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APPLICATIONS BASED ON VARIABLE FREQUENCY ROTATING MAGNETIC FIELD. ELECTROMECHANICAL AGITATOR WITH DUAL DIRECTION

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ABSTRACT

This paper presents a series of experimental results obtained by studying the specific effects and phenomena of the rotating magnetic field. During the research, an interesting phenomenon, specific to the variable frequency rotating magnetic field, was noticed. Thus, a ferromagnetic metal ball placed in the rotating magnetic field, rotates in the field direction until it reaches a critical speed. If the speed of the magnetic field continues to increase, the ball reverses its rotation direction, even if the magnetic field direction remains the same. This has led to the development of stands and experimental installations including the dual direction electromechanical agitator described in this paper.

KEYWORDS: rotating magnetic field, fluid agitator, ferromagnetic balls

1. Introduction

The research on the behavior of magnetic liquids and ferromagnetic objects placed in rotating magnetic fields was based on the study of Kagan's effect. According to the magnetic liquid experiments carried out by R. Moscowitz and R. E. Rosensweig in 1967, it was shown that in a constantly rotating magnetic field, the magnetic liquid drive is given by the dipolar torque applied to each particle from the suspension composition. Later, in 1973, Kagan studied the phenomenon of ferrofluid spinning when it is exposed to the rotating magnetic field action. This reflects the magnetic liquid behavior which develops a rotative motion opposite to the magnetic field, in the context where electrically conductive liquids are spinning in the same direction as the field. Moreover, it was observed that all cylindrical dielectric bodies immersed in ferrofluid rotate in reverse direction as the rotating magnetic field [4].

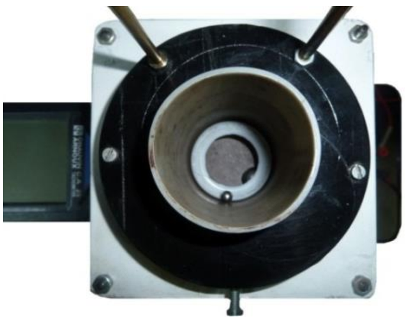
Continuing the research in this area, the EMAD (Research Centre in Electrical Engines, Apparatus and Driving) researchers started a series of experiments based on the characteristic phenomena and the magnetic field applications.

2. Variable frequency rotating magnetic fields specific phenomena

In 2001, in a series of experiments, Professor Dorel Cernomazu accounts for the action of a steel magneto-active particle spread in water. The solution described had been submitted to a rotating magnetic field generated by the stator of a three-phase asynchronous motor. Initially, the spread analyzed tended to revolve in the same direction as the rotating magnetic field, whereupon, suddenly, it has started a reverse rotary flow [1].

In subsequent experiments, we used a ball from ferromagnetic material placed in a rotary magnetic field with rotational frequency varying between 0 and 6000 rot/min. It was noticed that the ferromagnetic ball, under the rotating magnetic field action, is spinning initially in the same direction as the field, and subsequently, by increasing rotational frequency, the ball direction is reversing. The reversal moment depends on the ball position related to the rotary magnetic field, ball dimensions and composition, the medium where it is placed and the field rotational speed. The experimental stand is shown in Figure 1.

a)



b)

Fig. 1. *Stand for generation of variable frequency rotating magnetic field: a) side view; b) top view – insulating vessel detail*

The reproduction of the stand presented in the patent application [3], and the experiments described in the thesis [4], presented a number of interesting physical phenomena.

The device for variable frequency rotating magnetic field generation is actuated by a motor M2, supplied by an autotransformer AT, through an isolating transformer. Continuous adjustment of M2 motor supply voltage is achieved through the fact that the autotransformer potentiometer is actuated by a DC motor M1, supplied by a source AC/DC as it is shown in Figure 2.

