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New Aspects Concerning the CEUS Figures Identified at Ferrofluid Utilisation in Rotating Magnetic Field

Within the EMAD Research Center was initiated researches about CEUS figures obtained by exposing the content of a cylindrical container on the progressive action of the magnetic field produced by a special winding associated with GROSU stator. Inside the recipient was stored a quantity of ferrofluid which surface were scattered gold or bronze particles. The assembly thus obtained was studied using a suitable video camera, obtaining the so-called CEUS figures that constitute true stamps that highlight and identify the particularities of the studied types of electric drives.

Keywords: Ferrofluid, CEUS effect, rotary field

1 Introduction

CEUS figures study was initiated at EMAD Research Center from University „Ştefan cel Mare", Suceava. CEUS figures name (CEUS – Departament of Electrotechnics, University of Suceava), was suggested by the great scientist and professor Emanuel DIACONESCU, on the occasion of assisting a report in the internship doctoral training [34]. The suggestion made by academician Emanuel DIACONESCU, a member of the committee for analysis and evaluation of the essay, was a gesture of appreciation for the department endeavor, generally, underprivileged by fate. The indication has been taken as the scientific coordinator and by the author of the thesis [42].

Getting the CEUS figures was possible with a GROSU stator, designed and built by the eminent manufacturer of electrical drives Ştefan GROSU [74]. The asynchronous motor had been compared in terms of performance with a transformer, although in the literature, there are few cases in which the outlined approach to be translated by similar constructions.

Figure 1 present the GROSU three-phase motor and in figure 2 are shown the two versions of the experimental model used to obtain the CEUS figures. The dimensions of the magnetic core, afferent to the experimental model are presented in figure 3.

The real rotor was replaced by a sample container made by insulating material and filled with a slurry of ferromagnetic particles. To highlight the movement of ferrofluid and to obtain the CEUS figure, on the liquid surface was sprinkled a gold or bronze extrafine powder [34, 42, 51, 52, 66].

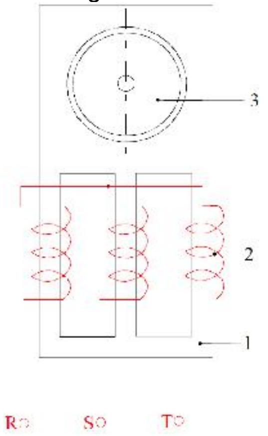
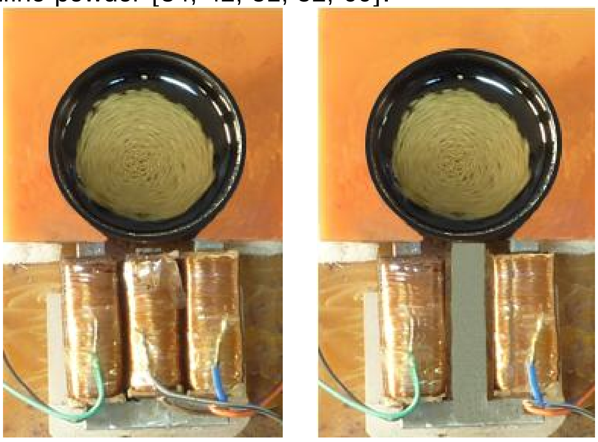


Figure 1. GROSU three – phase motor [67, 68, 69, 70, 71]:
1 - stator; 2 – phase windings;
3 – cage armature.



a) b)

Figure 2. Experimental model [66]:
a). Three- phase winding solution;
b). Two phase windings solution.

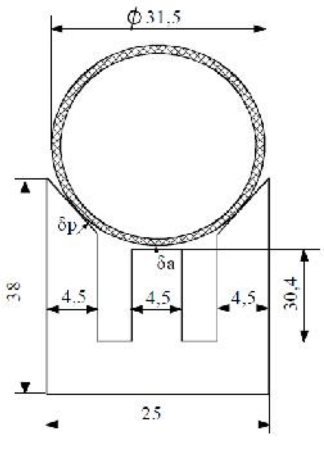


Figure 3. Dimensions of the magnetic core of the GROSU motor stator used in the experiments [42].

The stator magnetic core is made of steel OL 37, of the dimensions presented above, and the windings are made from glaze insulated copper wire, each coil having 12.000 spires.

Subjecting the container content on the progressive action of the magnetic field created by the GROSU stator winding and shooting the movement of gold and bronze particles with a proper camera, were obtained the images which the thesis author [42], taking the academician Emanuel DIACONESCU suggestion, called the CEUS figures.

