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Use of gas bubbles as local tracers in Liquid Metal MHD Flows

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Use of gas bubbles as local tracers in Liquid Metal MHD Flows

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1. Introduction

For the cooling of fusion reactors the concept of a selfcooled liquid metal (LM) blanket offers a number of advantages (SMITH et al. (1984)). The employment of liquid lithium (or Li/Pb) was proposed because, besides the high heat capacity and conductivity of the liquid metals, it can be used for tritium breeding and serves as a good protection against the neutron radiation. On the other hand specific MHD-problems have to be solved. The lithium has to be circulated across the strong magnetic field needed for the plasma confinement. Thus, undiserable pressure losses appear, associated with the interaction of the B-field with the induced currents in the liquid metal.

Another important point is to estimate the intensity of the heat transfer properties of a liquid metal flow in the presence of strong magnetic fields. Until recently it was assumed that the flow is completely relaminarized if it is exposed to sufficiently strong magnetic fields. This assumption seems to be confirmed by the experimental fact that the overall pressure drop corresponds to the predicted value for a mean laminar flow if the ratio Ha/Re is sufficiently high (BROUILETTE, LYKOUDIS (1967)). However, even in a very strong magnetic field some specific velocity perturbations persist which was shown experimentally, for instance, by BRANOVER et. al (1965, 1974) or HUA, LYKOUDIS (1974). This type of turbulence, which is unknown in usual hydraulic engineering, can be explained in terms of two-dimensional MHD-turbulence. However, some questions remain unresolved with respect to the detailed flow structure and, in particular, concerning the heat and mass transfer in this special type of flow. A promotion of this two-dimensional turbulence should consequently lead to a distinct heat transfer enhancement. Indeed, some first model experiments showed an increase of the Nusselt number by a factor of 5 or even more (see ANDREEV, KOLESNIKOV (1993) or SUKORIANSKY, BRANOVER (1988) or BARLEON et al. (1994)).

If such two-dimensional perturbations are also relevant at the parameters typical for fusion blankets, the mainly used laminar approach can lead to wrong, design restricting conclusions.

There is an ongoing research in the FZR MHD-group on local transport phenomena in a turbulent liquid-metal (LM) duct flow exposed to a transverse magnetic field. In the present state of the experiment argon gas bubbles are injected into a sodium flow in order to study the dispersion of the gas phase and the influence of the magnetic field on flow quantities such as mean void fraction, slip ratio, velocity and size of the bubbles.

Some proposals exist concerning the use of LM two-phase flows in the fusion reactor cooling system. FRAAS (1973) investigated the possibility to bring the liquid metal into a boiling regime before it enters the magnetic field. The use of a lithium/helium two-phase flow for blanket cooling was studied by ARITOMI et. al (1989) or INOUE et. al (1987). The advantages of such a design should be a reduction of the MHD pressure drop due to the resulting lower bulk electrical conductivity and a promotion of the turbulent fluid motion induced by the dispersed gas phase. However, the goal of the present paper is not set in this direction.

At first we want to try to extract information on typical characteristics of MHD channel turbulence from our two-phase measurements. The idea was to consider small gas bubbles as local tracers for monitoring the flow structure depending on the magnetic field strength. However, it should be emphasized that the bubbles cannot be considered as pure passive tracers. Due to their own velocity caused by the gravity force the bubbles may also act as turbulence promoters. In general, the nature of the velocity fluctuations encountered in a (single phase) turbulent shear flow is not identical with the fluctuations of the liquid velocity in a two-phase flow. In an ordinary bubbly flow (without external electromagnetic forces) these fluctuations may be considered as a superposition of the shear turbulence due to the mean flow, the perturbations induced by the random movement of the bubbles as well as the turbulent fluctuations caused by the bubble wakes.

It is well known that the possibilities for local measurements of turbulent fluctuations in LMMHD flows (especially in alkali metals) are presently very limited. The problem of local measuring techniques must be considered as a crucial one for any LMMHD research and development. So it is a logical step in this process to use our existing two-phase test section and the established, resistivity probe based measuring system in order to analyse the bubble transport in a LMMHD flow.

Heat transfer measurements are planned as a next step in this experimental program. The comparison promises to become very interesting between the transport properties of a really passive scalar (heat) and the present results concerning the transport of a dispersed gas phase in the sodium flow exposed to a transverse magnetic field.

2. Experimental set-up

A sketch of our experimental equipment is shown in Figure 1. The facility of FZR operates with a sodium/argon flow in a vertical test section consisting of a vertical rectangular channel with a cross sectional area of 45x50 mm^2. The walls consist of stainless steel. Their thickness of 5 mm leads to a wall conduction ratio of $c = 0{,}013$. The flow is driven by an electromagnetic pump and passes a transverse magnetic field produced by a conventional electromagnet. The length of the homogeneous field region is 320 mm. A field strength up to 0.45T can be reached.

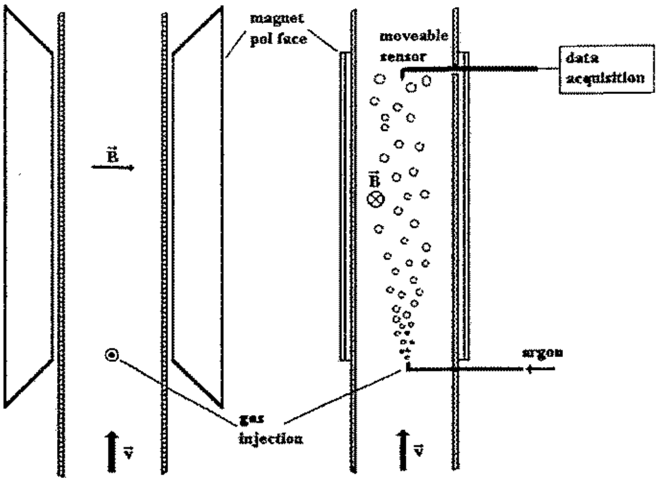


Figure 1: Scheme of the two-phase test section

The gas is injected through a single orifice located just at the beginning of the magnetic field region. The bubbles were injected in the centre of the channel cross section as well as nearby the channel wall. In order to guarantee a pure bubble flow regime it is necessary to work with small values of the volumetric gas flow rate Q_g. Consequently, the volumetric quality ($\beta = Q_g/Q_g+Q_l$) was limited to values lower than 0.1.

Single wire resistivity probes installed at the end of the homogeneous magnetic field region are used for the measurement of the local void fraction. The probe is connected with a traversing mechanism allowing to move the probe over the channel cross section.

The use of liquid sodium as working fluid gives the possibility to reach high values of the Stuart number with a moderate magnetic field strength. The working region of our facility in the (N, Re)-parameter space is displayed in Figure 2.

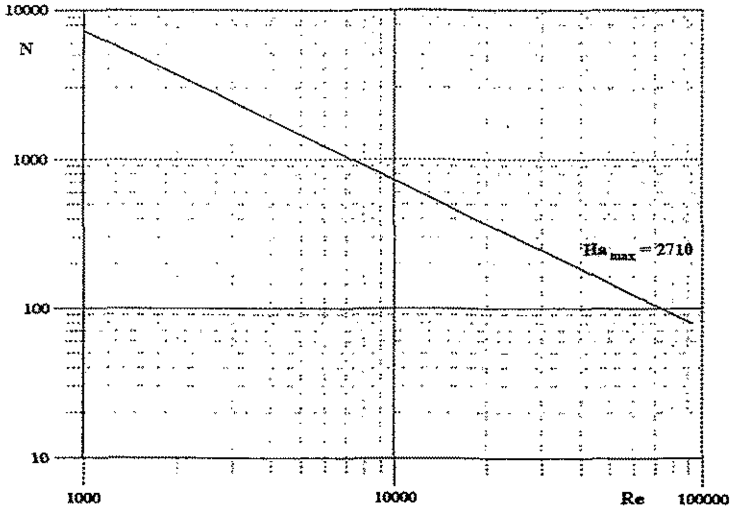


Figure 2: Working region (below the line) of the FZR-facility

In a second series of experiments a system of four cylindrical bars was installed in the test section a few centimetres beyond the entrance of the flow into the magnetic field region. The material of these bars is stainless steel, the same material like the channel walls. The bars are rotatably mounted, so that any angle from 0...90° between the directions of the bars and the magnetic field lines can be selected. The grid is combined with the single orifice in order to inject the bubbles approximately 1cm above the cylinders (see Figure 3).

