An Experimental Comparison of Induction Balance Systems and Pulse Induction Systems

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Abstract—In this study; two methods of measuring magnetic susceptibility with Induction Balance (IB) and Pulse Induction (PI) are described which are especially convenient for detection of metal particles into cheese. The paper also includes a simple approximate experiment of the induction balance and Pulse Induction concerning detection of iron objects into cheese. This experiment is described which can make use of either of the two methods for detecting iron metals into cheese.

As a result; we obtained very good results in diagnosis of iron particle in the cheese. The results of analyses carried out indicated that the controls performed with Pulse Induction system provide reliable and consistent diagnosis and that they are feasible in real life.

Keywords—IB System, PI System, Iron Particles, Cheese, Determining.

I. INTRODUCTION

A typical metal detector used for detecting buried coins, gold, or landmines consists of a circular horizontal coil assembly held just above the ground. Other uses of more specialized metal detectors include usage in medicine, security etc. Metal detectors have been used for diagnostic purposes since 1881. They have been utilised to localise a myriad of foreign objects including bullets, intraocular metallic fragments, swallowed coins and other foreign bodies and medical devices. Rapid detection of metallic objects may facilitate diagnosis or treatment.

Metal detectors are diagnostically useful because of their low expense, lack of radiation exposure and ease of use [1]. Other uses include demining (the detection of land mines), the detection of weapons such as knives and guns, especially at airports, geophysical prospecting, archaeology and 'treasure hunting'. Metal detectors are also used to detect foreign bodies in food, and in the construction industry to detect steel reinforcing bars in concrete and pipes and wires buried in walls and floors [2].

Metal detectors used in searching for buried metallic objects are also similar in concept to those used for detecting iron metals into food.

Metal detectors use one of three technologies [3]:
- Very Low Frequency (VLF) or Induction Balance (IB)
- Pulse Induction (PI)
- Theta Beat-frequency Oscillation (BFO)

In this work; we have studied only IB systems and PI systems. Later, we made an experiment to find which one is more useful to determine for iron particle that into cheese. In order to his, firstly, we made a PI detector and BI detector. Subsequently, we produced iron samples and put them into the cheese. Finally, we put this cheese into both PI system and BI system detector and noted that the values of detector voltages.

II. METHOD AND MATERIAL

A. IB Systems

Towards the end of the 19th century, many scientists and engineers used their growing knowledge of electrical theory in an attempt to devise a machine which would pinpoint metal. The use of such a device to find ore-bearing rocks would give a huge advantage to any miner who employed it. The German physicist Heinrich Wilhelm Dove invented the induction balance system, which was incorporated into metal detectors a hundred years later. Early machines were crude, used a lot of battery power, and worked only to a very limited degree. Alexander Graham Bell used such a device to attempt to locate a bullet lodged in the chest of American President James Garfield in 1881; the attempt was unsuccessful because the metal bed Garfield was lying on confused the detector [4].

Many manufacturers of these new devices brought their own ideas to the market. Whites Electronics of Oregon began in the 50's by building a machine called the Oremaster Geiger Counter. Another leader in detector technology was Charles Garrett, who pioneered the BFO (Beat Frequency Oscillator) machine. With the invention and development of the transistor in the 50's and 60's, metal detector manufacturers and designers made smaller lighter machines with improved circuitry, running on small battery packs. Companies sprang up all over the USA and Britain to supply the growing demand [5].

Larger portable metal detectors are used by archaeologists and treasure hunters to locate metallic items, such as jewelry, coins, bullets, and other various artifacts buried shallowly underground [6].

An IB metal detector circuit includes a receiver coil output which is connected to one input of a unique phase detector circuit. The reference transmitter coil signal is connected to a
second input of the phase detector. The phase detector comprises circuitry which provides an output equal to the smaller of the two input signals. The output is doubled and integrated, then compared to a current indicative of the integrated reference signal in a differential amplifier. The output of the differential amplifier is passed through a dead band and used to excite a first indicator in response to phase difference between the inputs to the phase detector indicative of the location of ferrous metals. A second indicator is excited in the event the phase difference indicates the presence of non-ferrous metals. A balance and threshold control is established between the transmitter and the receiver coils in order to adjust the phase and amplitude of the received signal. A feedback loop is established between the ferrous metal output and the threshold and the balance control. The ferrous metal output is integrated to provide an indication of mineralized soil in the environment. This integrated output is utilized to change the impedance at the receiver coil in order to null out the effects of the mineralized soil. The circuitry is adapted for use in integrated circuit form [7]. Fig.1 shows IB Technology.