The study developed aimed the following constructive types and variants of electromotors:

- shielded pole monophase induction motor with a single pair of poles;
- shielded pole monophase induction motor with two pairs of pole;
- GROSU motor with three-phase winding;
- GROSU motor with „V" connection for three-phase supply with direct and reverse sequence;
- GROSU motor with „V" connection after suppressing a phase;
- GROSU – CERNOMAZU monophase motor, supplied for both sense of rotation.

The CEUS figures ensemble obtained represents true stamps that customise and highlight the peculiarities of the studied motors type.

In the first stage, the CEUS figures were obtained using a magnetoactive particle slurry obtained electrolytically [42, 66]. The authors of these paper, continuing research, try to highlight the CEUS figures particularities for the utilisation of a real ferrofluid (Ferrotec EFH1). To that effect where approached the same research direction described previously. For lack of space, in the paper are presented only the results for GROSU motor three-phase winding made after Y-connection, monophase GROSU – CERNOMAZU motor supplied for both sense of rotation and GROSU motor with „V" connection for three-phase supply with direct and reverse sequence.

Contributions to the CEUS figures study for Grosu motor three – phase winding made after Y- connection

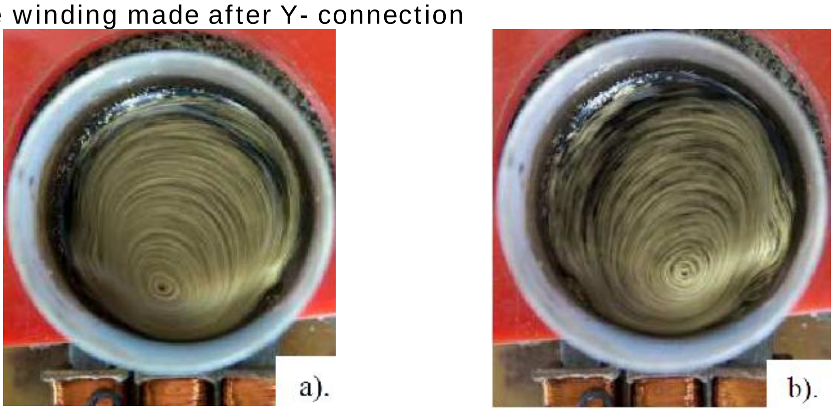


Figure 4. The movement spectrum for the use of a magnetoactive particles slurry, according to the phase sequence [42]: a). Direct sequence (R-S-T); b). Reverse sequence (T-S-R).

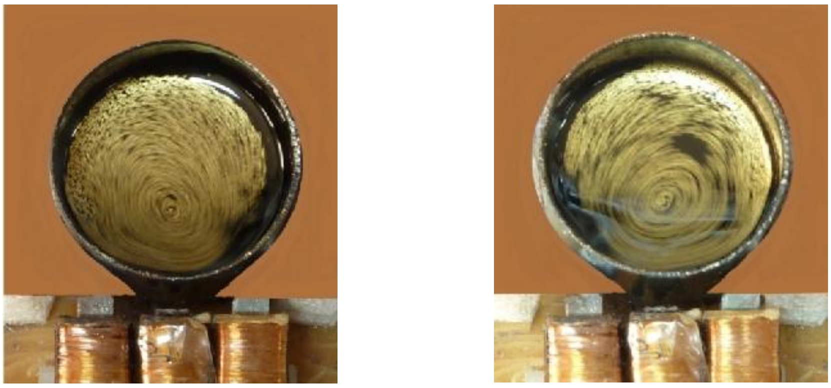


Figure 5. The movement spectrum for the use of a real ferrofluid, according to the phase sequence: a). Direct sequence (R-S-T); b). Reverse sequence (T-S-R).

The movement spectrum comparison from figure 4 and figure 5 shows a near resemblance. In both cases, the experimental study, emphasize the movement spectrum dependence from phase sequence and highlight the existence of an active zone, near the fixed coil, which develop the influence of the progressive magnetic field created by the fixed coil. For direct sequence (R-S-T), the movement pole, located in the active zone, is placed between columns A and B, or between B and C – for the reverse sequence.

The movement picture consists of a family of figures each one having a similar shape to that of a circle with a diameter in the ascending evolution, and whose centers are placed on a bent line, that pass trough the movement pole and through the midst of the considered active area. The axis that is bent to the right when rotary magnetic field rotates left or the left, or is bent to the left when rotary magnetic field rotates to the right.

Contributions to the study of CEUS figures for GROSU – CERNOMAZU monophase motor, supplied for the two rotation course

The CEUS figures comparison highlight a near resemblance, which proves, for the studied case, that the movement spectrum configuration remain the same when passing from a magnetoactive particles slurry to a real ferrofluid.

