International Journal of Innovation and Scientific Research
ISSN 2351-8014 Vol. 4 No. 2 Jul. 2014, pp. 145-152
© 2014 Innovative Space of Scientific Research Journals
http://www.ijisr.issr-journals.org/

Measurement of void fraction in magnetic two-phase fluids using Microwave technique

Abdulhadee Muhammed Reehan

Department Physics,
College of Science, University of Baghdad,
Baghdad, Iraq

ABSTRACT: The ferrofluid Fe_3O_4/water had been prepared by chemical precipitation method and stabilized by the addition of long chain of polybutadien polymer. A Microwave technique (transmitter- receiver) has been used to measure the void fraction in two-phase ferrofluid flow. The system of the Microwave technique consists of transmitter of microwave generated by Gunns diode. New theoretical equations were derived. In this radio-absorption technique, because the relative difference of absorption of microwave energies between air and ferrofluid the idea is valid in somehow.

KEYWORDS: Magnetic two-phase fluid; Void fraction; Bubbly flow; Bubble column.

1 INTRODUCTION

The magnetic fluid is a suspension of fine solid magnetic particles like Fe_3O_4 in a host liquid such as water. The suspension behaves as a fluid with magnetization effects in a magnetic field. Some of the applications of magnetic fluids are the following: production of zero-leakage rotary shaft steels for use in computer disk drives, vacuum feed through for semiconductor manufacturing, pressure seals for compressors, magnetic fluid dampers and actuators, etc. An energy conversion system using magnetic fluids was proposed by Resler and Rosenwieg [1]. It was based on the principle that the magnetization of magnetic fluids changes with temperature. However, no significant results were obtained due to the difficulty of the preparation of temperature-sensitive magnetic fluids. In order to overcome this limitation, Kamiyama et al. [2] contrived a new energy conversion system using magnetic two-phase flow then a larger driving force than in conventional system can be expected to induce the magnetic fluid flow because the properties of magnetization changed not only by temperature but also by gas inclusion (that is, void fraction). Void fraction in magnetic two-phase flow is defined as the ratio of the volume of gas to the total volume of gas-magnetic fluid mixture in a finite length of the pipeline. This ratio is useful for the determination of the average density, pressure drop, flow pattern, changes of magnetic susceptibility, etc. Kamiyama et al. [2] stressed the need for the development of a measuring technique for void fraction in two-phase magnetic fluid flow. The aim of the present work is to satisfy this need.

2 THEORY

The measurement of void fraction in the colloidal magnetic fluid (ferrofluid) is based upon the fact that the radio absorption of the magnetic liquid is different from that of the gases. So the use of surface density of power P_d is useful and represented by [3]:

$$P_d = \frac{P}{4\pi R^2} \tag{1}$$

where R represents thew distance between transmitter and receiver, P is the power emitted from the transmitter and if the surface area of the receiver is A_R then the power intered the receiver is:

$$P_R = P_d A_R = \frac{PA_R}{4\pi R^2} \qquad (2)$$

In this case any change in the surface area in front of the receiver will change the received power of the receiver and then the current recorded.

The ferrofluid is an excellent absorber of microwave energy so it might be considered as a shield despite its thickness in front of the receiver.Any change in the height of the ferrofluid in the bubble column as a result of gas inclusion means changing in the shielding surface area and finally in the power and current recorded as illustrated in figure (1). So equation (2) will be rewritten in the form of:

$$P_R = P_d A_R = \frac{Pl_r f_r}{4\pi R^2} \qquad (3)$$

$where\ l_r$ represents the width of the surface of the receiver and f_r represents the height of the face of the receiver and it will be changed under the action of gas inclusion where the rise of ferrofluid in the bubble column as a result of gas inclusion means decreasing of A_R and then in power received where the received power as a function of Δh (rise of ferrofluid).

