because angle of it has different application in different areas for example in broad band transformer. Above mention each application depends upon the nature of hysteresis loop and hence for each application area demands simulated hysteresis loop, as a result simulation hysteresis model requirement for each application. Functioning simulation model is developed on only hysteresis concept but in scope of future it can be extended in concept of magnetic material model for characterization, magnetic material model for optimization, simulation of system. The basic aim of this chapter is to make available java based computer simulation model for hysteresis phenomenon of magnetic material with efficiently and accurately.

In magnetic studies, some of the characteristic are strongly requires like exact information of magnetic parameters and finding methods of them. These parameters are not only very important as per the academic point of view but also they are very important for manufacturers and magnetic material users.

For defining the quality of magnetic material commonly four parameters are used that are value of coercivity, retentivity of the magnetic material after removing external magnetic field, saturation of magnetization at high value of applied magnetic field and hysteresis loss. Along with these one characteristic also required that is a number of magnetic phases present in system which is useful for understanding magnetic substance performance and for improvement of quality of substance.

The above mentioned all the characteristics of magnetic substance can be measure from the hysteresis curve. In practical methods of hysteresis tracer requires different forms of sample like ring, thin film, wires, rocks or mineral forms but the most useful form of sample is ring or Toroidal in which the arrangement of magnetic circuit is closed and hence there is no chance of demagnetization process. Practically it is not possible to design all material in ring forms without free ends.

In case of open magnetic circuit samples, the free ends produces demagnetizing effects and hence applied field of specimen decreases and it causes non uniform field
around specimen. That is why in case of magnetic material requires the reduced hysteresis loop.

Eddy current is one of a factor generated due to the periodic variation in external magnetic field surrounding the specimen and it creates different extra issues in conducting ferromagnetism process. These current produces extra magnetic field in the sample and that magnetic field neutralizes changes of the external field because these field is having different value of magnitude and phase from the applied field. The eddy current also produces resistive heating of the substance and makes the different in the path of forward and backward of magnetic field near saturation. And hence it replaces horizontal line with a small loop in graph of magnetic polarization (J) verses magnetic field (H).

A retentivity is the intercept on magnetic polarization axis and saturation point is the tip of magnetic polarization at which the value of magnetic field becomes very high. From above discussion, retentivity ($J_r$) of the magnetic substance and value of saturation magnetic polarization ($Js$) are the intercept value on J and height of tip respectively.

The exact value of coercivity obtained from the intercept of H axis is equal to zero when the value of eddy current becomes zero. And hence the value of eddy current will be more for thicker sample as compare to slim one.

In Magnetic materials, there are some topics which are very hard to understand and calculate by the theoretical or mathematical methods and thus they are waiting for deal with simulation. Today’s, some of the issues in magnetic materials are following that are waiting for good simulation model which can be able to resolve and give answer of following issues with simulation:

- Comprehensive core hysteresis modelling
- Comprehensive core structure that is domain modelling
- Influential behavioral of magnetic material under external temperature
- Precise simulation model of the Relationship between Magnetic Hysteresis and Electrical Waveform
- Characterization model from the physical data for device
- Precise simulation modelling of frequency effect in core and windings that is eddy currents
g. Characterization model of inductance leakage and losses
h. Simulation model for different waveforms
i. Precise measurement of distortion model
j. Precise model for impedance

Above all the issues are the important part in applications of magnetic material, Passive Fault Current Limiters and Switch Mode Power Supplies; Thus in this chapter, the first issue considered for simulation model and remaining available for future work modelling.

4.2.2 Design principal behind the B-H curve apparatus:
The solenoid is connected to the electrical supply hence the coil produces alternating type of magnetic field.
A cylindrical simple is kept in solenoid along the axis is then simple under goes in to influence of the magnetic field and it acquires periodic variations. The solenoid produces magnetic field after the passing periodic variation type of electric signal is Ha and hence the resultant field acts on a cylindrical sample would be (H)

\[ H = Ha - NM \]  

(1)

Where M is quantity of sample magnetization,
Or

\[ H = Ha - NJ / \mu_o \]

Where N is factor of normalized demagnetization of sample and the magnetic polarization (J) is derived from magnetic induction equation as

\[ B = \mu_o H + J \]  

and also

\[ B = \mu H = \mu_o (H + M) \]

A electric field is applied to the solenoid can be written as,
\[ E_1 = C_1 H_a \]  

(2)

Where \( C_1 \) is a constant

The emf is produce in pick coil whose area is \( A_c \) due to the a cylindrical sample which is fixed inside the pickup coil and for are of sample is \( A_s \)

\[ \varphi = \mu (A_c - A_s) H' + A_s B \]  

(3)

In above equation the quantity \( H' \) is magnetic field value measure when the pick coil area will be absent. The value of \( H' \) is not equal to the value of \( H \), the difference between this two quantity is nothing but the value of magnitude of demagnetizing field and the value of magnetite of demagnetization filed will be small or negligible if the value of magnitude of division between the length of sample rod and pick up coil diameter is greater than 10 hence the above equation becomes

\[ \varphi = \mu (A_c - A_s) H' + A_s B = \mu_0 A_c H + A_s (B - \mu_0 H) \]

\[ \varphi = \mu_0 A_c H + A_s J \]  

(4)

The emf produces in pick up coil is \( e_2 \) and it is directly proportional to \( \frac{d\varphi}{dt} \).