The GROSU – CERNOMAZU variant (figure 6) is characterized by the fact that in one of the outside columns is mounted the main coil, connected to a single – phase power supply (in experiment case 380 V and 50 Hz), while on the other columns are mounted two concentrated windings, made with the same number of spire as the primary winding and connected in short – circuit. The magnetic core used is the same as that used in the previous case. The primary winding and the shielded coil have each one 10.000 spire, with 0.05 mm diameter and are enamel insulated. In the described manner, there was obtained a fixed coil with a primary pole and with two shielded pole. In contradistinction to the rule encount at the shielded pole motor, made in the usual variant, where the progressive field is oriented from the unshielded section to the shielded section, at the studied motor, the progressive field moves from the shielded section to the unshielded section of the fixed coil.

That fact is important because the rotating magnetic field sense determines the ferrofluid movement direction. Reverse of the rotating magnetic field is achieved by reversing the main pole position regard to the shielded pole.

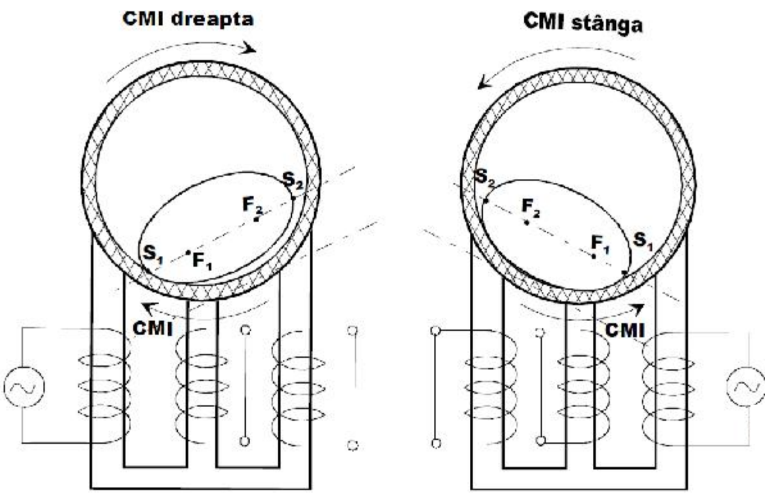


Figure 6. GROSU-CERNOMAZU motor. The ferrofluid movement spectrum has the shape of a distorted ellipse, with the major axis oriented in the shielded pole direction [15].

Figure 7. The movement spectrum for the use of a magnetoactive particles slurry for GROSU – CERNOMAZU motor, according to the phase sequence [15]: a). Direct sequence (R-S-T); b). Reverse sequence (T-S-R)

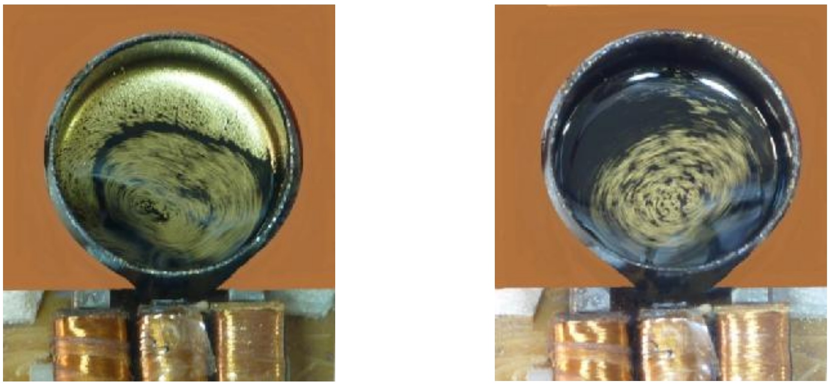


Figure 8. The movement spectrum for the use of a real ferrofluid for GROSU – CERNOMAZU motor, according to the phase sequence: a). Direct sequence (R-S-T); b). Reverse sequence (T-S-R)

The analysis of the set of images shown in figures 7 and 8 lead to further observation:

- the movement ferrofluid ensemble has the shape of a ellipse slightly deformed, with major axis oriented on shielded pole termination direction (figure 6);
- the S1 crest of the ellipse is always placed in the area between the main pole and the first shielded pole; the main vortex F1 of the ellipse concur with the movement pole, as it is indicated by the images sequence shown in figure 7 and 8;
- the image analysis reveals that the ferrofluid movement, in GROSU – CERNOMAZU fixed coil, represents only a fraction of the recorded area in GROSU motor with Y connection case, previously presented in figures 4 and 5.