The power received as a function of height of ferrofluid in the bubble column is given by:

$$P_R(\alpha) = P_d A_R = \frac{Pl_r(f_r - \Delta h)}{4\pi R^2} \qquad (4)$$

An empirical relation has been used to express the effect of void fraction to the current registered in the receiver technique

$$P_R = KI_{max} \qquad (5)$$

And

$$P_R(\alpha) = KI_\alpha \qquad (6)$$

Dividing eq (4) by (3) and eq (6) by (5) leads to:

$$\frac{P_R(\alpha)}{P_R} = \frac{\frac{Pl_r(f_r - \Delta h)}{4\pi R^2}}{\frac{Pl_r f_r}{4\pi R^2}} = \frac{KI_\alpha}{KI_{max}} \qquad (7)$$

and

$$\frac{I_\alpha}{I_{max}} = \frac{(f_r - \Delta h)}{f_r} = 1 - \frac{\Delta h}{f_r} = 1 - \alpha \qquad (8)$$

3 MATERIALS, APPARATUS AND EXPERIMENTAL PROCEDURE.

The colloidal magnetic fluids (ferrofuid) were prepared by the chemical precipitation method [4] in the laboratory. X-ray line broadening indicates that the mixture contains fine particles of magnetite with an average particle size of d =120.5 A°. This was obtained by using Scherer's equation [5] as follows:

$$d = \frac{K\lambda}{\beta\ Cos\ \theta} \qquad (4)$$

where λ is the X-ray wavelength (1.5406 A°), K is the shape factor (0.89) for magnetic particles [5]. β is the line broadening measured at the half-height of the peak and expressed in units of 2θ (β= 0.800°), θ is the Bragg angle in degree (θ=35.395). β must be expressed in units of radians in Scherer's equation. Particles diameter measurements were done by (Philips Analytical-PC 286 DIFFRACTOMETER of Germany). Magnetite particles were stabilized by the addition of the Polymer (Polybutadiene) to the mixture. This polymer normally forms a thin layer around the particles. This polymer was chosen in the laboratory on the basis that it has long molecular chains and adsorbs easily in water solutions around the magnetite particles. Fig. 1 shows the experimental apparatus of the microwave technique for void fraction measurements. This apparatus consists of a transmitter and receiver for microwave pulses generated by gunn s diode penetrating the rectangular column of thin walled glass container filled partially with ferrofluid in a shape describing a fluid height changed according to its value of gas included in any mechanism feasible and easy to measure so any change in height reflects a change in volume of the mixture of gas and ferrofluid so the perpendicular face area in front of the transmitter and receiver will be changed and as a result the received energy of microwave pulses.

4 RESULTS AND DISCUSSION

The results of X-ray analysis were shown in Fig. 2 reflect that the results of chemical precipitation method was successes in making magnetite particles with particle size d≤120 A° which are suitable to maintain the suspension and the particles remain buoyant in the host of water but this results are no longer enough to make the suspension remain stable and does not segregate under the influence of magnetic field, so the addition of polybutadien polymer as a surfactant agent is feasible to enhance the mechanical stabilities of magnetic liquid. The associated component in magnetic fluid as a results of chemical method is the salt which is harmful and must be removed from the liquid. After a multy stage of washing of ferrofluid the agglomeration of ferrofluid particles is decreased as illustrated in Figs. 4 and 5 before and after washing respectively. This figures are of the laser particle size analyzer and the values of particle size is in the range of micrometer which give us a proof that the particles are coated with the molecules of polybutadien polymer and reflect the laser beam. Results about void fraction are clear and reliable as illustrated in Fig. 2 and the relation as expected from equation (8) is linear and the registered dimensionless current is decreased with the increased of void fraction.