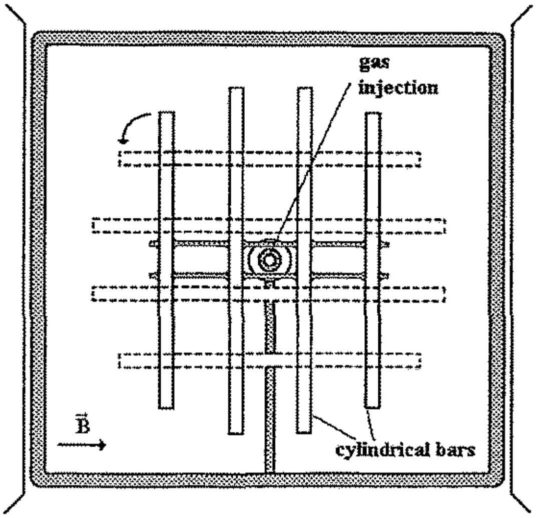


Figure 3: Grid consisting of 4 cylindrical bars in the channel cross section

3. Distributions of the local void fraction

Results have been obtained for mean liquid velocities in the range of 0.1...0.5 m/s. At first, our interest was focused on the influence of the transverse magnetic field on the turbulent dispersion of an initially narrow distribution of the gas phase. The strength of the magnetic field was varied between zero and the maximal value (0.45T). It must be emphasized that in this first set of experiments there were no special turbulence promoters (like mechanical inserts or local variations of the wall conductance ratio). Only the entrance of the flow into the magnetic field serves as a promoter for the origin of two-dimensional vortices. In such a case only a relatively weak persistence of typical two-dimensional MHD vortices could be expected. In this context, attention has to be paid on the influence of the rising bubbles on the turbulent structure of the flow. This question will be discussed below.

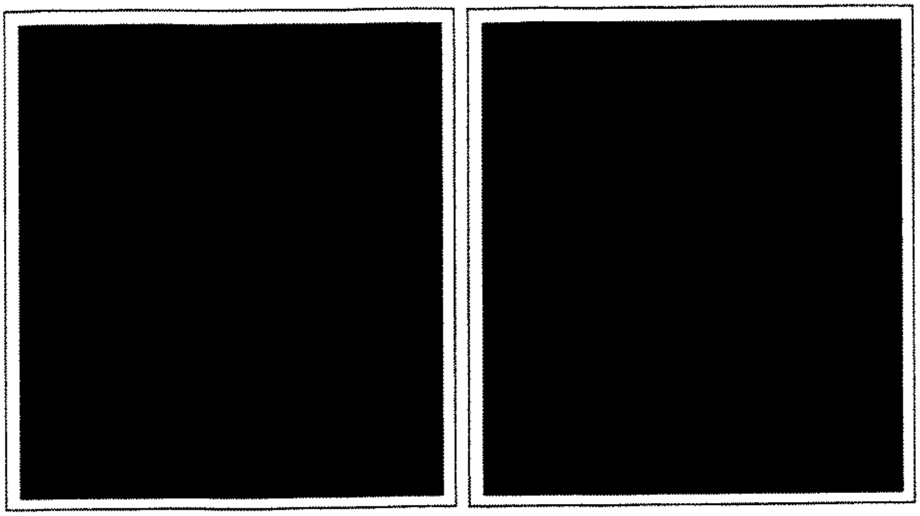
Figure 4a-e) shows some local distributions of the gas phase for a Reynolds number of 9300 and various values of the magnetic field. In the case of vanishing magnetic field a nearly constant void fraction of about 3% was measured over the cross section. A magnetic field of 0.05T, that corresponds to a Hartmann number of 300, causes a serious concentration of the gas phase. With increasing magnetic field this tendency is intensified and for a Stuart number of 790 the gas distribution is nearly restricted to its region of injection. The reason for this focusing effect is the damping influence of the B-field on the turbulent fluctuations.

On the other hand, a clear anisotropy of the bubble dispersion can be observed in the range of Stuart numbers up to approximately 700. The suppression of the gas dispersion is more pronounced in the direction of the field lines than perpendicular to it. This indicates a favourite existence of vortices in the flow with axes parallel to the magnetic field. The character of the turbulent flow becomes more and more two-dimensional.

For high enough values of the Stuart number the distribution of the void fraction becomes very narrow and almost isotropic. Thus, in the case of sufficiently strong magnetic fields the two-dimensional perturbations are also damped and an almost relaminarized flow is obtained.

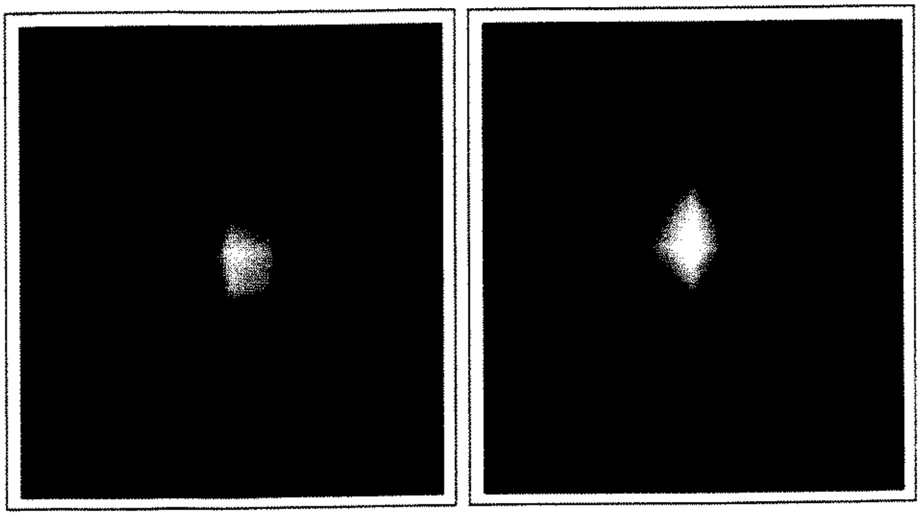
This situation is generally confirmed by void fraction measurements at a Reynolds number of 18600 (Figure 5a-e)). Figure 5a) demonstrates the nearly equal distribution for the case without magnetic field. Just as we have already seen above, a distinct anisotropy can be observed provided that the flow is exposed to a magnetic field.

Figure 6a-e) and Figure 7a-e) display local void distributions obtained at Reynolds numbers of 27900 and 46500, respectively. Again, the concentration of the gas phase affected by the B-field as well as anisotropic distributions can be observed. However, at Hartmann numbers greater than 2000 a new tendency can slightly be detected: A rewidening of the void distribution in the direction ***parallel*** to the magnetic field. The reason for this behaviour might be the pinch effect which is connected with the occurence of a pressure profile across the channel cross section due to the induced magnetic field. SAITO et al. (1978) showed that the pinch effect leads to a void fraction broadening parallel to the field lines due to the pressure



