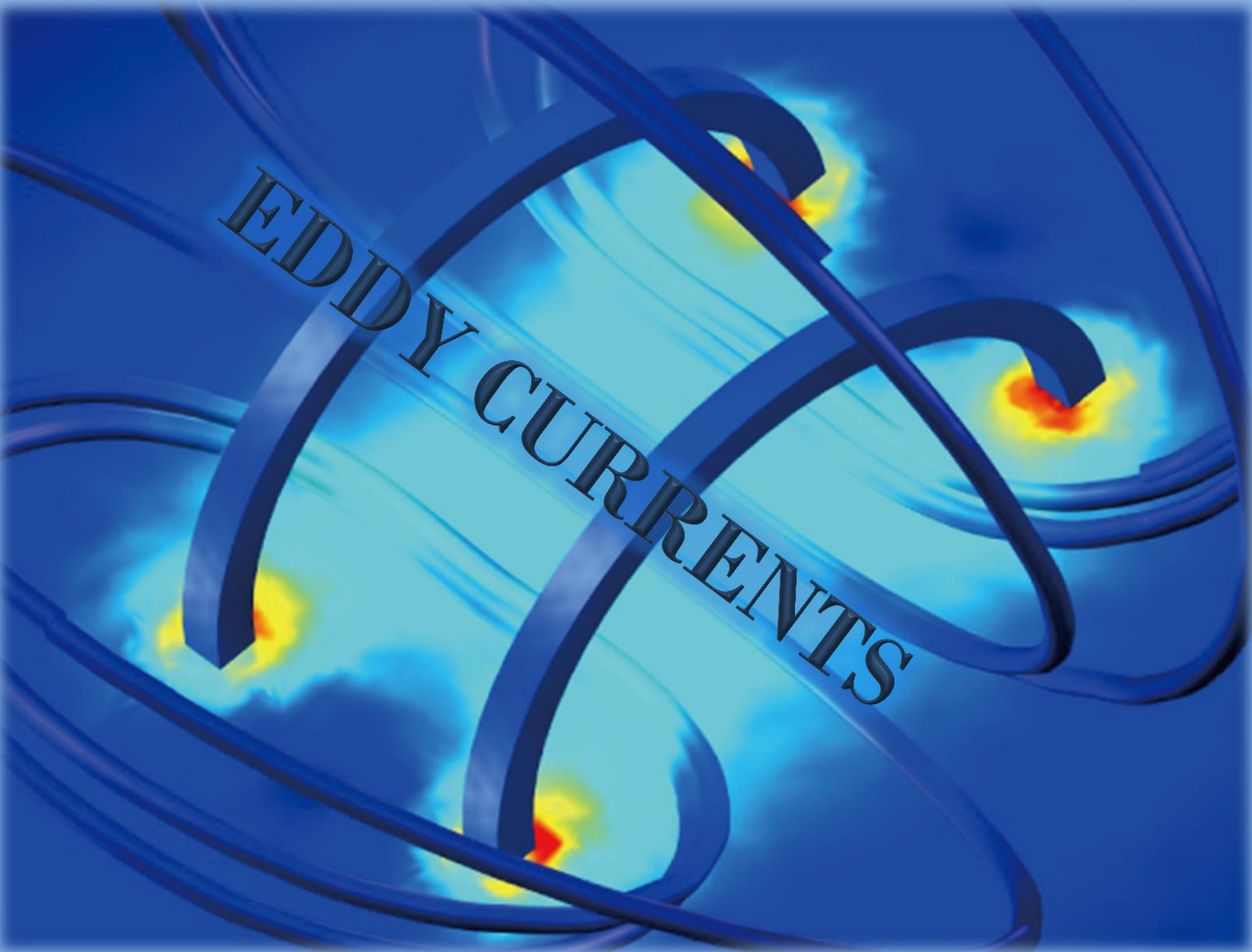
Syrian Arab Republic

Agency of Distinction and Innovation

National Center for the Distinguished



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Introduction

Science was walking on the way of advancement and development, and in each step it gives us a new creation…

But for how long will it continue developing?

And will it ever come to an end or complete to infinity?