5 CONCLUSIONS

1. The microwave was a new method suggested to measure the void fraction in colloidal two-phase magnetic fluid.

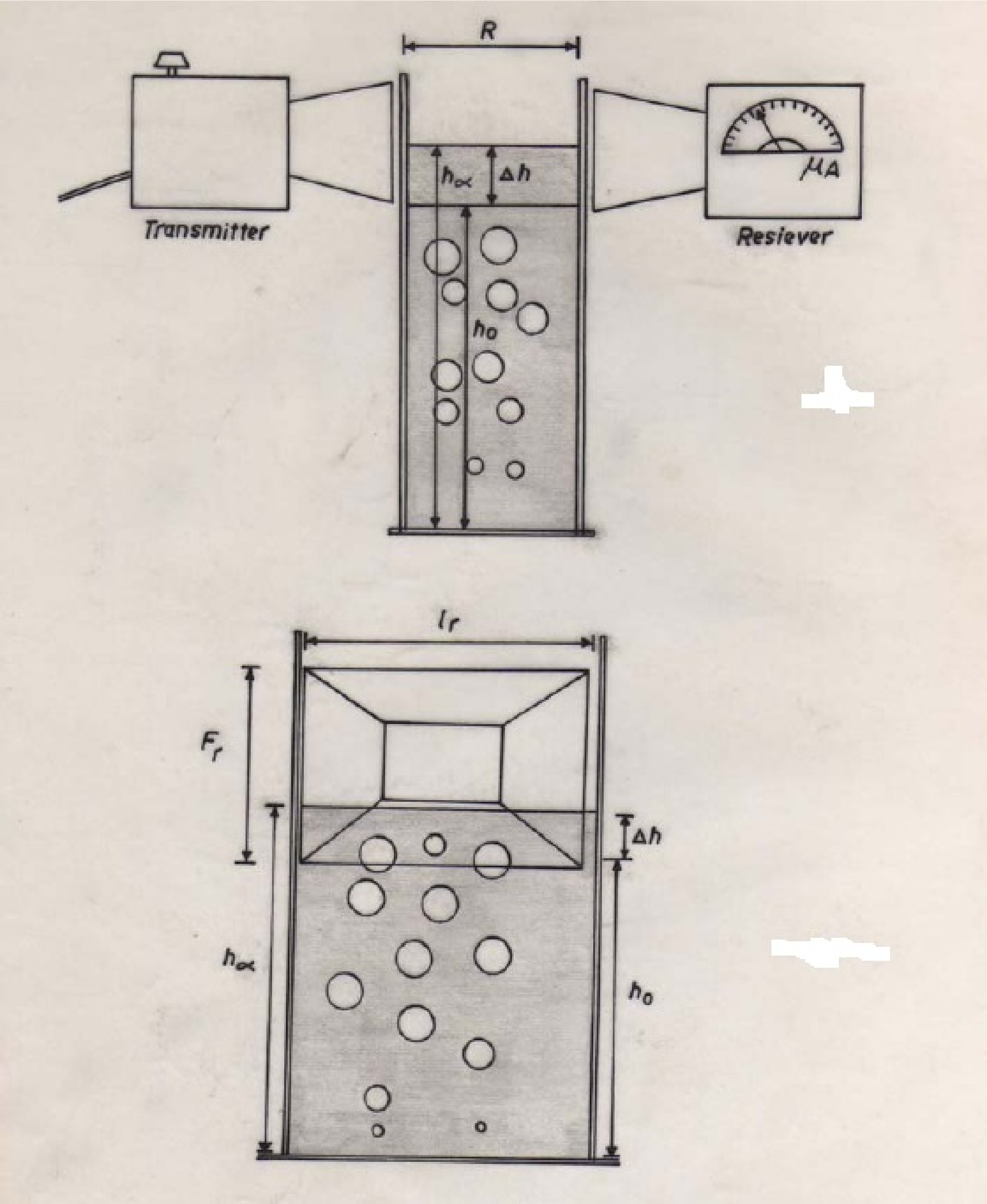


Fig. 1. Bubble column filled with ferrofluid and a fraction of gas in bubble phase.

2. The ferrofluid is opaque medium; therefore optical methods could not be used for the measurement of void fraction.
3. Steel walled test section cannot be used in this technique, because all the microwave flux lines will concentrate in the steal wall.

