FEEDER PIPELINE WALL THICKNESS MEASUREMENT
Using
Pulse Eddy Current Technique

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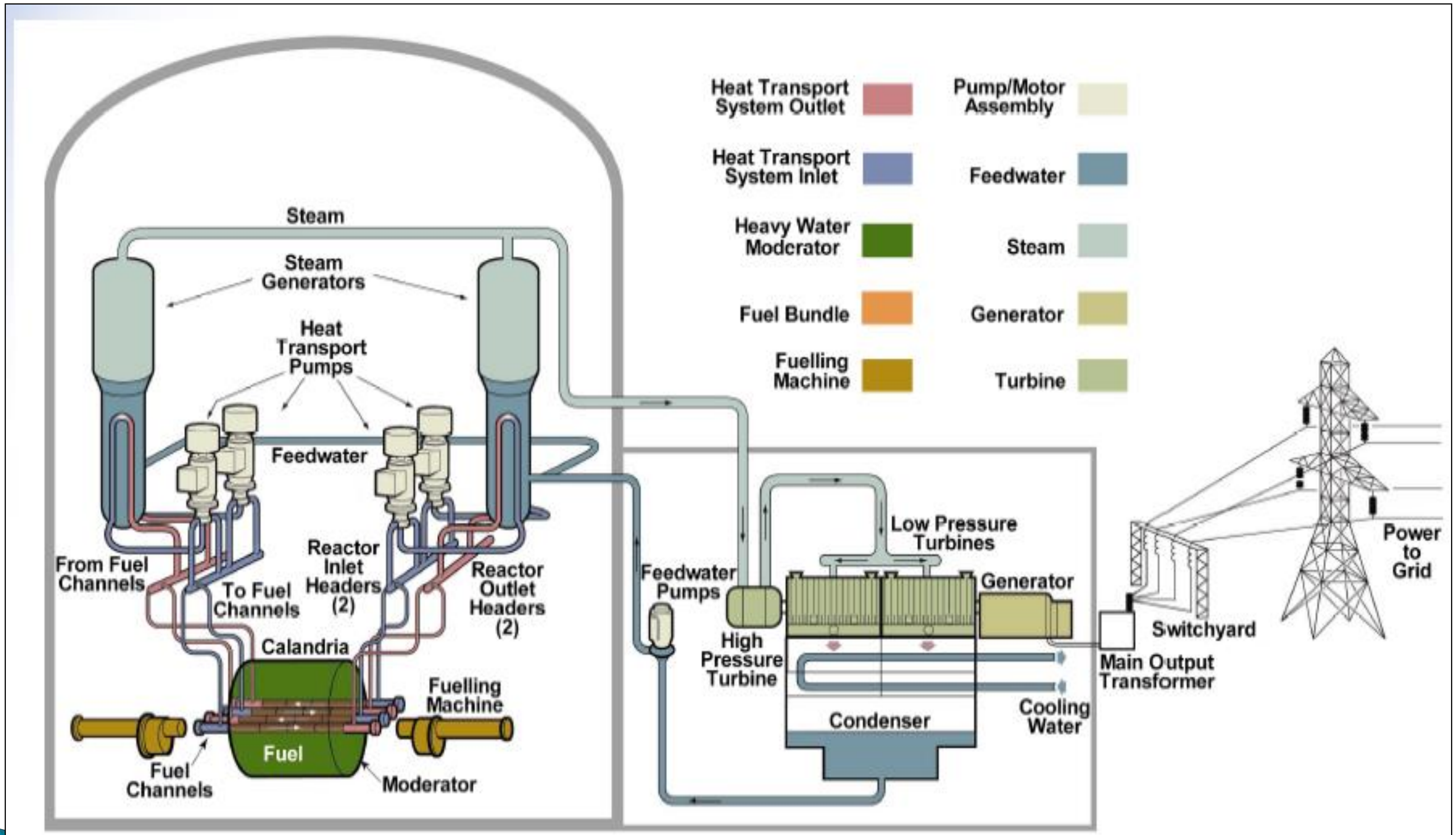
The Indian PHWR



The Indian PHWR

- The **220 MWe** Indian CANDU Type PHWR are horizontal Pressure tube type reactors.
- There are **306** Pressure tube with each channel consisting of **12** Fuel bundles, with each fuel bundle consisting of **19** zircalloy clad Natural Uranium based fuel.
- The maximum temperature at the inlet and the outlet of the fuel channels Is **249** degree C and **293.4** degree C.
- The Pressure at the inlet being **101** Kg/cm^2 and **87** Kg/cm^2 respectively.
- Heavy water is used as a coolant as well as a moderator.
- Each day around **8** fuel bundles are replaced from one coolant channel from one side and fresh fuel bundles are given from the opposite side using robotic fuelling machines.

What are feeder pipes

- Feeder pipes are used to carry the coolant from the headers in PHWR’s to the pressure tubes and again to the Steam generator.
- They are made up of carbon steel.(SA – 333 , grade – 6)
- In the process of coming down from the headers they have bends and elbows. It is seen that they suffer from flow accelerated corrosion in the elbows.
- The rate of corrosion is found to be maximum at the outlet elbows because of higher temperature.

Factors Affecting The FAC Rate

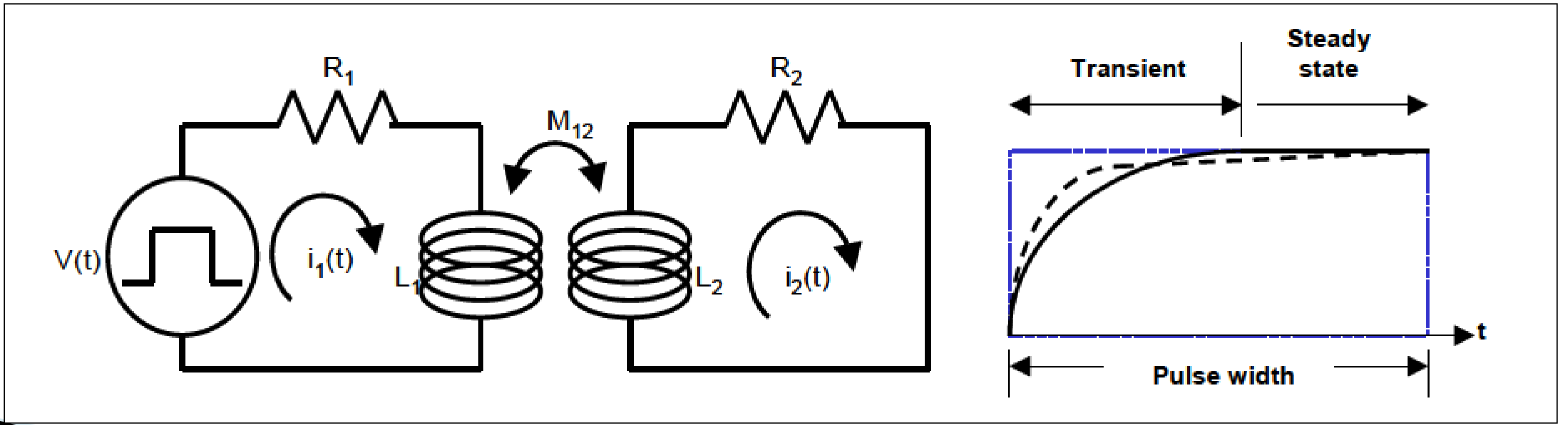
- Physical Factors :- It includes the Factors like Temperature and the Shear Stress distribution as well as the velocity profile. Proportional to Q*V .
- Chemical factors :- Depends on the Oxygen concentration and the PH of the coolant.
- Geometrical factors :- Depends on the structure of the pipes. Bends leads to formation of turbulance.