Our research talking about one of science's steps which although it will be used for the military purposes at most, it has positive usage in many applications.

We are going to talk about the part of magnetism which is the base of work of the electric machine which we are going to talk about it.in our research; this part called Eddy Currents.

So, What are Eddy currents?

What are its contents?

Who are the scientists interested in it?

We will answer this question and show you a major application for Eddy currents.

Chapter [1]: Eddy currents (definition and history)

Part (1): What are Eddy currents?

Eddy current are circular closed induced currents arise from induced fields which is resulting from the current flowing in the coil, and parallel to the coil's rolls.

Eddy Current concentrate near to the surface adjacent to the excitation coil and their strength is inversely proportional with distance from the coil. Eddy Current density decreases exponentially with depth.

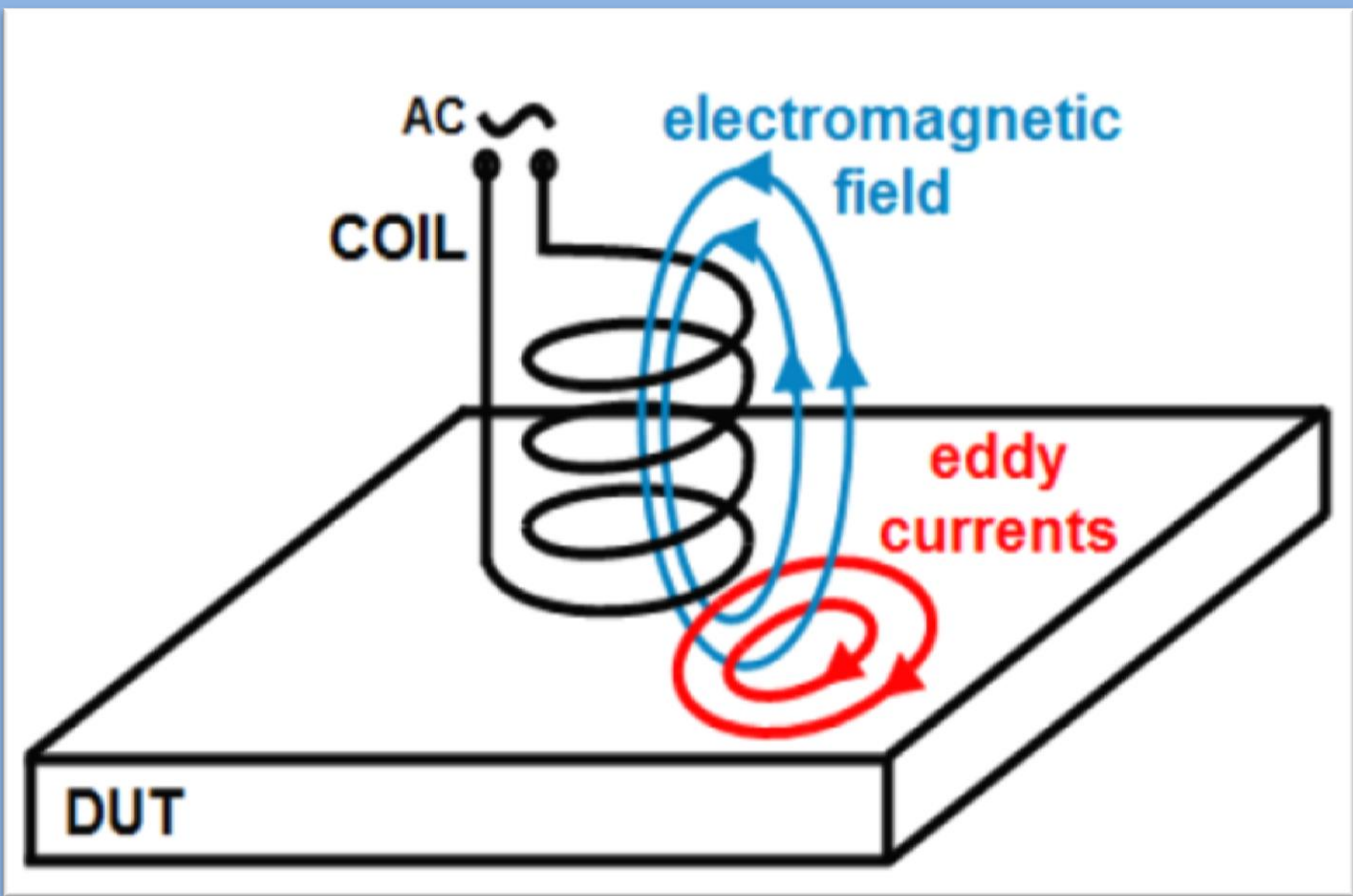

Photo (1): Electric circuit expresses the mechanism of formation Eddy currents

Part (2): **History and Development**.