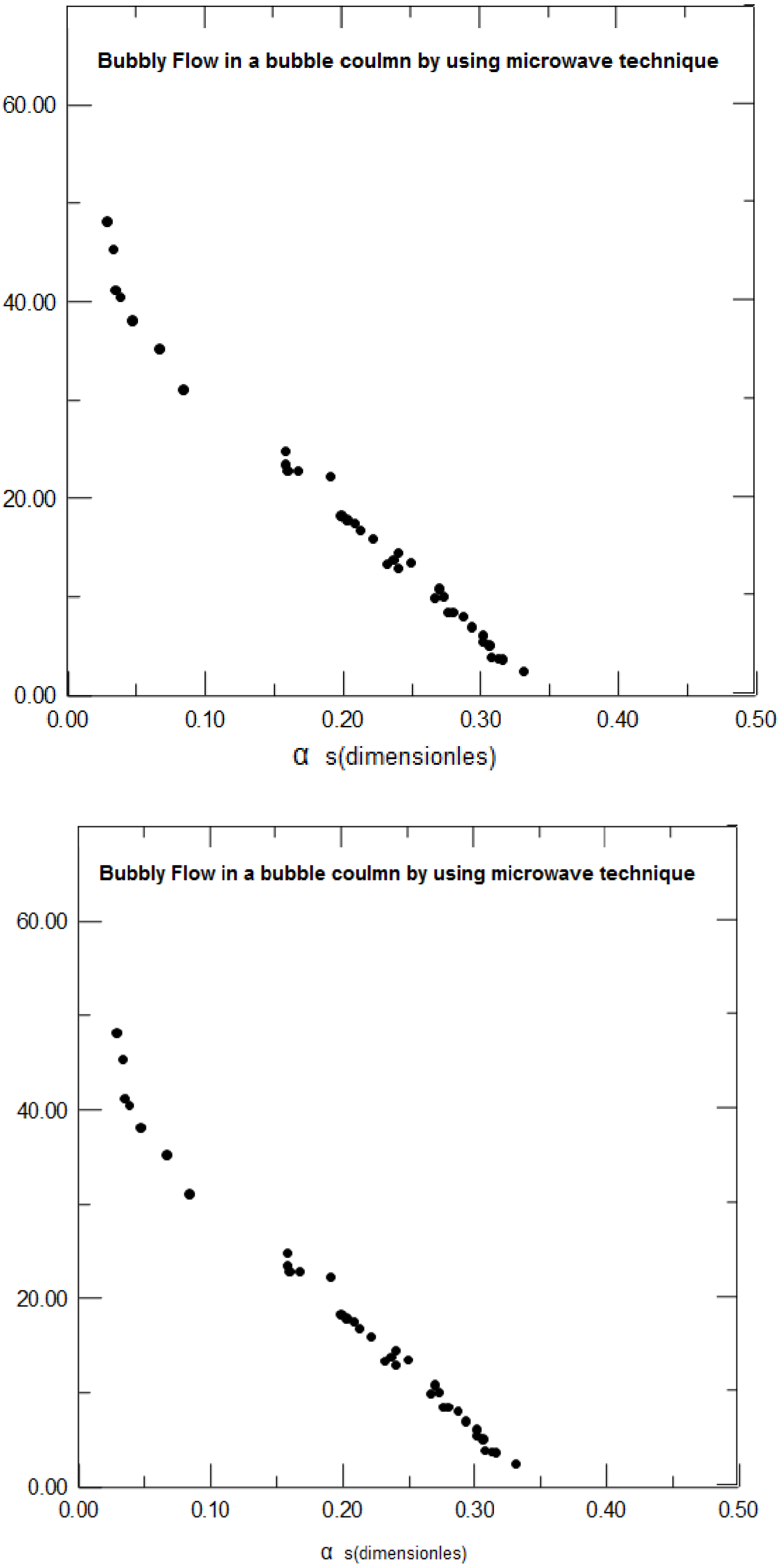