By integrating the value of \( e_2 \) the new equation will be obtained that is the equation of signal \( e_3 \) being -

\[ e_3 = C_3 \varphi = C_3 \mu_0 A_c H + C_3 A_s J \]  

(5)

by simplifying equation 1,2,and 5 then the modified equation in the form of \( J \) and \( H \) are as fallow-

\[ C_1 C_3 A_c \left( \frac{A_s}{A_c} - N \right) J = C_1 e_3 - \mu_0 C_3 A_c e_1 \]  

(6)
The sample may be designed by same type of magnetic materials or different type of magnetic materials. If the sample material is designed from the ingredients having the different magnetic property then each component of sample produces its own loop, each individual loop may be in different phase of other loop that means all the loops will be in different phases. By the summing of all this value of individual loop the resultant loop will be formed. The final aim of this calculation to produce the value of J and H and that can be seen on CRO screen.

The multilayer solenoid is subjected under the AC signal at 50Hz and it can change with transformer. This arrangement produces the magnetic field inside and outside the coil. The solenoid magnetic field produces small current and it passes into the resistor which is connected in series to solenoid. A pick up coil which is turn around on none conducting sample holder tube produces emf that is represented with notation e2.

All the required arrangement is properly done before the placing sample i sample holder and in pick up coil. The output signal is connected to CRO and it is equal to value of J.

When the current I is passing through the solenoid then the magnetic field of solenoid at centre position will be

\[ H_a = K_i \text{ or } e_1 = R_1 i \]

\[ E_1 = R_1 / K H_a \]

Then by putting the value \( \phi \) of in e2 equation, we have

\[ e_2 = n \mu_0 Ac (dH / dt) + nAs (dJ / dt) \]

But we know that integration of e2 is e3 and hence-

\[ \int e_2 dt = -G_1nuvAcH - G_1nAs \]

\[ \int e_2 dt \]

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By the grouping of phase shifter and integrator causes the gain of the system $G_1$.

As per the above discussion $G_y$ is the amplification value from the admission of $e_1$ and $e_3$. Hence

$$
ey = -G_y(e_1 - e_3) = -G_y(C_1H + \frac{C_1NJ}{\mu_0} - G_1\eta A_s f)$$

After setting the value of $c_1$ is equal to H, above equation becomes-

$$
ey = G_y G_1 \eta A_c \left(\frac{A_s}{A_c} - N\right) J. \quad (8)$$

Ex is the input value of signal of $x$ and it is the resultant of addition and amplification of signal $e_1$ and $-e_3$ respectively hence it gives-

$$
ex = G_x(e_1 - B e_3) = -G_x G_1 \eta A_c B H + G_x G_1 \eta A_c (N - B \frac{A_s}{A_c}) J$$

The value of $J$ is replaced with $\alpha$ and $\beta$ in the right hand side of above equation and simplifying it –

$$
\alpha = \frac{A_s}{A_c}, \quad \beta = N
$$

The simplified equation for $e_x$ is-

$$
ex = G_x G_1 \eta A_c \left(\frac{A_s}{A_c} - N\right) H \quad (9)$$

by using equation (8) and (9), we may derived the equation for $H$ and $J$ as given below-

$$
H = G_0 \frac{\ex}{\frac{A_s}{A_c} - N} = G_0 \frac{\ex}{\frac{A_s}{A_c} - N}
$$
\[ J = \frac{G \mu_0 \phi y}{G y (\frac{A_i}{A_c} - N)} \]  \hspace{1cm} (10)

Where
\[ Go = \frac{1}{G x G \mu_0 A_c} \]  \hspace{1cm} (11)

From Equations (10) and (11) the value of H and J can be calculated with the signals and ey.

4.2.3 Set-Up, Procedure and Calibration (Hysteresis Loop Tracer Model: HLT-111):

Fig: 4.6 - actual apparatus of HYSTERESIS LOOP TRACER Model: HLT-111
Manufactured by Scientific Equipment & Services
1. Make the arrangement of apparatus as shown in fig-4.6 with CRO, here we have used the model: HLT-111 for hysteresis parameter measurement.

2. Before taking the reading apparatus should be calibrated, this can be possible as following way:- put the sample holder i.e. picks coil in the solenoid and observe the output of magnetic field representation line on CRO. This line obtained on CRO is due to only flux linking with coil area. If the line is not in the form of straight line, then adjust with phase knob of the instrument. By this way, the calibration of instrument can be possible.

3. If we use any sample for the studying its hysteresis characteristics then the value of factor of demagnetisation of that sample and area ratio of that sample depends upon the dimension of respective sample and these two values are standard and therefore we can obtain from the reference of appendix of user manual of model: HLT-111.

4. After knowing the value of demagnetisation factor and area ratio, adjust this value with demagnetisation and area ratio knob on the apparatus.