Significant discoveries about Electromagnetism:

Development of the eddy current method was based on certain discoveries made during the early nineteenth century about the relationship between electricity and magnetism. In fact, the relevant electromagnetic principles were discovered in the same sequence in which they occur during an eddy current test.

In 1820, Hans Christian Oersted, a Dane, discovered electromagnetism _ the fact that an electrical current flowing through a conductor causes a magnetic field to develop around that conductor. By accident, Oersted discovered electromagnetism. While demonstrating that heat is developed when an electric current passes through a wire, Oersted observed that the needle of a magnetic compass deflected perpendicular to the wire while the current was passing through it. Electromagnetism is the principle on which eddy current coils operate. Whereas Oersted was using direct current developed from a battery voltage when he discovered electromagnetism, an eddy current instruments employs alternating electric current flowing through the test coil in order to develop an alternating magnetic field around the coil.

in 1831, an Englishman, Michael Faraday discovered electromagnetic induction _ the fact that relative motion between a magnetic field and a conductor induces a voltage in that conductor, causing an electric current to flow. Consequently, when the alternating magnetic field of an eddy current instrument's coil is brought in contact with a conducting test object, a voltage is developed, causing a current to flow in the test object. Thus, electromagnetic induction is considered to be the operating principle of eddy current testing. Joseph Henry also independently discovered electromagnetic induction in the United States at about the same time. In fact, the unit of measure for induction is named after him.

In 1834, Heinrich Lenz stated the principle that defines how the properties of the test object are communicated back to the test system. Lenz's law states that the direction of current flow in the test object will be such that its magnetic field will oppose the magnetic field that caused the current flow in the test object. This means that, in practice, the eddy currents communicate with the test coil by developing a secondary flux that cancels a portion of the coil's flux equivalent to the magnitude and phase of the flux developed by the eddy currents. The theory describing the chain of an eddy current test may thus be fully described by the discoveries of Oersted, Faraday, Henry, and Lenz. Eddy currents wasn't discovered until 1864. They were discovered by James Maxwell, who is famous for stating the defining equations of electromagnetic theory. The first use of eddy currents for nondestructive testing was in 1879 when D.E. Hughes used these basics to conduct metallurgical sorting tests.

Modern eddy current testing:

In the late 1940s, Dr. Friedreich Foerster founded the Institute Dr. Foerster, which made great strides in developing and marketing practical eddy current test instruments. The development of the eddy current method progressed was slow before that. By the late 1960s the Institute had developed a product line covering virtually every application of the eddy current test method a worked with American manufacturers to firmly establish the method in the United States. Two major contributions of Foerster were the development of impedance plane display, which greatly aided in communication of test information to the practitioner, and formulation of the law of Similarity, which enables the practitioner to duplicate the same eddy current performance under a variety of test situations.

The next major contribution to the advancement of the method multifrequency testing, was also developed by equipment manufacturer, Intercontrolle of France, in 1974. Driving a test coil at multiple frequencies helps to overcome what has traditionally been the major limitation of the eddy current method, the fact that the various conditions to which the method is sensitive can vector into a single displayed signal that is difficult to interpret .Originally developed to suppress the display of undesired test variables, multifrequency testing can also optimize an eddy current test for normally conflicting performance variables such as sensitivity and penetration as well as aid in identifying the nature of a particular test response. Multifrequency testing is a very significant innovation that has markedly advanced the state of the art.