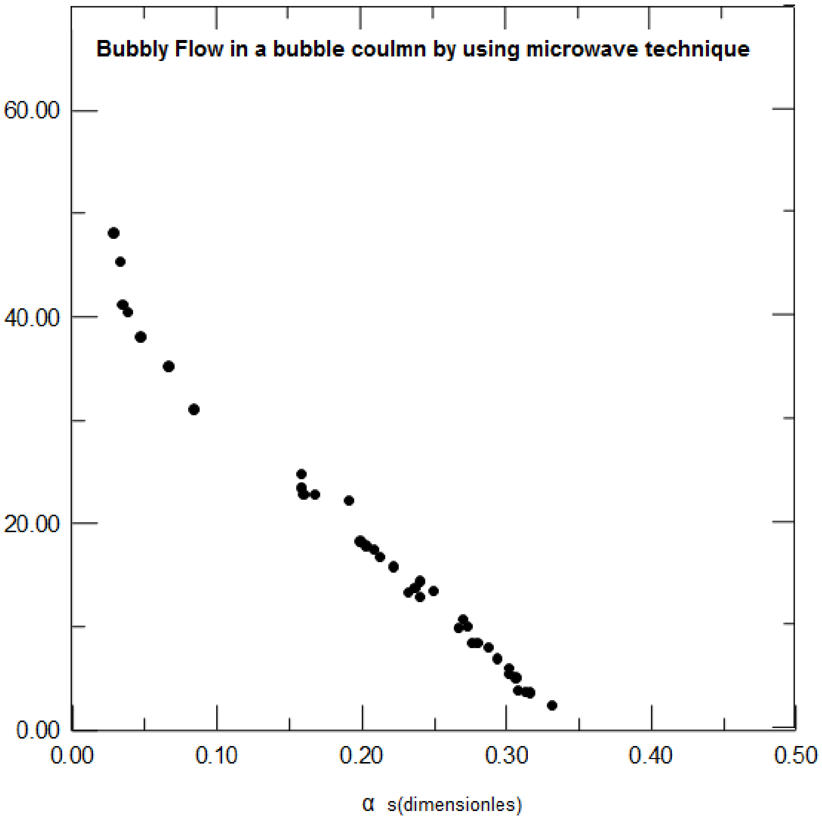