5. Now fix the Nickel sample in sample holder and keep the sample holder coaxially inside the solenoid. When the flow of current will starts and solenoid will produces the magnetic field. these value can be read on display.

6. Already the output signal is connected to the CRO and at this time it shows the loop on it instead of straight line.

4.2.3.1 Laboratory Experiment of M-H curve:

The actual experiment set up of M-H curve apparatus (HLT-111)is useful for the study and measurement of magnetic hysteresis phenomenon. In whish with the help
of magnetic loop the calculation and measurement of the retentivity, coercivity and saturation magnetization factor can be possible by controlling the external applied magnetic field.

4.2.3.2 Laboratory apparatus of M-H curve:-
The simulation model of M-H curve experiment is developed on the basis of actual reading data and actual calculation which was performed on the actual experiment kit. The equipment having the following features-
1. For the measurement and collecting the data HLT-111 is applicable.
2. Observations.
Diameter of coil turn around the non conduction sample tube (pickup coil) = 3.22 mm.
Value of Gx factor = 100.
Value of Gy factor = 1
Used Sample type: Commercial Thin Nickel cylindrical rod
Complete cylindrical rod Length = 38 mm.
Diameter of cylindrical rod = 1.19 mm.
Demagnetization = β= N= 0.0028.
3. The complete experiment set can be calibrated with calibration method.

A. M-H curve Apparatus Settings before Calibration:
Before the calibration, the following settings are very important:
The pickup coil should be empty that no sample in the sample tube
The value of H should be fixed at set of scales
The DC current should be fixed at set of scales
The value of demagnetisation factor set to be 0
Area ratio between As and Ac is being 0.389
Root mean square value of applied magnetic field (Ha) will be = 209 Gauss

B. M-H curve Apparatus Calibration And Observations:
As per the discussion above discussion, the apparatus has been set for calibration. Then the value of ex is recorded 7 volts from the apparatus other setting remains as calibrated and the value of area ratio was very small (0.389).
For calculating the value of $G_0$, the Area ratio between $A_s$ and $A_c$ is set as 1.00 and other position of the apparatus remains as it is then the recorded value of signal $e_x$ was equal to 18 V. Hence the value of $G_0$ in terms of relation is

$$e_x = \frac{H_a}{G_0}$$

$G_0(\text{rms}) = \frac{H_a}{e_x} = \frac{209}{18} = 11.61$ gauss/volt

$G_0(\text{rms}) = \frac{H_a}{e_x} = \frac{209}{18} = 11.61$ gauss/volt

$G_0(\text{peak}) = \frac{G_0(\text{rms})}{2\sqrt{2}} = \frac{11.61}{2\sqrt{2}} = 4.105$ gauss/volt

### 4.2.3.3 Lab Procedures:

1. Connect the apparatus to electrical supply and make power switch position of apparatus at ON.
2. The magnetic field knob on the front panel of apparatus is useful for changing the magnetic field of the solenoid. Hence vary the magnetic field of the system with magnetic field switch.
3. The M-H loop will be displayed on the CRO screen whenever the value of magnetic field switch is stopped.
4. Now measure the width of loop from left to right in horizontal way as well as measure the pick to pick distance of loop and record all this values for each magnetic field in observation table.
5. Draw the graph loop width verses applied magnetic field
6. From this graph, find the value of intercept of straight line and width of loop, put this value in following equation and calculate the value of coercivity.
\[ H = G_0 \frac{e^x}{A_s A_c - N} \]

\[ H_e = \frac{e x (0.5 \times \text{loop width})}{(A_s - N)} \]

7. From the graph of loop width verses applied magnetic field find the value of tip to tip length and put this value in following equation for calculation value of saturation magnetization

\[ M_s = \frac{G_0 \mu r x (0.5 \times \text{tip to tip length})}{4\pi G_x \times (A_s - N)} \text{ gauss} \]

8. Now measure the distance between the two points from reference point on graph at which value of H becomes zero but still M will not be zero. This is point of retentivity. It can be calculated with

\[ M_r = \frac{G_0 \mu r x (0.5 \times \text{intercept distance})}{4\pi G_x \times (A_s - N)} \text{ gauss} \]
4.2.4 Observation Tables:-

4.2.4.1 For Coercivity:-

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Mag. Field (rms)</th>
<th>2xLoop width</th>
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<tr>
<td></td>
<td>(Gauss)</td>
<td>(mm)</td>
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4.2.4.2 For Saturation Magnetization:

<table>
<thead>
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<th>Tip to tip height (mv)</th>
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4.2.4.3 For Retentivity:-

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<tr>
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4.2.5 Calculations:-

By using the above readings, we drawn grapes of a) Magnetic Field verses loop width, b) Magnetic Field Verses Tip to tip Height and c) Magnetic Field verses intercepts. From the graphical calculation of above three graphs the following value can be obtained:-

Coercivity: 37.3
Saturation magnetization: - 461 gauss

Retentivity: - 267

Now In next chapter we have described the simulation model of above two cases which are developed on the basis of actual results.