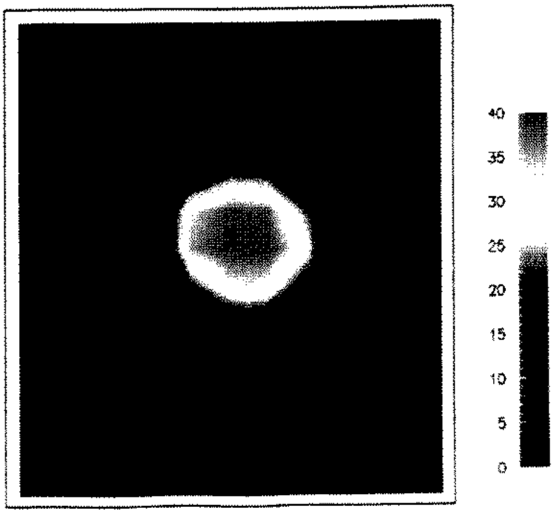
a) Ha = 300, N = 10

b) Ha = 845, N = 77



c) Ha = 1505, N = 244

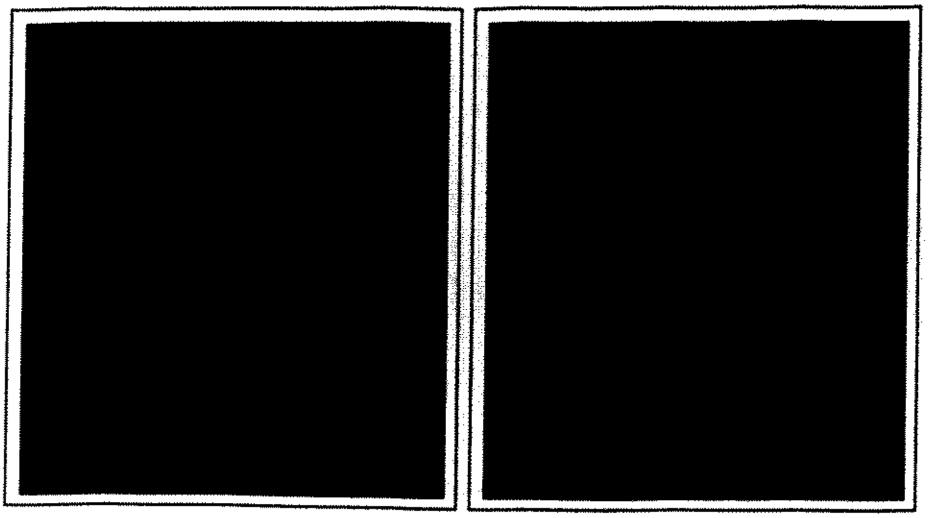
d) Ha = 2410, N = 625



e) Ha = 2710, N = 790

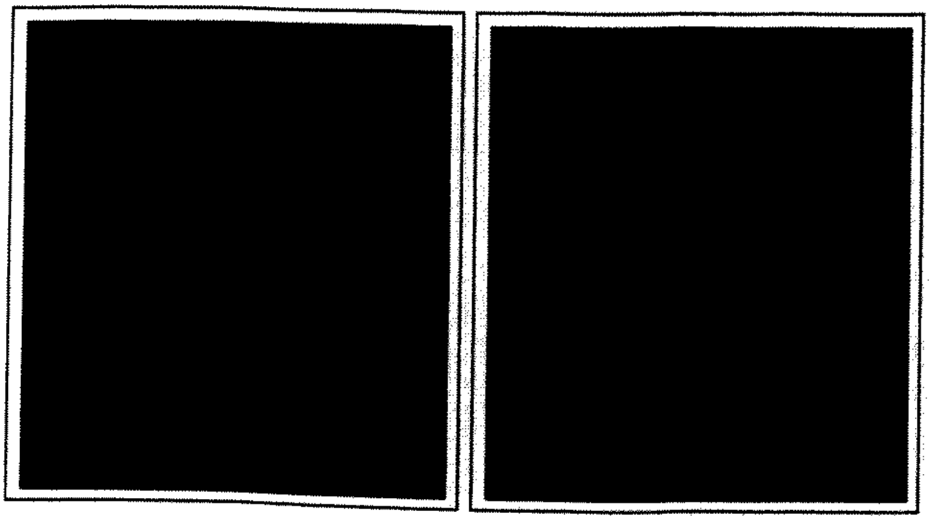
→ direction of the B-field →

Figure 4:
Void fraction distributions
at Re = 9300



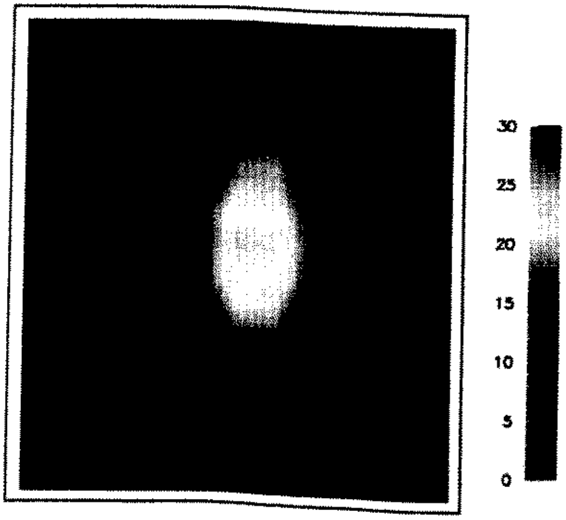
a) Ha = 0, N = 0

b) Ha = 600, N = 19



c) Ha = 1200, N = 78

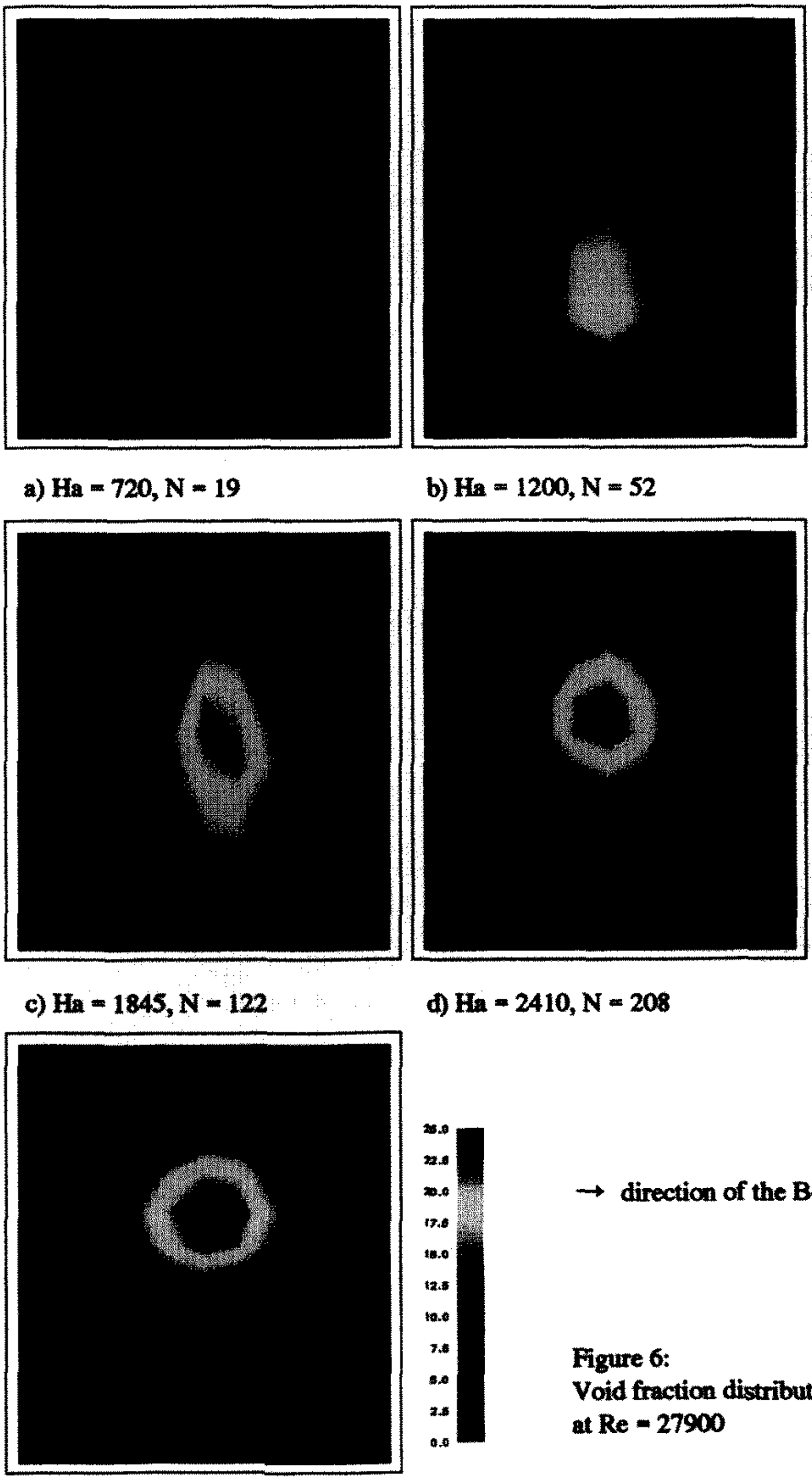
d) Ha = 1505, N = 122



e) Ha = 2110, N = 239

→ direction of the B-field →

Figure 5:
Void fraction distributions at Re = 18600



a) Ha = 720, N = 19

b) Ha = 1200, N = 52