During the first experiments, the ball placed in the rotating magnetic field had a different behavior. The results were influenced by many factors:

- the rotation speed of the shaft which drives the permanent magnets;
- the physical (size, weight) and magnetic properties of the ball;
- the position of the container and the position of the ball in the magnetic field lines;
- the viscosity of the environment in which the ball is placed (air, water, oil, glycerin).

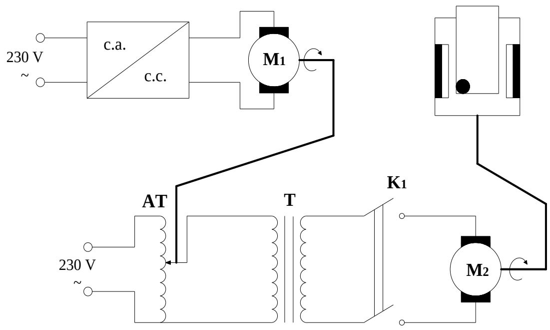


Fig. 2. *Feeding electrical diagram of the stand*

To obtain conclusive results, the variables influencing the test results were reduced and several sets of measurements were made with the following constants:

The ball used	Fe – 97.5%; Cr – 1.6% diameter: 11.1 mm weight: 5.6 g
The environment where the ball is placed	air
Growth rate of speed for motor M_2	constant
Ball placement	in the center of the permanent magnets

In order to verify the obtained results, three sets of measurements were performed for five different motor (M_1) supply voltages, thus identifying four critical points of the rotating magnetic field speed:

v_1 – the speed of the first reversal in direction of rotation - to the left;

v_2 – the maximum speed;

v_3 – the speed at which the ball remains in balance (at decreasing speed);

v_4 – the speed of the second reversal in direction of rotation (at decreasing speed) – to the right.

To illustrate the behavior of the ferromagnetic ball in time, we drew the graph shown in Figure 3, for the first group of values, for 14-volt supply voltage of the engine M_1.

U_{M1} = 14 V_{cc}		
Group I	Group II	Group III
v_1 = 596 [RPM]	v_1 = 614 [RPM]	v_1 = 622 [RPM]
v_2 = 3380 [RPM]	v_2 = 3392 [RPM]	v_2 = 3387 [RPM]
v_3 = 339 [RPM]	v_3 = 341 [RPM]	v_3 = 323 [RPM]
v_4 = 206 [RPM]	v_4 = 204 [RPM]	v_4 = 217 [RPM]

Analyzing the chart above, one can notice, in the diagram, five areas in which the ferromagnetic ball has different behaviors:

At increasing speed

$0 - v_1$ the ferromagnetic ball rotates clockwise (right), and when the speed reaches 595 RPM, it suddenly changes its direction of rotation to the left;

$v_1 - v_2$ the ball continues to rotate to the left up to the maximum speed of 3380 RPM;

At lowering speed

$v_2 - v_3$ the direction of rotation is kept to the left until it reaches a speed of 339 RPM;

$v_3 - v_4$ in this range, the ferromagnetic ball remains in balance;

$v_4 - 0$ at the speed of 206 RPM the second reversal occurs in the direction of rotation (to the right), the direction of motion was kept up to the speed of 0 RPM.

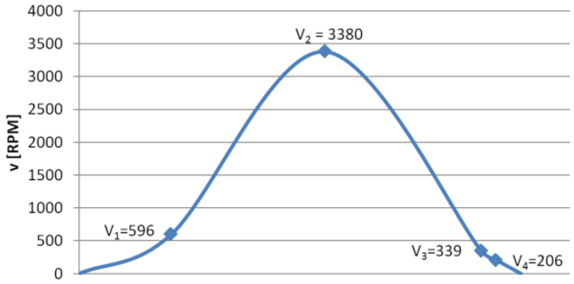


Fig. 3. *The rotational speed of the ball in time*

Based on the results obtained with one ball, with different diameters, materials and weights, placed in agents with different viscosities, a double-acting electromechanical stirrer was conceived, developed and tested. This stirrer is described in the following chapter.