IB, also known as Very low frequency (VLF), is probably the most popular detector technology in use today. In an IB metal detector, there are two distinct coils:

- **Transmitter coil** - This is the outer coil loop. Within it is a coil of wire. Electricity is sent along this wire, first in one direction and then in the other, thousands of times each second. The number of times that the current's direction switches each second establishes the frequency of the unit.

- **Receiver coil** - This inner coil loop contains another coil of wire. This wire acts as an antenna to pick up and amplify frequencies coming from target objects in the ground. [8]

The current moving through the transmitter coil creates an electromagnetic field, which is like what happens in an electric motor. The polarity of the magnetic field is perpendicular to the coil of wire. Each time the current changes direction, the polarity of the magnetic field changes. This means that if the coil of wire is parallel to the ground, the magnetic field is constantly pushing down into the ground and then pulling back out of it.

One difficulty with IB metal detectors exist when such detectors are used in area containing magnetite and other conductive minerals in the soil. These elements cause unwanted amplitude and phase changes in the received signals which can result in either false indications being made by the detector or the absence of indications when valuable objects are in the vicinity. It is possible to provide a coupling between the transmitted and received signals in order to null out these “ground effect” [7].

### B. PI Systems

A less common form of metal detector is based on PI. Unlike IB, PI systems may use a single coil as both transmitter and receiver, or they may have two or even three coils working together. This technology sends powerful, short bursts (pulses) of current through a coil of wire. Each pulse generates a brief magnetic field. When the pulse ends, the magnetic field reverses polarity and collapses very suddenly, resulting in a sharp electrical spike. This spike lasts a few microseconds (millions of a second) and causes another current to run through the coil. This current is called the **reflected pulse** and is extremely short, lasting only about 30 microseconds. Another pulse is then sent and the process repeats. A typical PI-based metal detector sends about 100 pulses per second, but the number can vary greatly based on the manufacturer and model, ranging from a couple of dozen pulses per second to over a thousand. Pulse Induction detectors are now widely used in the construction industry including area; detecting metal particles in foods, finding embedded bomb or guy.. Fig.2 shows block diagram of PI systems;

![Figure 1: IB transmitter and receiver antennas, the object directed towards the waves hit the object is to return to seen](image1)

All instruments depend on the measurement of a magnetic field associated with eddy currents induced in the target by a primary magnetic field. The two main groups of metal detector are the continuous wave type where normally a sinusoidal primary magnetic field produces eddy current in target, and the PI system where the primary fields is a series of pulses. In a continuous wave detector, coupling between the transmitter and receiver.

Early metal detectors were mainly continuous wave type because simple circuits could be used. However, PI systems have been described in the geophysical context by Grant and West [9] and in the archaeological context by Colane [10].
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III. RESULTS

Firstly, the metal detectors were used to test for various sizes of metal at various distances from the search coil and the following results were obtained. These results were similar in both systems:

1. The larger the metal, the louder the sound output from the loudspeaker and smaller the metal, the lower the sound output from the loudspeaker – though this also dependent on the size of the search coil.

2. The closer the distance between the search head and the metal, the greater the sound output from the loudspeaker and the farther the distance the fainter the sound output from the loudspeaker, to extent the sound die off at some critical distance where theoretically the magnetic field due to the search head is zero.

Secondly, iron samples in various size and weight were created and placed into the cheese.

Finally, the part of this cheese is divided through both detectors and detector voltages were measured and recorded in table 1 and 2.

Table 1: PI System detector voltages.

<table>
<thead>
<tr>
<th>Iron Size (mm)</th>
<th>Iron Weight (mg)</th>
<th>Voltage (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>73.2</td>
<td>3.86</td>
</tr>
<tr>
<td>15</td>
<td>61.5</td>
<td>3.75</td>
</tr>
<tr>
<td>10</td>
<td>30.7</td>
<td>2.73</td>
</tr>
<tr>
<td>7.5</td>
<td>27</td>
<td>1.89</td>
</tr>
<tr>
<td>6</td>
<td>20.5</td>
<td>1.09</td>
</tr>
<tr>
<td>5</td>
<td>16.7</td>
<td>0.99</td>
</tr>
<tr>
<td>2.5</td>
<td>9.4</td>
<td>0.63</td>
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</tbody>
</table>

Table 1: IB System detector voltages.

<table>
<thead>
<tr>
<th>Iron Size (mm)</th>
<th>Iron Weight (mg)</th>
<th>Voltage (V)</th>
</tr>
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<tbody>
<tr>
<td>20</td>
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Figure 5: Comparison of the both systems’ voltages.

IV. CONCLUSION

In this study, PI and IB system metal detectors examined on a test. According to the results of the experiment, we found that PI system metal detectors are more successful in finding iron particles in cheese than BI system detectors. Furthermore, PI system detectors are more useful and reliable in food sector.

REFERENCES