Contributions to the study of CEUS figures in GROSU motor case with three – phase winding performed after „V" connection

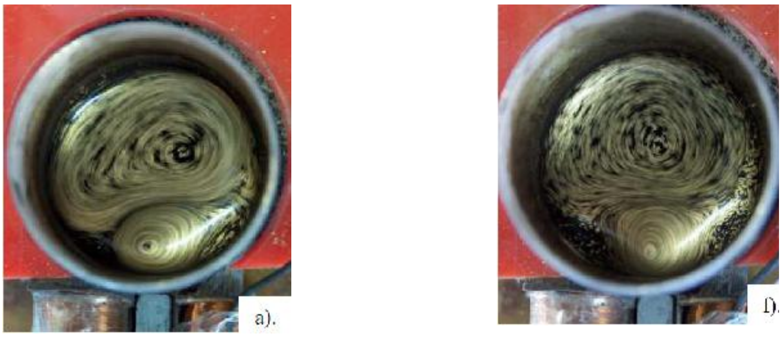


Figure 9. The movement spectrum for the use of a magnetoactive particles slurry, for a GROSU three-phase motor with "V" connection [15]:
a). Direct sequence (R-S-T); b). Reverse sequence (T-S-R).

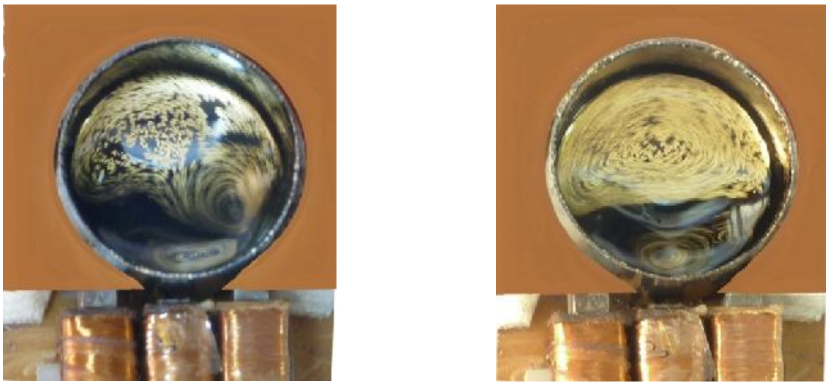


Figure 10. The movement spectrum for the use of a real ferrofluid, for a GROSU three-phase motor with “V” connection:
a). Direct sequence (R-S-T); b). Reverse sequence (T-S-R).

The image contains two distinct moving areas (two vortices), an active area (engines) powered by rotating magnetic field and other passive, driven through friction by the active area, after the movement transmision model from the transmissions with friction wheels.

The contact between the two parts comprise an input portion and an output portion. Within the contact portion, the two areas have the same movement direction. The movement direction can be identified by the placement of the input and output (the ferrofluid movement direction is oriented from input to output).

The output can be recognized by several criteria. One of them is that the output can be associated with the appearance of turbulences only in that area. Another criterion is that the active area undergoes a slight deformation by elongation, towards the ferrofluid movement direction in the area of contact.

Unlike the previous case, where the rotating magnetic field was produced by a three-phase winding, connected after Y connection, in this case („V” connection case) the active area and the movement pole were placed on the central column axis (the column without winding). The movement pole, placed within the active area, is slightly offset, in one direction or other of the central column axis, in the interlinking of phases order.

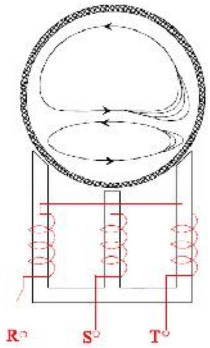


Figure 11. Explanatory at the forming of ferrofluid movement spectrum exposed to the rotating magnetic field action produced by a three – phase GROSU fixed coil with „V“ connection supplied by a three-phase source 3X380 V; 50 Hz [15].

Conclusions

1. The experimental study effectuated in this paper shows that by passing from a slurry of magnetoactive particles to a real ferrofluid, the movement spectrum, as evidenced by CEUS figures, remains unchanged.
2. In this paper are presented only the results for the following cases:
   - GROSU motor with three-phase winding performed by Y connection;
   - GROSU – CERNOMAZU monophase motor;
   - GROSU motor in „V” connection for the three-phase feed with direct and reverse sequence.
3. Within the Research Center EMAD, the previous conclusion was verified and for other cases:
   - shielded pole monophase induction motor with a single pair of poles;
   - shielded pole monophase induction motor with two pairs of pole;
   - GROSU motor with „V” connection after supressing a phase;
4. The results create the basis of developing a study about the use of CEUS figures for induction motor diagnosis for: short – circuit between spires; short – circuit between phases; reverse of the connection at one of the stator phase; disequilibrium between phases because of a inadequate contact.

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