Fig. 2: Relative dimensionless current registered vs void fraction



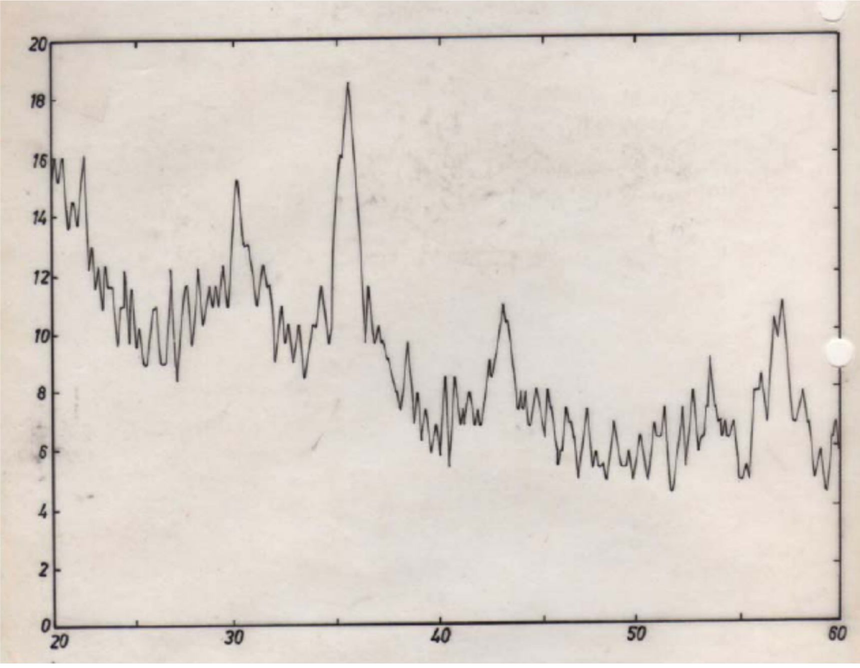
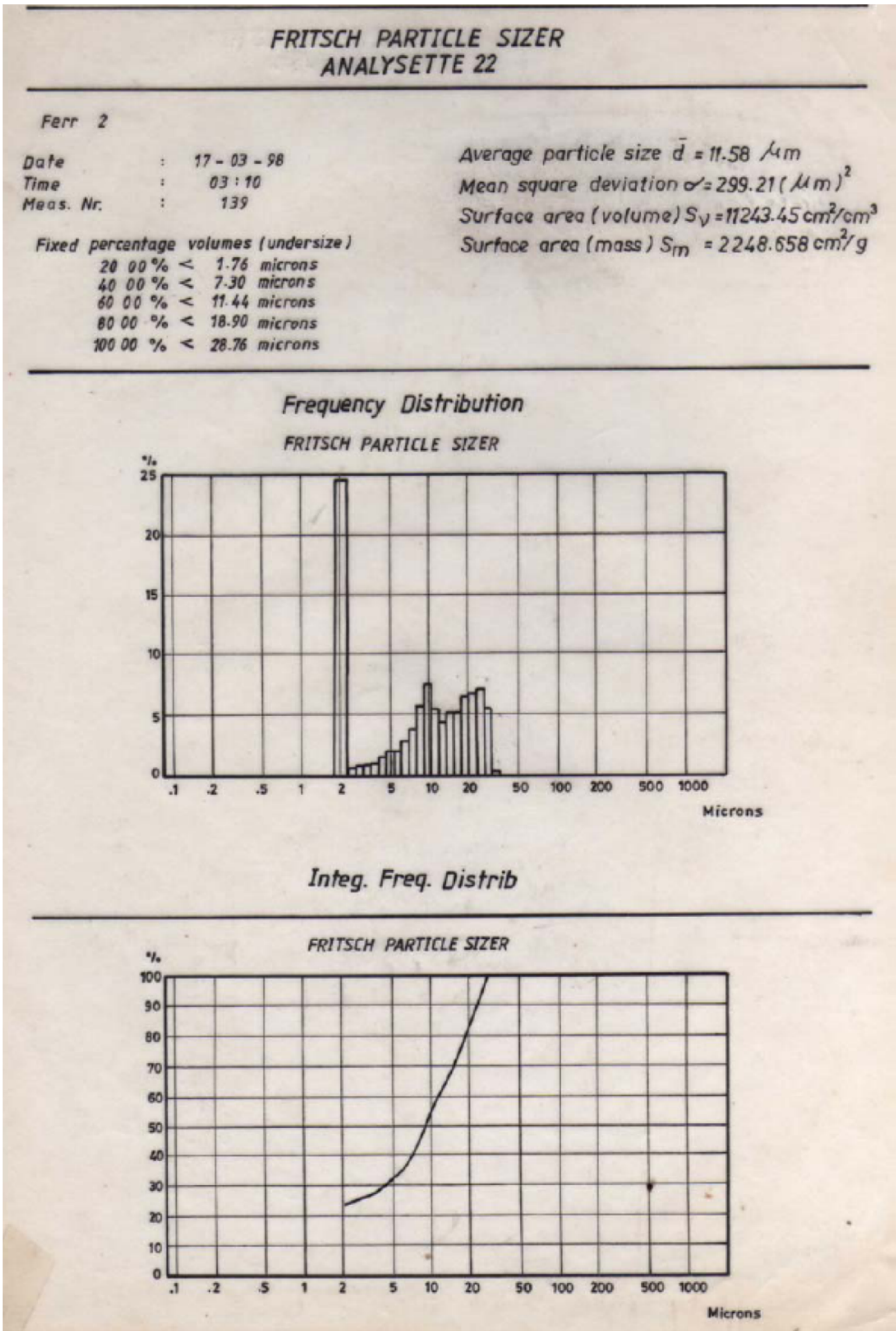