3. Double-acting electromechanical stirrer

The double-acting electrochemical stirrer offers a number of advantages over the appliance described above, in that two stirring systems made of two ferromagnetic balls, with different diameters, isolated, placed under the same rotating magnetic field action, move along different tracks with different movement directions. In this manner an increased stirring effect was obtained, which reduces the time adequate for stirring and increases the device efficiency.

The double-acting electrochemical stirrer is made of an electrically insulating vessel 1 fitted in an electrically insulating support 2, in which a rotating assembly is placed. The rotating assembly consists of a ferromagnetic vessel as a glass 3, which presents on its inner surface two permanent magnets 4, fixed in diametrically opposite positions. The ferromagnetic vessel is driven in rotary flow by means of an arbor 5, of a DC motor 6 supplied from an auto-transformer with sliding contact. Two electrically insulating ferromagnetic balls 7 and 8 are placed inside the electrically insulating vessel 1. One of the balls is placed at the bottom of the vessel, and the other one on an annular chamber 9 made from an insulating material, bonded on the inner side of the vessel, under the fluid level.

The ferromagnetic balls 7 and 8, of different sizes, placed in different areas of the same variable frequency rotating magnetic field, are moving differently: one clockwise and the other one counterclockwise, within the vessel containing dielectric fluid. The balls direction of rotation depends on the relative position within the magnetic field and on the critical frequency at which the magnetic synchronous torque breaks for one of the balls [1].

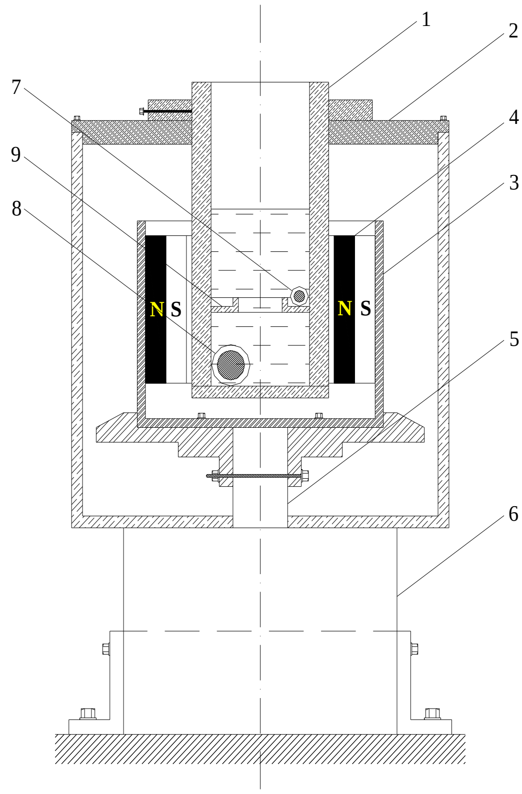


Fig. 4. *Double-acting electro-mechanical stirrer* [1]*: 1 - insulating vessel; 2 - insulating support; 3 - ferromagnetic support; 4 - permanent magnets; 5 - axle; 6 - DC motor; 7, 8 - ferromagnetic balls; 9 - annular chamfer*

4. Conclusions

The phenomenon studied, namely changing the ball direction of rotation when increasing the frequency, was named the CEUS effect by the researchers from the Electrotechnical Department of the University of Suceava.

The CEUS effect was the basis for the practical creation of fluids stirrers designed in a first variant with a single ferromagnetic ball with reversible direction of rotation when increasing the rotating magnetic field frequency.

An improved version of the stirrer is the one presented in the paper, characterized by the fact that the stirring effect is carried out by two balls placed in different planes, under the action of the same rotating magnetic field, which rotates in opposite directions.

The studied CEUS effect can be applied to achieve an electric motor with reversible direction of rotation at the change of frequency.

Another research direction detached from experiments is the study of a possible breaking torque generated by the leak flow over the ball bearing.

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