The development of microprocessor-based eddy current instruments since the mid-1980s has also enhanced the potential and user-friendliness of the method. It has improved recording capability, provided sophisticated post inspection signal analysis, and has allowed automatic mixing of multifrequency signals. Modern microprocessor-based eddy current instruments offer a breadth of useful features virtual unimaginable in the days of analog equipment. Manufactures such as Zetek, Hocking, Foerster, Nortek, ETC, and Magnetic Analysis have been important contributors.

In addition to mainstream eddy current testing, more specialized techniques are employed for certain applications. These include flux leakage, remote field eddy current, and modulation analysis inspection. In classifying nondestructive test methods for the purpose of qualifying certifying test personnel, the American Society for Nondestructive Testing (ASNT) classifies all of these techniques under the umbrella of the Electromagnetic Testing method (ET).

Part (3): Electricity and Magnetism into Eddy current…!!

– Electricity:

All matter is made up of atoms, the atom being the smallest unit of any element that retains the properties of that element. The center of an atom, the nucleus, has a positive electrical charge. Orbiting the nucleus and rotating on their own axes are negatively charged particles called electrons. As shown in the illustration of the copper atom, orbits of electrons around the nucleus resemble the orbits of planets around the sun in that there can be several orbits, called "shells". However, atomic structure differs from the solar system in that a given shell can contain multiple electrons. From the perspective of eddy current testing, one is concerned specifically with the outer shell of a material's atoms, because the number of electrons in the outer shell determines whether the material will conduct electricity. The outer shell can contain a maximum of eight electrons, and when the outer shell contains as many as seven or eight electrons, the material will not conduct electricity and is called an insulator. However, materials whose atoms have only one, two, or three electrons in the outer shell can conduct electricity and are, in fact, called conductors. Materials whose outer shells contain an intermediate number of electrons are called semiconductors and, although important in the design of computer circuitry, are not significant here. If undisturbed by outside forces, a conductor's electrons will repeatedly orbit the nucleus. However, when voltage [also called electromotive force (EMF) or potential] is applied to a conductor, its electrons will advance from one atom to the next. That is, there is a flow of electrical charges called current or electricity. Voltage causes electrons to flow because it can attract and repel them; that is, voltage applies polarity to electrons. A battery is an example of a voltage source. Electrons, being negatively charged, will be attracted to a battery's positive terminal and repelled by its negative terminal. As shown in the illustration of a flashlight circuit, electrons flow through the bulb's filament from the negative to the positive terminal of the battery.

Although conductor's atoms will permit current flow when voltage is applied, there is always some opposition to flow, due to the attraction of electrons to their atoms. This opposition varies among the atoms of different materials. Willingness of a test specimen to allow current flow is a key point in eddy current testing, detailed in the following definitions:

1. Conductivity is the relative ability of material's atoms to conduct electricity

2. Resistivity is opposition of a material's atoms to the flow of electricity; it's the inverse of conductivity.

3. Conductance is the ability of a particular component to conduct electricity. Conductance depends on a component's conductivity, length, and cross section.

4. Resistance is the inverse of conductance. It is the opposition that a particular component offers to the flow of electricity. Like conductance, it depends on a component's conductivity, length, and cross section.

Conductivity is the material property of most interest to us in eddy current testing, whereas resistance is an important element in the display of test information. Material conductivities are compared on a scale called the International Annealed Copper Standard (IACS). Pure unalloyed annealed copper at 20°C is the base value on this scale, with a value of 100%. Other materials are assigned a percentage depending on their ability to conduct electricity relative to copper.

Having now identified resistance, as well as voltage and current, these terms can betide together, showing their units, using the most basic formula of electricity, Ohm's law:

$$I = \frac{V}{R}$$

Thus, current flow increases when voltage increases and current flow decreases when resistance increases. There are two types of current: direct current (Dc), which flows only one direction; an alternating current (Ac), which continually reverses direction.

– Magnetism:

The magnetism is one of the most important kinds of science, it has a very important role in generating electricity and communication…etc. One of its application is the telephone that works with the magnet, it has also used in electrical generating machines and electrical motors. Greeks in 800 B.C had noticed the electrical and the magnetic phenomenon, they had discovered the magnet stone (Fe_3O_4) and its ability to pull the metallic materials.

