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MEASUREMENT OF THE AZIMUTHAL COMPONENT OF THE VELOCITY OF PROBE FALLING PARTICLES IN GLOW DISCHARGE IN MAGNETIC FIELD

The azimuthal component of the velocity of falling probe particles in an unstratified glow discharge in a longitudinal magnetic field is measured. We use a discharge tube and solenoids participating in an experiment to observe the rotational motion of the dust structures in strata. The influence of the divergence of magnetic field lines on the anode and cathode ends of the solenoids on the appearance of an azimuthal momentum of dust particles is checked. The dependences of the angular velocity of probe particles on the longitudinal magnetic field are determined.

Keywords: azimuthal component of velocity, probe falling particle, glow discharge, magnetic field.

1. Introduction

There are a number of works [1–3], in which the movement of the dust structures created in striations of a glow discharge in a magnetic field was studied. It is known that the imposing of a longitudinal magnetic field leads to the rotation of dust structures around the axis of symmetry of the discharge. The projection of the angular velocity onto the direction of the magnetic induction vector has a nonlinear sign-variable dependence on the magnetic field. Among the hypotheses which have been put forward for the explanation of this phenomenon, there are ones, which consider the influence of a dust structure on plasma flows or consider the influence of a construction of the solenoids creating a magnetic field.

In this work, the influence of the divergence of magnetic lines at the anode and cathode edges of solenoids on the emergence of an azimuthal impulse of the dust particles is checked. In addition, we tried to find out the role of the discharge narrowing. The azimuthal component of the velocity of falling probe particles was measured in a longitudinal magnetic field. Experiments were made in an unstratified discharge, when there is no condition for the formation of a dust trap.

2. Experimental Setup

The scheme of a setup is presented in Fig. 1. Its construction was the same as that in experiments with dust structures in [1]. The vertical discharge tube is 70 cm in length and 3.5 cm in diameter. The cathode was placed from below vertically; the anode was placed from above in a lateral appendix. The discharge tube had a removable insert, which provided the narrowing of the current channel to 5 mm. Without the insert, the diameter of the tube in this place was 1.5 cm. The magnetic field was created by two solenoids having a height of 15 cm and a radius of 15 cm; the distance between them was 9 cm. The tube had opportunity to shift along the axis by 5 cm. Illumination was made sideways by a parallel beam 1 cm in width. Video filming was made from above through the optical window. Experiments were made in argon. Particles of $LiNbO_3$ with sizes of 1–4 microns were used.

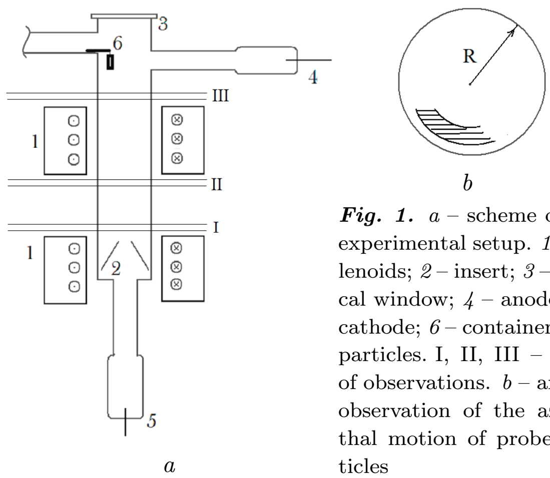
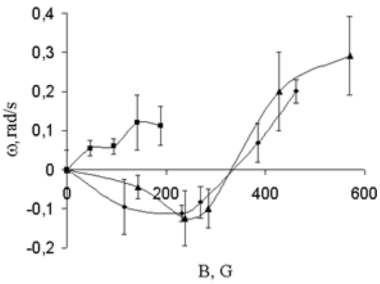


Fig. 1. *a* – scheme of the experimental setup. *1* – solenoids; *2* – insert; *3* – optical window; *4* – anode; *5* – cathode; *6* – container with particles. I, II, III – areas of observations. *b* – area of observation of the azimuthal motion of probe particles

3. Measurements

The area of observation is schematically shown in Fig. 1, *b*. Observations were made in three sections: above the lower solenoid, above the upper solenoid (at their anode edges), and under the upper solenoid (at its cathode edge). Measurements were carried out with any single solenoid and with two solenoids. The direction of a magnetic field in all cases was identical (upward).