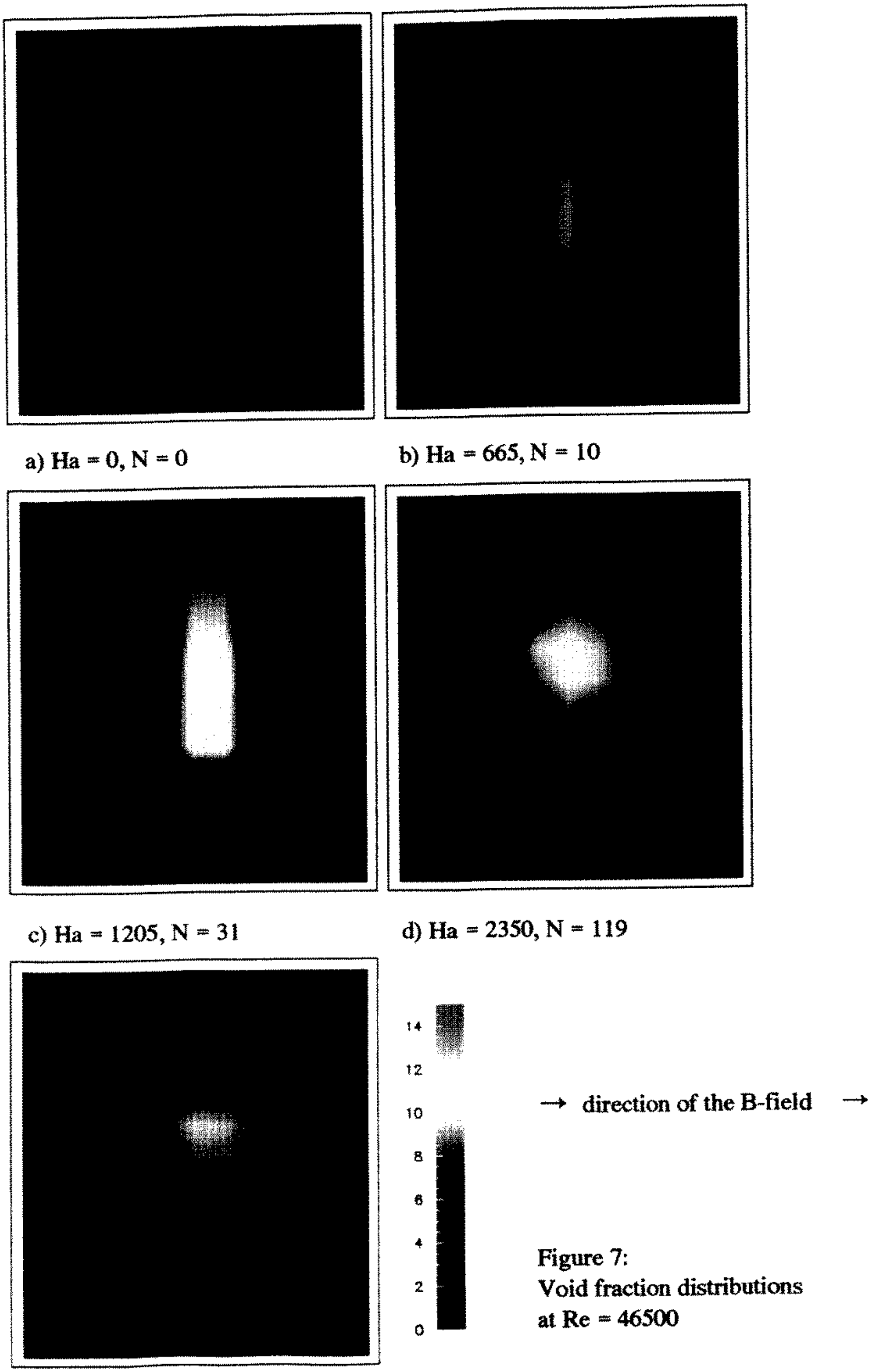
c) Ha = 1845, N = 122

d) Ha = 2410, N = 208

e) Ha = 2710, N = 263

→ direction of the B-field →

Figure 6:
Void fraction distributions
at Re = 27900



a) Ha = 0, N = 0

b) Ha = 665, N = 10

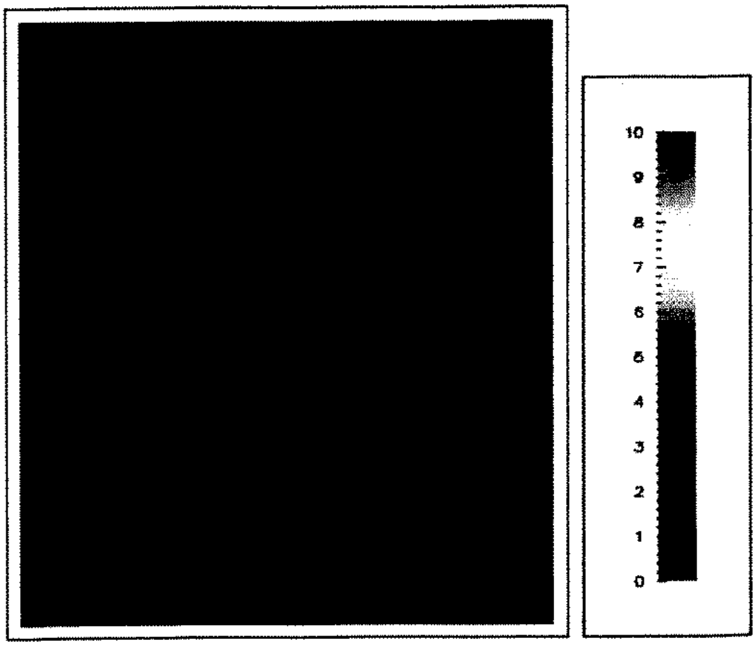
c) Ha = 1205, N = 31

d) Ha = 2350, N = 119

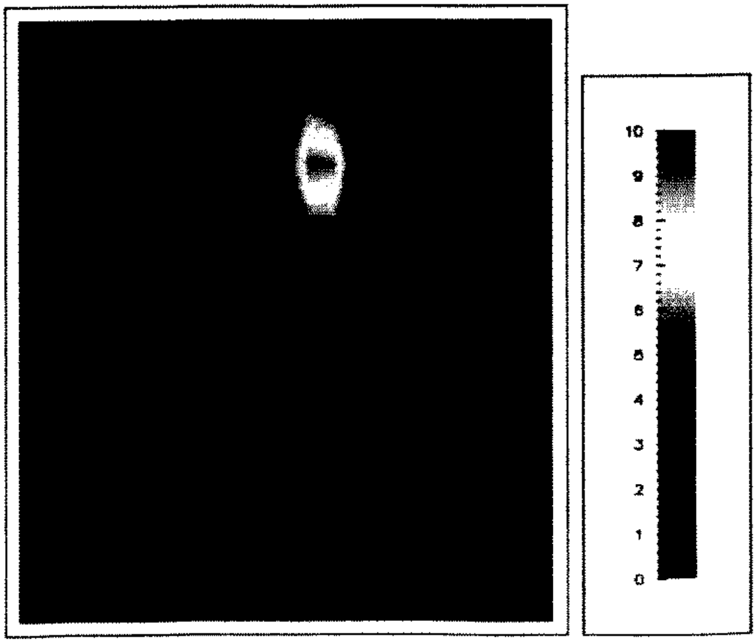
e) Ha = 2710, N = 158

→ direction of the B-field →

Figure 7:
Void fraction distributions
at Re = 46500



a) Ha = 0, N = 0



b) Ha = 1200, N = 156

→ direction of the B-field →

Figure 8: Void fraction distributions at Re = 9300 (gas injection nearby the wall)