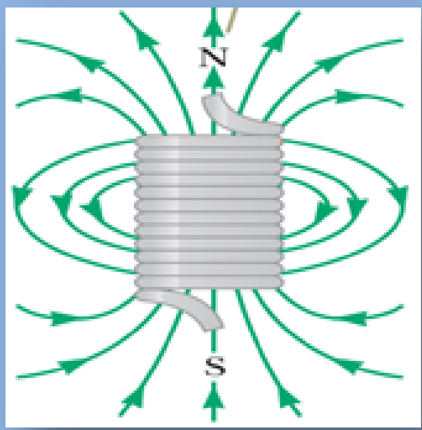

Photo (2): Coil's magnetism failed.

– Flux:

The magnetic flux through a surface is defined as the number of the magnetic field lines passing through the surface perpendicular on it. And from this definition we conclude that the flux is related to both the surface and the magnitude of the field.

The magnetic flux is given by the relation:

$\Phi_B = \int_{surface\ s} \vec{B}.d\vec{A}$ [The unit of magnetic flux is wb where 1 wb = 1 Tesla.m^2]

Magnetic induction and Faraday's law:

The magnitude of the magnetic flux changes according to three factors, which are:

1. The magnitude of the magnetic field.
2. The surface area of the circuit.
3. The angle between the magnetic field and the surface vector.

Faraday's law states that:

An induced current is generated in a closed circuit when the magnetic flux that penetrates the surface of the circuit changes with time, and the current keeps on going as long as the change is occurring.

We can also say that the induced current shows actions that are opposite to its generation in the first place. For example, when we put a magnet near a coil the magnetic flux through the coil increases, so the induced current creates a magnetic field that has the opposite direction to that of the magnet, and this is known as Lenz's law.

From experiments, and by using a voltmeter, we found that the electromotive force is proportional to the change of the magnetic flux and inversely proportional to the change in time, mathematically speaking this can be reformulated in terms of the law:

$$\varepsilon = -\frac{d\emptyset}{dt}$$

Where the minus sign indicates Lenz's law,.

Chapter [2]: Advantages and Applications

Part (1): Advantages:

It is very useful for military operations, especially for defending soldiers who are not taking cover in tanks or in armored cruisers. It is a good replacement for the usual armor; because the usual armor is heavy and it doesn't cover the whole body, but the physical shield is unwearable and it doesn't have to be carried around and it protects everything behind it.

Part (2): Multiple applications.

The results of versatility of the eddy current method are tangible in broad applications usage. However, the major application areas include the following:

- In-service inspection of tubing at nuclear and fossil fuel power utilities, at chemical and petrochemical plants, on nuclear submarines, and in air conditioning systems.

- Inspection of aerospace structures and engines.
- Production testing of tubing pipe, wire, rod and bar stock.

Part (3): The major application of eddy current for non-martial purposes:

The Safe Thermal Food Heater:

It's one of the safest modern methods of using Eddy Currents, and it is considered safe; because despite its electric and thermal nature, it is electrically ad thermally safe, that we

We can even touch with our bare hands without being harmed. We shall see its components and how it works.

Photo (3): The Safe Thermal Food Heater.

- **The components**:

The heater consists of a base with an electric troidal on it; The troidal is a 22 wire-wrap of copper wires wraped on each other. The troidal is connected to a manual control circuit, the user sees it as a controlling process of velocity and heat and the time of heating, while internally it is nothing but of the current's intensity, then there is the cover which forms the place where we put the food. This cover has a circle mark on it which marks a place made from Al-Melamine material which is able to endure heat not the fire.

Photo (4): Inside of the machine.

- **How it work**:

When we turned on the machine the circuit was connected. Then the current cross the troidal. After that the vectors of magnetic failed is formed and make circles in the troidal.

We saw that in each magnetic circle there are circles vertical on the mean circle. These are the eddy currents which has thermal act only in the non-ferromagnetized metals. So this is the case of its unharmed act for human skin or another materials.