Fig. (3) X- ray analysis for ferrofluid dry sample



FRITSCH PARTICLE SIZER
ANALYSETTE 22

Ferr 2

Date	:	17 - 03 - 98
Time	:	03 : 10
Meas. Nr.	:	139

Average particle size $\bar{d}$ = 11.58 μm

Mean square deviation $\sigma = 299.21 (\mu m)^2$

Surface area (volume) $S_V = 11243.45 \ cm^2/cm^3$

Surface area (mass) $S_m = 2248.658 \ cm^2/g$

Fixed percentage volumes (undersize)

20 00 % < 1.76 microns
40 00 % < 7.30 microns
60 00 % < 11.44 microns
80 00 % < 18.90 microns
100 00 % < 28.76 microns

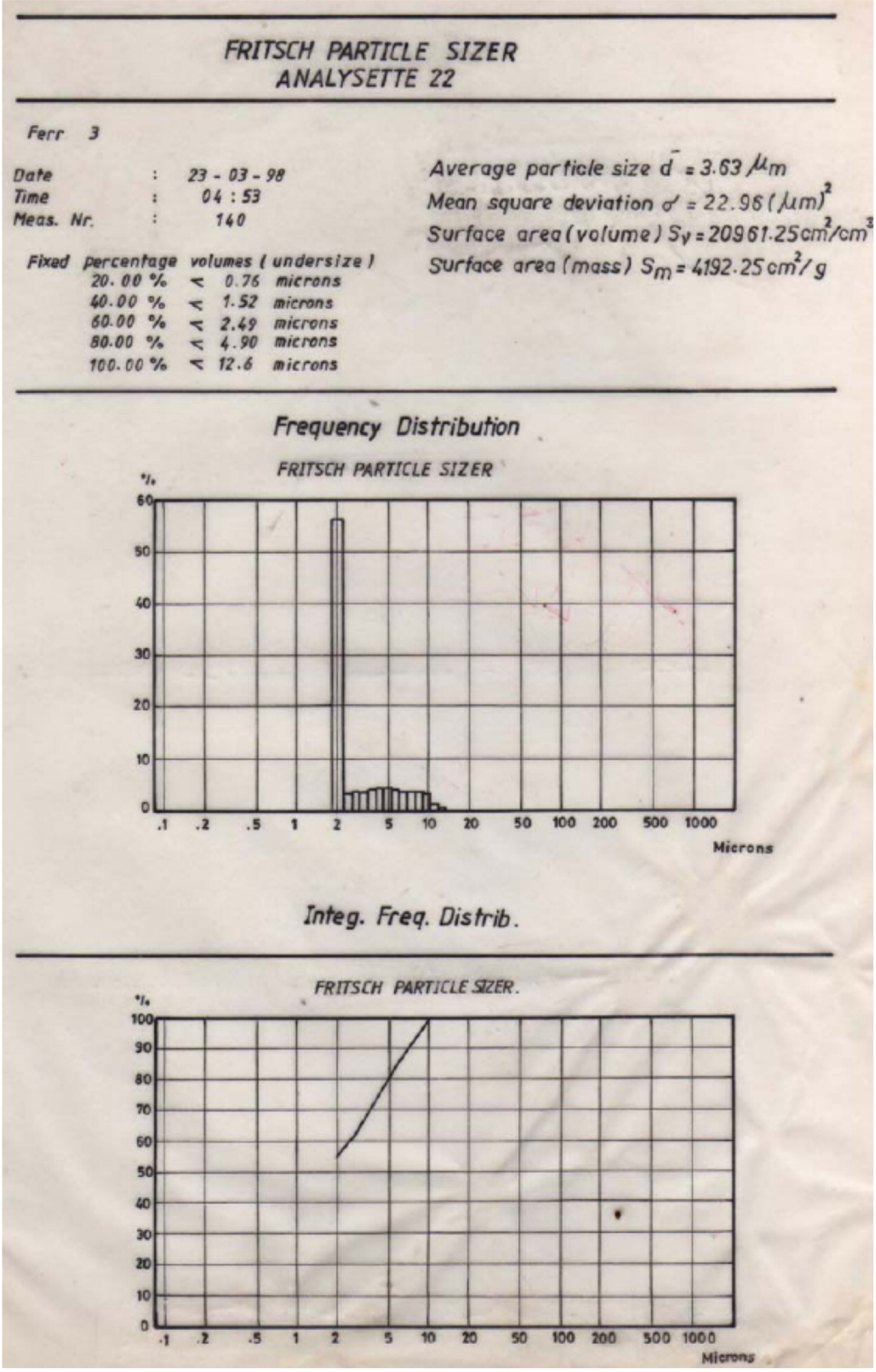
Frequency Distribution

FRITSCH PARTICLE SIZER

Integ. Freq. Distrib

FRITSCH PARTICLE SIZER

Fig. 4: LASER particle size analyser for ferrofluid wet sample before washing and removing salt.



FRITSCH PARTICLE SIZER
ANALYSETTE 22

Ferr 3

Date : 23 - 03 - 98
Time : 04 : 53
Meas. Nr. : 140

Average particle size $\bar{d} = 3.63\ \mu m$
Mean square deviation $\sigma = 22.96\ (\mu m)^2$
Surface area (volume) $S_V = 20961.25\ cm^2/cm^3$
Surface area (mass) $S_m = 4192.25\ cm^2/g$

Fixed percentage	volumes (undersize)
20.00 %	< 0.76 microns
40.00 %	< 1.52 microns
60.00 %	< 2.49 microns
80.00 %	< 4.90 microns
100.00 %	< 12.6 microns

Frequency Distribution

Integ. Freq. Distrib.

Fig. 5: LASER particle size analyzer for ferrofluid wet sample after washing and removing salt