# EXPERIMENTAL TESTING OF THE MASS EXCHANGE ON THE FERROFLUID SURFACE

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**Abstract:** The experimental investigation is carried out to evaluate the effect of the gradient magnetic field on the mass exchange during the bubbles run through the ferrofluid. The results show the influence of the magnetic field on the volume of the mass exchange cell.

## 1. Introduction

The border between gas and ferrofluid is sensitive to applied magnetic field - it warps the free surface of ferrofluid very strongly. The gradient magnetic field increases the floatation of nonmagnetic bodies in the ferrofluid that has an influence on the size of the bubbles in the ferrofluid. The external magnetic field determines also the shape and the movement of the bubbles [1]. Consequently, it gives the opportunity to impact the mass exchange between gas and fluid as it is determined by the surface area and movement intensity.

Due to these properties the utilization of the ferrofluids is a promising technology in the mass exchange techniques. For example: it may be effective for purification of air or other gases from impurities, gas enrichment and processing, as well as gas transport inside ferrofluid, gas recovery for analysis, etc. Usage of the magnetic fluid gives a possibility to control listed processes by the magnetic field.

## 2. Experiment

The ferrofluid consist of ferromagnetic particles suspended in the liquid carrier. For reported experiments the liquid carrier is composed by two components. One of the components easily evaporates as the boiling temperature is low, while another component has high boiling temperature and therefore remains longer in the liquid carrier. The concentration of the volatile liquid carrier component in the air passing through the ferrofluid is measured during the experiment. The data are collected by the IR spectrometer. Subject of the present work is experimental examination of the influence of a magnetic field on the removing volatile components from the higher-boiling magnetic fluid.

The experimental setup is shown in fig. 1. The permanent airflow was supplied by the peristaltic pump. Tetradecane is used as a high-boiling carrier for the ferrofluid, and the small quantity of hexane composes a low-boiling addition to the ferrofluid. IR spectrum of the gas at the output has a stripe of hexane, which intensity depends on the experiment duration or quantity of the air passing through. The obtained data presents the information about hexane concentration in the measured air. The influence of the magnetic field on the mass exchange may be tested as the change of hexane concentration in the measured airflow with or without the magnet .

The magnetic field is formed by two joined permanent rectangle magnets with vertical magnetization in opposite directions, see fig.1. At the horizontal side the magnetic field induction of the above described system reaches its maximum value in the point above the central area. Due to the symmetry of the magnetic system the induction vector at that point is headed horizontally. The correlation between the maximum values of the magnetic field induction and the distance to the surface of the magnetic system is displayed in fig. 2.

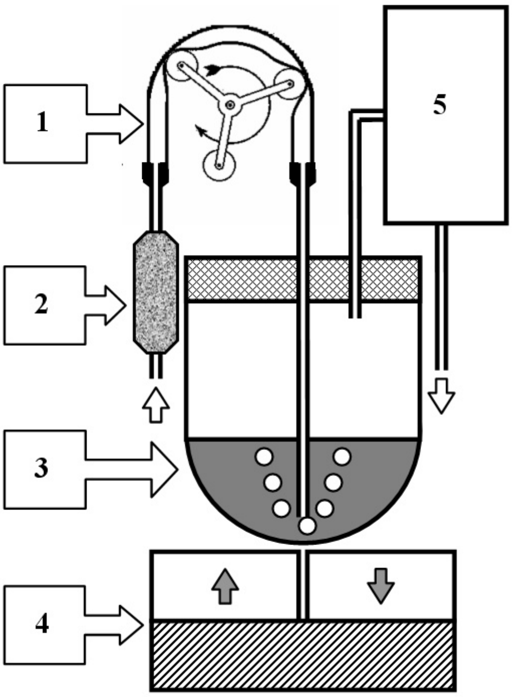



Figure 1: Experimental setup. 1 – peristaltic pump, 2 – dehumidifier, 3 – ferrofluid, 4 – magnet system, 5 – IR analyzer.