Dimensions of Feeder pipes in 220 Mwe PHWR

SL.NO	Nominal Size	ID (mm)	Feeder Pipeline WT(mm)	Feeder Elbow WT(mm)
1	32mm	31.5	5.5	6.35
2	40mm	38.10	5.8	7.15
3	50mm	49.25	6.75	8.70
4	65mm	59	7.40	---

Pulsed eddy current testing

- Earlier Ultrasonic testing was popularly used.
- High MAN- REM consumption during application of couplant while surface preparation.
- PECT is an advanced NDT technique which has evolved from conventional ECT and uses pulses for excitation other than using continuous sinusoidal single frequency or multi frequency excitation.
- Both **Time domain** as well as **Time - Frequency** analysis can be done on the waveform to correlate with thickness.



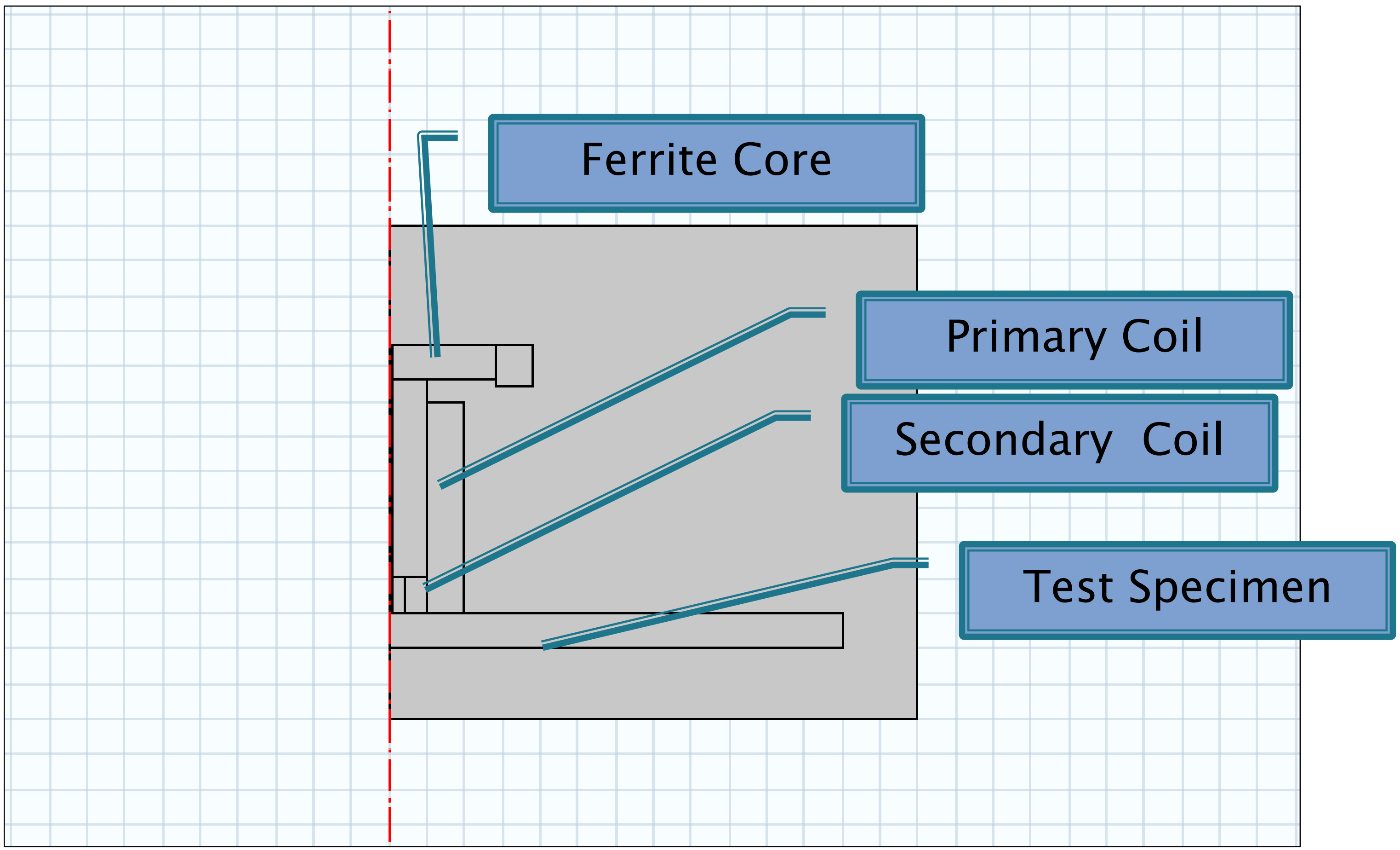
Principle of PECT

- The **Pulsed Excitation** having multiple frequency components will have a flux of it’s own.
- The Magnetic Flux will penetrate the specimen which in this case is **Carbon Steel Feeder Pipes.**
- The Varying flux in the specimen will induce a **voltage** on the surface of the specimen.
- Due to this induced voltage currents , called **EDDY** currents will flow in circular paths.
- Eddy Current will have a **Magnetic** field of it’s own.(Opposite to the Magnetic field of excitation coil following **Lenz law**)
- The net Magnetic field sensed by the **Receiver coil** is the vector difference of the magnetic field of the Excitation coil and the eddy current .
- The voltage induced in the **Receiver coil** is due this change in **Magnetic flux** in the **Receiver**.

