Measuring and analyzing the magnetic field in (SERAJ system) theta pinch device using the Magnetic probes.

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Abstract:

By using the internal and the external magnetic probes in different positions inside and outside plasma discharge chamber of Seraj's Theta-pinch system (L = 150cm, D = 8.4cm), the generated magnetic field on the coil of Seraj's system was calculated. When the plasma is discharged (by discharging a four capacitor bank connected on parallel, capacity of each is (12.5μF) in the system coil (12nH)) the characteristics of plasma is defined by how much magnetic field is effected. By comparing the magnetic field in (absence and presence) of plasma, trapped magnetic field and Diamagnetic effect could be determined in the Theta pinch system. In such study, we could determine the appropriate operating circumstances to produce suitable plasma with specific features (density & electron temperature) to take advantage for different applications of plasma.

Key words: (Magnetic probes), (plasma diagnostic), (Theta pinch system), (Magnetic field), (Diamagnetic field), and (Trapped magnetic field).

1.Preamble:

High and regular magnetic fields are to be generated by plasma generating systems in order to trap and control plasma motion in definite direction and by this, we realize how important it is to define the magnetic field well and precisely. In Seraj's system, trap concept is established. In details, the electric current that flows through the system coil generates a magnetic field that traps plasma gradually. Because of the magnetic forces that were generated by the coil, plasma can be trapped and confined and it takes a cylindrically shape inside a Pyrex tube (150cm, ~ cm) . In this case, the Hydrogen gas is ionized between two electrodes (Cathode, anode) by a preionized bank (pre-ionize cap. 1.3 F, 40kV). Then the main bank of the system (Main bank cap.12 F – 40kV) which can be varied to certain voltages will fully ionize the gas as in figure (1).

Technology used for measuring magnetic fields herein contains thin wire coils (N=1,5,10,), known as magnetic probes.

Although there have become many technological ways available to measure magnetic fields characteristics of plasma hereto without (direct perturbation) of system, the incapability to avoid this(direct perturbation) is obvious in case of measuring magnetic field of(intermixed field-plasma structure) otherwise static systems which are much simple(duiscentsys), and one of them is used generally to measure magnetic field distribution in case of plasma absence comparing it with plasma presence by (Thrust)(Magnetic probe) direct in plasma, and hoping for the best. By measuring magnetic field and thus find magnetic stream, we will be able to make a plain concept about magnetic effects of materials without resorting to practical difficulties to measure magnetic field from distributing specific mode of magnetization.

2.Theoretical Part

1.2. (Magnetization)

Magnetic field effect appears by recognizing difference of reaction to different modes of magnetic materials [3] thus plasma is a highly ionized material ; it contains equal numbers of (ions) and (free electrons) restricted to magnetic field lines in which the are submerged .Simple atomic example that assumes that electrons composing atoms is magnetic double poles whether they are resulted from its(orbital motion) or (spinning).thus the outcome of magnetic moment for these doubles and its rate of influence by magnetic field determines generally magnetic mode of material which is known by(magnetization)[8].

2.2.Magnetic materials nature:

Generally, if any material is put in an external magnetic field, it is, to some extent, magnetized and mostly, magnetization is little or very tiny ; and its direction will be anti magnetic field wise or external magnetic field wise and its magnetization features disappears by disappearance of effective magnetic field where it depends on features or magnetic features of the material , these materials were divided into:

Diamagnetic materials: materials to which occurs little magnetization resulted from external magnetic field effect, and the direction of magnetization is external magnetic field wise, as in (quartz, glass, graphite).

Paramagnetic materials: materials to which occurs little magnetization resulted from external magnetic field effect, as in(aluminum, platinum , and sodium)

Ferromagnetic materials : materials which have high magnetization value and does not lose its magnetic characteristics even after removing external magnetic field , as in(Iron , Nickel , and Cobalt) as well as a number of molds which have special magnetic characteristics, which naturally contain the main magnetic material.[2],[3].

3.practical part

1.3. Experiment preparations:

1- Seraj's system (40kJ), [6] was prepared according to experiment requirements which are (voltages, pressure and gas size) as shown figure (1).

