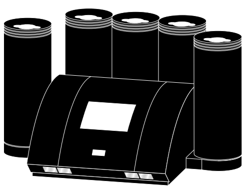
Application Note

Studying the particle size distribution of a polystyrene suspension based on sedimentation

Most suspensions are polydisperse systems, meaning that solid particles of various sizes are dispersed in a fluid. A particle size distribution study yields insights into the width of the particle distribution. Such studies enable the analysis of powders, granular materials, and particles suspended in liquids in great detail. Particle size distribution studies are used in research and quality control in many industries, including the cosmetics, pharmaceutical, and food industry. In this application note, a MultiScan MS 20 dispersion stability analysis system from the German manufacturer DataPhysics Instruments is used to analyse the particle size distribution of polystyrene particles in water.

Measurement device
MultiScan dispersion stability analysis system



Measurement method
Optical dispersion stability analysis

Measured quantities
Mean particle size
Particle size distribution

Environmental conditions
25 °C

Samples
Polystyrene

Industries
Cosmetics
Chemistry
Pharmacy
Food

dataphysics
Understanding Interfaces

Fig. 1: DataPhysics Instruments stability analysis system MultiScan MS 20 with six independent Scan Towers.

Introduction

The MultiScan MS 20 from the German manufacturer DataPhysics Instruments is a dispersion stability analysis system. In addition, it can determine the mean particle size of solid particles dispersed in liquids. We have shown how to calculate the mean particle size in our previously published application note[1].

Most real-life dispersions are polydisperse systems, meaning that the particles in it are not all of the same, but varying sizes. In this case, a particle size distribution study can yield even deeper insights. In detail, a particle size distribution study yields the width of the particle size distribution, indicating which percentage of particles are of a certain size. To analyse powders, granular materials and particles in fluids in even more detail, the MultiScan MS 20 can also calculate the particle size distribution, as we will show in this application note.

The particle size distribution is a key parameter in research and development experiments as well as quality assurance tests. This method is used, amongst others, in the cosmetics, pharmaceutical, and food industry.

Technique and Method

The particle size distribution in suspensions can be determined by studying the sedimentation process. To do so, a MultiScan MS 20 dispersion stability analysis system (Fig. 1) from DataPhysics Instruments can be used. The MS 20 is a versatile measuring device for automatic optical stability analyses of dispersions.

To conduct the experiment, the suspension is poured in a sample vessel, which is then placed in one of the measuring chambers of the MultiScan MS 20. The MS 20 contains a light source, a detector opposite the light source to measure the transmitted light, as well as a second light source, positioned in a 45 degree angle from the detector, for measuring the backscattered light (Fig. 2). The light sources and detector move up and down the sample vessel for each measurement so that position-resolved light intensities can be recorded.

According to Stokes' law[2], Beer-Lambert's law[3], and Bernhardt[4], it is possible to calculate the particle size distribution function from the light intensity. This approach assumes that the total cross section is the average of the cross sections of all particle sizes involved. For evaluating the particle size distribution, the MSC device software is using the Richardson-Zaki equation[5] to correct the sedimentation rate due to volume fraction.

Experiment

To prove the accuracy of the particle size distribution analysis provided in the MSC software, commercial polystyrene particles with a predefined particle size were used in this application note (Table 1). The particle diameter of the polystyrene particles is given as 20 µm according to the supplier information sheet. The liquid phase of the polystyrene-suspensions is water. The density and viscosity of water are 0.998 g/cm³ and 1.002 mPas at room temperature, respectively.

20 ml of the polystyrene-suspension were poured in a transparent sample vessel and measured at a temperature of 25 °C every minute for one hour. The measured zone was between 0 mm (bottom of the vial) and 57 mm (top of the vial).

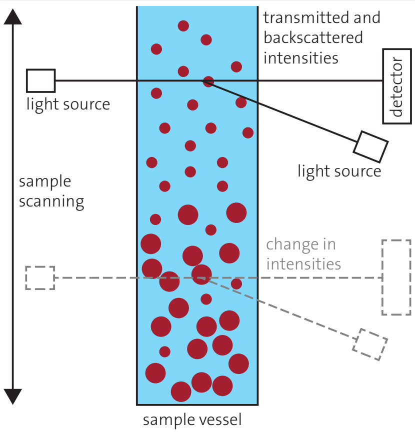


Fig. 2: MultiScan measuring principle

Table 1: Properties of the polystyrene solution according to the supplier

Particle	Diameter	Density	Volume concentration
Polystyrene	20 µm	1.06 g/cm³	5 %

Table 2: Sedimentation rates and mean particle diameters evaluated using transmission and backscattering intensities of the polystyrene sample