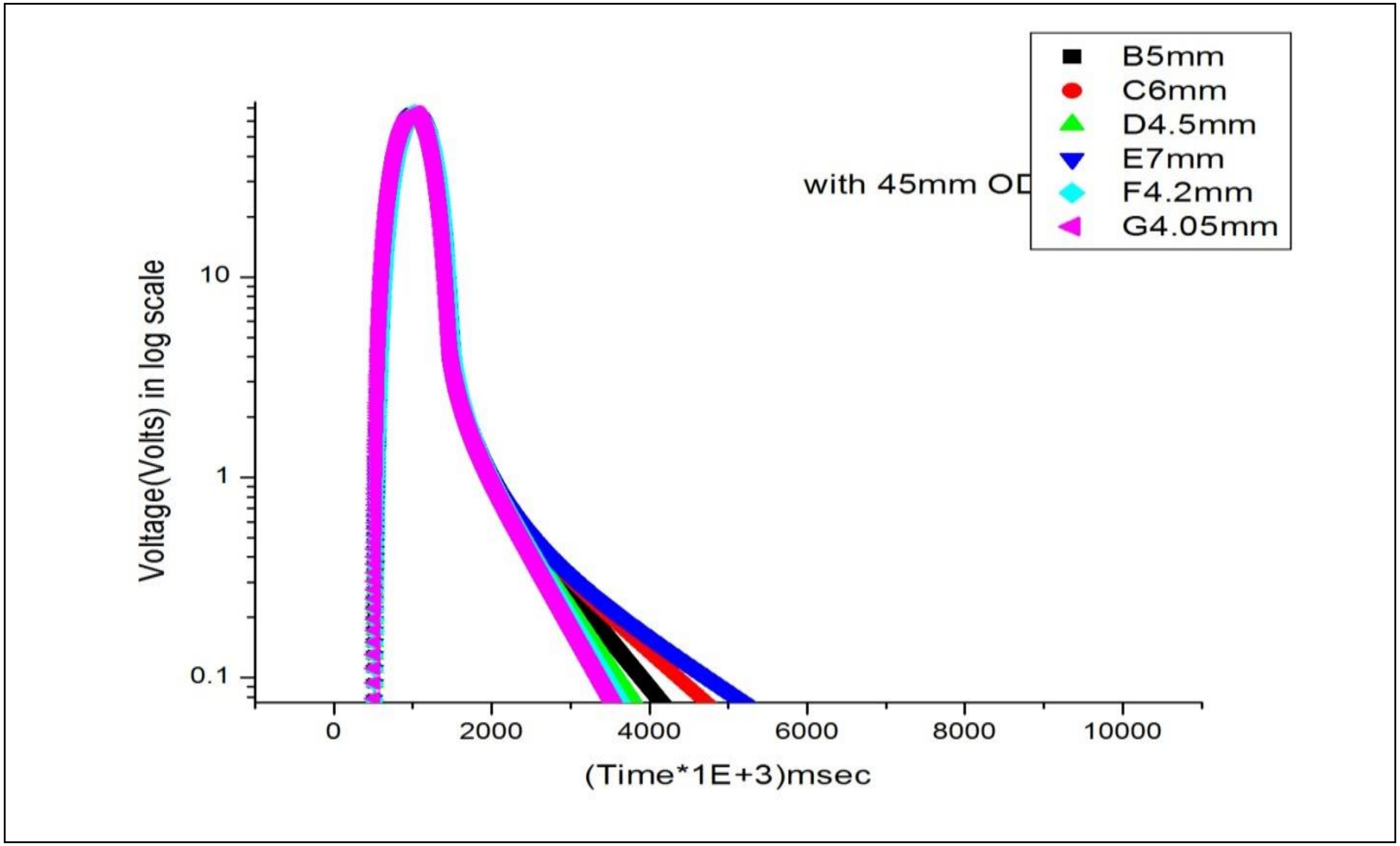
Advantages of PECT

- As it uses pulses instead of single frequency excitation hence it has multiple frequencies and hence can give both surface and depth information.
- Energy delivered to the coil per pulse is much higher than A.C. excitation.
- Power consumption is also less in PECT than conventional ECT.
- Instrumentation is also simpler.

2D Modeling Of PEC Probe

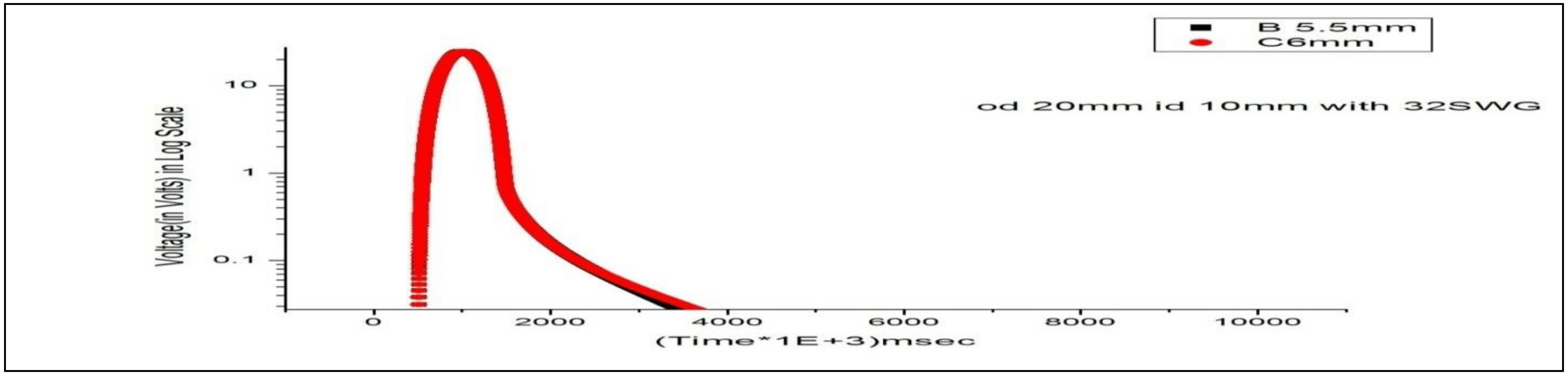


Results of PEC probe with air core modeling

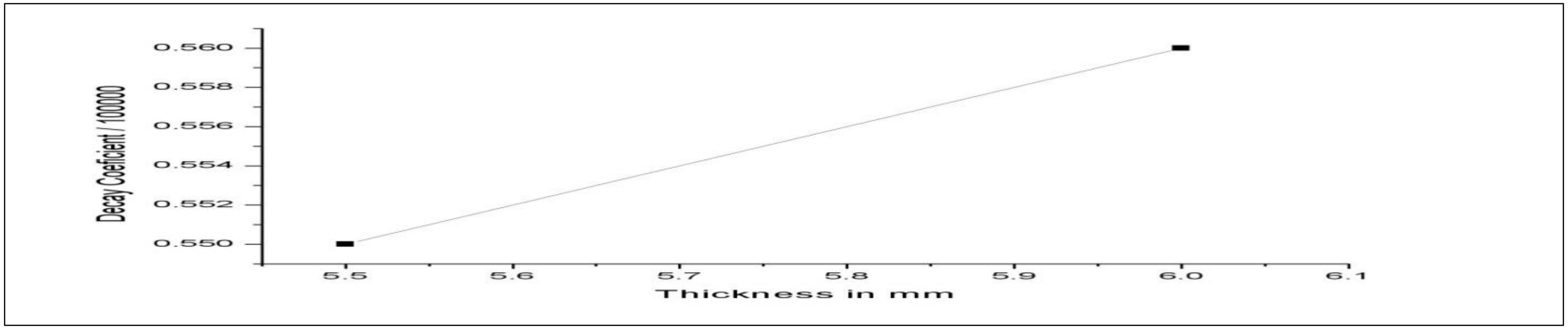


Response of The Sensor With Transmitter Coil OD- 45mm and ID – 15mm

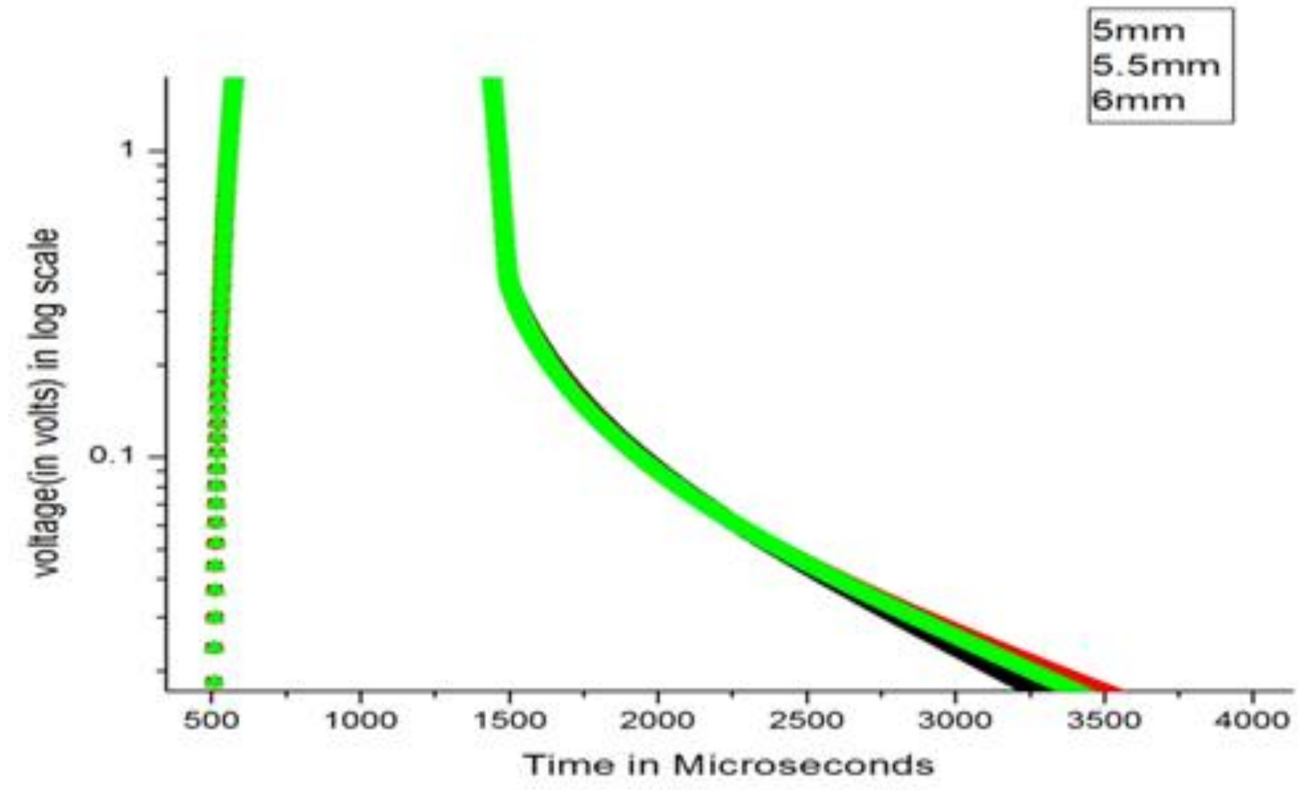
Results of Modeling of PEC probe with air core



Response of the sensor With Transmitter Coil having OD – 20mm and ID – 10 mm with 32 SWG wire gauge with Air Core.