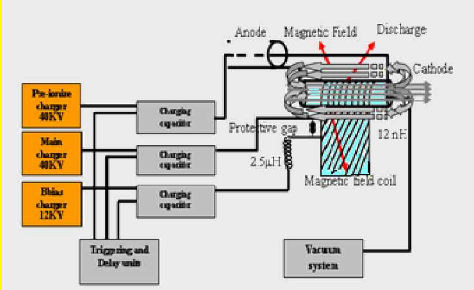

Figure (1) Theta-pinch system

2.3 (magnetic probe):- magnetic probe which is used in this experiment divided into (external magnetic probe) and (internal magnetic probe):

1.External magnetic probe :

A Probe with single roll is used (diameter 84mm, for a copper wire its diameter is 0.62mm) at different positions of Seraj's system, table (1), figure (2, 3) . Two topical probes , one of them is(5rolls, size of its cross section is 11.84x10-6m2 , for a copper wire its diameter is 0.33mm rolled over a piece of plastic)at different positions of system, table(2).

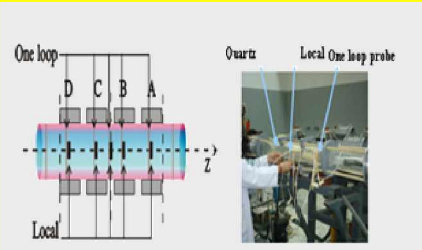

Figure (2, 3) Magnetic probes on theta-pinch system.

Table (1) the location of one loop probes on the tube chamber.

Probe's area (m^2)	The place of the probes	Number of turns (N)	Probe's direction	Probe's name
11.84×10^{-6}	(A) +30cm from the center of the tube.	5	Θ	$CACL_1Θ$
	(B) +10cm from the center of the tube.			$CBCL_2Θ$
	(C)-30cm from the center of the tube.			$CCCL_3Θ$
	(D)-10cm from the center of the tube.			$CDCL_4Θ$
	The right side from the main coil -50cm from the center of the tube.			$CDCL_+Θ$
	The left side from the main coil +50cm from the center of the tube.			$CDCL_-Θ$

Table (2) the location of local probes on the tube chamber.

Probe's area (m^2)	he place of the probes	Number of turns (N)	Probe's direction	Probe's name
	(A) +30cm from the center of the tube.			One loop1
	(B) +10cm from the center of the tube.			One loop3
	(C)-30cm from the center of the tube.			One loop5
5.51×10^{-3}	(D)-10cm from the center of the tube.	1	ϴ	One loop6
	The right side from the main coil -50cm from the center of the tube.			One loop+
	The left side from the main coil +50cm from the center of the tube.			One loop-

1. **(Internal magnetic probe)** four files (10 rolls for each with a diameter 0.3mm were put vertically in a glass tube ,space between them is about 1 cm)table(4), connected to a bar to control the position of probe inside the system electric discharge room.

Figure (4) Four Internal magnetic probes (N=10)

3.4 Experiment procedures:-

1- Magnetic probe was connected after fastening at the specified positions at table (1,2) by (Oscilloscope) through (Ferrite Core), and integral circuits(RC =200Os) afterwards the oscilloscope was adjusted at appropriate range to ensure picking up signal from the probe.

2- The system was operated in presence and absence of plasma, and a signal was picked up , figure(5),from external probe (one loop) table (4).

3- By adjusting operating circumstances for voltages of:

(Main, Bias, pre-ionize) with fixing pressure and vice versa (fixing voltages and adjusting pressure value), one signal was chosen, figure (6) from internal probe to be tested, table (3).

status	Pressure (Torr)	Main cap. Bank (kV)	Bias (kV)	Pre-ionize (kV)
With out plasma	$5X10^{-6}$	18	5	15
With plasma	$8X10^{-2}$	18	5	15

4.results and discussions :-

1.4. Determination of magnetic field direction:

three external probe were used (local probe) in the directions(r, Ø, z) of magnetic field line to determine the direction of magnetic field of system. Where a single signal was picked up from the three probes and it was on parallel to field lines (which means in the direction Z) thus magnetic field lines of Seraj's system is in the direction (z).