Signal	Sedimentation rate	Mean particle diameter
Transmission	0.6262 mm/min	19.88 µm
Backscattering	0.6294 mm/min	19.93 µm

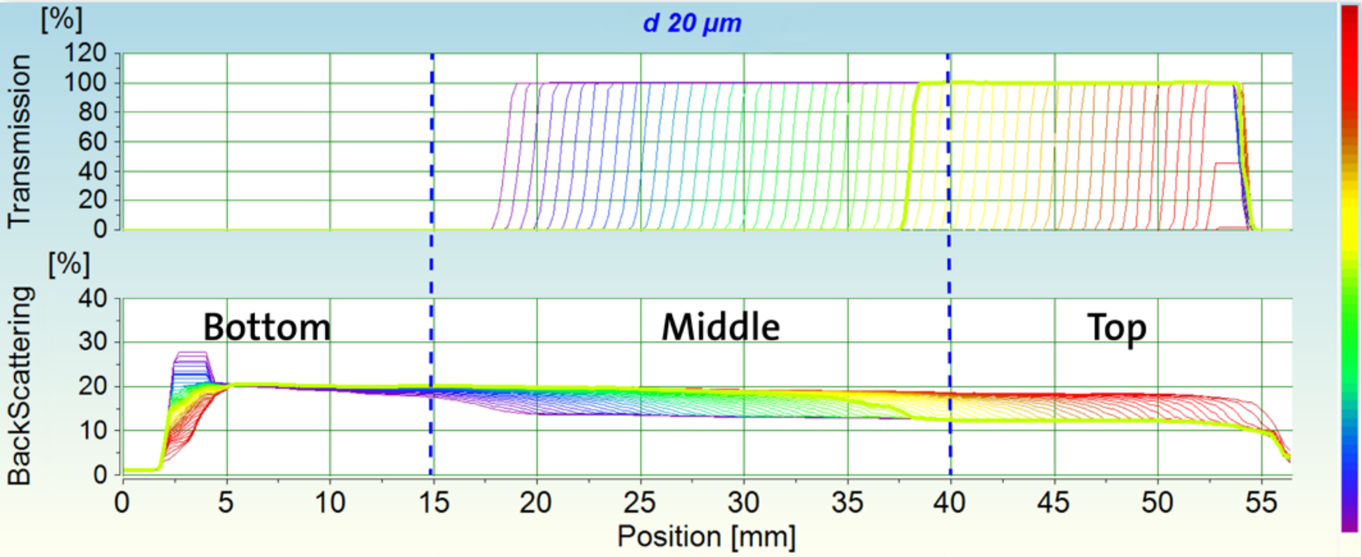


Fig. 3: Transmission and backscattering intensity diagram of polystyrene suspensions

Results and Discussion

In Fig. 3, the transmission and backscattering intensities are plotted against their height in the polystyrene suspension. The colour-coding of the curves indicates the time at which the measurements were recorded, from red (first measurement, t = 0 s) to purple (last measurement, t = 1 h). Every curve represents an individual measurement. The diagrams in Fig. 3 show time- as well as position-dependent changes of the transmission and backscattering signals, indicating a typical sedimentation process.

Calculating the mean particle size
To begin with, the sedimentation rate and the mean particle size are calculated. This measurement procedure has been described in detail in the previously published application note 'Mean Particle Size Determination'. In short, the sedimentation rate and the mean particle size of the polystyrene particles can be obtained using the 'Migration Front'-method of the MSC software[1]. As displayed in Table 2, the mean particle diameters of the tested polystyrene particles are 19.88 µm, using the transmission signal, and 19.93 µm, using the backscattering signal. These values are in good agreement with the value given by the supplier (Table 1). This confirms that it is possible to calculate the mean particle size using the sedimentation rate.

Calculating the particle size distribution
Additional information about the distribution of the particle size can be obtained, using the sedimentation process as starting point. To do this, the following parameters must be known:
• density difference
• solvent viscosity
• start line
• volume concentration

The value for the volume concentration is not necessary at solid particle concentrations below 0,1 %, as it is without significant influence for small concentrations. However, it is important to note here that Stoke's law can also be used at concentrations exceeding 0,1 %.