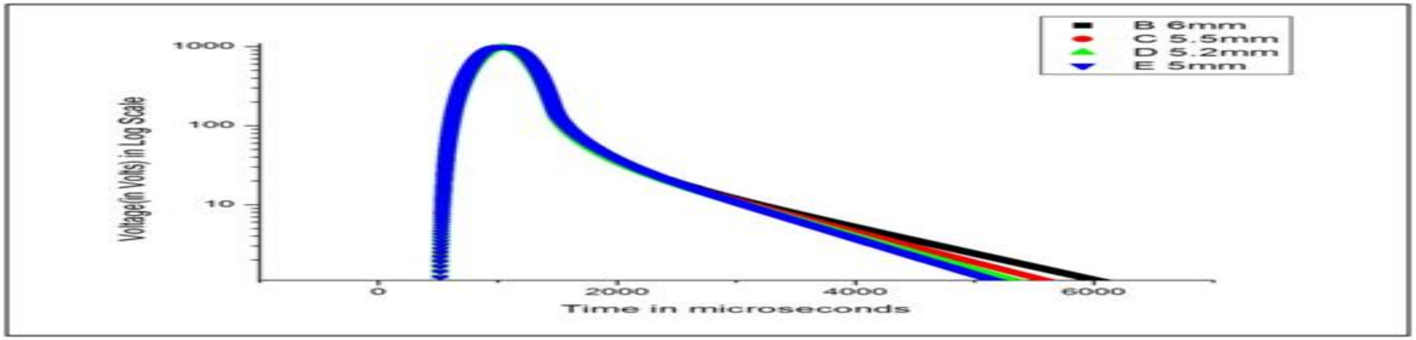


Results of PEC probe with Ferromagnetic Core

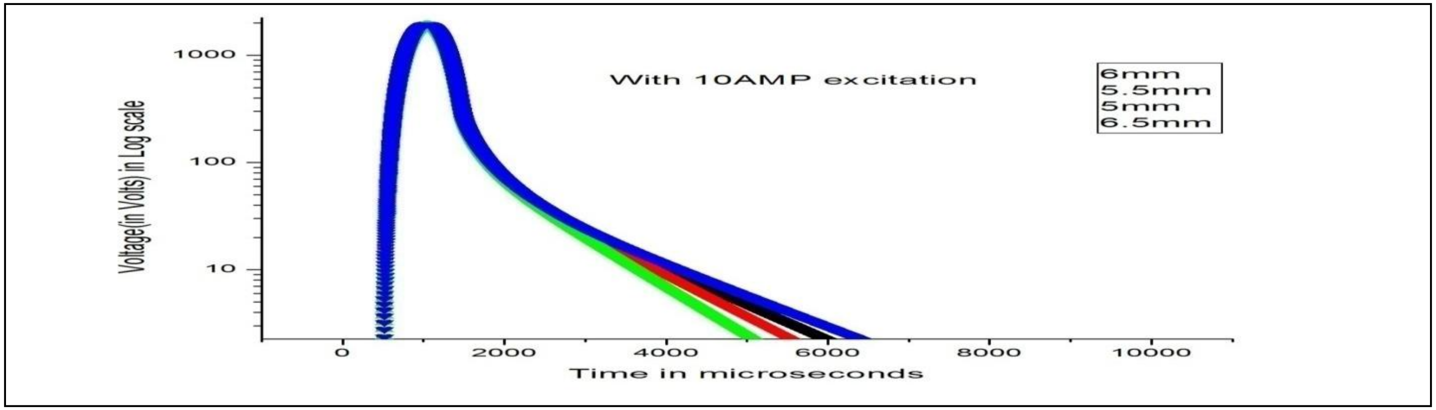


Response of the sensor With Transmitter Coil having OD – 20mm and ID – 10 mm with 32 SWG wire gauge with Ferrite Core