For the determination of the angular velocity of a particle, the azimuthal component of its linear ve-



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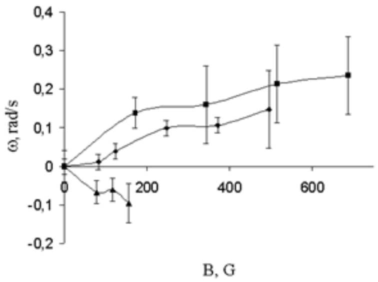

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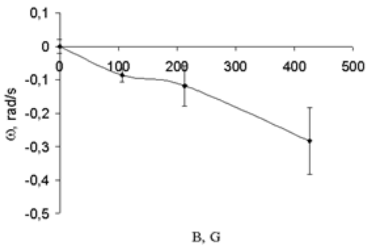

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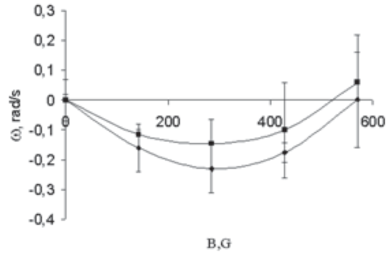
Fig. 2. Dependence of the projection of the angular velocity of falling probe particles on the longitudinal component of the magnetic field. Conditions: argon, 1.8 Torr, 1.6 mA, the insert was 4 cm below the upper edge of the lower solenoid. *a* – in area I. *b* – in area II. *c* – in area III. Designations: squares – only the upper solenoid is switched-on; triangles – only the lower solenoid is switched-on; rhombs – both solenoids are switched-on



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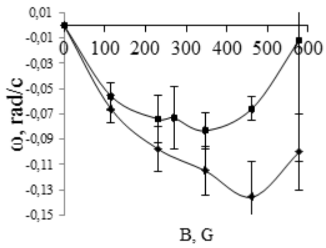

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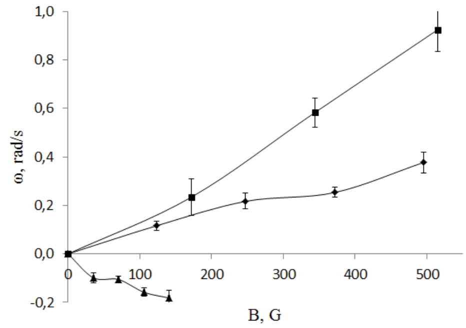

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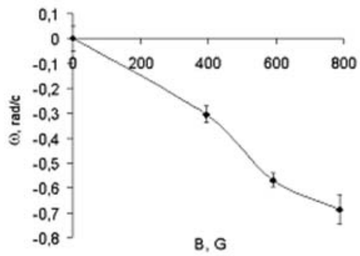

d

Fig. 3. *a*) – in area I. Only the upper solenoid is switched-on; the insert was 8 cm (rhomb), 5 cm (square) below the upper edge of the lower solenoid. *b*) – in area I; both solenoids are switched-on; the insert was 8 cm (rhomb); 5 cm (square) – below the upper edge of the lower solenoid. *c*) – in area II; square – only the upper solenoid is switched-on; triangle – only the lower solenoid is switched on; rhomb – both solenoids are switched-on. *d*) – in area III; only the upper solenoid is switched-on

locity was calculated (tracks on several frames were imposed, and their length was measured), and the radial coordinate was determined. The particles which moved through the area of observation with vertical velocities from 3 to 10 cm/c were chosen. The positive direction of the angular velocity is the one, which corresponds to the vector of a magnetic field.

4. Results

In the case where the discharge tube has an insert (narrowing of the current channel is 5 mm), one can see from Fig. 2, *b* that, in the area under the upper solenoid at its cathode edge (area II), the probe particles have a positive projection of angular velocities if the upper solenoid or both of them are switched-on. The angular velocity of particles grows with the magnetic field. If only the lower solenoid is switched-on, the particles have a negative projection of the angular velocity.

Above the lower solenoid at its anode edge (area I), the particles have a positive projection of the angular velocity if only the upper solenoid is switched-on. The dependence of the projection of the angular velocity on the magnetic field has a more complicated character, which recalls the dependence of the angular velocity on the magnetic field for dust structures in striations [1], if the lower solenoid or both solenoids are switched-on.

Measurements at the anode edge of a solenoid were made also above the upper solenoid (area III). The result is presented in Fig. 3, *d*. The projection of the angular velocity of particles in this area is negative. Its value increases with the magnetic field. Unlike the result obtained for area I, no sign change of the dependence of the angular velocity on the magnetic field is present.

If the discharge tube has no insert (narrowing of current channel is 15 mm), the result is presented only for area I, Fig. 3, *a*. The dependence of the projection of the angular velocity on the magnetic field is similar to that shown in Fig. 2, *a* (for the case where only the lower coil is switched-on), but the sign change happens at bigger magnetic fields.

5. Conclusion

Some of the found effects can have impact on the dynamics of dust structures in the magnetic field. At the creation of theoretical models of dust structures, their rotation in the magnetic field should be considered.

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ВИМІР АЗИМУТАЛЬНОГО КОМПОНЕНТА ШВИДКОСТІ ПРОБНИХ ПАДАЮЧИХ ЧАСТИНОК В ТЛІЮЧОМУ РОЗРЯДІ В МАГНІТНОМУ ПОЛІ

Р е з ю м е

Вимірювалася азимутна складова швидкості падаючих пробних частинок в нестратіфіцірованному тліючому розряді в поздовжньому магнітному полі. Використовувалися розрядна трубка і соленоїди для спостереження обертового руху пилових структур в стратах. Перевірявся вплив розбіжності магнітних ліній на анодному та катодному торцях соленоїдів на виникнення азимутального імпульсу у пилових частинок. Визначено залежності кутової швидкості пробних частинок від величини поздовжнього магнітного поля.