peak in the center of the channel. The linear variation of the induced magnetic field along the field lines creates a pressure peak in the channel center-line forcing the bubbles to migrate in the direction of the channel walls. However, SAITO et al. concluded that the value $S = N \cdot Rm$ should be the determining non-dimensional parameter in the sense that $S > 1$ indicates a measurable pinch effect. In our experiments the maximum value of S is appr. 36 and, therefore, a strong influence of this pinch effect should be detectable. However, no pinch effect comparable to SAITO's measurements was found. The explanation is that due to our analysis the nondimensional parameter which determines the strength of the pinch effect is not S but $S' = Rm \cdot \lambda^2 / N$ where λ is the nondimensional pressure drop of the channel flow. The value of λ is proportional to $c \cdot N / (1+c)$ where c denotes the wall conductance ratio, provided $c \cdot Ha \gg 1$. If (as usual) $c \ll 1$ the parameter S' is given by $S' = N \cdot Rm \cdot c^2$ which differs from SAITO's value by c^2. Their value of c is by a factor of appr. 6 higher than in our experiments which explains the occurence of the pinch effect in their experiments and not in our's. Nevertheless, the beginning rewidening of the void distribution above Ha = 2000 might be a first indication of this pinching influence also in our measurements. It would be interesting to clearly detect this pinch effect also in our experiments which is possible either by increasing S' or by adding an additional coil providing a longitudinal magnetic field.

As a next step the position of the gas injection was changed to a position near the channel wall parallel to the magnetic field. The distance between wall and orifice is about 5mm. In Figure 8a) and b) the corresponding gas distributions are shown. There does not appear a principle difference to the case of the bubble injection in the centre of the channel. The exposition of the flow to a transverse magnetic field leads to a concentration of the gas phase. Moreover, the void distribution has kept its anisotropic shape.

4. Coefficients of the turbulent dispersion

As a next step it is necessary to get a quantitative description of the observed transport phenomena and its anisotropy. Therefore, turbulent dispersion coefficients parallel as well as perpendicular to the direction of the magnetic field are determined from the measured data.

For this reason the process of bubble dispersion is simply modelled by a two-dimensional diffusion equation with a convective term in flow direction:

$$\bar{u}_g \frac{\partial \alpha}{\partial x} = D_y \frac{\partial^2 \alpha}{\partial y^2} + D_z \frac{\partial^2 \alpha}{\partial z^2}$$

The mean flow is considered as one-dimensional in x-direction the transverse magnetic field is parallel to the y-direction. Starting with a δ-distribution of the local void fraction α in the plane $x=0$ we obtain for the void fraction downstream the following expression:

$$\alpha\left(x_m, y, z\right) = \frac{Q_g}{2\pi x_m \sqrt{D_y D_z}} e^{-\frac{1}{2}\frac{\bar{u}_g (y-y_0)^2}{x_m D_y}} \; e^{-\frac{1}{2}\frac{\bar{u}_g (z-z_0)^2}{x_m D_z}}$$

Q_g - volumetric gas flow rate,

$\bar{u}_g$ - mean bubble velocity,

D_y, D_z - coefficients of the bubble dispersion,

y_0, z_0 - y- and z-position of the single gas injector

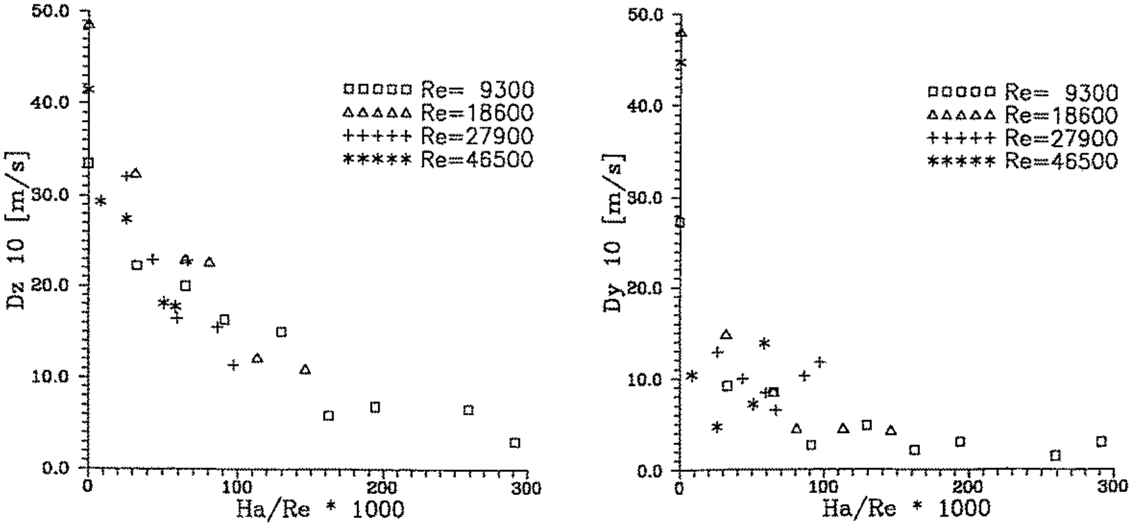
This solution, which describes the widening of a given δ-distribution in the lapse of time, is well-known from standard diffusion problems.

Eventually, the turbulent dispersion coefficients were obtained from the experimental data in the following way: From the measured distributions the values of the local void fraction are taken along the chords parallel and perpendicular to the field lines, respectively, and fitted to a gaussian curve. Then, the respective dispersion coefficients can be calculated from the corresponding standard deviation.

The volumetric gas flow rate as well as the bubble velocity can be considered as constant for small distances between gas injector and probe and moderate changes of the pressure in flow direction.

Due to buoyancy the velocities of the bubble and the surrounding liquid are not identical. Generally, a slip ratio $S = v_{gas}/v_{liquid} > 1$ can be observed. In detail, the quantity S depends on the flow parameters (superficial velocities, bubble size, ...) as well as on the strength and the direction of the applied magnetic field. Therefore, the mean gas velocity was calculated by means of a one-dimensional bubbly flow model, which was developed in our group in order to describe the mean quantities of a bubbly flow under MHD conditions (ECKERT et al. (1993)). Here we are confronted with the first restriction of the assumption that the gas bubbles can be considered as ***passive*** local tracers. However, the motion of the bubbles can be conceived as a superposition of their own velocity caused by the buoyancy force and the turbulent velocity fluctuations of the flow. The influence of such an own particle velocity on the dispersion process is called as "crossing-trajectory effect" (YUDINE (1959)). It can be elucidated by the following plausible picture: Due to their own velocity the particle gets faster from one vortex to another compared with the typical decay times. Thus, the influence of the decaying vortices on the dispersion and accordingly the value of the dispersion coefficient decreases with increasing particle velocity. Consequently, the values of the turbulent dispersion coefficients obtained from the experimental results by means of the described procedure should be lower than the real ones. A more detailed analysis of this "crossing trajectory effect" and the influence of a magnetic field on it is given by GERBETH, HAMANN (1989).

