Measuring Sprays Containing Propellants or Volatile Components

Detection and Elimination of Beam Steering

Introduction

The technique of laser diffraction relies on the fact that the passage of light is affected by changes in the Refractive Index (RI) of the material through which it is transmitted. In a spray, for instance, the particulate phase normally has a significantly different RI compared to the gas phase. This causes light to be diffracted from the interface of the spray particles, producing a characteristic light scattering pattern. A laser diffraction system measures the intensity changes observed within this scattering pattern in order to calculate the spray particle size.

Beam steering in laser diffraction measurements

The presence of particles or droplets is sometimes not the only source of light scattering within a spray. Many sprays contain volatile components which are present as gas or vapour. These components could be caused by droplet evaporation, as is seen for fuel sprays, or could be caused by the presence of a propellant, as is found in many domestic sprays and pharmaceutical Metered Dose Inhalers (MDIs). The presence of these volatile components can cause changes in the RI of the gas phase within the spray, leading to refraction of the laser beam. This effect is know as beam steering and causes a scattering response to be observed at small angles.

The scattering predictions used within the laser diffraction analysis show that large particles tend to scattering light primarily at small angles whereas small particles tend to scatter at large angles. The presence of the low-angle scattering caused by beam steering will therefore cause laser diffraction analysis to report a mode of very large particles which are not present within the spray. Often the beam steering effect is so dominant that the analysis is unable to resolve the presence of any fine particles.

Overcoming the effects of beam steering

The analysis settings used within the Malvern Spraytec laser diffraction system allows users to eliminate the effects of beam steering. This is achieved by removing, or "killing", the low-angle data channels affected by beam steering prior to calculating the particle size distribution of the spray. Although this reduces the dynamic range of the Spraytec measurement (the removal of low angle data will reduce the upper size limit), it does enable the calculation of realistic particle size distributions for sprays containing propellants or other volatile components.

Scattering data collection

An example of the scattering data collected from a spray containing a volatile propellant is shown in figure 1. This graph shows the light scattering intensity recorded on each of the system's detectors. Detector 0 records the unscattered light intensity whereas detectors 1 to 36 show the intensity of light scattered at different angles, with the measurement angle increasing as the detector number increases. The scattering from the particles in this spray can be seen on detectors 9 to 30. However, this is not as intense as signal seen on detectors 1 to 5. It is this signal which relates to beam steering.

Analyzing the data set using all of the detector channels produces the first of the results shown in figure 2. The Spraytec analysis reports an extremely large particle size, with the median (Dv50) of around 620 microns. No fine particles are reported, despite the fact that direct observations of the spray plume

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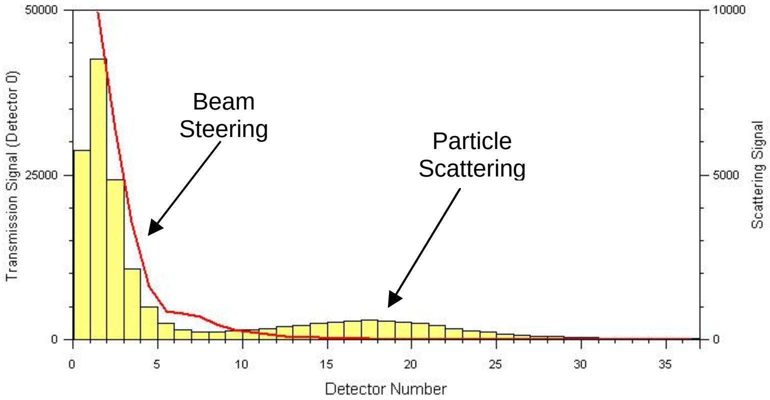
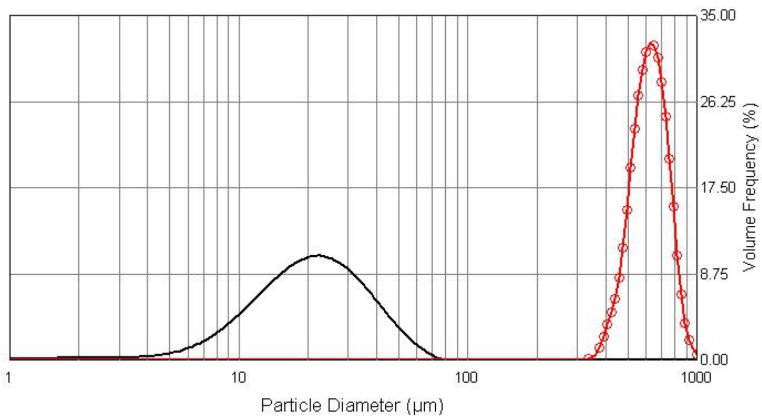


Figure 1: Spraytec data set containing beam steering are low angles.



	Date-Time	File	Sample	Dv(10)	Dv(50)	Dv(90)
(black line)	14 Aug 2006-11:...	kill	Deoderant	9.16	20.55	40.48
(red line)	14 Aug 2006-11:...	no kill	Deoderant	488.75	621.76	771.89

Figure 2: Spray particle size distributions calculated before (red) and after (black) applying a data kill at detector 8.

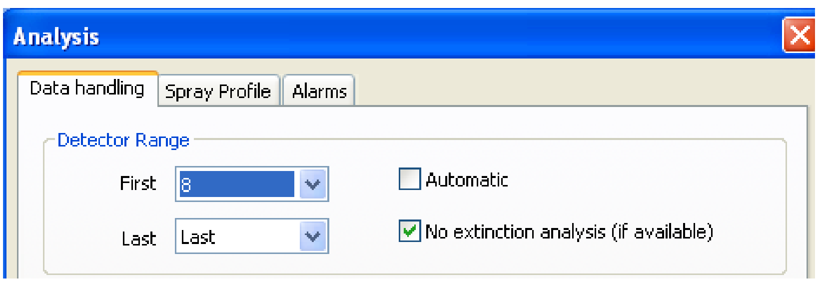


Figure 3: Data handling options with the Spraytec system's analysis settings. The first detector is set to 8 to eliminate beam steering in this case.

suggested that they were present. This is because the scattering data is dominated by the beam steer signal on the low angle detectors.

The scattering pattern shown in figure 1 displays a minimum between the beam steer response and the scattering response observed from the spray particles. Killing the data at a point just above this (detector 8) allows realistic particle size distributions to be calculated. This is achieved by adjusting the first detector channel used in the analysis, as specified within the Spraytec software's Data Handling options (figure 3). Reanalysis of the data set using these settings yields the second of the results show in figure 2, where the median particle size is now 20 microns. This is much more realistic for this type of spray (a deodorant).

Summary

Beam steering is an important phenomenon when measuring the particle size of sprays containing propellants or other volatile components. Failure to account for beam steering can lead to the reporting of extremely large particles which are not present within the spray. Correct use of the Spraytec's Data handling options can overcome this, enabling the calculation of realistic results.

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