2.4. measuring magnetic field values(Bz):

magnetic field value measurements (B_Z)of picked up signals , figure(6,5)of external and internal magnetic probe, values are recorded at table(4,3) by using the following equation :

$$\mathbf{B} = \frac{\mathbf{VRC}}{\mathbf{NA}}$$

Where B: magnetic field & V: the maximum voltage picked up signal of a probe, RC: Circle fixed time, N: Number of probe rolls, A: probe cross section size, table (1, 2)

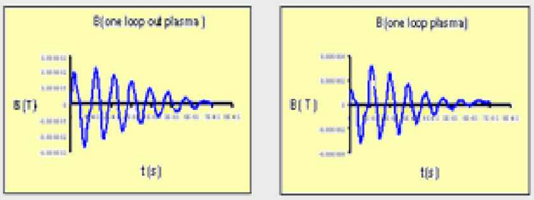

Figure (5) the change of magnetic field in case of plasma and without plasma using external magnetic probes.

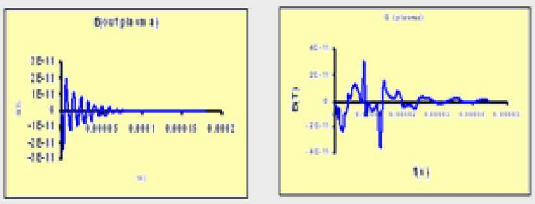

Figure (6) the change of magnetic field in case of plasma and without plasma using internal magnetic probes.

Table (3)

Local probe				
Local probe Voltage $V_{(\text{with plasma})}$	**$B_{o+p\ (\text{with plasma})}$ (Tesla)**	**Local probe Voltage $V_{(\text{with out plasma})}$**	**$B_{o\ (\text{out plasma})}$ (Tesla)**	**B_p (Tesla)**
2.90E-02	3.27E-12	2.02E-02	4.69E-12	-1.42E-12
2.19E-02	1.38E-12	1.08E-02	2.79E-12	-1.41E-12
2.63E-02	1.60E-12	1.26E-02	3.35E-12	-1.75E-12
3.02E-02	1.82E-12	1.43E-02	3.85E-12	-2.03E-12
3.36E-02	2.05E-12	1.61E-02	4.28E-12	-2.23E-12
3.70E-02	2.30E-12	1.81E-02	4.71E-12	-2.41E-12
4.02E-02	2.57E-12	2.02E-02	5.12E-12	-2.55E-12
4.35E-02	2.84E-12	2.23E-02	5.54E-12	-2.70E-12
4.61E-02	3.06E-12	2.40E-02	5.87E-12	-2.81E-12
4.89E-02	3.31E-12	2.60E-02	6.23E-12	-2.92E-12
5.21E-02	3.41E-12	2.68E-02	6.63E-12	-3.22E-12
5.42E-02	3.53E-12	2.77E-02	6.90E-12	-3.37E-12
5.61E-02	3.44E-12	2.70E-02	7.14E-12	-3.70E-12
5.74E-02	3.46E-12	2.72E-02	7.31E-12	-3.85E-12
5.78E-02	3.53E-12	2.77E-02	7.36E-12	-3.83E-12
5.85E-02	3.63E-12	2.85E-02	7.45E-12	-3.82E-12

Table (4)

One loop probe				
One loop probe Voltage $V_{(\text{with plasma})}$	**$B_{o+p\ (\text{with plasma})}$ (Tesla)**	**One loop probe Voltage $V_{(\text{with out plasma})}$**	**$B_{o\ (\text{out plasma})}$ (Tesla)**	**B_p (Tesla)**
1.00E-01	1.38E-07	1.03E-05	1.08E-07	3.00E-08
1.80E-01	2.49E-07	1.04E-05	1.99E-07	5.00E-08
3.00E-01	4.14E-07	1.05E-05	2.96E-07	1.18E-07
4.50E-01	6.21E-07	1.06E-05	4.10E-07	2.11E-07
6.30E-01	8.70E-07	1.07E-05	5.34E-07	3.36E-07
8.30E-01	1.15E-06	1.08E-05	6.67E-07	4.83E-07
1.04E+00	1.44E-06	1.09E-05	8.05E-07	6.35E-07
1.26E+00	1.74E-06	1.10E-05	9.32E-07	8.08E-07
1.47E+00	2.03E-06	1.11E-05	1.06E-06	9.70E-07
1.68E+00	2.32E-06	1.12E-05	1.19E-06	1.13E-06
1.85E+00	2.55E-06	1.13E-05	1.32E-06	1.23E-06
2.00E+00	2.76E-06	1.14E-05	1.45E-06	1.31E-06
2.12E+00	2.93E-06	1.15E-05	1.58E-06	1.35E-06
2.21E+00	3.05E-06	1.16E-05	1.69E-06	1.36E-06
2.26E+00	3.12E-06	1.17E-05	1.81E-06	1.31E-06
2.29E+00	3.16E-06	1.18E-05	1.92E-06	1.24E-06