Modeling results for different current Primary Excitation

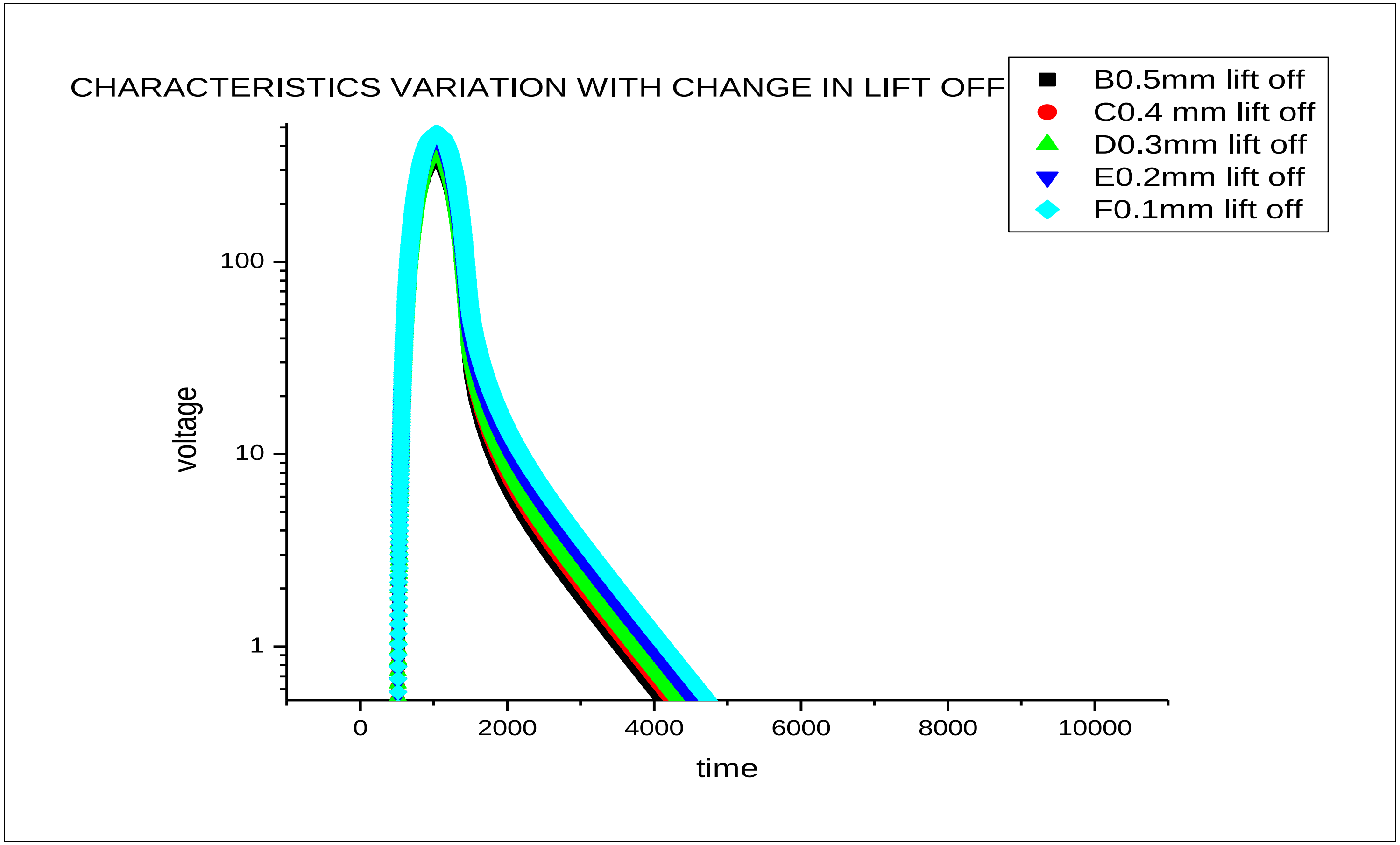


For 5 Amps Excitation

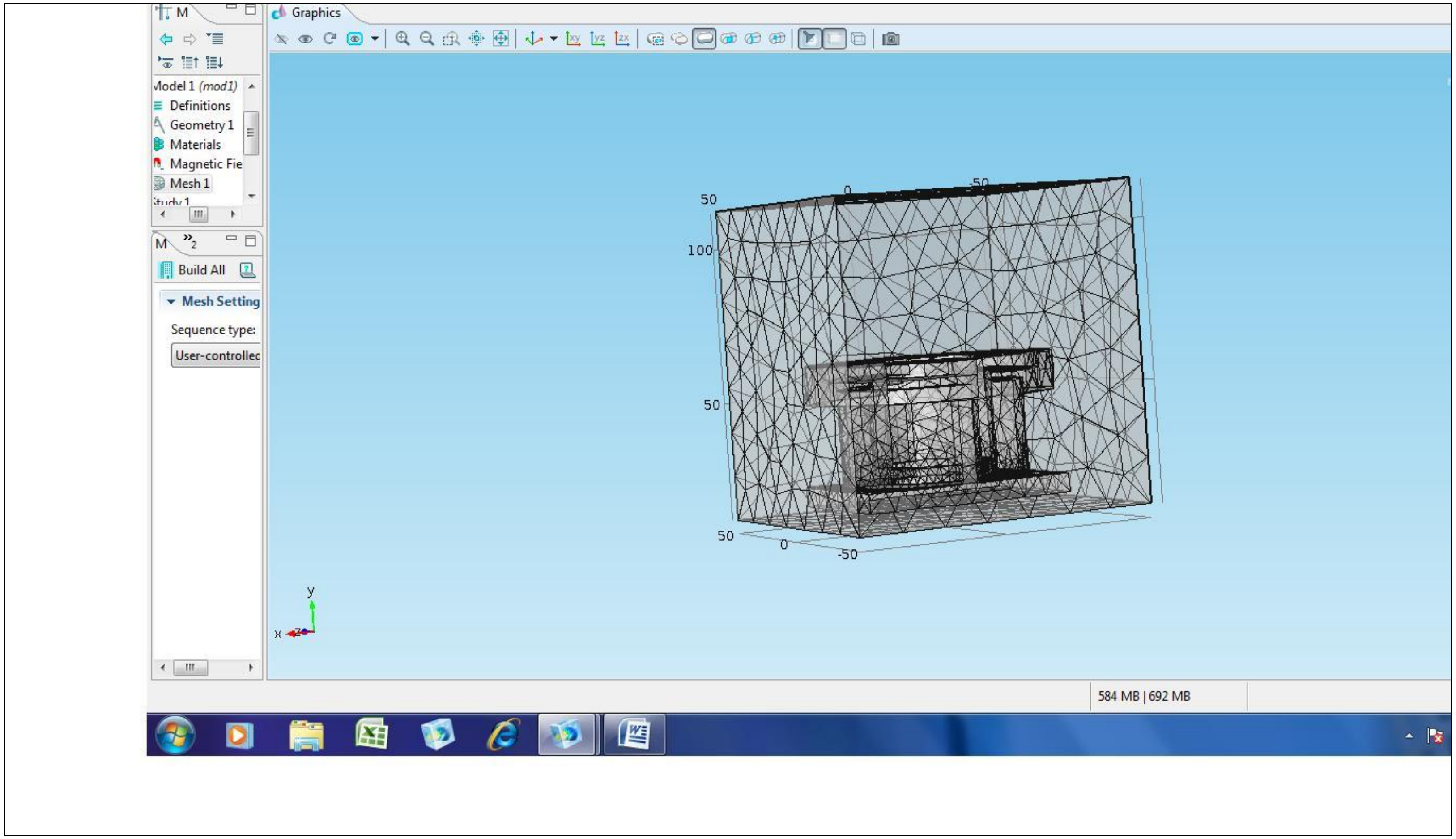


For 10 Amps Excitation

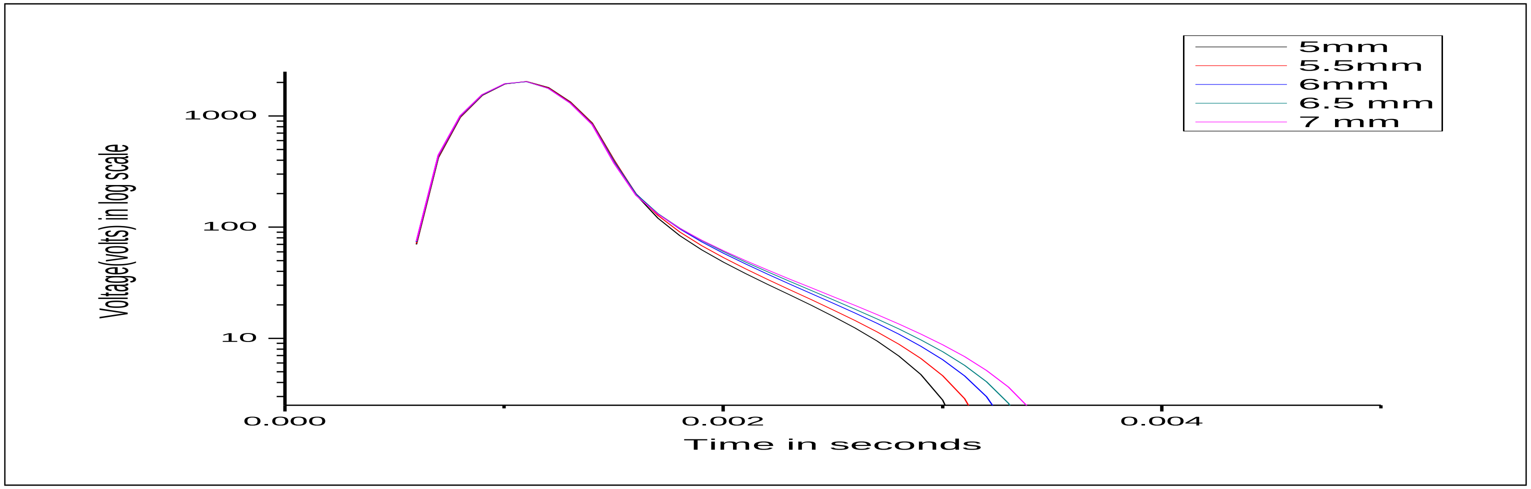
Lift-Off Variation

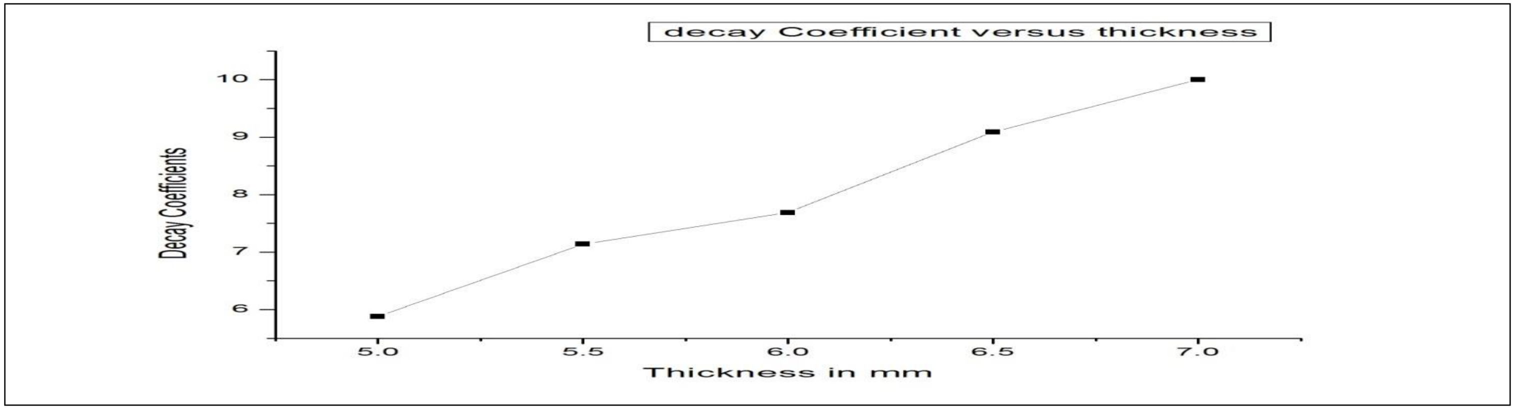