According to the isoplots of the local void fraction distributions (Figs. 4-8) a remarkable difference between the dispersion coefficients in field direction and perpendicular to it can be expected. The dispersion coefficients case are displayed in Figure 9a) and b) as a function of the ratio Ha/Re. It demonstrates clearly, that the turbulent mass transfer is generally reduced for an increasing strength of the magnetic field. This fact is also confirmed by measurement of the turbulence intensity using a potential probe (Figure 11) in a single-phase sodium flow. Here the fluctuations of the longitudinal velocity component were evaluated. The turbulence intensity shows a steep decrease and reaches values below 1% for a ratio of Ha/Re > 0.02.



a)

b)

Figure 9: Bubble dispersion coefficients as a function of the ratio Ha/Re
a) in the direction perpendicular to the magnetic field
b) in the direction parallel to the magnetic field

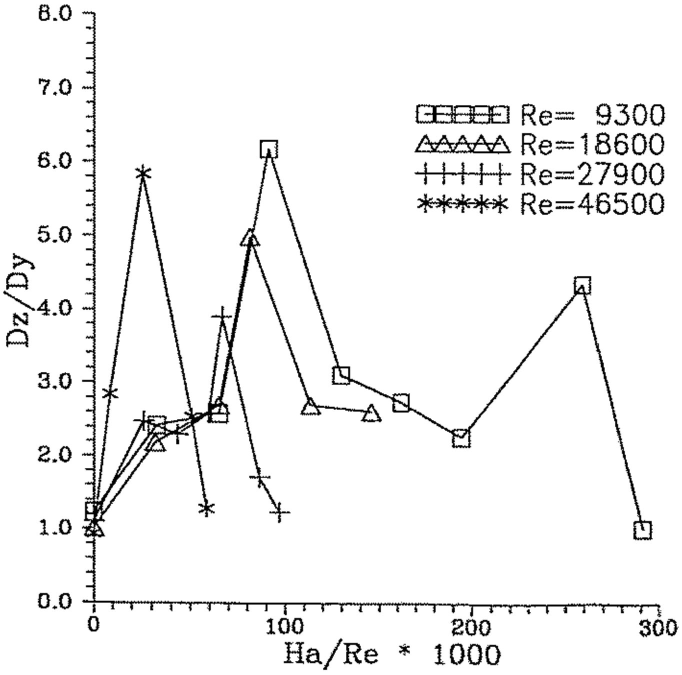


Figure 10: Ratio of the dispersion coefficients D_z/D_y versus the ratio Ha/Re

Furthermore, the dispersion of the bubbles is already damped rapidly for small values of the Stuart number (N=10), while the decrease of the coefficient in the direction perpendicular to the B-field is more slightly. The anisotropic character of the external transverse field on the turbulent mass transfer is completely revealed in Figure 10, where the ratio between both coefficients is plotted versus Ha/Re. A distinct maximum can be noted for all series of different Reynolds numbers. The ratio between the coefficients reaches values up to about 6. The position of the maximum is shifted to smaller values of Ha/Re with increasing Re. A second maximum can be detected for Re = 9300 at Ha/Re ≈ 0.15. However, this result should be confirmed by some additional measurements. Due to the limitations regarding the field strength of the used magnet it was not possible to extend the measurement series connected with the higher Reynolds numbers on this parameter region. In the case of sufficient strong magnetic fields (N=790 at Re=9300) the ratio of the turbulent dispersion coefficients becomes again unity.

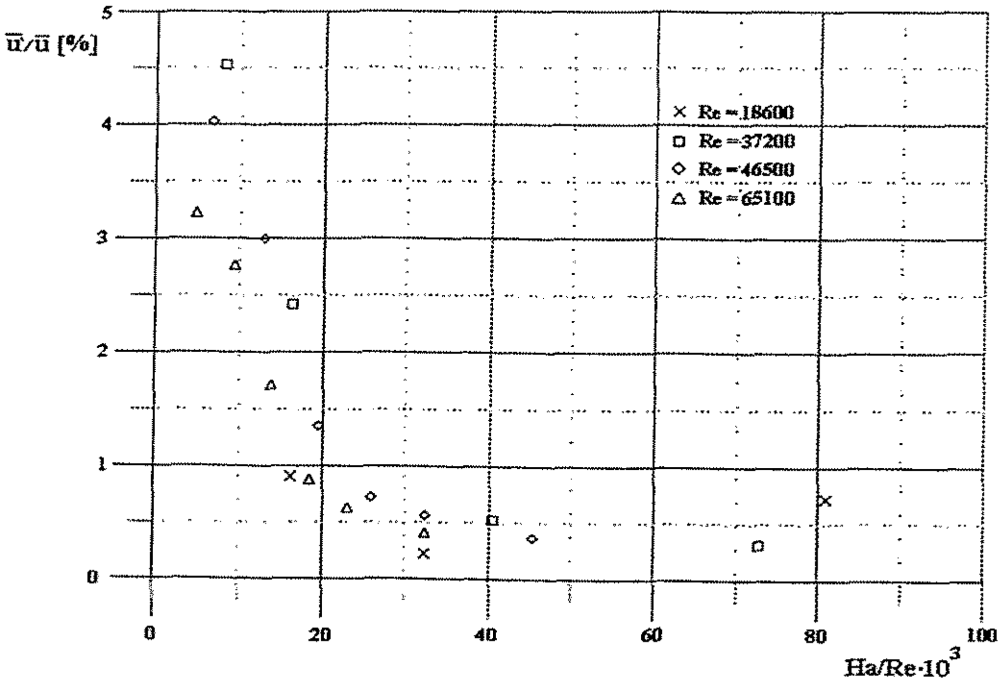


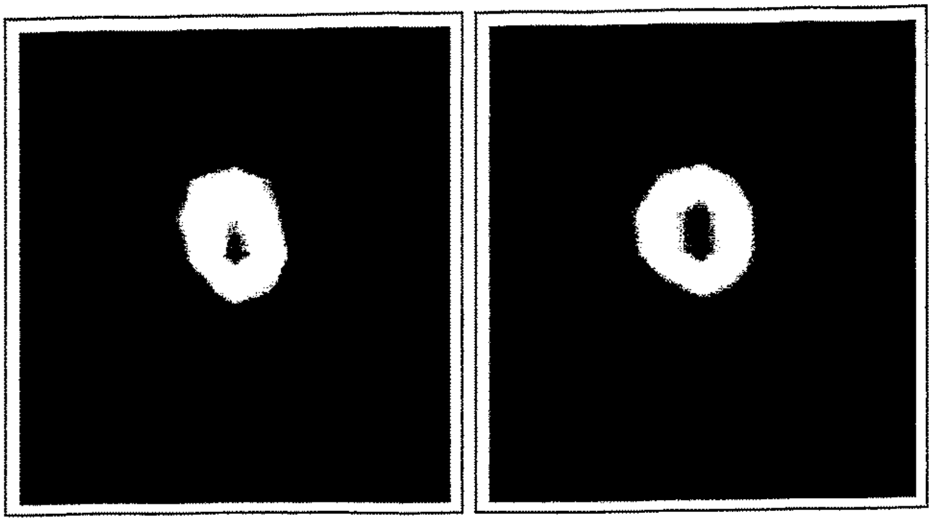
Figure 11: Turbulence intensity as a function of the ratio Ha/Re

5. The influence of flow inserts on the bubble dispersion

It is well-known from many publications, that a desired excitation of two-dimensional turbulence can be initiated by mechanical inserts, by passive electrical means such as changes in the wall conductivity or the magnetic field strength as well as by active electrical amplification. For instance BRANOVER, GERSHON (1979) were able to show experimentally the possibility of turbulence enhancement in the presence of an external transverse magnetic field by mechanical means. They inserted a grid with cylindrical bars parallel to the magnetic field and observed a significant enhancement of turbulent fluctuations transverse to the field.