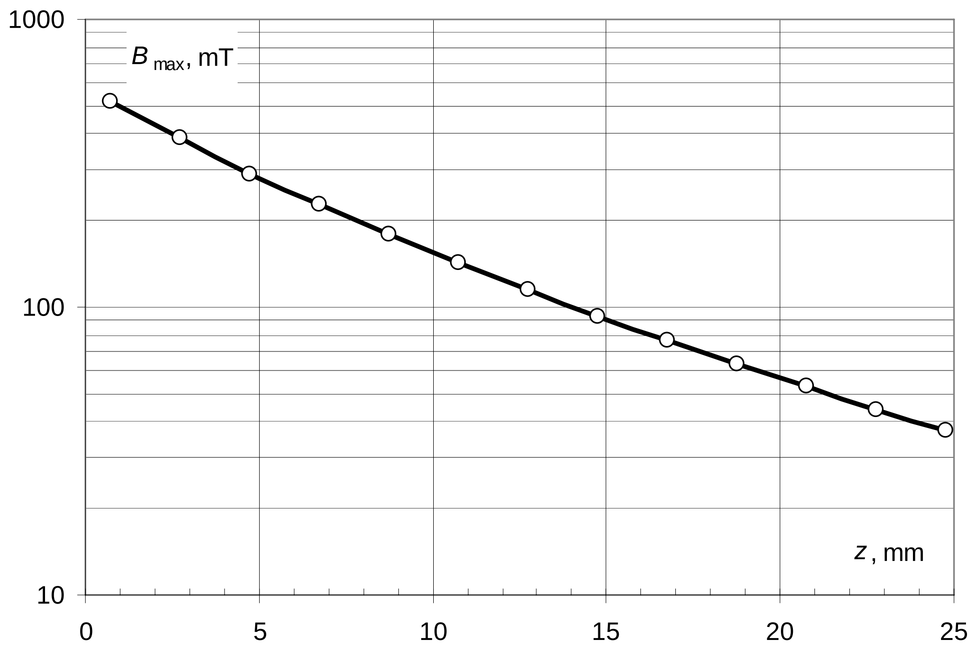



Figure 2: The maximum magnetic field induction from the distance to the magnet surface.

The initial ferrofluid is composed by magnetite particles dispersed in tetradecane, stabilized by the oleic acid. The particle size of magnetite varies from 5 to 13 nm (the sample

DF-105 is produced at the Institute of Physics of Latvia University), the density of the ferrofluid is 1070 $kg/m^3$. The curve of the ferrofluid magnetization is displayed in fig. 3.

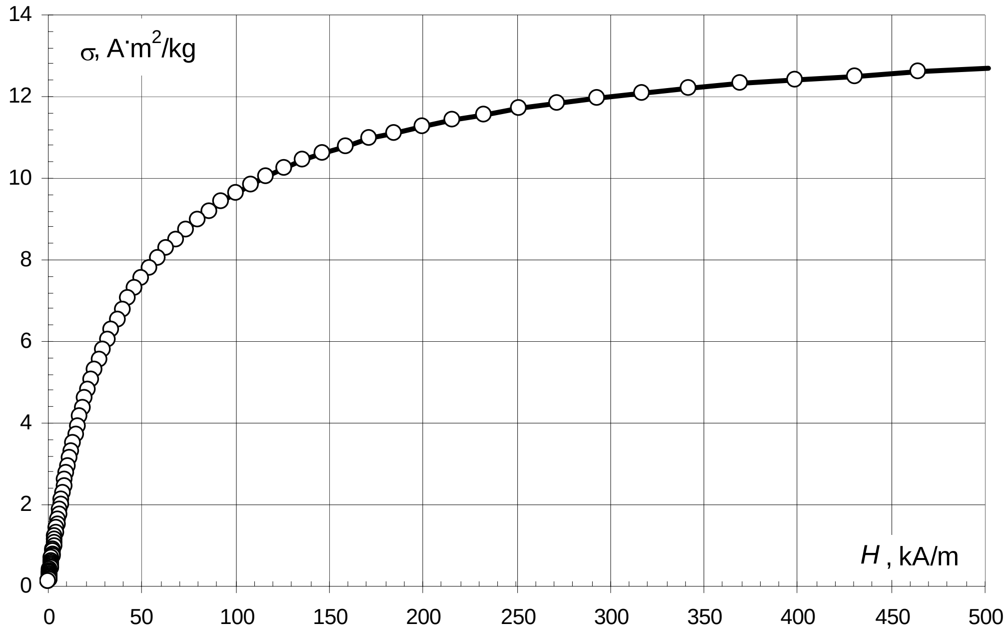



Figure 3: Magnetization curve of ferrofluid.