3D Modeling of PEC probe with Flat Plate test specimen



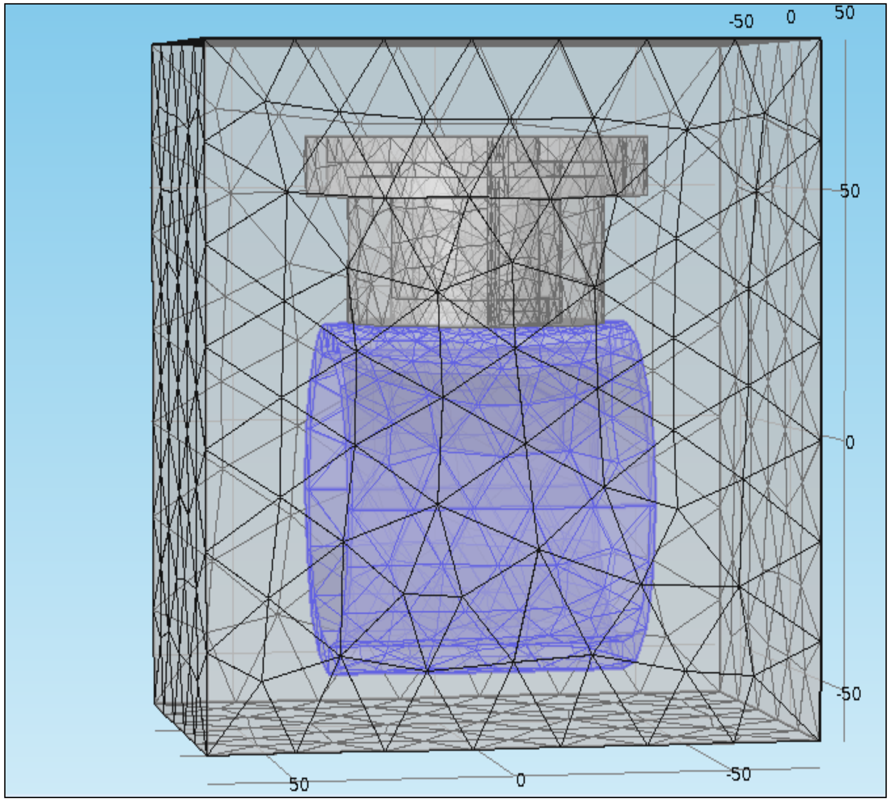
3D Modeling Results for Flat Plate specimens

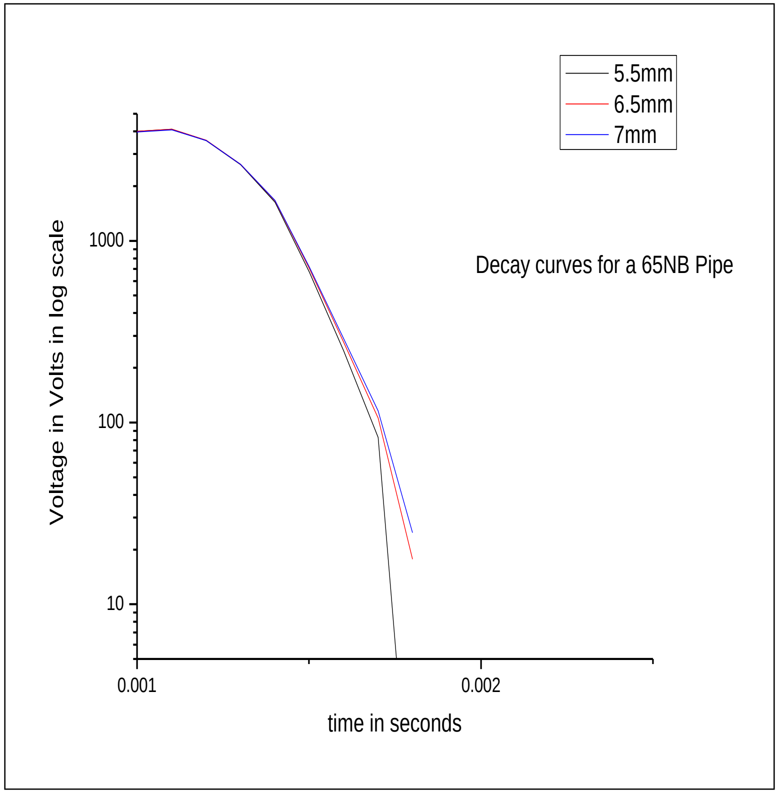




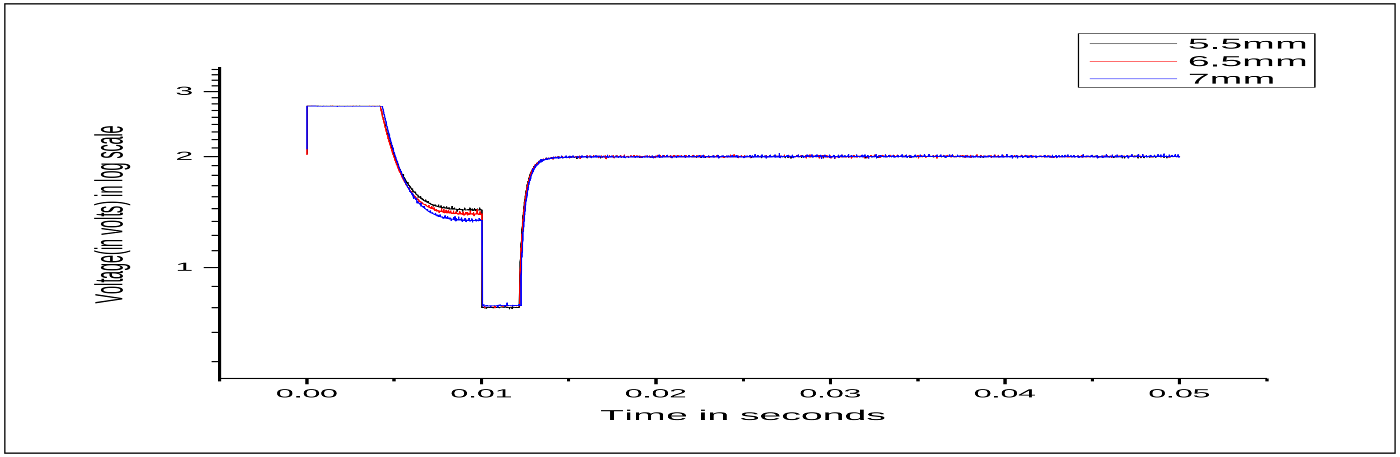
Decay Coefficients for various thickness of Carbon Steel Plates