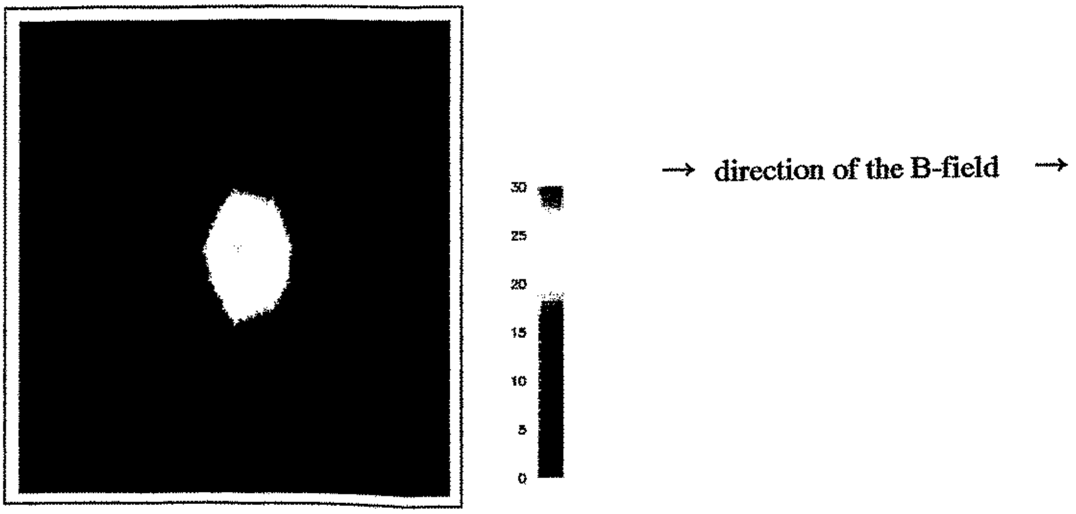
Thus, it was obvious to examine the influence of such mechanical inserts on the distribution of the local void fraction. A grid with cylindrical bars of diameter 2mm (see Figure 3) was installed in our test section. Then the bubble distribution was measured in the same way and for the same parameters as described above.

In Figure 12 the isoplots of the local void distribution are displayed at N=244 for the cases with the bars aligned with the field lines a), perpendicular to the field direction b) and without any inserts c). However, the obtained results do not show the expected tendency. An anisotropic distribution can only be observed, if the bars are removed from the flow. Moreover, the direction of the bars seems to have no remarkable influence on the dispersion process. The impression, that the inserted cylinders, whatever their direction is, cause not a promotion but rather a damping of the mass transfer perpendicular to the magnetic field, is confirmed by the corresponding bubble dispersion coefficients shown in Figure 13a) and b). The difference between the cases with and without grid becomes very clear in the plot of the dispersion coefficients ratio versus Ha/Re (Figure 14). If the grid is present, the level of anisotropy is generally lower compared to the case of a pure channel. Namely, the curves shows also a maximum, but a very slight one with a value of about 2. The hope of an enhancement of the bubble dispersion in the direction perpendicular to the field lines was not fulfilled. The reason for this behaviour has not completely become clear until now.



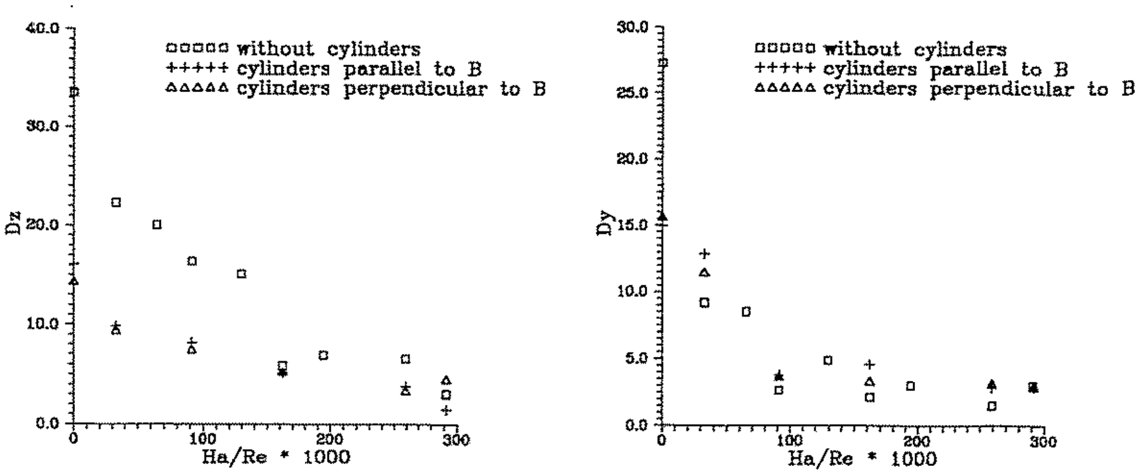
a) bars perpendicular to b-field

b) bars parallel to b-field



c) without bars

Figure 12: Void fraction distributions at Re =9300, Ha = 1505, N = 244



a) b)

Figure 13: Bubble dispersion coefficients as a function of Ha/Re (inserted grid)
a) in the direction perpendicular to the magnetic field
b) in the direction parallel to the magnetic field

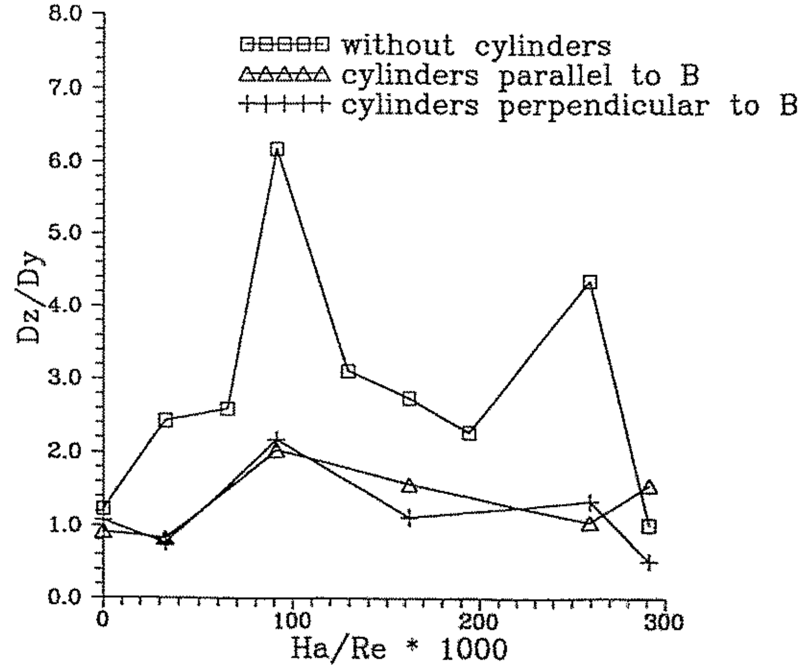


Figure 14: Ratio of the dispersion coefficients D_z/D_y versus the ratio Ha/Re

The following reflections may serve as a first explanation of these results:
For technical reasons the size and length of the bars were limited, some regions near to the walls remain without grid. In this case disadvantages regarding turbulence enhancement prevail. A considerable stimulation of two-dimensional turbulence was not reached likely due to the small diameter of the bars. Therefore, the installation of only two bars but with a larger diameter is recommended for the next experiment. Moreover, measurements of the channel velocity profile by means of potential probes show a low velocity region behind the bars in the core flow region, while higher values of the velocity arise near the channel walls in both directions. A decrease of the liquid metal velocity supports the closure of the induced currents. Supplementary, the channel walls as well as the inserted grid itself were not made from an insulating material but from stainless steel. Thus, the damping of the two-dimensional perturbations is intensified. This fact could be the reason for the reduced mass transfer perpendicular to the magnetic field in comparison to the situation without grid.

Apart from this, the interaction between the turbulent fluctuations induced by the grid and the bubbly flow in the zone of an external magnetic field seems to be very complex. For this reason, some additional measurements, for instance of the bubble velocity profiles, are necessary in order to get better understanding of the action of mechanical turbulence promoters.