Before the experiments an amount of 0.2 ml of ferrofluid is located into the test-tube with a diameter 12 mm. 0.01 ml of hexane is added and the liquid is stirred. Afterwards the copper capillary tube with a diameter 1 mm is put into the test-tube down to the bottom. The air is blown through the capillary tube into the ferrofluid at velocity 0.23 ml/s. The air flow upwards through the ferrofluid, then being collected into the IR spectrometer gas probe. Absorption spectra are measured by the IR spectrometer every 2 minutes. Duration of the experiment is about 2 hours. The experiment with the magnetic field is carried out similarly, in this case the bottom of the test tube is located in the central surface area of the magnet set.

## 3. Results

The IR spectral analysis showed that of the tetradecane stripe increases at the beginning of the experiment and afterwards remains constant. The intensity of the hexane stripe shows an increase at the beginning of the experiment that is followed by decreasing of the spectral lines down to complete disappearance. Fig. 4 shows the change of the IR hexane stripe in the outflowing air during the experiment. The relative concentration of hexane in the air passing through the ferrofluid is calculated from the spectral area. Fig. 5 shows the relative concentration of the hexane vapor in the gas probe of IR spectrometer. The increase of the concentration at the beginning of the experiment is caused by the filling of the gas probe with the test gas, while the subsequent decrease of the concentration is determined by hexane separation from the ferrofluid.

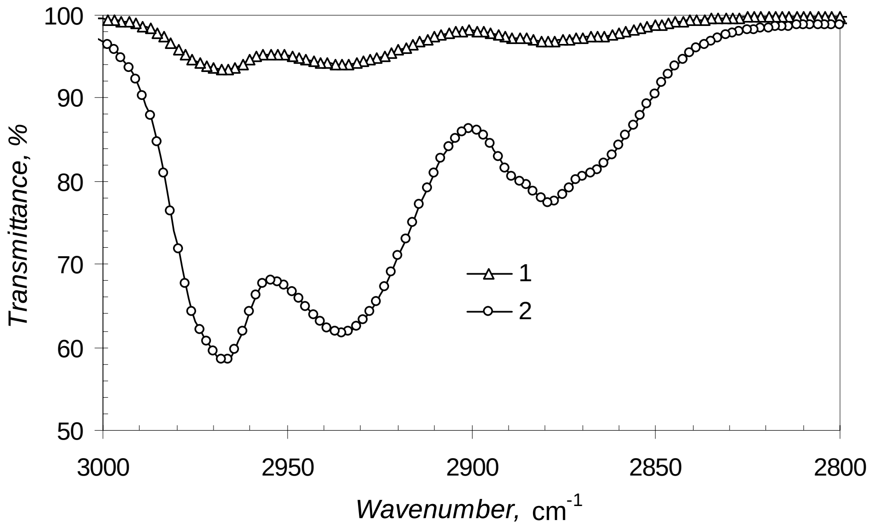



Figure 4: The stripe of hexane in the IR spectrum of the air at the set output. 1 - 48 min., 2 – 24 min. after flow beginning.