3.4 Defining magnetic properties and trapped field of plasma: we notice that magnetic field values (B with plasma) which is picked up from probe (one loop), table 4) is a construction for two magnetic fields (referential magnetic field "B O" and magnetic field for plasma "B p"). By subtracting referential magnetic field value (B O) from picked up field value by probe, we can get magnetic field value of plasma (B P). And when comparing the two magnetic fields (B P , B O) , we notice that referential magnetic field value (B O) is higher than magnetic field value of plasma (B p) thus we can describe magnetic property of plasma that it is diamagnetic , figure(7).

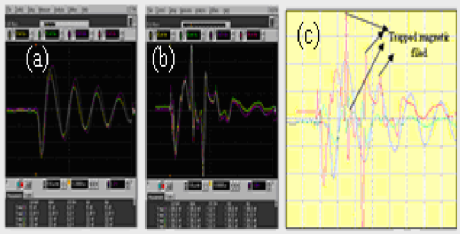

Figure (7) magnetic properties (a) without plasma (b) with plasma (c) Trapped field

4.4 Determination of magnetic pressure value (p) and modulus (B): modulus value (B) is the ratio of plasma pressure to magnetic pressure resulted from external magnetic field, described at following table (5) . We notice here that this value of ratio will be restricted between zero and one as magnetic field intensity in plasma will always be less intensive than it is outside because single charges in plasma generate power, which takes counter direction to magnetic field focused on plasma, which confirms that plasma is diamagnetic

Table (5)

One loop probe			
B_o (out plasma) (Tesla)	**B_p (Tesla)**	**Magnet pressure(P)**	**β**
1.08E-07	3.00E-08	4.28E-09	9.23E-01
1.99E-07	5.00E-08	1.48E-08	9.37E-01
2.96E-07	1.18E-07	2.93E-08	8.41E-01
4.10E-07	2.11E-07	4.92E-08	7.35E-01
5.34E-07	3.36E-07	6.85E-08	6.04E-01
6.67E-07	4.83E-07	8.42E-08	4.76E-01
8.05E-07	6.35E-07	9.74E-08	3.78E-01
9.32E-07	8.08E-07	8.59E-08	2.48E-01
1.06E-06	9.70E-07	7.27E-08	1.63E-01
1.19E-06	1.13E-06	5.54E-08	9.83E-02
1.32E-06	1.23E-06	9.13E-08	1.32E-01
1.45E-06	1.31E-06	1.54E-07	1.84E-01
1.58E-06	1.35E-06	2.68E-07	2.70E-01

5.Summary;

From results concluded from this experiment by using (external and internal magnetic probes) of (SERAJ Theta Pinch System) according to operating circumstances: P (without plasma)= 5x10-6 torr, p(with plasma) = 8x10-2 torr , pre-ionize cap. Bank = 18 kV, Main cap. Bank = 15 KV .Bias = 5Kv.

Generated magnetic field direction and value (Bz) of system file as well as considering magnetic pressure value(p) which is necessary to trap plasma and modulus(B) to define trapped magnetic field and magnetic property of plasma, was defined as diamagnetic effect of Theta pinch system and by this study, we could define appropriate operating system circumstances to produce stable plasma with specific features according to its characteristics(density, and electrons temperature) in order to take advantage of it by different applications of plasma.

6.Gratitude and appreciation

After fulfilling this research, which is considered to be one of the research projects for plasma research laboratories.(Alfateh University), related to national office for research and development , we should thank everyone participated in this work by efforts or support in order to achieve and accomplish it .specifically, Dr. M. Mgdelden Alghadban , plasma labs manager, in addition to appreciating efforts of all participants of this work for their constant quest to reach the best results. We appreciate efforts of dr. Mohamed Mohamed Masoud and Dr. Tawfeq Algadoay as well as Eng. Yussef Altomy and Eng. Mohamed Alwdad for their cooperation and supervision on system operation during the experiment , appreciation also to technician Waled Omar Salem for his cooperation with us to achieve mechanical missions of this work.

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