6. Discussion and conclusions

The effect of a transverse magnetic field on the mass transfer of small argon gas bubbles has been studied. The mass transfer is generally suppressed due to the influence of the transverse magnetic field.

However, as main result a strong anisotropy was found in the local void distribution measured in the cross sectional channel area. In a definite parameter region (see Figures 9 and 10) the bubble dispersion is much more restricted parallel to the magnetic field than perpendicular to it. The anisotropic shape of the distributions can be considered as a clear indication for the presence of a flow structure typical for two-dimensional MHD turbulence. It is not clear which effect mainly serves as the origin of the two-dimensionality: Either the magnetic field entrance or the bubble motion. It cannot be excluded, that the bubbles act as the promoters for the turbulence. FABRIS et al. (1978) carried out local mesurements in a NaK/N_2 two-phase flow by means of hot-film probes. They found, that the fluctuations in the liquid flow appear to increase in magnitude as the magnetic field strength increases, while for pure liquid flows the fluctuations are damped. Moreover, the higher-frequency components appear to be damped.

On the first view our findings regarding the anisotropy of the local void distribution are in contradiction to experimental results obtained in mercury/nitrogen(argon) two-phase flows by LYKOUDIS (1985) and MICHIYOSHI (1989), respectively. They reported a nearly equal dispersion of gas bubbles in both directions parallel and transverse to the magnetic field lines, with a slightly stronger focussing effect perpendicular to the field direction. These experiments were yet carried out with a complete different set of dimensionless parameters in a circular channel geometry. According to BRANOVER (1978), in the case of a transverse magnetic field the critical value of the ratio Ha/Re at which the pressure drop begins to correspond to laminar flow can be determined as follows:

$$\left(\frac{Ha}{\mathrm{Re}}\right)_{cr} = \left[215 - 85 \cdot e^{(-0.35\beta)}\right]^{-1} \quad ; \quad \beta = \frac{b}{a}$$

a - half-width of the cross section parallel to the magnetic field
b - half-width of the cross section perpendicular to the magnetic field

For $\beta=1$ we get a critical value of about $6.5 \cdot 10^{-3}$. While this value was clearly exceeded in our sodium/argon flow, the critical ratio was just reached by LYKOUDIS or not reached by MICHIYOSHI in their experiments. In addition, a circular cross section does not provide if at all a good prerequisite for the development of two-dimensional MHD turbulence. So the crucial difference between the mentioned references and our experiment is that the preconditions for a well-developed two-dimensional MHD turbulence were given only in our case.

Because of the highly empirical nature of the LMMHD two-phase flows, it is not so easy to find a quantitative description for the mass transfer of the dispersed phase.

In the frame of our work the analysis of the experimental data was focussed on the estimation of turbulent dispersion coefficients. Some serious difficulties (statistical behaviour of the flow, buoyancy driven motion of the bubbles, etc.) prevent a proper determination of the "real" coefficients, but this procedure has been proved to be a good tool in order to show the dependence of the mass transfer process from the magnetic field intensity.

Furhermore the influence of the electromagnetic forces on the liquid velocity profiles has also to be taken into account. For technical reasons it was not possible to install a honeycomb in the regions of the inhomogeneous magnetic field or to investigate the *flow in a channel with non-conducting walls. Thus, a M-shaped liquid velocity* profile has to be expected in the direction perpendicular to the field. This M-shaped profile was measured in the test channel by means of potential probes (Figure 15). In the region of moderate Reynolds numbers (Re<50000) the M-shape is not so strong established. Moreover, measurements of the bubble velocity profile by means of two-wire resistivity probes do not give an indication on a development of the M-shape in the gas velocity profiles, too (Figure 16). So it can be concluded, that the M-shaped velocity profiles do not distort the obtained results considerably.

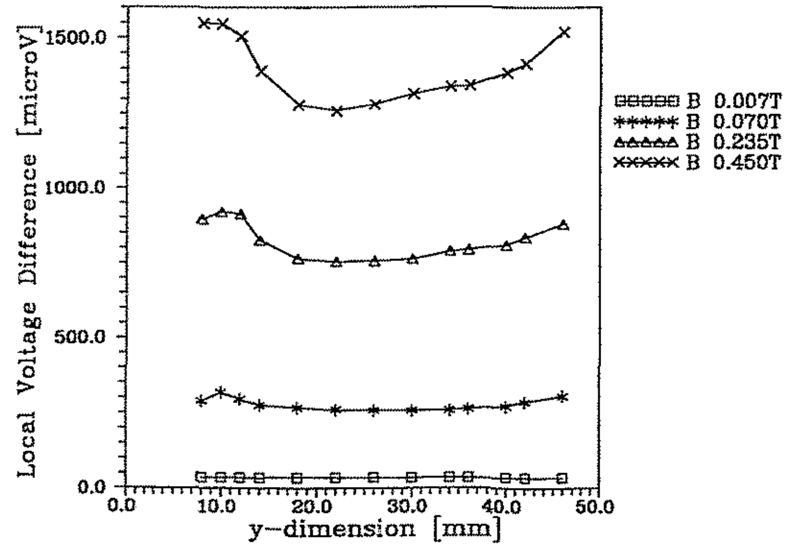


Figure 15: Measured sodium velocity profiles for various b-field intensities ($v_{So} = 0.8$ m/s)

Until now some two-phase specific influences are disregarded. For instance, the modifications of the induced currents paths due to inhomogenity of the local electrical conductivity (particularly in the region of the gas injection) are neglected. Their effect on the turbulent bubble dispersion is still an open question.

Note, that the proposed bubble tracer method is able to deliver a survey about the general flow properties relative quickly and plasticly (isoplots of the local void distributions). By means of the calculation of the corresponding turbulent dispersion coefficients the dependence of the mass transfer on the flow parameter can be quantified. Because of the complexity of the LMMHD two-phase flow, it is difficult to extract more detailed informations concerning a local characterization of the turbulent flow. Besides the detection of the local void fraction some additional measurements, for instance liquid and bubble velocity profiles, are recommended for a deeper understanding.

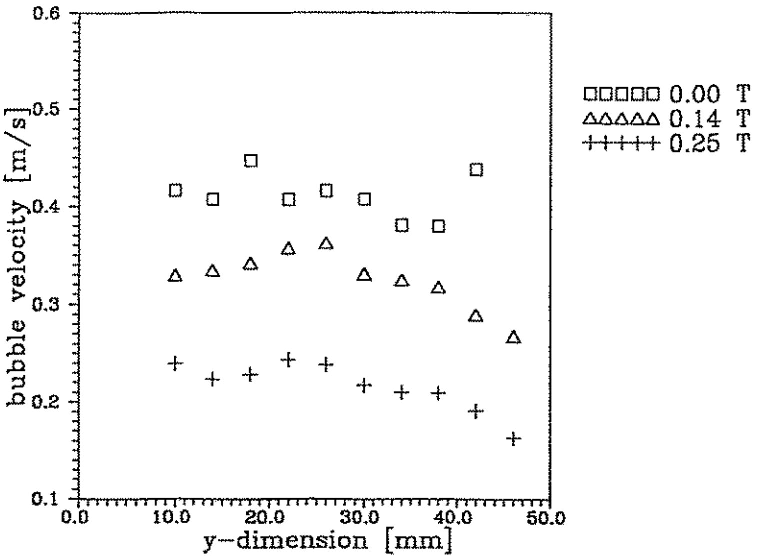


Figure 16: Measured bubble velocity profiles for various b-field intensities

Furthermore, the obtained experiences advise some modifications of the experimental equipment with regard to a continuation of the measurements such as

- the installation of honeycombs in order to get a definite flow structure at the entrance of the magnetic field

- the improvement of the electrical boundary conditions (reduction of the wall conduction ratio by means of special inserts at the channel walls perpendicular to the applied magetic field)
- variation of the construction of the mechanical inserts

These points were taken into account for the construction of the new test section for heat transfer measurements. Here we have organized constructive solutions which guarantee a high level of flexibility concerning the experimental configuration.

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