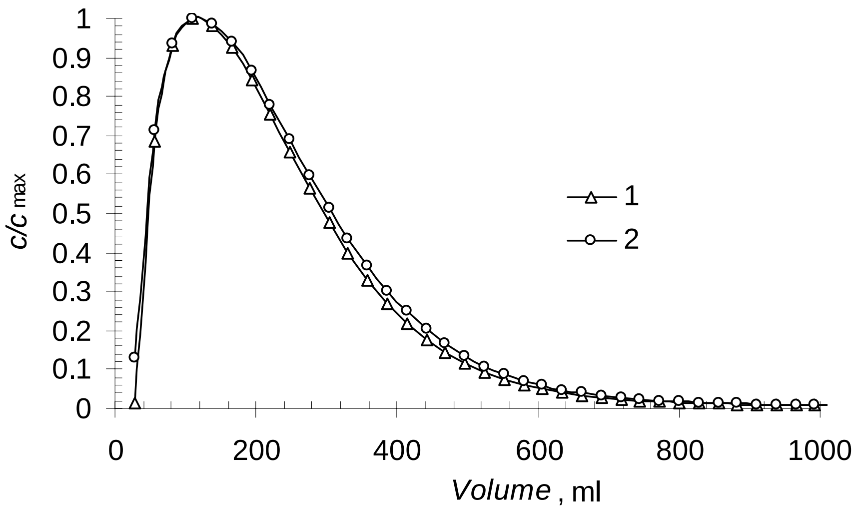
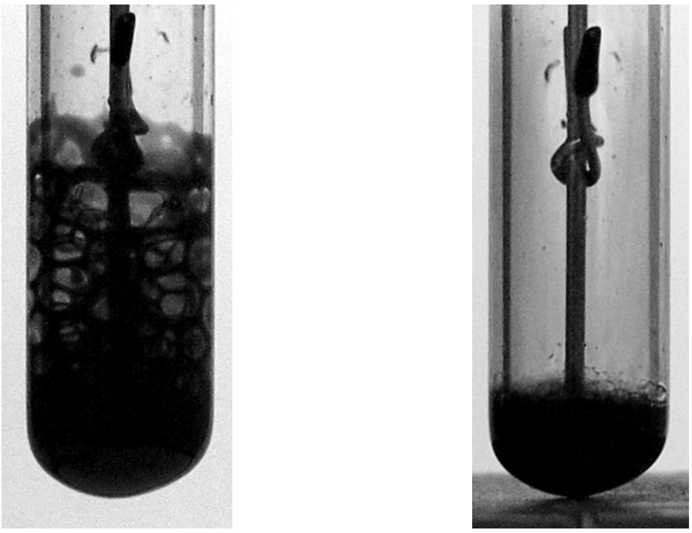



Figure 5: Dependence of hexane vapor concentration in the output air from its quantity with magnet and without magnet. 1 - without magnet, 2 - with magnet.

Fig. 6 shows the condition of ferrofluid cell during the air bubbles run with and without gradient magnetic field.



a b

Figure 6: The view of the mass exchange cell: *a* – without magnet, *b*-with magnet.

## 4. Conclusion

The impact of the Archimedes principle on the bubble formation can be evaluated by considering the magnetic field effect, its gradient and the ferrofluid magnetization curve. According to the formula for calculation of the ferrofluid effective density in the gradient magnetic field [1]:

$$\frac{\rho_{eff}}{\rho} = 1 + \frac{M\left|\nabla H\right|}{\rho g}$$

According to data from fig. 2 and fig. 3 the lifting force at the distance of 1 mm from the magnet surface increases about 85 times than that one without field. If assuming that the bubble volume is inversely proportional to the lifting force, while the surface area to maintain the spherical shape is proportional to the volume in the degree of 2/3 and simultaneously not considering the bubble deformation and gas compression, the amplification coefficient of the relative surface area to the gas mass reaches app. 19 times. It should make an impact on the mass exchange process.

However, under these physical conditions the magnet does not have an influence on the result of the mass exchange (fig. 5). One of the eventual reasons may be the achievement of the equilibrium concentration of the hexane vapor in the airflow in both cases. Nevertheless, the impact of the magnet on the volume of the two phase system of the mass exchange cell is very significant (fig. 6) as the two phase system volume is many times smaller when the magnet is set.

## 5. References

[1] Blums E., Cebers A., Maiorov M. M., Magnetic Fluids. Berlin, New York, Walter de Gruyter & Co 1997