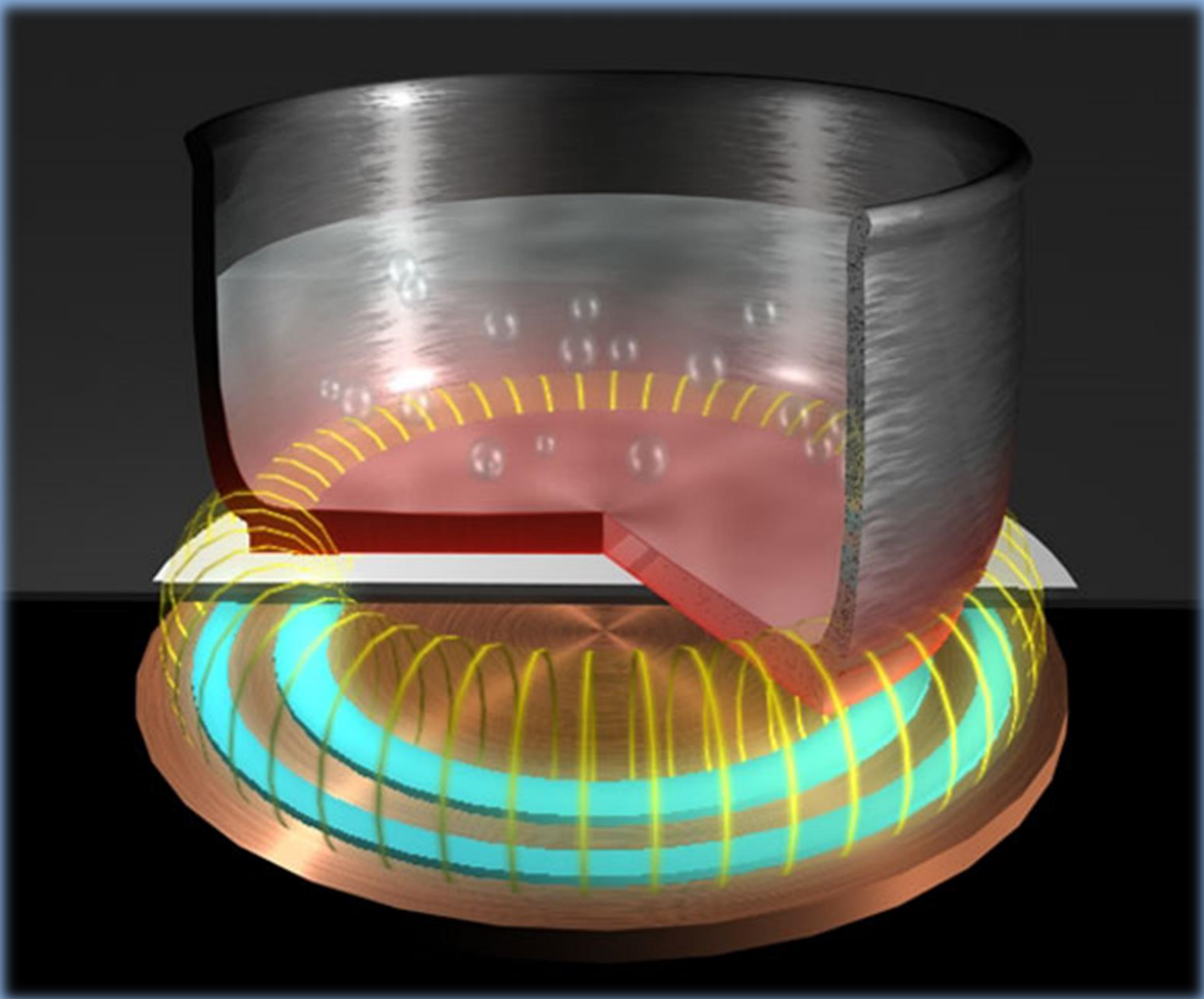

Photo (5): The real act of Eddy's.

Conclusions and Results:

In this research and in our theoretical studies we found out a lot of things that helped us answer the questions we have put:

There are currents that are created between the magnetic field and the non-ferromagnetic metals, these currents can heat those metals according to the power of this field, and they are called Eddy currents. Eddy currents have a thermal effect, which raises the temperature of the non-ferromagnetic metals, and we call it Induction Heating. Induction heating is faster than the usual heating methods.

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