To calculate the particle size distribution in the MSC software, a single measurement profile, showing a steep middle part and two horizontal parts on top and bottom, must be selected (see Fig. 3). Using this selection, the particle size can be easily evaluated by selecting its position range and then clicking on 'Calculate'. In this example, we have chosen the 31st transmission and backscattering signals from the measurement series.

Using the 31st transmission signal, the mean diameter of polystyrene particles is calculated to be 19.68 µm with a standard deviation of 0.31 µm (Fig. 4). Additional particle size distribution parameters can also be obtained from the measurement. They are given as Dx, where x denotes the percentage of particles equal or below the indicated diameter. Particle size distribution parameters such as D50, D90 and D95 were calculated as 19.68 µm, 20.08 µm and 20.20 µm, respectively.

The particle size distribution can also be calculated using backscattering signals. As shown in Fig. 5, the mean particle diameter of polystyrene particles calculated this way is around 20.06 µm with a standard deviation of 0.87 µm using the

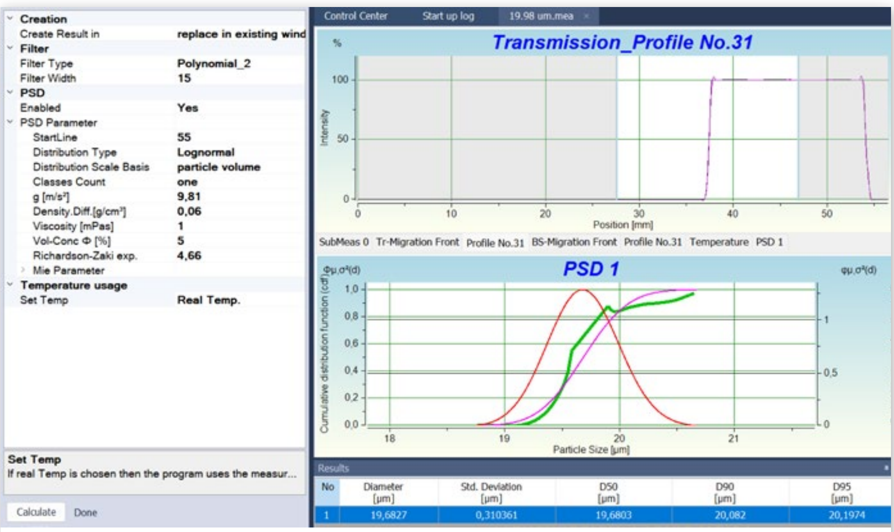
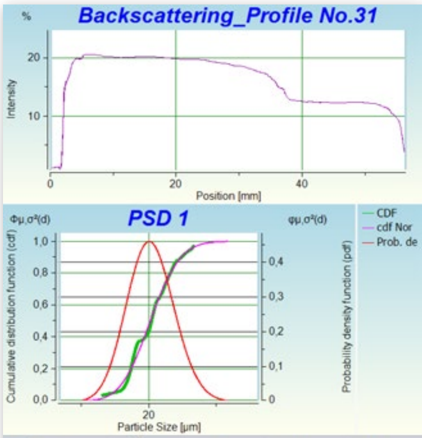


Fig. 4: Transmission profile 31 with evaluated particle size distribution



No	Diameter [µm]	Std. Deviation [µm]	D50 [µm]	D90 [µm]	D95 [µm]
1	20,0597	0,869131	20,0409	21,1847	21,5206

Fig. 5: Backscattering profile 31 with evaluated particle size distribution

31st backscattering signal. These values are similar to the results obtained using the transmission signals earlier. The standard deviation is larger, however, owing to a higher background noise in the backscattering profile. Additionally, D50, D90 and D95 were calculated as 20.04 µm, 21.18 µm and 21.52 µm.

Notably, as the particle size of the sample used is very specific, the particle size distribution is evaluated by assuming only one particle species. The method can however also be applied to multi-particle-species-mixtures.

Summary

It can be concluded that the changes in both transmission and backscattering signals can be used to evaluate the particle size distribution. To do so, the function of 'Particle size distribution analysis' in the MSC software is available.

Evidently, the above results underline the excellent applicability of MS 20 not only to analyse dispersion stability, but also to calculate mean particle size and particle size distribution with high validity.

Using the MS 20 stability analysis system and its corresponding MSC software, an easy and fast way to evaluate particle size distributions as well as mean particle sizes could be demonstrated. It has been proven that MS 20 can provide a valid measurement of mean particle size and particle size distribution based on the sedimentation process, which is helpful in a wide range of research and industry fields, such as cosmetics, food and pharmaceuticals.

References

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