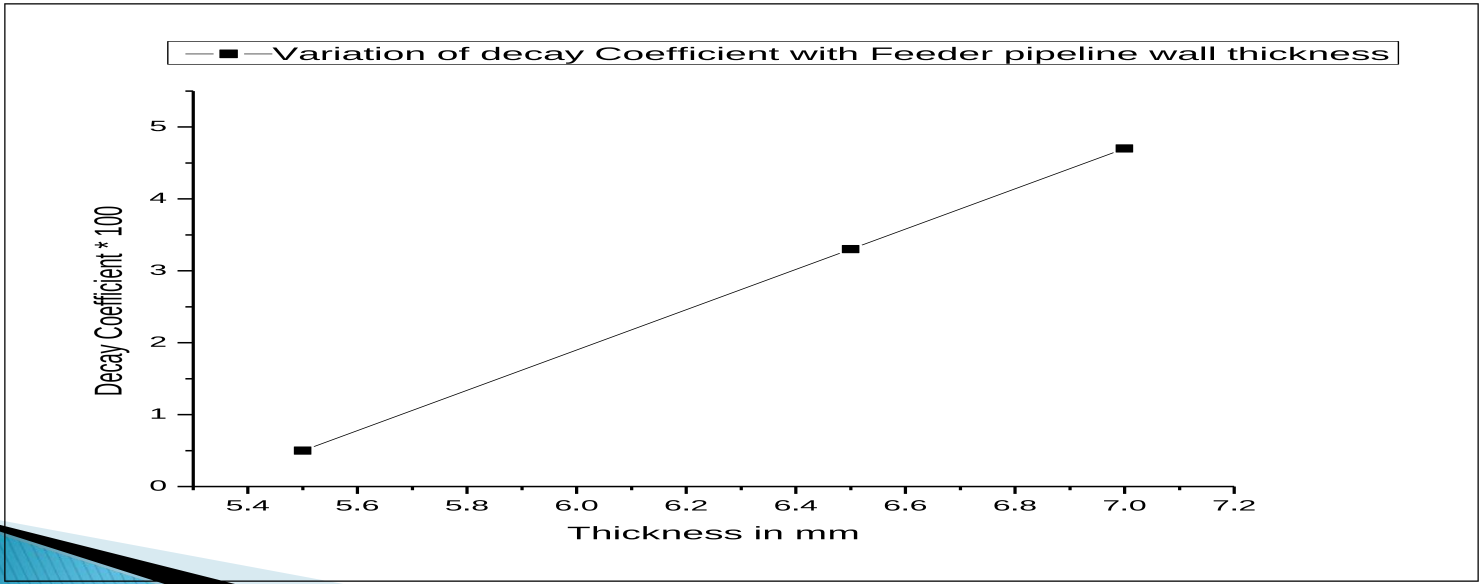
Curved Surface Modeling



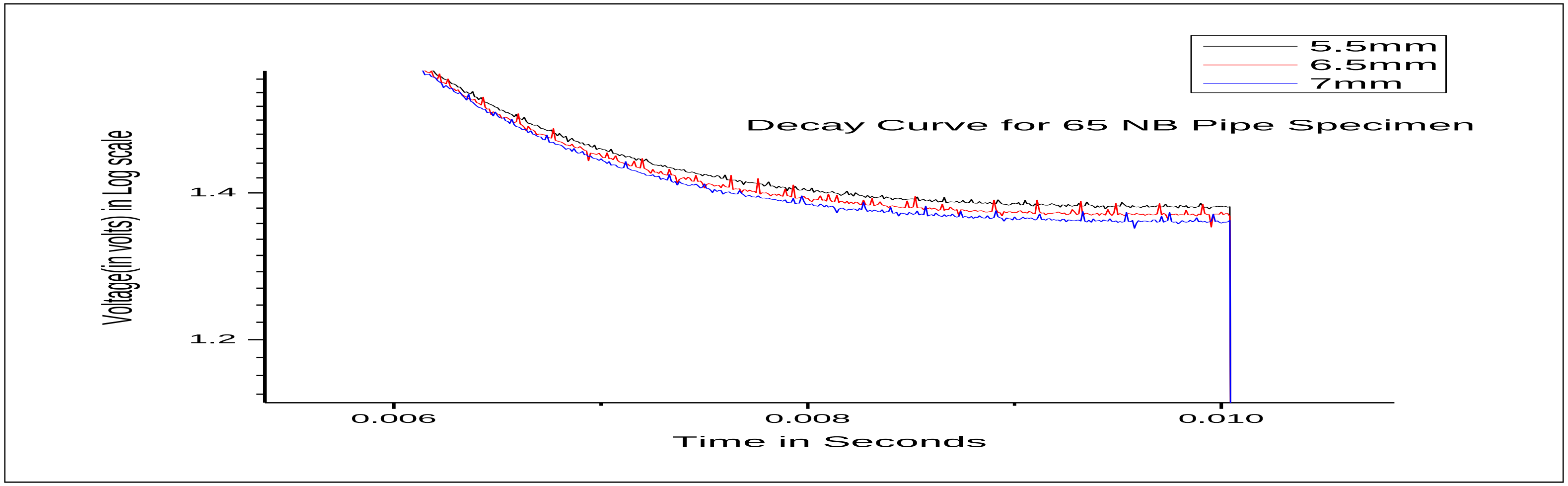


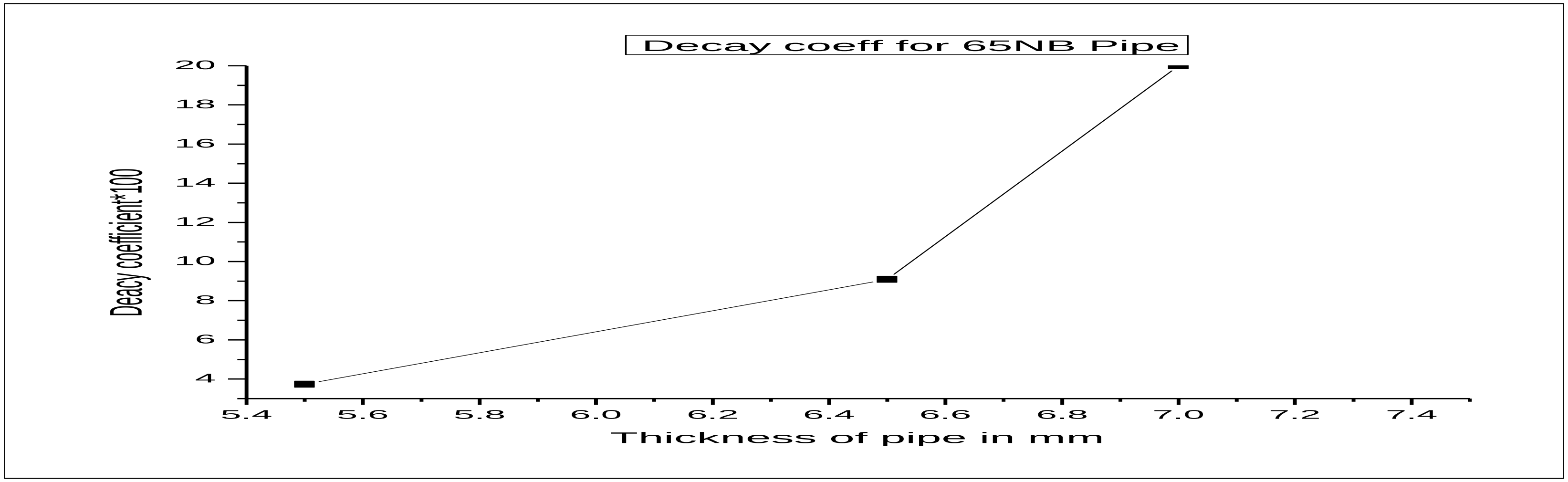
Experimental Validation for CS plates



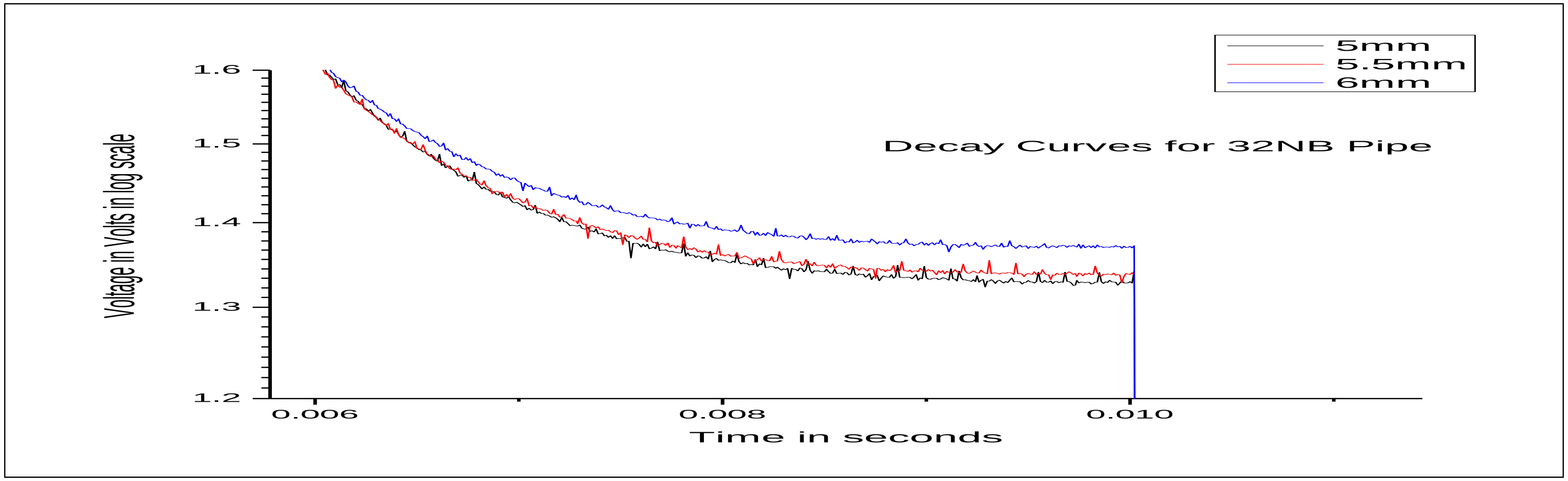


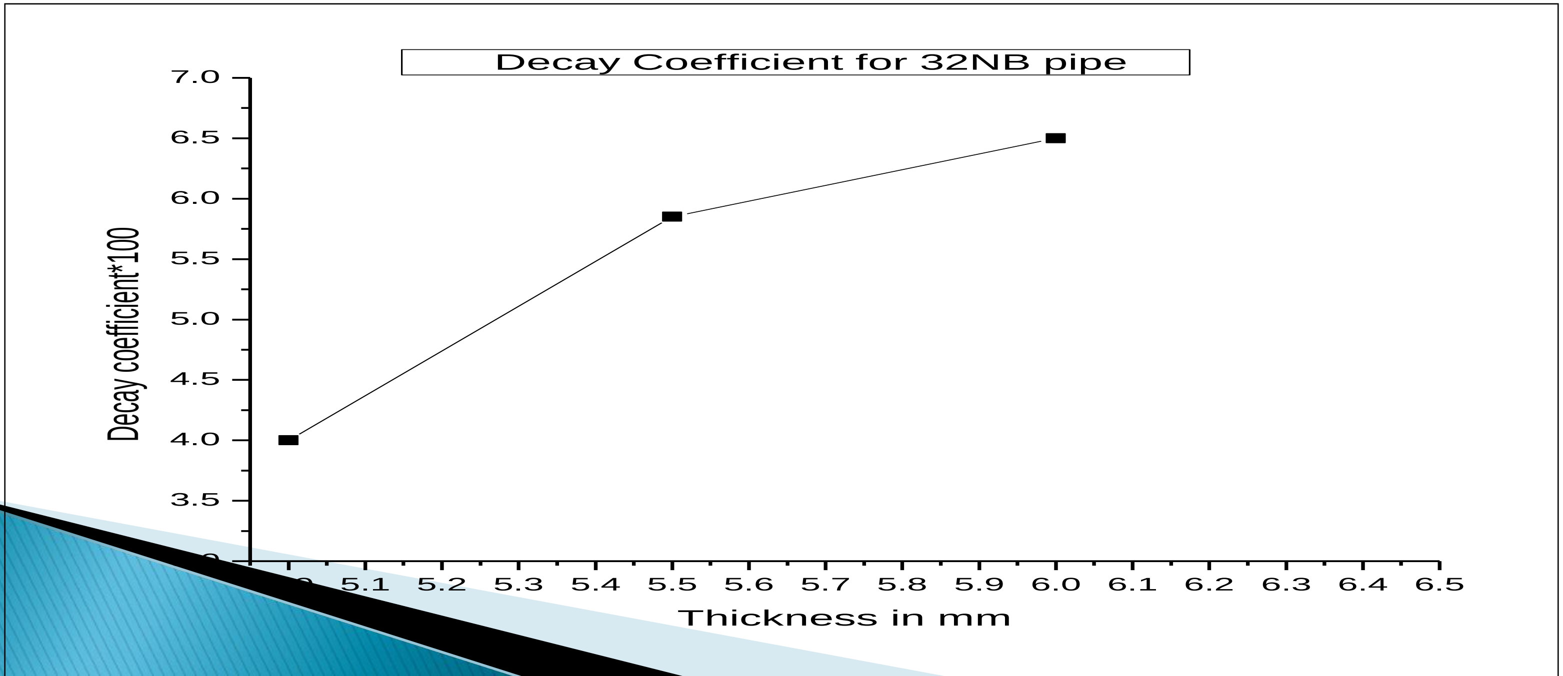
Experimental Validation on 65 NB pipe





Experimental Validation for 32 NB pipe





Results & Discussions

- **The Pulsed Eddy Current based sensor was able to predict the wall thinning phenomenon observed in Feeder Pipelines in PHWR's.**
- The response showed that **Internal Pickup based coil** sensor with **external Excitation coil** and a **Ferrite core** would be the ideal choice of design.
- **From the Time domain analysis** of the received waveform , the slope of the logarithm of the received waveform was directly correlated with thickness.
- The simulation results gave a resolution of **0.3mm** , whereas in case of Experimental validation resolution was less than **0.5mm**.

Contd.

- The decay Coefficients scaled by a factor of **100** observed for the CS Plates for 5.5mm , 6.5mm and 7 mm thickness were **7.3,9.0** and **10.0** respectively whereas those for the CS tube simulated model were **1.08,1.92 & 3**.
- The Decay Coefficients showed an increasing trend with **Thickness** in both the cases.
- The reduction in Decay coefficients for **CS tube** from **CS plates** was due to attenuation of Magnetic flux as the contact area between Cylindrical tube and plates is not a flat surface and there is always some air gap between the sensor & the specimen leading to attenuation of the magnetic flux.
- From the Decay coefficients the Thickness parameter can be easily differentiated both in case of Plates as well as Flat specimen.

References

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Thank You